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Training Manual

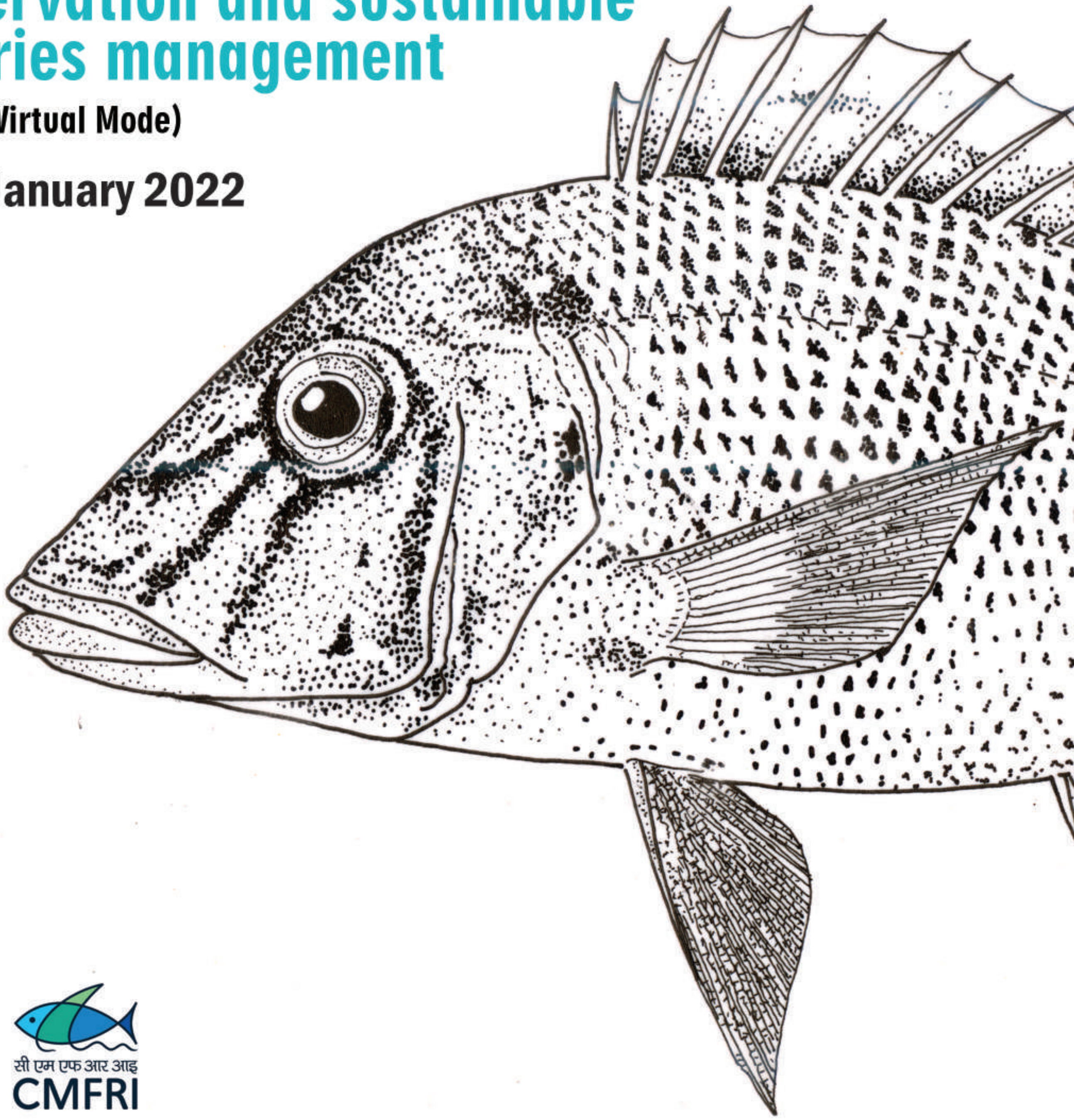
आज़ादी का अमृत महोत्सव

ICAR Sponsored Winter School on

Recent development in taxonomic techniques of marine fishes for conservation and sustainable fisheries management

(Through Virtual Mode)

03-23 January 2022



भाकृअनुप ICAR

सी एम एफ आर आइ CMFRI

Organised by

ICAR-Central Marine Fisheries Research Institute
Post Box No. 1603, Ernakulam North P.O., Kochi-682 018
Kerala, India

ICAR Sponsored

WINTER SCHOOL

on

Recent development in taxonomic techniques of marine fishes for conservation and sustainable fisheries management

03 -23 January 2022.

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FOREWORD

Ocean drives global systems that make the Earth habitable for humankind and hence is one of the most important resources to be studied in the century. Marine biodiversity is critical to the health of people and our planet. Marine protected areas need to be earmarked and effectively managed, and regulations need to be put in place to reduce overfishing, With the Covid-19 not dying down ocean conservation and action should not come to a halt while we tackle the COVID-19 pandemic.Fishing the world ocean will change the biological diversity of its ecosystems substantially; studies to determine the effects of fishing on marine biodiversity requires a variety of data, the most important among them being the correct taxonomic identification of organisms. Since the information and identification of all organisms in an ecosystem is physically impossible, target taxonomic groups are only studied and this all the more increases the importance of the taxonomic study. Understanding of evolutionary relationships will advance with the use of modern methods. This may require training new experts in the systematics of the group in question, or enticing existing experts to publish reviews of the group. Records of species occurrences from existing databases and literature must be assessed carefully for reliability. If reliability of existing records cannot be evaluated, then caution is advisable when ascribing importance to the records.

The ICAR-Central Marine Fisheries Research Institute (CMFRI) established by the Government of India on February 3rd 1947 under the then Ministry of Food, Agriculture Community Development and Cooperation, Government of India emerged as a leading tropical marine fisheries research institute in the world. This year the Institute completes its glorious 75 years along with the country when it celebrates Azadi ki Amrit Mahostav. During the first half of the seven decades of its existence, the CMFRI devoted its research attention towards the estimation of marine fisheries landings and effort, taxonomy of marine organisms and the bio-economic characteristics of the exploited stocks of finfish and shellfish and developing and promoting mariculture systems for sustainable growth of marine fish production in the Indian EEZ. With over 221 new species being described by the Scientists of Institute, it is only apt that a training of this capacity is being organised by the Institute to commemorate its 75th year of research expertise in the area of tropical marine fisheries.

The Course Manual released on this occasion covers important aspects of taxonomy, marine fisheries, nomenclature rules, taxonomy of several fish groups including clupeids, myctophids, balistids, eels, billfishes, besides deep sea crustaceans, cephalopods, mammals in addition to analytical methods, trade rules prepared by experts in their respective fields. I congratulate the Course Director, Dr. Rekha J Nair, Principal Scientist and her team Shri Dr. Ratheesh Kumar R, Scientist, Dr. V. Mahesh, Scientist, Dr.Subal Kumar Roul, Scientist, Course Co-Directors and Team Winter School for their efforts in bringing out the Manual on time and to arrange the programme in a befitting manner

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Director
ICAR-Central Marine Fisheries Research Institute Kochi, Kerala

January 2022

PREFACE

Indicator 14.4.1 of SDG 14 deals with proportion of fish stocks within biologically sustainable levels. The sustainability of global fishery resources continues to decline, having dropped from 90 percent in 1974 to 65.8 percent in 2017. Fish stocks within biologically sustainably levels contributed 78.7 percent of the global marine fish landings in 2017, which have remained relatively stable at around 80 million tonnes since 1995. Despite the continuous deterioration, the rate of decline has slowed down in the most recent period. But how do we effectively study our resources? Management is to be done on a species level as biological characters vary from species to species. Sexual dimorphism is shown by many species and it is this ground reality that has caused classical taxonomy to revive in this millennium. Fish stock assessment starts with proper and clear fish identification. Furthermore, if decisions are to be made about preserving species, then relationships among species must be known to determine the evolutionary uniqueness of the species. the role of taxonomy comes here; we need to get our basics right. For biodiversity exploration, the greatest information return for the investment of resources will come from including taxonomic groups for which reliable information is not currently available. Species new to science can be expected in these poorly known groups. Understanding of evolutionary relationships will advance with the use of modern methods. This may require training new experts in the systematics of the group in question, or enticing existing experts to publish reviews of the group. Records of species occurrences from existing databases and literature must be assessed carefully for reliability. If reliability of existing records cannot be evaluated, then caution is advisable when ascribing importance to the records.

The present ICAR Sponsored Winter School on Recent development in taxonomic techniques of marine fishes for conservation and sustainable fisheries management aims to relook at the present status of the taxonomy of major groups of marine fishes. Recent updates in the taxonomy have been highlighted in the Course Manual by the Faculty and the classes will be dealt by expert taxonomists. The Course is designed to acquaint the participants with the nuances of taxonomy, Red List assessments, their importance, and the future of systematics in the present world. In the light of SDG-14 and the importance of the diversification of resources for capture and culture, it is imperative that new fishery resources must be explored and identified. Correct identification is the pillar to the fisheries world and classical taxonomy is the basis for any conservation activity. Rules for conservation, IUCN activities, WLPA, CITES all works on the basis of correct taxonomy. Hence training on these lines is very essential not only to conserve biodiversity but also to diversify fisheries in India.

I wish to thank Dr. Trilochan Mohapatra, Director General, ICAR, Dr. Joykrushna Jena, Deputy Director General (Fisheries Science) and Dr. Seema Jaggi, ADG, Human Resource Development of Indian Council of Agricultural Research, for giving us an opportunity to organize this Winter School. I am also grateful to Dr. A. Gopalakrishnan, Director, ICAR-CMFRI, for his unstinct support and constant guidance in organising the Winter School. We thank Dr. P.U Zacharia, Head, Demersal Fisheries Division for his support for the programme.

The different faculty members we approached were very prompt in contributing their material and we thank each one of you for sparing your valuable time and effort helping us bring out this Manual on time. I wish to thank my Co-Directors Shri Dr. Ratheesh Kumar R, Scientist, Dr. V. Mahesh, Scientist, Dr. Subal Kumar Roul, Scientist, Course Co-Directors, Dr. J Jayasankar, Principal Scientist and Scientist In Charge, AKMU Cell, CMFRI, Shri ManuV K, Shri. Manjesh R and Shri. Abhilash P.R who have supported me throughout in organising the Winter School. The help and support provided by the technical, supporting and administrative staff is also acknowledged. I am sure the participants will find this Course Manual very valuable in their future research. I hope this 21 day programme will strengthen the participants' knowledge and expertise in the area of fish taxonomy and help in the conservation and sustainable fisheries management

January 2022

Rekha J Nair
Course Director
ICAR Winter School

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CHAPTER 1

Marine Fisheries in India: Outlook and Challenges Ahead

1.0 Introduction

India is endowed with a wide diversity of water resources, which sustain a large fisheries sector in the country. India has a coastline of 8,118 km with an Exclusive Economic Zone (EEZ) stretching over 2.02 million sq. km, and a continental shelf covering 0.53 million sq.km.

Fisheries have a very important role for food supply, nutritional security and livelihood in India. The sector is one of the important revenue-earning and employment-opportunity sectors, contributing significantly to the economy of the country. Marine fisheries in India are a shared responsibility between the national and state governments. In a legal and constitutional sense, state governments are responsible for waters inside the 12 nautical mile territorial limit (22 km) while the Government of India (GOI) is responsible for waters between 12 nautical miles and the country's 200 nautical mile (370 km) EEZ.

Fisheries represent the best example of the exploitation of living natural resources. One of the most important characteristics of capture fisheries is that the resources are a common property, the access to which is free and open. Irrespective of the type of exploiters: artisanal fishers or large fleet owners, their operation will not be limited until the zero profitability threshold is reached. Hence, there is a need for a manager to intervene and regulate their activity. The general objectives of fisheries management are to achieve nutritional security, maintain sustainability of the resources, and ensure gainful employment and economic benefits. To achieve this, a multidisciplinary approach involving biological, environmental, social, economic and administrative instruments is necessary. The present status of marine fisheries in India and the growing challenges call for early implementation of effective management measures to gradually shift the focus from harvesting increasing volumes of fish to a more holistic approach based on a long-term goal of maximising net economic, social and environment benefits from sustainable fish production.

2.0 Overview

During 1950 - 2010, marine fish production in India increased from 0.5 million tonnes (m t) to 3.3 m t. Contrary to global marine fish production, which decreased from the year 1970, the

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production in India was increasing during the 60-year period. In the last 9 years (2011-2019), however, the annual marine fish catch in India fluctuated between 3.5 million tonnes in 2011 and 3.8 m t in 2019, without an increase (Fig. 1). While the catch stagnated, the value of the catch increased during this period from Rs 24,000 crore in 2011 to 60,800 crore in 2019 at the landing centre level (Fig. 2). The corresponding value at retail markets increased from Rs 39,000 crore to Rs 92.356 crore. This shows the increase in the unit price of fish from about Rs 70 per kg to Rs 160 per kg at landing centre level, and from Rs 111 per kg to Rs 243 per kg at retail level. The increase in the value without increase in the catch is the result of (i) decrease in the per capita fish supply with growing human population; (ii) increase in demand for marine fish among the people, and (ii) increase in the cost of fishing necessitating increase in the selling price.

Fig 1. Trend in estimated marine fish landings during 2011 – 2019 (Source: Annual Reports of ICAR-CMFRI)

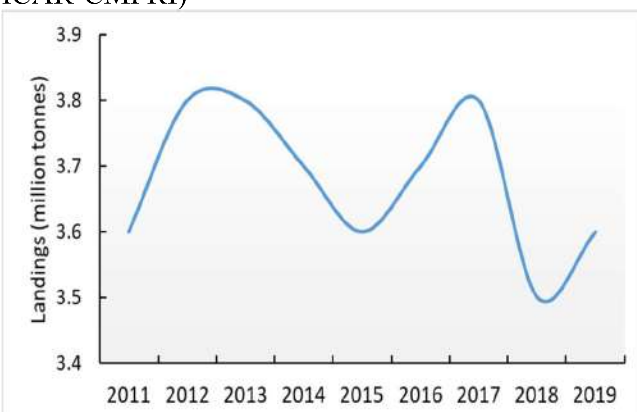
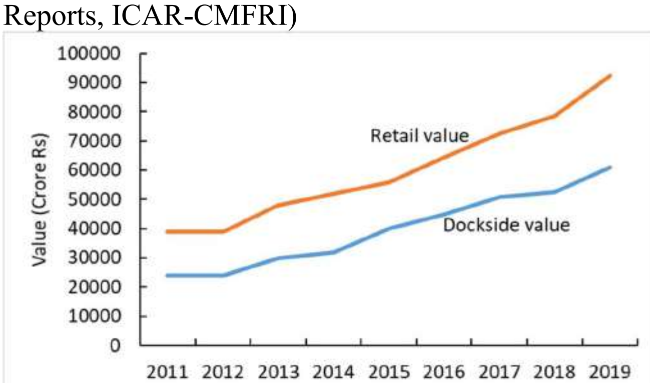


Fig 2. Trend in estimated value of marine fish landings during 2011-2019 (Source: Annual Reports, ICAR-CMFRI)



Potential yield estimates indicate that the annual harvestable potential yield (PY) from the Indian EEZ is 5.31 m t (DAHDF, 2018). Besides the conventional resources, the PY for non-conventional resources has been estimated as oceanic squids (0.63 m t), myctophids (1 m t), jellyfish (0.2 m t) and marine algae (17,775 t). While the estimates on landings and PY indicate the potential to increase the catches from 3.65 m t to 5.31 m t, it is a challenge to close the gap of 1.66 m t due to the following reasons: (i) The unfished/underfished resources are in the oceanic/deep sea regions in India's EEZ and fishing in these waters will be expensive, and requires improved fishing technologies. (ii) Many resources in the oceanic of waters do not have ready market demand (except tunas and tuna-like fishes and deepsea shrimps), and require improved processing technologies. Considering this, it may be stated that from the currently fished areas, the country has reached a stage in which further increase in fishing effort and production have to be viewed with caution.

India is a country with a large number of fishermen harvesting multispecies resources with an array of craft-gear combinations. The livelihood of fishermen directly depends upon the availability of natural resources. The number of fishermen involved in active fishing increased from an estimated 0.5 million in 1980 to 1.6 million in 2019 (DoF, 2020). This includes those involved in actual fishing on full-time and part-time basis. Though the fish catch increased from 1.5 m t to 3.6 m t during this period, the increase is not proportional to to that of active fishermen population. Irrespective of three-time increase in the dependent-population in 40 years, the annual catch per fisherman decreased from 3.0 t in 1980 to 2.3 t fish per year in 2019. In comparison, a fisherman in several European Union countries catches > 100 t in a year. In Norway, one of the advanced countries in fisheries and in best practices in fisheries management, for example, only 11,000 fishermen are engaged in fishing, and they catch 2.76 m t of fish (in 2018), *i.e.*, each fisherman catches 250 t in a year (OECD, 2021). The number of fishing vessels are 5982 and 92% of boats are less than 15 m overall length. Though India and Norway have totally different biological, environmental, administrative and cultural setting, it is worth taking a note of the difference in the fisheries prevailing between these two countries. The comparison shows that in India (i) the population depending directly on fishing is so very great, (ii) large investments have gone into fishing in the form of fishing boats, and (iii) it would be a challenge to find quick solution to the problem of overcrowding in the sector. It would be difficult to achieve goals related to sustainability in this type of situation and long-term solutions are required.

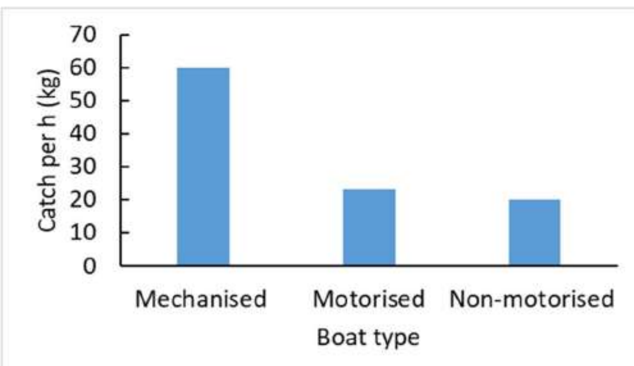
In the last 60 years, the number and efficiency of marine fishing boats have increased in India. Following introduction of mechanisation in the mid-1960s, there were 19,210 mechanised boats in 1980, 58,911 in 2005 and 74,059 in 2016 (Table 1). In addition to the number of boats, the efficiency of boats also increased in terms of boat size, engine power, sea endurance, etc. Motorisation of traditional boats was introduced in the mid-1980s, which became very popular immediately. In 2016, there were 64,449 motorised boats in addition to 25,689 non-motorised boats. Motorisation substantially increased the mobility of the smaller craft. These developments have helped extend fishing to deeper waters as well as into new geographical areas. At present, overcapacity is an issue in capital-intensive mechanised fishing sector as well as in the employment-oriented motorised sector. It has been estimated that optimum number of different types of fishing craft needed for exploiting the potential yield is 76,967 (DAHDF, 2018). At present, 1,64,197 boats of different categories are operating, showing that the number of prevailing boats is twice the required number of boats. In spite of overcapitalisation and overfishing, the catch has not declined, as additional resources from distant water fishing grounds are being harvested.

Table 1. Number of marine fishing boats in India (Source: publications of ICAR-CMFRI & DoF)

Year	Mechanised	Motorised	Non-motorised
1961	6708	0	93099
1973	8086	0	106480
1980	19210	0	142669
1998	49070	50922	76596
2005	58911	75591	74270
2010	72559	71313	50618
2016	74059	64449	25689

For many years, the mechanised boats remain as the highest contributor (83.0% of total catch followed by the motorised boats (16.1%). The non-motorised boats contribute only 0.9% CMFRI, 2020). The catch rates in terms of per boat was high (2175 kg/trip) for the mechanised boats whereas it was only 144 kg/trip for motorised boats and 45 kg/trip for non-motorised boats. In terms of hours of operation also, the catch rates were high for mechanised boats (Fig. 3).

Fig. 3. Catch per h (kg) of boat types in 2020 (Source: CMFRI, 2020)



3.0 Opportunities

India's marine fisheries has the following broad opportunities to show a better performance (see also World Bank, 2010):

(i) Building more productive fish stocks by following best management practices;
(ii) Generating a higher level of sustainable net economic, social and environmental benefits in the future; and
(iii) Utilising and improving the distribution of these benefits by providing better equity among stakeholders.

The sector has the strengths provided by an experienced labour force, a long history of fishing and Indigenous Technical Knowledge, good local examples of fisheries management, and expanding global and domestic demand for high quality marine fish products.

4.0 Constraints

To seize the broad opportunities mentioned above, reforms are needed to guide improved biological, social and economic performances of the sector in both inshore and offshore fisheries. The following five key constraints need to be addressed to transform marine fisheries in India (see also World Bank, 2010):

(i) The current management system can serve only partially for reform and more progressive fisheries management system is required.

The policy on marine fisheries in India is informed by three key policy documents: (a) Five Year Plans developed by the Planning Commission from the year 1950, (b) Comprehensive Marine Fishing Policy (Government of India, 2004) defining various desired goals and identifying schemes on which the funds are spent, and (c) National Policy on Marine Fisheries, 2017 (NPMF, 2017) (DAHDF, 2017). The NPMF 2017 has defined the following major topics aimed at reform: Fisheries Management; Monitoring, Control and Surveillance; Fisheries Data and Research; Mariculture; Island Fisheries; Post-harvest and Processing; Trade; Marine Environment and Marine Pollution; Adaptation to Climate Change; Fisher Welfare, Social Security, Institutional Credits; Gender Equity; Additional/ Alternate Livelihoods; Blue Growth Initiative; International Agreements/Arrangements; Regional Cooperation; and Governance and Institutional Aspects.

The NPMF 2017, if implemented in full scale, will lead to far reaching reformation of the sector. To achieve this, it has to be supported by appropriate management system and management measures. Strengthening management and implementation mechanisms at the level of Government of India as well as State/Union Territory is necessary. At present, the State Governments and UTs implement Marine Fishing Regulation Act (MFRA), which needs to be revised to accommodate the transformation process. Coordination between national laws and authority (outside the 22 km territorial waters boundary) and state laws and authority (within the 22 km boundary) is another area where improvements could be made.

(ii) Biological and economic sustainability of marine fish stocks faces challenges.

There are many causes for the marine fisheries not yielding their full potential value. Overfishing occurs when more fish are caught than how much the fish population can replace through reproduction and growth. Gathering as many fish as possible may seem like a profitable practice, but overfishing has serious consequences. Increasing fishing effort, overfishing and overcapitalisation as well as unsustainable fishing practices over the years are pushing many fish stocks to the point of concern. Recently, it has been assessed that one-third of the marine fish stocks has been overfished (Sathianandan et al., 2021). The results not only affect the balance of life in the oceans, but also the social and economic well-being of the coastal communities who depend on fish for their way of life. Overcapacity contributes to fishing effort in excess of the effort required to harvest the biological Maximum Sustainable Yield (MSY), resulting in declining catches and lower net benefits. Hence, better implementation of appropriate reforms through consultative and analytical processes are needed that could lead to improved awareness, more efficient legal and policy frameworks, stronger institutions and stakeholder participation, and more effective fisheries management systems.

In addition to overfishing, the fish resources are suffering mounting effects of environmental degradation, pollution and climate change (BOBLME, 2012; Vivekanandan et al., 2019). Hence, for sustaining marine fisheries, it is important to leave enough fish in the sea, respect habitats of fish populations and maintain livelihoods of dependent human populations.

(iii) Small scale fishers are losing their livelihoods and opportunities for development.

The current situation with marine fishing is affecting inshore fishers through declining catches, reduced incomes, and increasing conflicts. This is particularly true for smaller boat owners and crew who do not possess mechanised boats. They are unable to protect their resource access effectively, or shift to newer and more distant fishing areas. The rapid growth of the mechanised fleet, often with the benefit of public subsidies, has increased the competition for those fishing with smaller inshore vessels. Education levels tend to be low for the fishermen and their families owning motorised and non-motorised boats, making it difficult for them to take advantage of alternative employment opportunities in the expanding national economy.

(iv) Fisheries management needs to be strengthened for both inshore and offshore fisheries.

Marine fisheries management objectives in India are largely based on biological criteria. For waters within the 22 km limit, states generally provide a basic regulatory and licensing regime for fisheries management. Seasonal fishing ban is promulgated by the Government of India every year and implemented by the maritime states and Union Territories. For regulating mesh size, and zoning of fishing areas, many state fisheries departments lack working patrol vessels, and enforcing regulations is quite challenging. In spite of promulgation of MFRAs by maritime state governments, licensing of craft, mesh size regulation, catch declaration, ceiling on number and efficiency of fishing craft, monitoring, control and surveillance of fishing vessels remain as issues. There is increasing conflict as smaller inshore vessels and larger offshore mechanised trawlers compete for fish within the 22 km boundary, as the shallow waters are traditionally more productive. The situation exerts fishery resources under pressure. The major dilemma is that if access to fisheries resources is restricted, it would affect livelihoods of coastal communities, while if the access is open, the resources will sooner or later decline beyond recovery.

Among the several input control measures in the MFRA, seasonal fishing ban (SFB) is being followed diligently in all the maritime States and Union Territories. While Kerala started implementing SFB in 1988 other States and UTs began to implement it in different years from 1989 to 2001. Thus, the SFB is being followed every year across the maritime states of India for the last 20 to 32 years (Vivekanandan, 2019). All the mechanised boats (with a fixed engine and a wheelhouse) are covered by the SFB. Motorised boats (with outboard motor and open deck), are covered by the SFB based on the engine horsepower of the fishing vessels. In some States, boats operating with horsepower 10 and above and in others, those above 25 hp only, are covered by the SFB. When SFB was introduced it was observed for 45 to 47 days during the southwest monsoon period of June to August by the States and Union Territories (UTs) on the west coast and during April and May on the east coast. In 2015, based on the recommendations of an appointed Technical Committee, the Union Ministry of Agriculture (MoA), raised the fishing ban period to 61 days along both the west and east coasts. Since then, the SFB is followed for 61 days during southwest monsoon months from June 1 to July 31 along the west coast (including Lakshadweep Islands) and during summer months from April 15 to June 14 along the east coast (including Andaman & Nicobar Islands).

For waters under the authority of the Government of India, between 22 km (12 nautical miles) and the 370 km (200 nautical miles) Indian EEZ, more effective mechanisms are needed to set out conservation and management measures, and their enforcement.

(v) Market channels, particularly for small-scale fishers, are inefficient and hinder delivery of high quality products at optimal prices.

Domestic marine fish market chains in India are generally characterised by unhygienic conditions, poor handling of fish and loss of quality (from the boat to the final market), and a subsequent reduction in profits. High levels of product losses through wastage (up to 15 percent of harvest) are common. While new developments in marketing channels such as super markets are emerging in large cities with modern fish handling practices and facilities, small-scale fishermen are often unable to gain access to these marketing channels due to poor quality of their product. Major contributors to this problem are the lack of easily accessible and low-cost credit, and affordability of basic infrastructure such as ice, cold storage, and cold chain that would enable fishers to maintain better quality and obtain higher prices. While demand for fish products in India is projected to rise significantly in the future along with the expected increase in the population, the small-scale fishermen appear to lack adequate information about market requirements and emerging market opportunities. In contrast, Indian fish products export passing through European Union certified processing plants usually meet high international health and safety standards. However, trade barrier citing that fishing does not adhere to eco-friendly practices is looming large against marine products export to the USA.

4.1 Other anthropogenic factors influencing fisheries

One of the often-ignored factors that causes degradation of environment and depletion of fish stocks is the anthropogenic interference other than fishing. The man-induced alteration of the physical, chemical, biological and radiological integrity of air, water, soil and other media is causing, in several cases, irreversible damage to the structure and function of ecosystems. Runoff from domestic, municipal and industrial wastewater discharges and agricultural fields, solid waste

disposals, discharge from ships, and oil spills from tankers, are some of the major sources that cause deterioration of water quality, and cause damage to the aquatic organisms, from phytoplankton to mammals. Dams divert nutrient-rich water from entering into the sea, and obstruct the migratory path of some fishes. Pollutants such as trace metals, plastics and organochlorine pesticides enter the biological systems through food webs. Animals in higher trophic levels experience the effects of bioaccumulation and biomagnification. Depending on the intensity of damage, the interferences affect the physiological processes of growth and reproduction of aquatic organisms, mass kills, biodiversity loss and displacement of species.
Fisheries management needs to be approached in an integrated way by considering the issues of all the anthropogenic interferences such as increasing fishing intensity and damage to the physical, chemical and biological integrity of the ecosystems. As fisheries are impacted by the developmental needs of several other important prime sectors such as agriculture, industries, power generation etc., it is not possible to find solution to the issues from fisheries sector alone. For instance, issues such as water contamination, enforcement of standards for water discharge, maintaining the quality of river runoff, and reducing greenhouse gas emissions and climate change, have to be addressed by non-fisheries sector.

4.1.1 Climate change implications for fisheries

It is often stated that the fisheries sector is dynamic and used to dealing with changes. However, the magnitude of future climate-driven changes indicate that global marine species redistribution and marine biodiversity reduction in sensitive regions will challenge fisheries productivity by the mid-twenty-first century. These changes will demand greater preparedness in responding to the changes as concluded by the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014). The IPCC considered freshwater systems to be among the most threatened on the planet because of the multiple anthropogenic impacts they are subject to from hydropower infrastructure, water use for irrigation and agricultural land-use. It is expected that these stressors will continue to dominate as human demand for water resources grows, together with urbanization and agriculture expansion. This will have implications for the fisheries and aquaculture sector, throughout the value chain. Species productivity and fish growth are already changing with consequences for fishing and farming yields, as a result of shifts in the distribution of fish, alteration of larval transport or thermal tolerance of farmed fish (Barange et al., 2018). Operations of fishing and farming activities are also expected to be affected, whether by short-term events such as extreme weather events or medium to long-term changes such as lake levels or river flow that could affect the safety and working conditions of fishers and fish farmers. Food control procedures will undergo major reshaping to protect consumers from potential increase in contaminants and toxin levels resulting from changes in water conditions.

Using Dynamic Bioclimate Envelope Model (DBEM), the maximum marine catch potential in the world's Exclusive Economic Zones (EEZs) has been projected to decrease by 2.8 percent to 5.3 percent and 7.0 percent to 12.1 percent by 2050 relative to 2000 under the "strong mitigation" (RCP 2.6) and "business-as-usual" (RCP 8.5) greenhouse gas emission scenarios, respectively (Cheung et al., 2018). The projected decrease in catch under RCP 8.5 becomes 16.2 percent to 25.2 percent by the end of the twenty-first century. The projected changes in maximum catch potential varied substantially across EEZs in different regions, with EEZs in tropical countries showing the largest decrease. In India, the catch potential is projected to decrease by 10.3% and 17.0% in the mid-century under RCP 2.6 and 8.5 scenarios, respectively. The reduction will be 43.6% in RCP 8.5 by the end of the century.

Considering the multiplicity of issues negatively influencing fisheries, fisheries management has to be modernised with an expanded scope with multiple objectives and inclusive approach.

5.0 Definition of fisheries management

There are no clear and generally accepted definitions of fisheries management. A working definition, for the purposes, may be taken as: *"The integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives"* (Cochrane, 2002).

Fisheries management is a process *of considering the following components to make* decisions and implement actions to achieve goals:

- Biological considerations
- Ecological and Environmental considerations
- Technological considerations
- Social and Cultural considerations
- Economic considerations
- Considerations imposed by ‘other parties’.

‘Other parties’ would include, for example, tourism, conservation, oil and gas exploration and exploitation, offshore mining and shipping, aquaculture and mariculture, and coastal zone development for business or industry. All these can impose significant constraints on fishing activities and may be impacted by fishing activities.

Modern fisheries management is required to be familiar not only with the national legislation governing fisheries, but also with international legislations and voluntary instruments dealing directly with or impinging on fisheries. There has been a proliferation of such instruments in recent decades. This process shows the highly complex nature of management, and the need for considering the above-mentioned six different, but interconnected and perhaps equally important elements for developing a management framework.

5.1 Principles of fisheries management

A number of key principles can be identified which serve to focus attention on effective fisheries
management (Cochrane, 2002):

1. Fish resources are a common property resource.
2. Sustainability is paramount and ecological impacts must be considered.
3. Decisions must be made on best available information but absence of, or any uncertainty in, information should not be used as a reason for delaying or failing to make a decision.
4. A harvest level for each fishery should be determined.
6. The total harvest across all sectors should not exceed the allowable harvest level.
7. If this occurs, steps consistent with the impacts of each sector should be taken to reduce the removal.
8. Management decisions should aim to achieve the optimal benefit to the community and take account of economic, social, cultural and environmental factors.

5.2 Types of management

Examination of fisheries management framework currently existing in different countries shows that the following four approaches are being adopted:

(i) Input control approach
(ii) Output control approach
(iii) Precautionary approach
(iv) Ecosystem approach

5.2.1 Input control approach

Input controls are restrictions put on the intensity of use of gear to catch fish. Most common restrictions are on the number and size of fishing boats (fishing capacity control), the amount of time fishing boats are allowed to fish (effort control) or the combination of both capacity and effort. The input control measures may take various forms such as closed areas (including Marine Protected Areas), closed seasons, minimum mesh size, minimum legal size-at-capture, prohibiting destructive gears, etc (Table 2).

Table 2. Different types of input control measures

Methods	Specific measures	Desired effects
Restriction of fishing effort	Reduction of fishing boats, Regulating fishing efficiency, Strict registration and licensing	Relieving fishing pressure
Closure of fishing areas	Area allocation, MPAs, fish refugia, No-take zone, fish sanctuary	Improving fish abundance and biomass in closed areas
Closure of fishing season	Closure during spawning season	Protecting spawners, improving recruitment
Minimum mesh size/Minimum Legal Size (MLS)	Specification of minimum mesh size; Ban catch, landings and trade of species below MLS	Protection of juveniles; Reducing low-value bycatch
Prohibiting selected fishing practices	Ban harmful fishing gear and practices	Improving fish abundance/biomass and health of ecosystem
Species protection	Place Endangered, Threatened and Vulnerable (ETV) species under Protection Act	Recovery of ETV species and health of ecosystem

5.2.2 Output control approach

In well managed fisheries, Maximum Sustainable Yield (MSY) or Maximum Economic Yield (MEY) or yield-per Recruit (Y/R) is used as biological reference point (BRP) to derive thresholds and targets to arrive at sound fisheries management decisions (Cadima, 2003). Spawning-recruitment relationship (S-R) is used as a key element for formulating fisheries management advice. A few other empirical reference points such as long-term mean size-at-capture also can be used as BRPs. By using the MSY approach and BRPs, countries like the USA, Canada, New Zealand, and a few countries in the Europe are following advanced rights-based management approach to limit the catch equal to or within the total allowable catch by following catch quotas. In these countries, Total Allowable Catch (TAC) is set with reference to maintaining the biomass at or above a level that can produce the MSY. Output control measures also take the form of certification and trade restrictions (Table 3).

Table 3. Different types of output control measures

Methods	Specific measures	Desired effects

Catch quality	Ban on landing and trade of low quality fish	Improving the quality of traded fish; protecting health of consumer health
Total Allowable Catch and Individual Quotas	Establishing maximum fishing limits during a timeframe and for each one of the species	Maintaining fish stocks at or above MSY
Certification/ Labelling	Linking fisheries products to their production process	Encouraging eco-friendly and sustainable fishing practices
Trade restrictions	Restricting import/export of fish from illegal, harmful fishing practices	Maintaining fish stocks at or above MSY

5.2.3 Precautionary approach

Although MSY is an appropriate basis for reference points, there are limitations of applying MSY approach in fisheries management in the absence of key BRPs like the S-R. However, non-availability of a whole range of scientific information should not deter taking management decisions. In this situation, precautionary approach should be the backbone of fisheries management. The UN Conference on Straddling Fish Stocks and Highly Migratory Stocks (UN 1995) first articulated the principle for fisheries under the following definition: *"The absence of scientific data shall not be used as a reason for postponing or failing to take conservation and management measures".* The precautionary approach requires, *inter alia*, maintenance of a flexible, resilient fishery system including the fish stock, the associated species, the fleet and the management agency regulating it. The precautionary approach emphasizes that, greater the information gaps and the amount of uncertainty, the management measures should be more cautious to avoid risks.

Whatever is the approach, stakeholder engagement in various levels of fisheries management and co-management systems are becoming popular in many parts of the world and demonstrating considerable levels of success. In its simplest form, co-management can be described as fisheries management where roles and responsibilities are shared between the government and resource users (Pomeroy, 1994).

5.2.4 Ecosystem approach

In recent years, it has been recognized that effective fisheries management could be achieved by following ecosystem approach, in which multiple regulatory measures and management actions could be applied in full consideration of aquatic species, the ecosystems in which they live and the developmental systems that degrade the ecosystems. The ecosystem approach to fisheries management (EAFM) offers a practical and effective means to manage fisheries more holistically. It represents a move away from conventional fisheries management that focuses on target species, towards systems and decision-making processes that balance environmental, human and social well-being within improved governance frameworks. In recent years, decentralization policies have left local units with the challenging task of developing management plans that not only work locally, but also fit into broader fishery/ecosystem strategies. EAFM caters for all levels, ensuring that local level plans align with higher level strategic decision-making. The features of EAFM are as follows *(www.eafmlearn.org)*:

- EAFM is an integrated management approach across land, water and natural resources that promotes both sustainable use and conservation of the systems that are already connected in the nature/environment;
- EAFM looks at the bigger picture. It recognises that fish and fisheries are part of a broader ecosystem that includes where fish live as well as the people who benefit from catching, trading and eating fish.
- EAFM recognizes the reality that fisheries depend on healthy ecosystems and that different components in an ecosystem, such as fish, habitats, fishers and other users are all connected and can impact each other.
- EAFM strives to find a balance between improving the well-being of the people and building or maintaining a healthy environment so that the benefits derived from fishing are sustained.
- EAFM strives to increase the benefits derived from catching fish without destroying the environment on which fish depend.
- EAFM considers the broader ecological, social and economic dimensions of sustainable development in fisheries and the interactions among ecosystem components. Examples include fish and fishing, post-harvest processing, habitats, pollution and other users;
- EAFM provides a framework to proactively address the underlying issues in a fishery by taking a more thoughtful long-term perspective to planning and management.
- EAFM provides a fisheries relevant framework to help you bring different management strategies/approaches/tools (e.g. co-management, coastal zone management, MPAs etc) together in a clear, logical and structured approach
- EAFM allows the threats to the long-term sustainability of the fishery to be viewed alongside shorter-term economic needs. Trade-offs and compromise agreements can be reached on actions to reduce impacts and enhance compliance.
- EAFM recognises that complex problems facing fisheries may require solutions outside the fishery sector. The use of an EAFM allows outside factors to be recognized and potentially opens the way for constructive dialogue. It also helps find solutions for mitigating negative impacts in different sectors, (e.g. labour and working conditions; vessel registration and licensing; interactions with tourism; improved sewage treatment; zoning of dredging to avoid nursery grounds).

Applying an ecosystem approach to fisheries management (EAFM) is considered the preferred option and the best practice for long-term sustainability of fisheries and the services that fisheries ecosystems provide to the society.

6.0 Conclusion

Marine fisheries can generate greater net benefits and become a stronger engine for rural economic growth and social development in India. However, to achieve this potential, carefully implemented management plan over an extended period of time at both national and state levels must address core policy, legal, institutional and fisheries management issues. It is important that the managers adopt a broader approach and recognise that adopting an inclusive approach with multiple objectives is a priority to fisheries sustainability to fulfil the aspirations of Blue Economy, Marine Spatial Planning, and Target 14 of Sustainable Development Goal.

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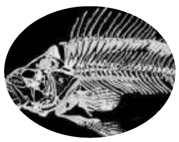
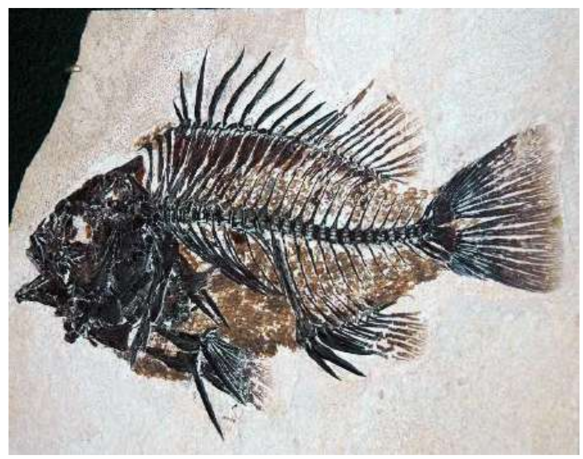
CHAPTER 2

History of Ichthyology

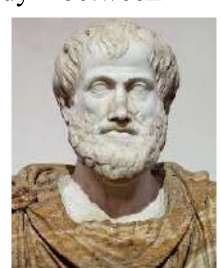


Ichthyology is simply the science of studying fishes. **Ichthyology-** word *ichthy*, deriving from the Greek word *ixthu,* combining form of *ixthus,* meaning "fish". This includes bony fish, cartilaginous fish and jawless fish. Historically, ichthyologists were naturalists who described fishes they collected.



Fish are the most diverse group of vertebrates, with more than one-half of the total vertebrate species. Approximately 33000 living species of fishes were described so far. Now, Ichthyology is considered to be the study of fish populations, their habitat requirements, and fisheries resources.Ichthyology originated near the beginning of the Upper Paleolithic period, about forty thousand years ago, and continues to the present day. Fishes would be just as diverse and successful without ichthyologists studying them, but what we know about their diversity is the product of the efforts of workers worldwide over several centuries

EARLY ICHTHYOLOGY(300 B.C.E.–1499 C.E.)The Greek philosopher and natural historian, Aristotle incorporated ichthyology into formal scientific study between 335 B.C.E. and 322 B.C.E., he provided the earliest taxonomic classification of fish, in which 117 species of Mediterranean fish were accurately described. Furthermore, Aristotle observed the anatomical and behavioural differences between fish and marine mammals. However, this system naturally contained a great number of errors of fact and of interpretation. In the first century B.C.E., Romans were practiced aquaculture according to Pliny the Elder. The Romans focused on trout and mullet and were quite adept at breeding fish in ponds.



Aristotile

THE DEVELOPMENT OF MODERN ICHTHYOLOGY
(1500 C.E.–1799 C.E.)

From 16th century onwards, so many works has been done by different authors. Belon, Salviani and Rondelet studied and wrote on the fishes of the Mediterranean and Europe.

Belon, Salviani and Rondelet

P. Belon travelled in the countries bordering on the eastern part of the Mediterranean, in the years 1547-50; he collected rich stores of positive knowledge, which he deposited in several works. The one most important for the progress of Ichthyology is that entitled *De aquatilibus libri duo*. Belon knows about 110 fishes, of which he gives rude, but generally recognizable, figures. In his descriptions he pays regard to the classical as well as vernacular nomenclature, and states the outward characteristics, sometimes even the number of fin-rays, frequently also the most conspicuous anatomical peculiarities.

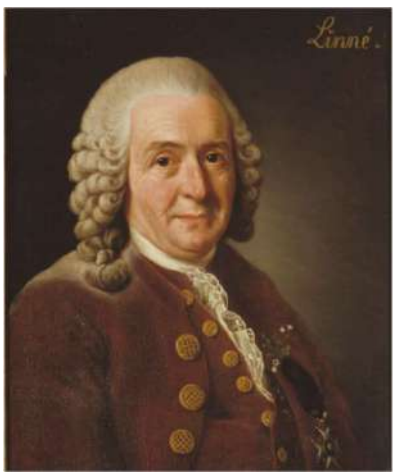
Guillaume Rondelet (1507-1557) work comprises not less than 197 marine and 47 fresh- water fishes in his work *De Piscibus Marinum*. His descriptions are more complete and his figures much more accurate than those of Belon. Hippolyte Salviani (1514-1572) a Roman ichthyologist studied fishes of Italy. He prepared the figures of 92 species on 76 plates. No attempt is made at natural classification, in this respect Salviani is not compared with Rondete and Belon.W. Piso and G. Margrav studied the fauna of Brazil. Margav's observations were published by his colleague, and embodied in a work *Historia naturalis Braziliae* (1648), in which the fourth book treats of the fishes. He describes about 100 species. He made a coloured drawings of the objects observed and described them.

Some anatomical researches were done by different authors, Borreli (1608-79), who wrote a work *Do mote animalium* (1680), in which he explained the mechanism of swimming, and function of the air-bladder; M. MALPIGHI (1628-94), who examined the optic nerve of the sword-fish; SWAMMERDAM (1637-80), who described the intestines of numerous fishes; and J. DUVERNEY (1648-1730), who entered into detailed researches of the organs of respiration.

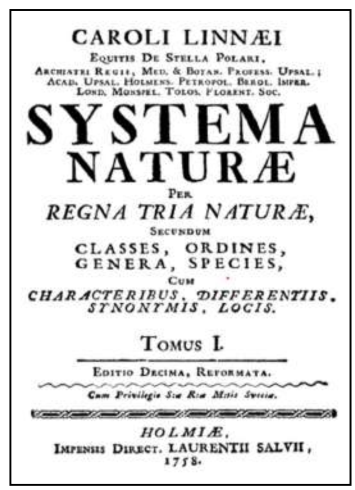
A new era in the history of Ichthyology commences with Ray, Willughby, and Artedi, who were the first to recognise the true principles by which the natural affinities of animals should be determined.

John Ray (1627-1705) and Francis Willughby (1635-1672) from England published *De Historia Piscium* (1686) in which a rational system of classification was proposed, the fishes proper are then arranged in the first place according to the cartilaginous or osseous nature of the skeleton; further subdivisions being formed with regard to the general form of the body, the presence or absence of ventral fins, the soft or spinous structure of the dorsal rays, the number of dorsal fins. Around 420 species are thus arranged and described by them.

Peter Artedi (1705-1735) one of Linnaeus's colleagues, who known as the "father of ichthyology" contributed to Linnaeus's refinement of the principles of taxonomy. He was very much interested in fishes rather than other animals. He collected and organised all of the available Iiterature from the time of Aristotle to his own day. Artedi's work included representatives of most of the major fish groups and he developed standard methods for making counts and measurements of anatomical features that are modernly exploited. He recognized five additional orders of fish: Malacopterygii, Acanthopterygii, Branchiostegi, Chondropterygii, and Plagiuri. He studied some major collections from Hans Sloane in London and Albertus Seba in Amsterdam. In 1735 Artedi drowned at the age of 30. Linnaeus posthumously published Artedi's manuscripts as *Ichthyologia* (1738). The work is divided into two parts *Bibliotheca Ichthyologica* and *Philosophia Ichthyologica*.



Carolus Linnaeus (1707–1778) The classification used within the *Historia Piscium* was improved upon by Carolus Linnaeus (1707–1778), the "father of modern taxonomy." In 1735, Linnaeus published his work on taxonomy, the *Systema Naturae* from Netherlands. The 10th edition of *Systema Naturae* was published in two volumes in 1758 and 1759, which marks the starting point of zoological nomenclature. He introduced the naming of living organisms using binomial nomenclature for animals, something he had already done for plants in his 1753 publication of *Species Plantarum*. Linnaeus work represented a great simplification and rationalisation of the data that had been published on the variety of living organisms. The immediate results were to provide a structure to the knowledge that was accumulating and to provoke more scientific and popular interest in botany and zoology. The *Systema Naturae* was the main framework which naturalists of the English and French explorations of the late 18th century used for classifying the organisms they discovered. Linnaeus's taxonomic approach became the systematic approach to the study of organisms, including fish. Several of Linnaeus students (Daniel Solander; Peter Forsskål; Carl Thunberg and Pehr Osbeck) made significant contributions to ichthyology and several worked in the Indo-pacific region.


CAROLI LINNÆI
EQUITIS DE STELLA POLARI,
ARCHIATRI REGII, MED. & BOTAN. PROFESS. UPSAL.; ACAD. UPSAL. HOLMENS. PETROPOL. BEROL. IMPER. LOND. MONSPEL. TOLOS. FLORENT. SOC.
SYSTEMA NATURÆ
PER
REGNA TRIA NATURÆ,
SECUNDUM
CLASSES, ORDINES, GENERA, SPECIES,
CUM
CHARACTERIBUS, DIFFERENTIIS, SYNONYMIS, LOCIS.
TOMUS I.
EDITIO DECIMA, REFORMATA.
Cum Privilegio S:æ R:æ M:tis Svecæ.
HOLMIÆ,
IMPENSIS DIRECT. LAURENTII SALVII, 1758.

Carl Peter Thunberg (1743—1828), a Swedish doctor and student of Linnaeus, undertook several expeditions in South Africa, Japan, Java and Ceylon. His work included the original descriptions of several species. Pehr Osbeck (1723—1805) described fishes from China and Japan. Forsskål (1732—1763) was worked on fishes of Red Sea. His work included collections of, and observations on, fishes of the Red Sea. Forsskål described nearly 200 species as new. Majority of the fishes he had described have a wide distribution in the Indo-pacific region.

MODERN ERA
(1800 C.E.–Present)

In the late 18th and early 19th centuries the influx to Europe Of new species, particularly from the Indo-Pacific region, provided a great stimulus for the study of these unfamiliar. Marcus Eliescr Bloch (1723-1799), studied fishes from the rivers of Germany and from foreign places. His associate and student, philologist and naturalist Johann Gottlob Theaenus Schneider (1750—1822), who completed the task, publishing *Systema Ichthyologiae Iconibus* (1801). The number of species enumerated in it amounts to 1519. The system of Bloch and Schneider was succeeded by that of Bernard Germain Etienne de Lacépede (1756—1826). Lacépéde completed a great work of compilation and original description that was of major importance to ichthyology. His *Histoire Naturelle des Poissons* was published in five volumes from 1798 to 1803. The author was only relayed on his notes and manuscript and his work was infinitely less than that of his fellow-labourer.

Georges Cuvier (1769-1832) was born in Montbeliard, Frnace. In 1816 he published *Régne Animal* in which he described the structural relationships of animal groups for the classification of fishes, defining orders, families and genera. He used a wide variety of morphological and anatomical characters to describe animals. His great work *Histoire Naturelle des Poissons* were published in different volumes from 1828 to 1849. After Cuvier death in 1832 his work continued by his assistant Achille Valenciennes (1794-1865). The *Histoire Naturelle des Poissons* provided a good foundation for classifying new species. It was the principal text used by zoologists who dealt with fishes.

Jean Jacques Dussumier (1792—1883), a ship-owner and merchant from Bordeaux, was referred to by Cuvier (1828) as 'a young man who has already made several voyages in his own ships to China and India' and credited him with sending collections of fishes from Malabar and the Seychelles to the Muséum National d'Histoire Naturelle in Paris.

Pierre Antoine Delalande (**1787—1823**) had been an assistant naturalist to Etienne Geoffroy Saint-Hilaire and so was a most informed collector. He travelled to Brazil, Cape Verde and the Cape of Good Hope and brought back extensive natural history collections, including large numbers of fishes. Valenciennes described the Yellowtail Kingfish, *Seriola lalandi*, from Delalande's specimens from Brazil.

Eduard Riippell (**1794—1884**), a German naturalist and explorer. He collected fish from the Gulf of Suez from 1826, reported his work in *Fische des Rothen Meeres* (Rüppell 1828), and provided Cuvier with specimens.

Heinrich Kuhl (1797—1821), another German naturalist. In 1820 Kuhl, in Company with his friend and colleague Jan Coenraad Van Hasselt (1797—1823) Of Holland, travelled to the Dutch East Indies.They travelled widely in western Java, collecting plants and animals, and made descriptions and drawings of many species.

Philipp von Siebold (1796—1866) was born in Germany. He joined a trading expedition to Japan as a naturalist-physician. During this time he studied fishes from Japan. Conraad Jacob Temminck (1778-1858) and his colleague Hermann Schlegel (1804-1848) studied von

Siebold's collection of specimens and drawings of fishes to produce the *Pisces* volume of *Fauna Japonica* (1842—1850). This included the description of approximately 40 species.

John Richardson (1787—1865), a British naturalist. He was born in Scotland. He was appointed Assistant Surgeon in the Royal Navy. He wrote accounts dealing with the natural history, and especially the ichthyology, of several other Arctic voyages, and was the author of *Icones Piscium* (1843), *Catalogue of Apodal Fish in the British Museum* (1856), the second edition of *Yarrell's History of British Fishes* (1860), *The Polar Regions* (1861) and *Arctic Ordeal: The Journal of John Richardson* Edited by C. Stuart Houston (1984).

Patrick Russell (1726—1805) was born in Edinburgh and studied medicine. He worked for 20 years in Aleppo, where he combined his work as a doctor with the study of natural history. He moved to the coastal city of Visakhapatnam, India where he was employed by the East India Company to study natural history. Russell (1803) published Descriptions and figures of two hundred fishes collected from Visakhapatnam on the coast of Coromandel.

Francis Buchanan (1762—1829) was also a medical officer in the East India Company. He was born in Scotland. He began his service with the East India Company in 1794 as a surgeon in Bengal. Buchanan's contributions to natural history were mostly in botany and ichthyology. He studied the fishes of the region, in particular the fishes of the Ganges.

John Whitchurch Bennett was a British army officer who worked as a Civil Servant in Ceylon (now Sri Lanka) from 1816 to 1827. He studied fishes from Ceylon and published his work as *Fishes found on the coast of Ceylon*.

Cantor Theodore Cantor (1809—1860) of the Bengal Medical Service (East India Company) was a Danish born physician and naturalist who wrote notes on Indian fishes and was later based in Penang. Here he obtained specimens from the local fishermen and published a *Catalogue of Malayan Fishes* (1850).

Johannes Peter Müller (1801—1858) was born in Nuremberg, Germany and studied medicine and natural science. His work on fishes included reviews of the most primitive of vertebrates (lampreys), primitive fishes (ganoid fishes and lungfish), cartilaginous fishes (sharks and rays) and a revision of Cuvier's fish classification. Friedrich Gustav Jacob Henle (1809-1885) was the student and co-worker of Müller. He studied medicine and became an assistant to Müller at Berlin. Henle worked in the fields of comparative anatomy, histology, physiology and pathology. Müller and Henle cooperated to produce major systematic works on sharks and rays, culminating in their *Systematische Beschreibung der Plagiostomen* (1838-1841). In this book, nearly 40 new genera were defined and most of these are retained today. In all, Müller and Henle described over 100 new species and about 60% of these are regarded as valid.

Peter Bleeker (1819-1878) published 500 separate contributions, chiefly on the fishes of the tropical Indo-Pacific. His book which was not only fully illustrated, it was one of the best 9 volumes from previous works of other authors. The book name is Atlas Ichthyologique des Indes Orientales Néerlandaises, 1862-1877. The literature from that work is the most accurate and comparable to many literature found today.

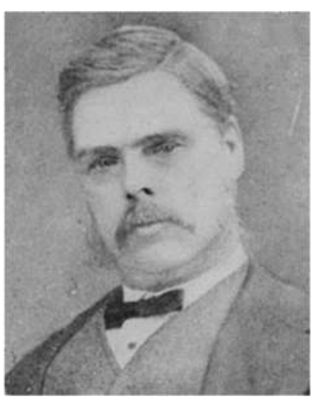
Albert C.L.G. Günther (1830-1914) published his Catalogue of the Fishes of the British Museum between 1859 and 1870, describing over 6,800 species and mentioning another 1,700. Generally considered one of the most influential ichthyologists.

Carl Benjamin Klunzinger (1834—1914), he studied fishes from Red Sea. He published his work named *Synopsis der Fische des Rothen Meeres* (1871). Klunzinger spent several more years collecting fishes from the Red Sea, and published another major work on them in 1884. His work on the Red Sea fishes constituted Klunzinger's major contribution to ichthyology.

Franz Steindachner (1834—1919) studied natural science in Vienna and specialised in ichthyology. He worked on the fish collections of the Kaiserlich-Königliches Hof-Cabinet, enlarging them through collecting in Europe, the Canary Islands and Africa during the 1860s. He directed deep sea expeditions in the Mediterranean between 1891 and 1893 and expeditions in the Red Sea between 1895 and 1898. Steindachner received fish collections by gift, exchange and purchase, from all over the world, describing over 1000 species of fish.

INDIAN ICTHYOLOGY

The foundation for fisheries research in India was laid by some of the early taxonomists notable among them were Cuvier, Valenciennes, Lacepede, Bloch, Schneider, Forsskal, Bleeker and Albert Gunther. There were also naturalists with different avocations in India, who collected and described fishes, other aquatic animals and plants and made observations on bionomics. Notable among those who had contributed to our knowledge are Patrick Russell, Hamilton-Buchanan, Edward Blyth, Stolizka, Sykes, J. McClelland and T.C. Jerdon. The most outstanding contribution was that of Dr. Sir Francis Day.



Francis Day (1829—1889)
A veterinary surgeon and naturalist who travelled extensively in India in the mid-nineteenth century. From 1859 to 1862, he collected and preserved fishes from Cochin and published *The Fishes of Malabar* (1865). He published his major work *The Fishes of India: being a Natural History of the Fishes known to inhabit the seas and fresh waters of India, Burma, and Ceylon* in two volumes (1875—1878) followed by FISHES in the *'Fauna of British India'* series in two volumes (1889) describing 1,418 species are the two most indispensable works on Indian fish taxonomy to date.

In 1975 *A comprehensive volume on Fish and fisheries of India* was authored by Dr. V.G.Jhingaran. The publications on *Commercial Sea Fishes of India* by Talwar and Kacker (1984) and *Fishes of the Laccadive Archipelago* by Jones and Kumaran (1980) are some of the major work done in India. There were many taxonomist contributed to the fisheries research in India during the 20th century. Some of the major contributors are S L Hora, A G K Meneon, K C Jayaram and E G Silas.

Sunder Lal Hora (1896 - 1955), was born in Punjab. He was the second Indian director of the Zoological Survey of India, succeeding Baini Prashad. He was an Indian ichthyologist and was known for his biogeographical theory on the affinities of Western Ghats and Indo-Malayan forms. Hora was also among the Indian pioneers of fish and wildlife conservation. A genus of ricefish, *Horaichthys* ("Hora's Fish"), was created in his honor. The catfish genus *Horabagrus* is named after him. He has to his credit about 425 publications.

A. G. K. Menon, full name Ambat Gopalan Kutty Menon (1921-2002), was an Indian ichthyologist and university professor. He was guided by S L Hora, Menon dealt intensively during his studies and in the years afterwards with the Satpura hypothesis. Menon dealt with a number of higher taxa of fish. During his more than fifty years of research, He published more than 100 scientific publications, many of them monographs. In addition to revisions of a number of taxa, Menon wrote the first descriptions of 43 fish species.

K. C. Jayaram, was the former Deputy Director of Zoological Survey of India. He has a rich experience in freshwater fish taxonomy and zoogeography. He was trained by the late Dr. S. L. Hora in the specialisation of Siluroid fishes. He was considered an authority on the Indian catfishes. He was invited as a consultant by the F A 0 for the preparation of identification sheets for the Siluroid families Ariidae and Plotosidae of the Western Indian Ocean. His major work, *The Handbook of Freshwater Fishes of India, Pakistan, Bangladesh, Burma and Sri Lanka* (1981) gives a full account of fish fauna of the region.

Eric Godwin Silas, born on 10 January 1928 at Demodhera, Ceylon (Sri Lanka). In 1963 he was appointed as Marine Biologist in Central Marine Fisheries Research Station, Mandapam Camp, where he started work on Tunas from the Indian Seas. The Mariculture projects and programmes in CMFRI were initiated by Dr. Silas as Head of the Marine Biology and Oceanography Division. He was appointed as the Director of CMFRI in June 1975. Many Inter-organizational collaborative programmes were initiated by him. The Marine Biological Association of India owes a lot to Dr. Silas for his untiring support for the Association and its Journal. He was its President, and also functioned as the Editor of Its Journal. His upgrading the Central Marine Fisheries Research Institute as a World Class Centre of Research, training and Extension by improving the physical infrastructure of land, buildings, laboratories and amenities, as well as developing trained manpower, both Scientific and Technical of high competence and calibre is well known. Two of the Units he developed at CMFRI, budded and grew to become National Research Centres, namely, The National Bureau of Fish Genetic Resources (NBFGR, ICAR) at Lucknow and the Centre for Marine Living Resources (CMLRE). He has published nearly 300 scientific papers and monographs during his research carrier of over sixty years.

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CHAPTER 3

Ichthyofaunal Diversity of India

INTRODUCTION

Indian fisheries have a great history, appearing with Kautilya's Arthasastra describing fish as a source for consumption and provide manifest that fishery was a well-established industry in India and fish was relished as an article of diet as early as 300 B.C, the ancient Hindus acquired significant knowledge on the habit of fishes and the epic on the second pillar of Emperor Ashoka enacting the prohibition of consumption of fish during a certain lunar period which can be interpreted as a conservation point of view. Modern scientific studies on Indian fishes could be traced to the first works by Linnaeus, Bloch and Schneider, Lacepède, Russell and Hamilton. Cuvier and Valenciennes (1828-1849) reported 70 nominal species off Puducherry, Skyes (1839), Gunther (1860, 1872, 1880) and The Fishes of India by Francis' day (1865-1877) and another book Fauna of British India Series in two volumes (1889) describing 1,418 species are the two most fundamental works on Indian fish taxonomy to date. Alcock (1889, 1890) reported 162 species new to science from Indian waters.

In the 20th century, the basis of comprehensive investigations on the various families and groups of freshwater fishes was made by Chaudhuri along with Hora and his co-workers. Misra published An Aid to Identification of the Commercial Fishes of India and Pakistan and The Fauna of India and Adjacent Countries (Pisces) in 1976. Jones and Kumaran described about 600 species of fishes in the work Fishes of Laccadive Archipelago. Talwar and Kacker presented a precise description of 548 species under 89 families in his work Commercial Sea Fishes of India. The FAO Species Identification Sheets for Fishery- Western Indian Ocean (Fischer and Bianchi) is yet a valuable guide for researchers. Recently, Talwar and Jhingran published report on 930 inland species of India recognized till date.

The elasmobranchs consist of sharks, saw fishes, rays, skates and guitar fishes. They are fished handling various types of gears and in later years have taken up considerable influence in the export market. They are utilized by a diversity of fishing gears like gill nets, long lines and trawls along the Indian coast by both traditional and mechanized sector (Raje et al. 2002). Even though there is no directed fishing for elasmobranchs in certain places of Tamilnadu, large meshed bottom set gillnets called as 'thirukkuvalai' are operated for fishing the rays. They are all predatory feeding on wide range, from zooplankton to benthic invertebrates, bony fishes, sharks, turtles, seabirds and marine mammals (Joshi, 2012). In India, we have recorded out about 110 species of elasmobranch, which comprises 66 species of sharks and 44 species of batoides. Later description of new records and new species may bring to this sum to about 150-170 species from Indian coast only. Whale shark is massive, slow, pelagic filter-feeder, usually

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known swimming on the surface. Viviparous and gravid female have 300 new ones of several stages of development.

SPECIES RICHNESS

Of the 33,059 all fish species from the world, India supports of about 2443 marine fishes owing to 7.4% of the total marine fish resources. Of the overall fish diversity known from India, the marine fishes make up 75.6 percent, containing 2443 species belonging to 927 genera, under 230 families of 40 orders. By revising the new descriptions and additions, the overall number of fish species of India was of the tune of 2492 species belonging to 941 orders, 240 families. Among the fish diversity-rich areas in the marine waters of India, the Andaman and Nicobar archipelago exhibits the highest number of species, 1431, followed by the east coast of India with 1121 species and the west coast with 1071. A list of 1785 species is prepared based on the data of Fish Base, FAO species identification sheets of Western Indian Ocean Area 51 and Eastern Indian Ocean Area 57 (Table 1). We recognize since 91 species of endemic marine fishes to exist in the coastal waters of India. As of now, about 50 marine fishes known from India fall into the vulnerable category as per the IUCN Red List, and about 45 species are Near-Threatened and on the track to vulnerability. But, hardly this species (10 elasmobranchs, 10 seahorses and one grouper) are listed in Schedule I of the Wildlife (Protection) Act, 1972 of the Government of India

Recent analysis shows that 18 resource groups fall under abundant category, five occur under less abundant category and one each fall under declining, depleted and collapsed category. The 18 stocks resource groups under the abundant category or less abundant category showing a good condition of their stock. The less abundant category includes elasmobranchs, threadfins, ribbon fishes, mullets and flat fishes. Big-jawed jumper under the declining category flying fishes under depleted and unicorn cod is in the collapsed category. While certain stocks such as those of Mackerel, Lesser Sardines, White bait, Seer fish, Coastal and oceanic tunas, Croakers, Pig face breams, Groupers, Snappers, Cat fish, Lizard fish, Silver bellies and Goat fishes are exploited all along the Indian coast. Bombay duck is caught mainly along the Gujarat and Maharashtra coast and, to a lesser extent, along certain pockets of Andhra, Orissa and West Bengal coasts. Hilsa is harvested mainly along the West Bengal coast and Gujarat coast.

CONCLUSION

The exploited marine fisheries resources from the coastal area have been reached a maximum from the present fishing grounds up to 200 m depth. The coastal fisheries face several threats such as indiscriminate fishing, habitat degradation, pollution, social conflicts, introduction of highly sophisticated fishing gadgets, need management measures and conservation of marine biodiversity to support sustainable use of marine biodiversity. Human activities are the major causes for losing biodiversity and degradation of marine habitats, which need immediate attention and comprehensive action plan to conserve the biodiversity for living harmony with nature. These measures such as control of excess fleet size, control of the gears, purse seines, ring seines, disco-nets, regulation of mesh size, avoid habitat degradation of nursery areas of that species, reduce the discards of the low value fish, protection of spawners, implementation of reference points and notification of marine reserves for protection and conservation of marine biodiversity.

Table 1. List fish species reported from India (Based on the species data of Fish Base, FAO Species Identification sheets of area 51 &57)

	Species
1	Abalistes stellaris
2	Ablennes hians
3	Abudefduf bengalensis
4	Abudefduf saxatilis
5	Abudefduf septemfasciatus
6	Abudefduf sexfasciatus
7	Abudefduf sordidus
8	Abudefduf vaigiensis
9	Acanthocepola indica
10	Acanthocybium solandri
11	Acanthopagrus arabicus
12	Acanthopagrus berda
13	Acanthopagrus bifasciatus
14	Acanthopagrus longispinnis
15	Acanthoplesiops indicus
16	Acanthosphex leurynnis
17	Acanthurus gahhm
18	Acanthurus leucosternon
19	Acanthurus lineatus
20	Acanthurus mata
21	Acanthurus nigricans
22	Acanthurus nigrofuscus
23	Acanthurus nigroris
24	Acanthurus pyroferus
25	Acanthurus tennentii
26	Acanthurus thompsoni
27	Acanthurus triostegus
28	Acanthurus xanthopterus
29	Acentrogobius caninus
30	Acentrogobius cyanomos
31	Acentrogobius ennorensis
32	Acentrogobius griseus
33	Acentrogobius masoni
34	Acentrogobius viridipunctatus
35	Acreichthys tomentosus
36	Acropoma japonicum
37	Aesopia cornuta
38	Aethaloperca rogaa
39	Aetobatus flagellum
40	Aetobatus narinari
41	Aetobatus ocellatus
42	Aetomylaeus maculatus
43	Aetomylaeus milvus
44	Aetomylaeus nichofii
45	Albula oligolepis
46	Albula vulpes
47	Aldrovandia affinis
48	Aldrovandia mediorostris
49	Aldrovandia phalacra
50	Alectis ciliaris
51	Alectis indica
52	Alepes djedaba
53	Alepes kleinii
54	Alepes melanoptera
55	Alepes vari
56	Alepisaurus ferox
57	Allenbatrachus grunniens
58	Alopias pelagicus
59	Alopias superciliosus
60	Alopias vulpinus
61	Alticus kirkii
62	Aluterus monoceros
63	Aluterus scriptus
64	Ambassis ambassis
65	Ambassis dussumieri
66	Ambassis gymnocephalus
67	Ambassis interrupta
68	Ambassis kopsii
69	Ambassis macracanthus
70	Ambassis miops
71	Ambassis nalua
72	Ambassis urotaenia
73	Amblyeleotris gymnocephala
74	Amblygaster clupeoides
75	Amblygaster leiogaster
76	Amblygaster sirm
77	Amblygobius albimaculatus
78	Amblyotrypauchen arctocephalus
79	Amoya madraspatensis
80	Amoya veliensis
81	Amphiprion bicinctus
82	Amphiprion chrysogaster
83	Amphiprion clarkii
84	Amphiprion ephippium
85	Amphiprion frenatus
86	Amphiprion nigripes
87	Amphiprion ocellaris
88	Amphiprion percula
89	Amphiprion polymnus
90	Amphiprion sebae
91	Anacanthus barbatus
92	Anampses caeruleopunctatus
93	Anampses meleagrides
94	Anarchias allardicei

95	*Anarchias cantonensis*
96	*Andamia reyi*
97	*Anguilla bengalensis*
98	*Anguilla bicolor*
99	*Anodontostoma chacunda*
100	*Anodontostoma selangkat*
101	*Anodontostoma thailandiae*
102	*Anoxypristis cuspidata*
103	*Antennablennius bifilum*
104	*Antennarius hispidus*
105	*Antennarius indicus*
106	*Antennarius pictus*
107	*Antennarius striatus*
108	*Antennatus coccineus*
109	*Antennatus nummifer*
110	*Antigonia indica*
111	*Antigonia rubescens*
112	*Anyperodon leucogrammicus*
113	*Aphanius dispar dispar*
114	*Aphareus furca*
115	*Aphareus rutilans*
116	*Apistus carinatus*
117	*Apocryptes bato*
118	*Apogon coccineus*
119	*Apogonichthyoides taeniatus*
120	*Apogonichthys ocellatus*
121	*Apolemichthys xanthurus*
122	*Aporops bilinearis*
123	*Aprion virescens*
124	*Apristurus investigatoris*
125	*Apsilus fuscus*
126	*Archamia bleekeri*
127	*Argyrops spinifer*
128	*Argyrosomus amoyensis*
129	*Argyrosomus hololepidotus*
130	*Argyrosomus japonicus*
131	*Ariomma indicum*
132	*Ariosoma anago*
133	*Arius arius*
134	*Arius gagora*
135	*Arius jella*
136	*Arius maculatus*
137	*Arius malabaricus*

138	*Arius subrostratus*
139	*Arius sumatranus*
140	*Arius venosus*
141	*Arnoglossus aspilos*
142	*Arnoglossus tapeinosoma*
143	*Arothron hispidus*
144	*Arothron immaculatus*
145	*Arothron leopardus*
146	*Arothron meleagris*
147	*Arothron nigropunctatus*
148	*Arothron reticularis*
149	*Arothron stellatus*
150	*Aspidontus tractus*
151	*Asterorhombus cocosensis*
152	*Asterropteryx semipunctata*
153	*Atelomycterus marmoratus*
154	*Atherinomorus duodecimalis*
155	*Atherinomorus lacunosus*
156	*Atherinomorus pinguis*
157	*Atherion africanum*
158	*Atrobucca alcocki*
159	*Atrobucca antonbruun*
160	*Atrobucca nibe*
161	*Atrobucca trewavasae*
162	*Atropus atropos*
163	*Atule mate*
164	*Aulacocephalus temminckii*
165	*Aulastomatomorpha phospherops*
166	*Aulostomus chinensis*
167	*Aurigequula fasciata*
168	*Auxis rochei*
169	*Auxis thazard*
170	*Awaous fluviatilis*
171	*Bahaba chaptis*
172	*Balistapus undulatus*
173	*Balistes ellioti*
174	*Balistes rotundatus*
175	*Balistes vetula*
176	*Balistoides conspicillum*
177	*Balistoides viridescens*
178	*Bascanichthys deraniyagalai*
179	*Bascanichthys longipinnis*

180	*Bassozetus glutinosus*
181	*Bathycallionymus kaianus*
182	*Bathyclupea hoskynii*
183	*Bathygadus furvescens*
184	*Bathygobius cyclopterus*
185	*Bathygobius fuscus*
186	*Bathygobius niger*
187	*Bathygobius ostreicola*
188	*Bathygobius petrophilus*
189	*Bathygobius smithi*
190	*Bathymyrus echinorhynchus*
191	*Bathypterois atricolor*
192	*Bathypterois guentheri*
193	*Bathypterois insularum*
194	*Bathytroctes squamosus*
195	*Bathyuroconger vicinus*
196	*Batrachocephalus mino*
197	*Bembras japonica*
198	*Bembrops caudimacula*
199	*Bembrops platyrhynchus*
200	*Benthobatis moresbyi*
201	*Benthodesmus oligoradiatus*
202	*Benthodesmus tenuis*
203	*Beryx decadactylus*
204	*Beryx splendens*
205	*Bhanotia fasciolata*
206	*Bleekeria kallolepis*
207	*Bleekeria murtii*
208	*Blenniella leopardus*
209	*Blenniella periophthalmus*
210	*Bodianus neilli*
211	*Boleophthalmus boddarti*
212	*Boleophthalmus dussumieri*
213	*Boleophthalmus pectinirostris*
214	*Bolinichthys pyrsobolus*
215	*Bostrychus sinensis*
216	*Bothus leopardinus*
217	*Bothus mancus*
218	*Bothus myriaster*
219	*Bothus pantherinus*
220	*Brachirus macrolepis*
221	*Brachirus orientalis*
222	*Brachirus pan*
223	*Brachirus panoides*

224	Brachypleura novaezeelandiae
225	Brachypterois serrulata
226	Bregmaceros mcclellandi
227	Brotula multibarbata
228	Butis amboinensis
229	Butis butis
230	Butis koilomatodon
231	Butis melanostigma
232	Bythaelurus hispidus
233	Caecula pterygera
234	Caesio caerulaurea
235	Caesio cuning
236	Caesio lunaris
237	Caesio teres
238	Caesio varilineata
239	Caesio xanthonota
240	Callechelys catostoma
241	Callionymus carebares
242	Callionymus erythraeus
243	Callionymus filamentosus
244	Callionymus fluviatilis
245	Callionymus hindsii
246	Callionymus japonicus
247	Callionymus kotthausi
248	Callionymus margaretae
249	Callionymus marleyi
250	Callionymus megastomus
251	Callionymus sagitta
252	Callionymus schaapii
253	Callogobius hasseltii
254	Callogobius seshaiyai
255	Calotomus spinidens
256	Calotomus viridescens
257	Cantherhines sandwichiensis
258	Canthigaster amboinensis
259	Canthigaster bennetti
260	Canthigaster cyanospilota
261	Canthigaster margaritata
262	Caracanthus maculatus
263	Caracanthus unipinna
264	Carangoides armatus
265	Carangoides chrysophrys
266	Carangoides ciliarius

267	Carangoides coeruleopinnatus
268	Carangoides dinema
269	Carangoides ferdau
270	Carangoides fulvoguttatus
271	Carangoides gymnostethus
272	Carangoides hedlandensis
273	Carangoides humerosus
274	Carangoides malabaricus
275	Carangoides oblongus
276	Carangoides orthogrammus
277	Carangoides plagiotaenia
278	Carangoides praeustus
279	Carangoides talamparoides
280	Caranx heberi
281	Caranx hippos
282	Caranx ignobilis
283	Caranx lugubris
284	Caranx melampygus
285	Caranx papuensis
286	Caranx sexfasciatus
287	Caranx tille
288	Carapus mourlani
289	Carcharhinus altimus
290	Carcharhinus amblyrhynchoides
291	Carcharhinus amboinensis
292	Carcharhinus brevipinna
293	Carcharhinus dussumieri
294	Carcharhinus falciformis
295	Carcharhinus hemiodon
296	Carcharhinus leucas
297	Carcharhinus limbatus
298	Carcharhinus longimanus
299	Carcharhinus macloti
300	Carcharhinus melanopterus
301	Carcharhinus sealei
302	Carcharhinus sorrah
303	Carcharias taurus
304	Carcharias tricuspidatus
305	Centriscus scutatus
306	Centroberyx spinosus
307	Centrobranchus andreae
308	Centrogenys vaigiensis
309	Centrophorus moluccensis
310	Centrophorus squamosus
311	Centropyge bicolor
312	Centropyge eibli

313	Centropyge flavipectoralis
314	Centropyge multispinis
315	Centroscyllium ornatum
316	Centroscymnus crepidater
317	Cephalocassis jatia
318	Cephalopholis argus
319	Cephalopholis aurantia
320	Cephalopholis boenak
321	Cephalopholis formosa
322	Cephalopholis leopardus
323	Cephalopholis miniata
324	Cephalopholis sexmaculata
325	Cephalopholis sonnerati
326	Cephalopholis urodeta
327	Cephalopsetta ventrocellatus
328	Cephaloscyllium silasi
329	Cephaloscyllium sufflans
330	Chaenogaleus macrostoma
331	Chaetodon andamanensis
332	Chaetodon auriga
333	Chaetodon bennetti
334	Chaetodon citrinellus
335	Chaetodon collare
336	Chaetodon decussatus
337	Chaetodon ephippium
338	Chaetodon falcula
339	Chaetodon gardineri
340	Chaetodon guttatissimus
341	Chaetodon interruptus
342	Chaetodon kleinii
343	Chaetodon lunula
344	Chaetodon melannotus
345	Chaetodon meyeri
346	Chaetodon octofasciatus
347	Chaetodon punctatofasciatus
348	Chaetodon speculum
349	Chaetodon trifascialis
350	Chaetodon trifasciatus
351	Chaetodon vagabundus
352	Chaetodon xanthocephalus
353	Chaetodontoplus melanosoma
354	Chalixodytes tauensis
355	Champsodon capensis
356	Champsodon vorax
357	Chanos chanos
358	Chascanopsetta lugubris

359	*Chauliodus pammelas*
360	*Chauliodus sloani*
361	*Chaunax penicillatus*
362	*Chaunax pictus*
363	*Cheilinus chlorourus*
364	*Cheilinus fasciatus*
365	*Cheilinus oxycephalus*
366	*Cheilinus trilobatus*
367	*Cheilinus undulatus*
368	*Cheilio inermis*
369	*Cheilodipterus arabicus*
370	*Cheilodipterus lachneri*
371	*Cheilodipterus quinquelineatus*
372	*Cheilopogon abei*
373	*Cheilopogon cyanopterus*
374	*Cheilopogon exsiliens*
375	*Cheilopogon furcatus*
376	*Cheilopogon intermedius*
377	*Cheilopogon nigricans*
378	*Cheilopogon spilopterus*
379	*Cheilopogon suttoni*
380	*Cheiloprion labiatus*
381	*Cheimerius nufar*
382	*Chelidoperca investigatoris*
383	*Chelidoperca maculicauda*
384	*Chelidoperca occipitalis*
385	*Chelmon rostratus*
386	*Chelon macrolepis*
387	*Chelon melinopterus*
388	*Chelon parsia*
389	*Chelon planiceps*
390	*Chelon subviridis*
391	*Chelonodon patoca*
392	*Chiloscyllium arabicum*
393	*Chiloscyllium griseum*
394	*Chiloscyllium indicum*
395	*Chiloscyllium plagiosum*
396	*Chiloscyllium punctatum*
397	*Chirocentrus dorab*
398	*Chirocentrus nudus*
399	*Chlorophthalmus agassizi*
400	*Chlorophthalmus corniger*
401	*Chlorurus enneacanthus*
402	*Chlorurus gibbus*
403	*Chlorurus oedema*
404	*Chlorurus sordidus*
405	*Choerodon anchorago*
406	*Choerodon robustus*
407	*Choeroichthys brachysoma*
408	*Choeroichthys sculptus*
409	*Choridactylus multibarbus*
410	*Chromis chrysura*
411	*Chromis dimidiata*
412	*Chromis opercularis*
413	*Chromis ternatensis*
414	*Chromis viridis*
415	*Chromis weberi*
416	*Chrysiptera biocellata*
417	*Chrysiptera brownriggii*
418	*Chrysiptera cyanea*
419	*Chrysiptera glauca*
420	*Chrysiptera unimaculata*
421	*Chrysochir aureus*
422	*Cirrhilabrus exquisitus*
423	*Cirrhitichthys aureus*
424	*Cirrhitichthys bleekeri*
425	*Cirrhitus pinnulatus*
426	*Cirripectes castaneus*
427	*Cirripectes filamentosus*
428	*Cirripectes perustus*
429	*Cirripectes polyzona*
430	*Cirripectes quagga*
431	*Cirripectes stigmaticus*
432	*Cirripectes variolosus*
433	*Cociella crocodilus*
434	*Cocotropus roseus*
435	*Coelorinchus flabellispinnis*
436	*Coelorinchus parallelus*
437	*Coilia dussumieri*
438	*Coilia grayii*
439	*Coilia neglecta*
440	*Coilia ramcarati*
441	*Coilia reynaldi*
442	*Colletteichthys dussumieri*
443	*Colletteichthys flavipinnis*
444	*Colletteichthys occidentalis*
445	*Coloconger raniceps*
446	*Conger cinereus*
447	*Congresox talabon*
448	*Congresox talabonoides*
449	*Congrogadus subducens*
450	*Corica soborna*
451	*Coris aygula*
452	*Coris cuvieri*
453	*Coris formosa*
454	*Coris gaimard*
455	*Coryphaena equiselis*
456	*Coryphaena hippurus*
457	*Coryphaenoides hextii*
458	*Coryphaenoides macrolophus*
459	*Coryphaenoides nasutus*
460	*Coryphaenoides woodmasoni*
461	*Corythoichthys intestinalis*
462	*Crenidens crenidens*
463	*Crenimugil crenilabis*
464	*Cromileptes altivelis*
465	*Crossorhombus valderostratus*
466	*Ctenochaetus striatus*
467	*Ctenochaetus strigosus*
468	*Ctenochaetus truncatus*
469	*Ctenogobiops crocineus*
470	*Cubiceps whiteleggii*
471	*Cyclichthys orbicularis*
472	*Cyclichthys spilostylus*
473	*Cyclothone microdon*
474	*Cyclothone signata*
475	*Cymolutes lecluse*
476	*Cynoglossus arel*
477	*Cynoglossus bilineatus*
478	*Cynoglossus carpenteri*
479	*Cynoglossus cynoglossus*
480	*Cynoglossus dispar*
481	*Cynoglossus dubius*
482	*Cynoglossus itinus*
483	*Cynoglossus kopsii*
484	*Cynoglossus lachneri*
485	*Cynoglossus lida*
486	*Cynoglossus lingua*
487	*Cynoglossus macrostomus*
488	*Cynoglossus monopus*
489	*Cynoglossus puncticeps*
490	*Cynoglossus semifasciatus*
491	*Cypselurus naresii*
492	*Cypselurus oligolepis*
493	*Cyttopsis rosea*
494	*Dactyloptena gilberti*

495	*Dactyloptena macracantha*
496	*Dactyloptena orientalis*
497	*Dactyloptena peterseni*
498	*Dascyllus aruanus*
499	*Dascyllus reticulatus*
500	*Dascyllus trimaculatus*
501	*Dasyatis bennettii*
502	*Dasyatis microps*
503	*Dasyatis pastinaca*
504	*Dasyatis zugei*
505	*Dayella malabarica*
506	*Daysciaena albida*
507	*Deania profundorum*
508	*Decapterus macarellus*
509	*Decapterus macrosoma*
510	*Decapterus russelli*
511	*Dendrochirus brachypterus*
512	*Dendrophysa russelii*
513	*Dermogenys brachynotopterus*
514	*Dermogenys pusilla*
515	*Desmodema polystictum*
516	*Diagramma pictum*
517	*Diaphus luetkeni*
518	*Diaphus splendidus*
519	*Dibranchus nasutus*
520	*Diceratias bispinosus*
521	*Dicrolene intronigar*
522	*Dinematichthys iluocoeteoides*
523	*Diodon holocanthus*
524	*Diodon hystrix*
525	*Diplodus noct*
526	*Diplodus sargus kotschyi*
527	*Diploprion bifasciatum*
528	*Dipterygonotus balteatus*
529	*Dipturus johannisdavisi*
530	*Dischistodus perspicillatus*
531	*Dischistodus prosopotaenia*
532	*Doryrhamphus excisus excisus*
533	*Drepane longimana*
534	*Drepane punctata*
535	*Drombus dentifer*
536	*Drombus globiceps*
537	*Dussumieria acuta*
538	*Dussumieria elopsoides*
539	*Ebosia falcata*
540	*Echeneis naucrates*
541	*Echidna delicatula*
542	*Echidna leucotaenia*
543	*Echidna nebulosa*
544	*Echidna polyzona*
545	*Echinorhinus brucus*
546	*Ecsenius midas*
547	*Ecsenius pulcher*
548	*Egglestonichthys melanoptera*
549	*Ehirava fluviatilis*
550	*Elagatis bipinnulata*
551	*Eleotris fusca*
552	*Eleotris lutea*
553	*Eleotris melanosoma*
554	*Eleutherochir opercularis*
555	*Eleutheronema tetradactylum*
556	*Ellochelon vaigiensis*
557	*Elops machnata*
558	*Encheliophis boraborensis*
559	*Encheliophis gracilis*
560	*Encheliophis homei*
561	*Enchelybrotula paucidens*
562	*Enchelynassa canina*
563	*Enchelyurus kraussii*
564	*Encrasicholina devisi*
565	*Encrasicholina heteroloba*
566	*Encrasicholina punctifer*
567	*Engyprosopon grandisquama*
568	*Enneapterygius elegans*
569	*Enneapterygius fasciatus*
570	*Enneapterygius pusillus*
571	*Entomacrodus striatus*
572	*Entomacrodus vermiculatus*
573	*Ephippus orbis*
574	*Epibulus insidiator*
575	*Epinephelus areolatus*
576	*Epinephelus bleekeri*
577	*Epinephelus chabaudi*
578	*Epinephelus chlorostigma*
579	*Epinephelus coeruleopunctatus*
580	*Epinephelus coioides*
581	*Epinephelus corallicola*
582	*Epinephelus diacanthus*
583	*Epinephelus epistictus*
584	*Epinephelus erythrurus*
585	*Epinephelus fasciatus*
586	*Epinephelus faveatus*
587	*Epinephelus flavocaeruleus*
588	*Epinephelus fuscoguttatus*
589	*Epinephelus hexagonatus*
590	*Epinephelus lanceolatus*
591	*Epinephelus latifasciatus*
592	*Epinephelus longispinis*
593	*Epinephelus macrospilos*
594	*Epinephelus maculatus*
595	*Epinephelus malabaricus*
596	*Epinephelus marginatus*
597	*Epinephelus melanostigma*
598	*Epinephelus merra*
599	*Epinephelus morrhua*
600	*Epinephelus poecilonotus*
601	*Epinephelus polylepis*
602	*Epinephelus polyphekadion*
603	*Epinephelus quoyanus*
604	*Epinephelus radiatus*
605	*Epinephelus rivulatus*
606	*Epinephelus spilotoceps*
607	*Epinephelus stoliczkae*
608	*Epinephelus summana*
609	*Epinephelus tauvina*
610	*Epinephelus tukula*
611	*Epinephelus undulosus*
612	*Epinnula magistralis*
613	*Equulites elongatus*
614	*Equulites leuciscus*
615	*Equulites lineolatus*
616	*Eridacnis radcliffei*
617	*Erythrocles acarina*
618	*Escualosa thoracata*
619	*Etelis carbunculus*
620	*Etelis coruscans*
621	*Etelis radiosus*
622	*Etmopterus pusillus*
623	*Eubleekeria jonesi*
624	*Eubleekeria rapsoni*
625	*Eubleekeria splendens*
626	*Eugnathogobius mas*
627	*Euleptorhamphus viridis*
628	*Eumecichthys fiski*
629	*Eupleurogrammus glossodon*
630	*Eupleurogrammus muticus*
631	*Eurypegasus draconis*
632	*Eusphyra blochii*
633	*Eusurculus andamanensis*

634	*Euthynnus affinis*
635	*Eviota distigma*
636	*Exallias brevis*
637	*Exocoetus monocirrhus*
638	*Exocoetus volitans*
639	*Exyrias puntang*
640	*Favonigobius reichei*
641	*Fenestraja mamillidens*
642	*Fibramia thermalis*
643	*Filimanus heptadactyla*
644	*Filimanus similis*
645	*Filimanus xanthonema*
646	*Fistularia petimba*
647	*Foa brachygramma*
648	*Forcipiger longirostris*
649	*Fowleria aurita*
650	*Fusigobius neophytus*
651	*Gadomus multifilis*
652	*Galeocerdo cuvier*
653	*Gazza achlamys*
654	*Gazza minuta*
655	*Gazza rhombea*
656	*Gempylus serpens*
657	*Gerres erythrourus*
658	*Gerres filamentosus*
659	*Gerres infasciatus*
660	*Gerres limbatus*
661	*Gerres longirostris*
662	*Gerres macracanthus*
663	*Gerres oblongus*
664	*Gerres oyena*
665	*Gerres phaiya*
666	*Gerres setifer*
667	*Giuris margaritacea*
668	*Glaucostegus granulatus*
669	*Glaucostegus halavi*
670	*Glaucostegus typus*
671	*Glossogobius giuris*
672	*Glossogobius kokius*
673	*Glossogobius minutus*
674	*Glyphis gangeticus*
675	*Glyptophidium argenteum*
676	*Gnathanodon speciosus*
677	*Gnathodentex aureolineatus*
678	*Gnatholepis cauerensis*
679	*Gobiodon citrinus*
680	*Gobiodon rivulatus*
681	*Gobiopsis canalis*
682	*Gobiopsis macrostoma*
683	*Gobiopsis woodsi*
684	*Gobiopterus smithi*
685	*Gobius bontii*
686	*Gomphosus caeruleus*
687	*Gomphosus varius*
688	*Gorgasia maculata*
689	*Grammatobothus polyophthalmus*
690	*Grammatorcynus bicarinatus*
691	*Grammistes sexlineatus*
692	*Grammoplites scaber*
693	*Grammoplites suppositus*
694	*Gymnapogon africanus*
695	*Gymnocaesio gymnoptera*
696	*Gymnocranius elongatus*
697	*Gymnocranius grandoculis*
698	*Gymnocranius griseus*
699	*Gymnomuraena zebra*
700	*Gymnosarda unicolor*
701	*Gymnothorax afer*
702	*Gymnothorax buroensis*
703	*Gymnothorax enigmaticus*
704	*Gymnothorax favagineus*
705	*Gymnothorax fimbriatus*
706	*Gymnothorax flavimarginatus*
707	*Gymnothorax hepaticus*
708	*Gymnothorax javanicus*
709	*Gymnothorax meleagris*
710	*Gymnothorax monochrous*
711	*Gymnothorax monostigma*
712	*Gymnothorax pictus*
713	*Gymnothorax pseudothyrsoideus*
714	*Gymnothorax punctatofasciatus*
715	*Gymnothorax punctatus*
716	*Gymnothorax randalli*
717	*Gymnothorax reticularis*
718	*Gymnothorax richardsonii*
719	*Gymnothorax rueppelliae*
720	*Gymnothorax thyrsoideus*
721	*Gymnothorax tile*
722	*Gymnothorax undulatus*
723	*Gymnura japonica*
724	*Gymnura micrura*
725	*Gymnura poecilura*
726	*Gymnura tentaculata*
727	*Gymnura zonura*
728	*Halaelurus buergeri*
729	*Halaelurus quagga*
730	*Halichoeres argus*
731	*Halichoeres cosmetus*
732	*Halichoeres hortulanus*
733	*Halichoeres leucoxanthus*
734	*Halichoeres marginatus*
735	*Halichoeres nebulosus*
736	*Halichoeres nigrescens*
737	*Halichoeres pardaleocephalus*
738	*Halichoeres scapularis*
739	*Halichoeres timorensis*
740	*Halichoeres zeylonicus*
741	*Halicmetus ruber*
742	*Halidesmus thomaseni*
743	*Halieutaea coccinea*
744	*Halieutaea indica*
745	*Halieutaea stellata*
746	*Halosaurus carinicauda*
747	*Hapalogenys bengalensis*
748	*Haptogenys bipunctata*
749	*Harpadon nehereus*
750	*Harpadon squamosus*
751	*Harpadon translucens*
752	*Helcogramma ellioti*
753	*Helcogramma gymnauchen*
754	*Helcogramma shinglensis*
755	*Helcogramma trigloides*
756	*Helotes sexlineatus*
757	*Hemigaleus microstoma*
758	*Hemigobius hoevenii*
759	*Hemigymnus fasciatus*
760	*Hemigymnus melapterus*
761	*Hemipristis elongata*
762	*Hemiramphus archipelagicus*
763	*Hemiramphus far*
764	*Hemiramphus lutkei*
765	*Hemitaurichthys zoster*
766	*Heniochus acuminatus*
767	*Heniochus chrysostomus*
768	*Heniochus monoceros*
769	*Heniochus pleurotaenia*
770	*Heniochus singularius*
771	*Heptranchias perlo*
772	*Herklotsichthys punctatus*

773	Herklotsichthys quadrimaculatus
774	Herpetoichthys regius
775	Hetereleotris zonata
776	Heteroconger hassi
777	Heteroconger obscurus
778	Heteromycteris oculus
779	Heteronarce prabhui
780	Heteropriacanthus cruentatus
781	Hexanchus griseus
782	Hexanematichthys sagor
783	Hexatrygon bickelli
784	Hilsa kelee
785	Himantura alcockii
786	Himantura bleekeri
787	Himantura fai
788	Himantura fava
789	Himantura gerrardi
790	Himantura imbricata
791	Himantura jenkinsii
792	Himantura leoparda
793	Himantura marginata
794	Himantura uarnak
795	Himantura undulata
796	Himantura walga
797	Hippichthys cyanospilos
798	Hippichthys penicillus
799	Hippichthys spicifer
800	Hippocampus fuscus
801	Hippocampus histrix
802	Hippocampus kelloggi
803	Hippocampus kuda
804	Hippocampus trimaculatus
805	Hipposcarus harid
806	Hirculops cornifer
807	Hirundichthys coromandelensis
808	Hirundichthys indicus
809	Hirundichthys oxycephalus
810	Hirundichthys speculiger
811	Histrio histrio
812	Holcomycteronus pterotus
813	Hologymnosus annulatus
814	Hologymnosus doliatus
815	Hoplolatilus fronticinctus
816	Hoplostethus mediterraneus
817	Hygophum reinhardtii
818	Hymenocephalus italicus
819	Hypoatherina barnesi
820	Hypoatherina temminckii
821	Hypoatherina valenciennei
822	Hyporhamphus affinis
823	Hyporhamphus balinensis
824	Hyporhamphus dussumieri
825	Hyporhamphus limbatus
826	Hyporhamphus quoyi
827	Hyporhamphus sindensis
828	Hyporhamphus unicuspis
829	Hyporhamphus unifasciatus
830	Hyporhamphus xanthopterus
831	Hyporthodus octofasciatus
832	Iago omanensis
833	Ichthyocampus carce
834	Ichthyscopus lebeck
835	Ilisha elongata
836	Ilisha filigera
837	Ilisha kampeni
838	Ilisha megaloptera
839	Ilisha melastoma
840	Ilisha obfuscata
841	Ilisha sirishai
842	Ilisha striatula
843	Incara multisquamatus
844	Inegocia japonica
845	Iniistius bimaculatus
846	Iniistius cyanifrons
847	Iniistius dea
848	Iniistius pavo
849	Iniistius pentadactylus
850	Iniistius twistii
851	Inimicus caledonicus
852	Inimicus cuvieri
853	Inimicus sinensis
854	Iso natalensis
855	Istiblennius dussumieri
856	Istiblennius edentulus
857	Istiblennius lineatus
858	Istiblennius spilotus
859	Istigobius ornatus
860	Istigobius spence
861	Istiompax indica
862	Istiophorus platypterus
863	Isurus oxyrinchus
864	Jaydia poecilopterus
865	Johnius amblycephalus
866	Johnius belangerii
867	Johnius borneensis
868	Johnius carouna
869	Johnius carutta
870	Johnius coitor
871	Johnius dussumieri
872	Johnius elongatus
873	Johnius glaucus
874	Johnius macropterus
875	Johnius macrorhynus
876	Johnius mannarensis
877	Johnius plagiostoma
878	Kajikia audax
879	Kali indica
880	Karalla daura
881	Karalla dussumieri
882	Kathala axillaris
883	Katsuwonus pelamis
884	Ketengus typus
885	Kraemeria samoensis
886	Kuhlia mugil
887	Kuhlia rupestris
888	Kumococius rodericensis
889	Kurtus indicus
890	Kyphosus bigibbus
891	Kyphosus cinerascens
892	Kyphosus vaigiensis
893	Labroides dimidiatus
894	Lactarius lactarius
895	Lactoria cornuta
896	Lagocephalus guentheri
897	Lagocephalus inermis
898	Lagocephalus lagocephalus
899	Lagocephalus lunaris
900	Lagocephalus spadiceus
901	Lalmohania velutina
902	Lamiopsis temminckii
903	Lamnostoma orientalis
904	Lamnostoma polyophthalmum
905	Lates calcarifer
906	Leiognathus berbis
907	Leiognathus brevirostris
908	Leiognathus equulus
909	Leiognathus longispinis
910	Leiognathus striatus
911	Leiuranus semicinctus

912	*Lepidocybium flavobrunneum*
913	*Lepidopus caudatus*
914	*Lepidotrigla bispinosa*
915	*Lepidotrigla faurei*
916	*Lepidotrigla longipinnis*
917	*Lepidotrigla omanensis*
918	*Lepidozygus tapeinosoma*
919	*Leptojulis chrysotaenia*
920	*Leptojulis cyanopleura*
921	*Leptomelanosoma indicum*
922	*Leptoscarus vaigiensis*
923	*Lepturacanthus pantului*
924	*Lepturacanthus savala*
925	*Lethrinus conchyliatus*
926	*Lethrinus erythracanthus*
927	*Lethrinus harak*
928	*Lethrinus lentjan*
929	*Lethrinus mahsena*
930	*Lethrinus microdon*
931	*Lethrinus miniatus*
932	*Lethrinus nebulosus*
933	*Lethrinus obsoletus*
934	*Lethrinus olivaceus*
935	*Lethrinus ornatus*
936	*Lethrinus rubrioperculatus*
937	*Lethrinus semicinctus*
938	*Lethrinus variegatus*
939	*Lethrinus xanthochilus*
940	*Liachirus melanospilos*
941	*Liopropoma randalli*
942	*Lipocheilus carnolabrum*
943	*Liza carinata*
944	*Liza klunzingeri*
945	*Liza mandapamensis*
946	*Lobotes surinamensis*
947	*Lophiodes gracilimanus*
948	*Lophiodes mutilus*
949	*Lophiodes triradiatus*
950	*Lophiomus setigerus*
951	*Lophodiodon calori*
952	*Lophodolos indicus*
953	*Loxodon macrorhinus*
954	*Lutjanus argentimaculatus*
955	*Lutjanus bengalensis*
956	*Lutjanus biguttatus*
957	*Lutjanus bohar*
958	*Lutjanus carponotatus*
959	*Lutjanus decussatus*
960	*Lutjanus dodecacanthoides*
961	*Lutjanus ehrenbergii*
962	*Lutjanus erythropterus*
963	*Lutjanus fulviflamma*
964	*Lutjanus fulvus*
965	*Lutjanus gibbus*
966	*Lutjanus guilcheri*
967	*Lutjanus indicus*
968	*Lutjanus johnii*
969	*Lutjanus kasmira*
970	*Lutjanus lemniscatus*
971	*Lutjanus lunulatus*
972	*Lutjanus lutjanus*
973	*Lutjanus madras*
974	*Lutjanus malabaricus*
975	*Lutjanus monostigma*
976	*Lutjanus quinquelineatus*
977	*Lutjanus rivulatus*
978	*Lutjanus rufolineatus*
979	*Lutjanus russellii*
980	*Lutjanus sanguineus*
981	*Lutjanus sebae*
982	*Lutjanus vitta*
983	*Macolor niger*
984	*Macropharyngodon meleagris*
985	*Macrorhamphosodes platycheilus*
986	*Macrospinosa cuja*
987	*Mahidolia mystacina*
988	*Makaira mazara*
989	*Makaira nigricans*
990	*Malacanthus latovittatus*
991	*Malacocephalus laevis*
992	*Malthopsis lutea*
993	*Manta birostris*
994	*Marleyella bicolorata*
995	*Megalaspis cordyla*
996	*Megalops cyprinoides*
997	*Meganthias filiferus*
998	*Meiacanthus smithi*
999	*Melichthys niger*
1000	*Mene maculata*
1001	*Microphis brachyurus*
1002	*Mimoblennius atrocinctus*
1003	*Minous dempsterae*
1004	*Minous inermis*
1005	*Minous monodactylus*
1006	*Mobula eregoodootenkee*
1007	*Mobula japanica*
1008	*Mobula kuhlii*
1009	*Mobula mobular*
1010	*Mobula thurstoni*
1011	*Mola mola*
1012	*Monocentris japonica*
1013	*Monodactylus argenteus*
1014	*Monodactylus falciformis*
1015	*Monomitopus conjugator*
1016	*Monomitopus nigripinnis*
1017	*Monotaxis grandoculis*
1018	*Moolgarda cunnesius*
1019	*Moolgarda seheli*
1020	*Moringua abbreviata*
1021	*Moringua bicolor*
1022	*Moringua guthriana*
1023	*Moringua javanica*
1024	*Moringua microchir*
1025	*Mugil cephalus*
1026	*Mulloidichthys flavolineatus*
1027	*Muraenesox bagio*
1028	*Muraenesox cinereus*
1029	*Muraenichthys gymnopterus*
1030	*Muraenichthys schultzei*
1031	*Mustelus mangalorensis*
1032	*Mustelus mosis*
1033	*Myctophum affine*
1034	*Myctophum aurolaternatum*
1035	*Myctophum indicum*
1036	*Myctophum spinosum*
1037	*Myrichthys colubrinus*
1038	*Myripristis adusta*
1039	*Myripristis botche*
1040	*Myripristis hexagona*
1041	*Myripristis murdjan*
1042	*Narcetes erimelas*
1043	*Narcine brunnea*
1044	*Narcine lingula*
1045	*Narcine prodorsalis*
1046	*Narcine timlei*
1047	*Narke dipterygia*
1048	*Naso brachycentron*
1049	*Naso brevirostris*
1050	*Naso lituratus*

1051	*Naso tonganus*
1052	*Naso tuberosus*
1053	*Naso unicornis*
1054	*Naso vlamingii*
1055	*Naucrates ductor*
1056	*Nealotus tripes*
1057	*Nebrius ferrugineus*
1058	*Nectamia fusca*
1059	*Nectamia savayensis*
1060	*Neenchelys buitendijki*
1061	*Negaprion acutidens*
1062	*Nemapteryx caelata*
1063	*Nemapteryx macronotacantha*
1064	*Nemapteryx nenga*
1065	*Nematalosa galatheae*
1066	*Nematalosa nasus*
1067	*Nemichthys scolopaceus*
1068	*Nemipterus bipunctatus*
1069	*Nemipterus furcosus*
1070	*Nemipterus hexodon*
1071	*Nemipterus japonicus*
1072	*Nemipterus marginatus*
1073	*Nemipterus mesoprion*
1074	*Nemipterus nematophorus*
1075	*Nemipterus nemurus*
1076	*Nemipterus peronii*
1077	*Nemipterus randalli*
1078	*Nemipterus zysron*
1079	*Neobythites multistriatus*
1080	*Neobythites steatiticus*
1081	*Neoepinnula orientalis*
1082	*Neoniphon argenteus*
1083	*Neoniphon opercularis*
1084	*Neoniphon sammara*
1085	*Neopomacentrus sororius*
1086	*Neopomacentrus taeniurus*
1087	*Neoscopelus macrolepidotus*
1088	*Neotrygon kuhlii*
1089	*Nettenchelys taylori*
1090	*Netuma bilineata*
1091	*Netuma thalassina*
1092	*Nibea chui*
1093	*Nibea coibor*
1094	*Nibea maculata*
1095	*Nibea soldado*
1096	*Novaculichthys taeniourus*

1097	*Nuchequula blochii*
1098	*Nuchequula gerreoides*
1099	*Obliquogobius cometes*
1100	*Ocosia ramaraoi*
1101	*Odontamblyopus roseus*
1102	*Odontamblyopus rubicundus*
1103	*Odonus niger*
1104	*Oedalechilus labiosus*
1105	*Okamejei powelli*
1106	*Oligolepis acutipennis*
1107	*Oligolepis cylindriceps*
1108	*Oligolepis dasi*
1109	*Omobranchus elongatus*
1110	*Omobranchus fasciolatus*
1111	*Omobranchus obliquus*
1112	*Omobranchus punctatus*
1113	*Omobranchus smithi*
1114	*Omobranchus zebra*
1115	*Oncorhynchus nerka*
1116	*Ophichthus altipennis*
1117	*Ophichthus apicalis*
1118	*Ophichthus cephalozona*
1119	*Ophichthus macrochir*
1120	*Opisthopterus tardoore*
1121	*Opistognathus nigromarginatus*
1122	*Opistognathus pardus*
1123	*Opistognathus rosenbergii*
1124	*Osteogeneiosus militaris*
1125	*Ostichthys acanthorhinus*
1126	*Ostichthys japonicus*
1127	*Ostorhinchus apogonoides*
1128	*Ostorhinchus bryx*
1129	*Ostorhinchus endekataenia*
1130	*Ostorhinchus fasciatus*
1131	*Ostorhinchus fleurieu*
1132	*Ostorhinchus holotaenia*
1133	*Ostorhinchus moluccensis*
1134	*Ostorhinchus novemfasciatus*
1135	*Ostorhinchus oxina*
1136	*Ostorhinchus pleuron*
1137	*Ostorhinchus taeniophorus*
1138	*Ostracion cubicus*
1139	*Ostracion meleagris*
1140	*Otolithes cuvieri*
1141	*Otolithes ruber*
1142	*Otolithoides biauritus*
1143	*Otolithoides pama*

1144	*Oxuderces dentatus*
1145	*Oxycheilinus bimaculatus*
1146	*Oxycheilinus digramma*
1147	*Oxymonacanthus longirostris*
1148	*Oxyporhamphus micropterus*
1149	*Oxyurichthys formosanus*
1150	*Oxyurichthys microlepis*
1151	*Oxyurichthys ophthalmonema*
1152	*Oxyurichthys paulae*
1153	*Oxyurichthys tentacularis*
1154	*Pampus argenteus*
1155	*Pampus chinensis*
1156	*Panna heterolepis*
1157	*Panna microdon*
1158	*Parablennius thysanius*
1159	*Paracaesio sordida*
1160	*Paracaesio xanthura*
1161	*Paracanthurus hepatus*
1162	*Paracentropogon longispinis*
1163	*Parachaetodon ocellatus*
1164	*Parachaeturichthys ocellatus*
1165	*Parachaeturichthys polynema*
1166	*Paracirrhites forsteri*
1167	*Paragaleus randalli*
1168	*Paragobiodon echinocephalus*
1169	*Paraluteres prionurus*
1170	*Parambassis thomassi*
1171	*Paramonacanthus choirocephalus*
1172	*Paramonacanthus japonicus*
1173	*Paramonacanthus oblongus*
1174	*Paramonacanthus tricuspis*
1175	*Paramugil parmatus*
1176	*Paranibea semiluctuosa*
1177	*Parapercis alboguttata*
1178	*Parapercis clathrata*
1179	*Parapercis hexophtalma*
1180	*Parapercis maculata*
1181	*Parapercis pulchella*
1182	*Parapercis punctata*
1183	*Parapercis tetracantha*
1184	*Paraplagusia bilineata*
1185	*Paraplagusia blochii*
1186	*Parapocryptes rictuosus*
1187	*Parapocryptes serperaster*
1188	*Parapriacanthus ransonneti*

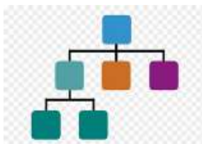
1189	*Parapterois macrura*
1190	*Parascolopsis aspinosa*
1191	*Parascolopsis boesemani*
1192	*Parascolopsis eriomma*
1193	*Parascolopsis inermis*
1194	*Parascolopsis townsendi*
1195	*Parascorpaena picta*
1196	*Parastromateus niger*
1197	*Paratrypauchen microcephalus*
1198	*Pardachirus marmoratus*
1199	*Pardachirus pavoninus*
1200	*Parexocoetus brachypterus*
1201	*Parexocoetus mento*
1202	*Parioglossus philippinus*
1203	*Parioglossus winterbottomi*
1204	*Parupeneus barberinus*
1205	*Parupeneus ciliatus*
1206	*Parupeneus cyclostomus*
1207	*Parupeneus heptacanthus*
1208	*Parupeneus indicus*
1209	*Parupeneus macronemus*
1210	*Parupeneus margaritatus*
1211	*Parupeneus minys*
1212	*Parupeneus multifasciatus*
1213	*Parupeneus pleurostigma*
1214	*Parupeneus trifasciatus*
1215	*Pastinachus sephen*
1216	*Pegasus laternarius*
1217	*Pegasus volitans*
1218	*Pelates quadrilineatus*
1219	*Pellona dayi*
1220	*Pellona ditchela*
1221	*Pempheris malabarica*
1222	*Pempheris mangula*
1223	*Pempheris molucca*
1224	*Pempheris nesogallica*
1225	*Pempheris oualensis*
1226	*Pempheris sarayu*
1227	*Pennahia anea*
1228	*Pennahia macrocephalus*
1229	*Pennahia ovata*
1230	*Pentapodus setosus*
1231	*Pentaprion longimanus*
1232	*Periophthalmodon schlosseri*
1233	*Periophthalmus argentilineatus*
1234	*Periophthalmus chrysospilos*
1235	*Periophthalmus minutus*
1236	*Periophthalmus novemradiatus*
1237	*Periophthalmus waltoni*
1238	*Periophthalmus weberi*
1239	*Perulibatrachus aquilonarius*
1240	*Petroscirtes breviceps*
1241	*Petroscirtes mitratus*
1242	*Petroscirtes xestus*
1243	*Photopectoralis bindus*
1244	*Phoxocampus belcheri*
1245	*Phtheirichthys lineatus*
1246	*Physiculus argyropastus*
1247	*Pinjalo lewisi*
1248	*Pinjalo pinjalo*
1249	*Pisodonophis boro*
1250	*Pisodonophis cancrivorus*
1251	*Pisodonophis hijala*
1252	*Plagiotremus rhinorhynchos*
1253	*Plagiotremus tapeinosoma*
1254	*Platax orbicularis*
1255	*Platax pinnatus*
1256	*Platax teira*
1257	*Platybelone argalus platyura*
1258	*Platycephalus indicus*
1259	*Platytroctes apus*
1260	*Platytroctes mirus*
1261	*Plectorhinchus albovittatus*
1262	*Plectorhinchus ceylonensis*
1263	*Plectorhinchus chubbi*
1264	*Plectorhinchus diagrammus*
1265	*Plectorhinchus gibbosus*
1266	*Plectorhinchus lineatus*
1267	*Plectorhinchus picus*
1268	*Plectorhinchus polytaenia*
1269	*Plectorhinchus schotaf*
1270	*Plectorhinchus vittatus*
1271	*Plectranthias alcocki*
1272	*Plectroglyphidodon dickii*
1273	*Plectroglyphidodon lacrymatus*
1274	*Plectroglyphidodon leucozonus*
1275	*Plectropomus areolatus*
1276	*Plectropomus maculatus*
1277	*Plesiobatis daviesi*
1278	*Plesiops coeruleolineatus*
1279	*Plesiops corallicola*
1280	*Pleurosicya bilobata*
1281	*Plicofollis argyropleuron*
1282	*Plicofollis dussumieri*
1283	*Plicofollis platystomus*
1284	*Plicofollis tenuispinis*
1285	*Plicofollis tonggol*
1286	*Plotosus canius*
1287	*Plotosus limbatus*
1288	*Plotosus lineatus*
1289	*Poecilopsetta colorata*
1290	*Poecilopsetta praelonga*
1291	*Pogonoperca punctata*
1292	*Polydactylus macrochir*
1293	*Polydactylus microstomus*
1294	*Polydactylus mullani*
1295	*Polydactylus multiradiatus*
1296	*Polydactylus plebeius*
1297	*Polydactylus sexfilis*
1298	*Polydactylus sextarius*
1299	*Polyipnus spinosus*
1300	*Polymixia fusca*
1301	*Polymixia japonica*
1302	*Polynemus dubius*
1303	*Polynemus paradiseus*
1304	*Pomacanthus annularis*
1305	*Pomacanthus imperator*
1306	*Pomacanthus semicirculatus*
1307	*Pomacentrus albicaudatus*
1308	*Pomacentrus azuremaculatus*
1309	*Pomacentrus brachialis*
1310	*Pomacentrus littoralis*
1311	*Pomacentrus pavo*
1312	*Pomacentrus similis*
1313	*Pomacentrus tripunctatus*
1314	*Pomadasys argenteus*
1315	*Pomadasys argyreus*
1316	*Pomadasys commersonnii*
1317	*Pomadasys furcatus*
1318	*Pomadasys guoraca*
1319	*Pomadasys kaakan*
1320	*Pomadasys maculatus*
1321	*Pomadasys multimaculatus*
1322	*Pomadasys olivaceus*
1323	*Pomadasys stridens*
1324	*Pomatomus saltatrix*
1325	*Porogadus trichiurus*
1326	*Premnas biaculeatus*
1327	*Priacanthus hamrur*

1328	Priacanthus macracanthus
1329	Priacanthus prolixus
1330	Priacanthus tayenus
1331	Priolepis eugenius
1332	Priolepis inhaca
1333	Prionace glauca
1334	Pristiapogon fraenatus
1335	Pristiapogon kallopterus
1336	Pristigenys refulgens
1337	Pristipomoides filamentosus
1338	Pristipomoides multidens
1339	Pristipomoides sieboldii
1340	Pristipomoides typus
1341	Pristipomoides zonatus
1342	Pristis microdon
1343	Pristis pectinata
1344	Pristis pristis
1345	Pristis zijsron
1346	Pristotis obtusirostris
1347	Prognichthys brevipinnis
1348	Promethichthys prometheus
1349	Promyllantor purpureus
1350	Protonibea diacanthus
1351	Psammogobius biocellatus
1352	Psammoperca waigiensis
1353	Psenes cyanophrys
1354	Psenopsis cyanea
1355	Psettina brevirictis
1356	Psettodes erumei
1357	Pseudaesopia japonica
1358	Pseudamia gelatinosa
1359	Pseudanthias cichlops
1360	Pseudanthias conspicuus
1361	Pseudanthias cooperi
1362	Pseudanthias squamipinnis
1363	Pseudapocryptes elongatus
1364	Pseudobalistes flavimarginatus
1365	Pseudobalistes fuscus
1366	Pseudocheilinus hexataenia
1367	Pseudochromis caudalis
1368	Pseudochromis tapeinosoma
1369	Pseudodax moluccanus
1370	Pseudogobius javanicus
1371	Pseudogobius melanostictus
1372	Pseudogramma polyacantha
1373	Pseudorhombus arsius
1374	Pseudorhombus dupliciocellatus
1375	Pseudorhombus elevatus
1376	Pseudorhombus javanicus
1377	Pseudorhombus malayanus
1378	Pseudorhombus micrognathus
1379	Pseudorhombus natalensis
1380	Pseudorhombus triocellatus
1381	Pseudotriacanthus strigilifer
1382	Pseudovespicula dracaena
1383	Pteragogus flagellifer
1384	Ptereleotris evides
1385	Ptereleotris microlepis
1386	Pterocaesio chrysozona
1387	Pterocaesio digramma
1388	Pterocaesio pisang
1389	Pterocaesio tessellata
1390	Pterocaesio tile
1391	Pteroidichthys amboinensis
1392	Pterois antennata
1393	Pterois mombasae
1394	Pterois radiata
1395	Pterois russelii
1396	Pterois volitans
1397	Pterotolithus maculatus
1398	Pterygotrigla arabica
1399	Pterygotrigla hemisticta
1400	Pterygotrigla macrorhynchus
1401	Rachycentron canadum
1402	Raconda russeliana
1403	Rastrelliger brachysoma
1404	Rastrelliger faughni
1405	Rastrelliger kanagurta
1406	Remora albescens
1407	Remora osteochir
1408	Remora remora
1409	Rexea bengalensis
1410	Rexea prometheoides
1411	Rhabdamia gracilis
1412	Rhabdosargus sarba
1413	Rhina ancylostoma
1414	Rhincodon typus
1415	Rhinecanthus aculeatus
1416	Rhinecanthus rectangulus
1417	Rhinobatos annandalei
1418	Rhinobatos lionotus
1419	Rhinobatos obtusus
1420	Rhinobatos thouiniana
1421	Rhinobatos variegatus
1422	Rhinoptera adspersa
1423	Rhinoptera javanica
1424	Rhizoprionodon acutus
1425	Rhizoprionodon oligolinx
1426	Rhynchobatus djiddensis
1427	Rhynchorhamphus georgii
1428	Rhynchorhamphus malabaricus
1429	Rhynchostracion nasus
1430	Richardsonichthys leucogaster
1431	Roa jayakari
1432	Rogadius asper
1433	Rogadius serratus
1434	Ruvettus pretiosus
1435	Sacura boulengeri
1436	Salarias fasciatus
1437	Samaris cristatus
1438	Samariscus longimanus
1439	Sarda orientalis
1440	Sardinella albella
1441	Sardinella brachysoma
1442	Sardinella fimbriata
1443	Sardinella gibbosa
1444	Sardinella jussieu
1445	Sardinella longiceps
1446	Sardinella melanura
1447	Sardinella sindensis
1448	Sargocentron caudimaculatum
1449	Sargocentron diadema
1450	Sargocentron ittodai
1451	Sargocentron microstoma
1452	Sargocentron praslin
1453	Sargocentron punctatissimum
1454	Sargocentron rubrum
1455	Sargocentron spiniferum
1456	Sargocentron violaceum
1457	Satyrichthys laticeps
1458	Saurida gracilis
1459	Saurida isarankurai
1460	Saurida longimanus
1461	Saurida micropectoralis
1462	Saurida nebulosa
1463	Saurida pseudotumbil

1464	*Saurida tumbil*
1465	*Saurida undosquamis*
1466	*Saurida wanieso*
1467	*Scalicus investigatoris*
1468	*Scartelaos cantoris*
1469	*Scartelaos histophorus*
1470	*Scartelaos tenuis*
1471	*Scartella emarginata*
1472	*Scarus ghobban*
1473	*Scarus globiceps*
1474	*Scarus niger*
1475	*Scarus prasiognathos*
1476	*Scarus psittacus*
1477	*Scarus quoyi*
1478	*Scarus rubroviolaceus*
1479	*Scarus russelii*
1480	*Scarus scaber*
1481	*Scarus tricolor*
1482	*Scatophagus argus*
1483	*Schindleria pietschmanni*
1484	*Schindleria praematura*
1485	*Sciades sona*
1486	*Scolecenchelys macroptera*
1487	*Scoliodon laticaudus*
1488	*Scolopsis aurata*
1489	*Scolopsis bilineata*
1490	*Scolopsis bimaculata*
1491	*Scolopsis ciliata*
1492	*Scolopsis frenata*
1493	*Scolopsis ghanam*
1494	*Scolopsis igcarensis*
1495	*Scolopsis lineata*
1496	*Scolopsis margaritifera*
1497	*Scolopsis taeniata*
1498	*Scolopsis taenioptera*
1499	*Scolopsis vosmeri*
1500	*Scolopsis xenochroa*
1501	*Scomber japonicus*
1502	*Scomberoides commersonnianus*
1503	*Scomberoides lysan*
1504	*Scomberoides tala*
1505	*Scomberoides tol*
1506	*Scomberomorus commerson*
1507	*Scomberomorus guttatus*
1508	*Scomberomorus koreanus*
1509	*Scomberomorus lineolatus*
1510	*Scopelengys tristis*
1511	*Scorpaenodes guamensis*
1512	*Scorpaenodes muciparus*
1513	*Scorpaenodes parvipinnis*
1514	*Scorpaenopsis cirrosa*
1515	*Scorpaenopsis gibbosa*
1516	*Scorpaenopsis neglecta*
1517	*Scorpaenopsis ramaraoi*
1518	*Scorpaenopsis venosa*
1519	*Scuticaria tigrina*
1520	*Scyliorhinus capensis*
1521	*Sebastapistes nuchalis*
1522	*Sebastapistes strongia*
1523	*Secutor insidiator*
1524	*Secutor interruptus*
1525	*Secutor ruconius*
1526	*Selar boops*
1527	*Selar crumenophthalmus*
1528	*Selaroides leptolepis*
1529	*Seriola lalandi*
1530	*Seriola rivoliana*
1531	*Seriolina nigrofasciata*
1532	*Setarches guentheri*
1533	*Setipinna breviceps*
1534	*Setipinna taty*
1535	*Setipinna tenuifilis*
1536	*Siganus argenteus*
1537	*Siganus canaliculatus*
1538	*Siganus corallinus*
1539	*Siganus fuscescens*
1540	*Siganus guttatus*
1541	*Siganus insomnis*
1542	*Siganus javus*
1543	*Siganus lineatus*
1544	*Siganus magnificus*
1545	*Siganus puelloides*
1546	*Siganus punctatus*
1547	*Siganus spinus*
1548	*Siganus stellatus*
1549	*Siganus vermiculatus*
1550	*Siganus virgatus*
1551	*Sigmops elongatus*
1552	*Silhouettea indica*
1553	*Sillaginopodys chondropus*
1554	*Sillaginops macrolepis*
1555	*Sillaginopsis panijus*
1556	*Sillago aeolus*
1557	*Sillago argentifasciata*
1558	*Sillago indica*
1559	*Sillago ingenuua*
1560	*Sillago intermedius*
1561	*Sillago lutea*
1562	*Sillago maculata*
1563	*Sillago parvisquamis*
1564	*Sillago sihama*
1565	*Sillago soringa*
1566	*Sillago vincenti*
1567	*Skythrenchelys zabra*
1568	*Snyderina guentheri*
1569	*Solea elongata*
1570	*Solea heinii*
1571	*Solea ovata*
1572	*Soleichthys heterorhinos*
1573	*Solenostomus cyanopterus*
1574	*Sorsogona tuberculata*
1575	*Sparidentex datnia*
1576	*Sparidentex hasta*
1577	*Sphagemacrurus pumiliceps*
1578	*Sphenanthias whiteheadi*
1579	*Sphyraena acutipinnis*
1580	*Sphyraena barracuda*
1581	*Sphyraena chrysotaenia*
1582	*Sphyraena flavicauda*
1583	*Sphyraena forsteri*
1584	*Sphyraena jello*
1585	*Sphyraena novaehollandiae*
1586	*Sphyraena obtusata*
1587	*Sphyraena putnamae*
1588	*Sphyraena qenie*
1589	*Sphyrna lewini*
1590	*Sphyrna mokarran*
1591	*Sphyrna tudes*
1592	*Sphyrna zygaena*
1593	*Spratelloides delicatulus*
1594	*Spratelloides gracilis*
1595	*Squalus mitsukurii*
1596	*Stegastes albifasciatus*
1597	*Stegastes nigricans*
1598	*Stegastes obreptus*
1599	*Stegastes punctatus*
1600	*Stegostoma fasciatum*
1601	*Stenogobius gymnopomus*
1602	*Stenogobius laterisquamatus*
1603	*Stethojulis albovittata*
1604	*Stethojulis balteata*
1605	*Stethojulis strigiventer*
1606	*Stethojulis trilineata*
1607	*Stigmatogobius minima*

1608	*Stolephorus andhraensis*
1609	*Stolephorus baganensis*
1610	*Stolephorus commersonnii*
1611	*Stolephorus dubiosus*
1612	*Stolephorus indicus*
1613	*Stolephorus insularis*
1614	*Stolephorus waitei*
1615	*Stomias affinis*
1616	*Strongylura incisa*
1617	*Strongylura leiura*
1618	*Strongylura strongylura*
1619	*Strophidon sathete*
1620	*Sufflamen chrysopterum*
1621	*Sufflamen fraenatum*
1622	*Suggrundus macracanthus*
1623	*Sunagocia carbunculus*
1624	*Sunagocia otaitensis*
1625	*Symbolophorus evermanni*
1626	*Symphurus trifasciatus*
1627	*Symphysanodon andersoni*
1628	*Symphysanodon xanthopterygion*
1629	*Synagrops philippinensis*
1630	*Synanceia horrida*
1631	*Synanceia verrucosa*
1632	*Synaptura albomaculata*
1633	*Synaptura commersonnii*
1634	*Synchiropus lineolatus*
1635	*Syngnathoides biaculeatus*
1636	*Synodus binotatus*
1637	*Synodus gibbsi*
1638	*Synodus indicus*
1639	*Synodus jaculum*
1640	*Synodus macrocephalus*
1641	*Synodus macrops*
1642	*Synodus myops*
1643	*Synodus oculeus*
1644	*Synodus sageneus*
1645	*Synodus variegatus*
1646	*Taeniamia fucata*
1647	*Taenianotus triacanthus*
1648	*Taenioides anguillaris*
1649	*Taenioides buchanani*
1650	*Taenioides cirratus*
1651	*Taeniura lymma*
1652	*Taeniurops meyeni*
1653	*Takifugu oblongus*
1654	*Tauredophidium hextii*
1655	*Tenualosa ilisha*
1656	*Tenualosa toli*
1657	*Terapon jarbua*
1658	*Terapon puta*
1659	*Terapon theraps*
1660	*Tetrapturus angustirostris*
1661	*Tetraroge niger*
1662	*Tetrosomus gibbosus*
1663	*Thalassoma amblycephalum*
1664	*Thalassoma hardwicke*
1665	*Thalassoma jansenii*
1666	*Thalassoma lunare*
1667	*Thalassoma purpureum*
1668	*Thalassoma quinquevittatum*
1669	*Thamnaconus modestoides*
1670	*Thryssa baelama*
1671	*Thryssa dayi*
1672	*Thryssa dussumieri*
1673	*Thryssa encrasicholoides*
1674	*Thryssa gautamiensis*
1675	*Thryssa hamiltonii*
1676	*Thryssa kammalensis*
1677	*Thryssa kammalensoides*
1678	*Thryssa malabarica*
1679	*Thryssa mystax*
1680	*Thryssa polybranchialis*
1681	*Thryssa purava*
1682	*Thryssa setirostris*
1683	*Thryssa spinidens*
1684	*Thryssa stenosoma*
1685	*Thryssa vitrirostris*
1686	*Thunnus alalunga*
1687	*Thunnus albacares*
1688	*Thunnus obesus*
1689	*Thunnus orientalis*
1690	*Thunnus tonggol*
1691	*Thyrsitoides marleyi*
1692	*Thysanophrys celebica*
1693	*Thysanophrys chiltonae*
1694	*Torpedo fuscomaculata*
1695	*Torpedo panthera*
1696	*Torpedo sinuspersici*
1697	*Torquigener brevipinnis*
1698	*Torquigener hypselogeneion*
1699	*Toxotes chatareus*
1700	*Trachicephalus uranoscopus*
1701	*Trachinotus baillonii*
1702	*Trachinotus blochii*
1703	*Trachinotus botla*
1704	*Trachinotus mookalee*
1705	*Trachyrhamphus serratus*
1706	*Triacanthodes ethiops*
1707	*Triacanthus biaculeatus*
1708	*Triacanthus nieuhofii*
1709	*Triaenodon obesus*
1710	*Trichiurus auriga*
1711	*Trichiurus gangeticus*
1712	*Trichiurus lepturus*
1713	*Trichiurus russelli*
1714	*Trichonotus cyclograptus*
1715	*Trichonotus setiger*
1716	*Trimma annosum*
1717	*Trimma winterbottomi*
1718	*Tripodichthys oxycephalus*
1719	*Tripterodon orbis*
1720	*Trypauchen vagina*
1721	*Trypauchenichthys sumatrensis*
1722	*Tylerius spinosissimus*
1723	*Tylosurus acus melanotus*
1724	*Tylosurus choram*
1725	*Tylosurus crocodilus*
1726	*Ulua mentalis*
1727	*Umbrina canariensis*
1728	*Upeneus guttatus*
1729	*Upeneus heemstra*
1730	*Upeneus indicus*
1731	*Upeneus japonicus*
1732	*Upeneus luzonius*
1733	*Upeneus moluccensis*
1734	*Upeneus sulphureus*
1735	*Upeneus sundaicus*
1736	*Upeneus supravittatus*
1737	*Upeneus taeniopterus*
1738	*Upeneus vittatus*
1739	*Uranoscopus crassiceps*
1740	*Uranoscopus guttatus*
1741	*Uraspis helvola*
1742	*Uraspis secunda*
1743	*Uraspis uraspis*
1744	*Uroconger lepturus*
1745	*Urogymnus asperrimus*
1746	*Uropterygius concolor*
1747	*Uropterygius macrocephalus*
1748	*Uropterygius marmoratus*
1749	*Valamugil buchanani*

1750	*Valamugil speigleri*
1751	*Valenciennea muralis*
1752	*Valenciennea sexguttata*
1753	*Valenciennea strigata*
1754	*Variola louti*
1755	*Velifer hypselopterus*
1756	*Verulux cypselurus*
1757	*Vinciguerria lucetia*
1758	*Wattsia mossambica*
1759	*Xenentodon cancila*
1760	*Xenomystax trucidans*
1761	*Xestochilus nebulosus*
1762	*Xiphasia setifer*
1763	*Xiphias gladius*
1764	*Xiphocheilus typus*
1765	*Xyrichtys rajagopalani*
1766	*Yongeichthys criniger*
1767	*Zanclus cornutus*
1768	*Zanobatus schoenleinii*
1769	*Zebrasoma flavescens*
1770	*Zebrasoma velifer*
1771	*Zebrasoma xanthurum*
1772	*Zebrias altipinnis*
1773	*Zebrias annandalei*
1774	*Zebrias keralensis*
1775	*Zebrias maculosus*
1776	*Zebrias quagga*
1777	*Zebrias synapturoides*
1778	*Zebrias zebra*
1779	*Zenarchopterus buffonis*
1780	*Zenarchopterus dispar*
1781	*Zenarchopterus gilli*
1782	*Zenarchopterus pappenheimi*
1783	*Zenopsis conchifer*
1784	*Zenopsis nebulosa*
1785	*Zoramia leptacantha*



CHAPTER 4
Taxonomy – A Foundation

Fish Taxonomy. -what is it? Is everyone a Taxonomist?

Taxonomy is basically the science of correctly naming species. The term has often been confused **with fish identification**, which basically refers to the use of the latest taxonomic information to identify fishes. The job of the Fish Taxonomist is to name and classify species in a way that makes it easier for fisheries scientists, and other "users", to correctly identify fish species during their work. In other words, fish taxonomy is practiced by very few, whereas fish identification is practised daily by many people.

Why do we need fish collections in fish taxonomy?

Any researcher who wishes to make an in depth study of the taxonomy, anatomy of fishes, reproductive biology or feeding habits of a particular species, needs to learn the details of the fish and its skeleton. This saves the time, expense, and conservation issues associated with capturing fresh specimens. For many species, capturing fresh specimens is often difficult or impossible, such as those which migrate, are found in the deep sea or are endangered.

The collection serves much as a library, with specimens being loaned and returned. Unlike a library however, the collection becomes more valuable after specimens have been studied and returned.

Collections and storage

Software

Symbiota can be found at: https://symbiota.org/docs/symbiota-introduction/symbiota-help-pages/

Arctos is yet another example to consider and is not very costly yet very comprehensive. It is used in various natural history museums: https://arctos.database.museum/

Specify, which is used at the Zoology Museum of USP, in São Paulo, Brazil

SeSam, the great piece of collection database from the Senckenberg Museum in Frankfurt, http://zmb.sesam.senckenberg.de

Rekha J Nair, Dinesh Kumar, Sangeetha AT and Vishnupriya K M *ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala*

Descriptive characters in taxonomy

Mouth:

The position of a fish's mouth can tell you a lot about the feeding habits, living style and type of behaviour it exhibits. Fishes mouth types are broadly divided based on three categories midwater feeders, surface feeders and bottom-feeders.

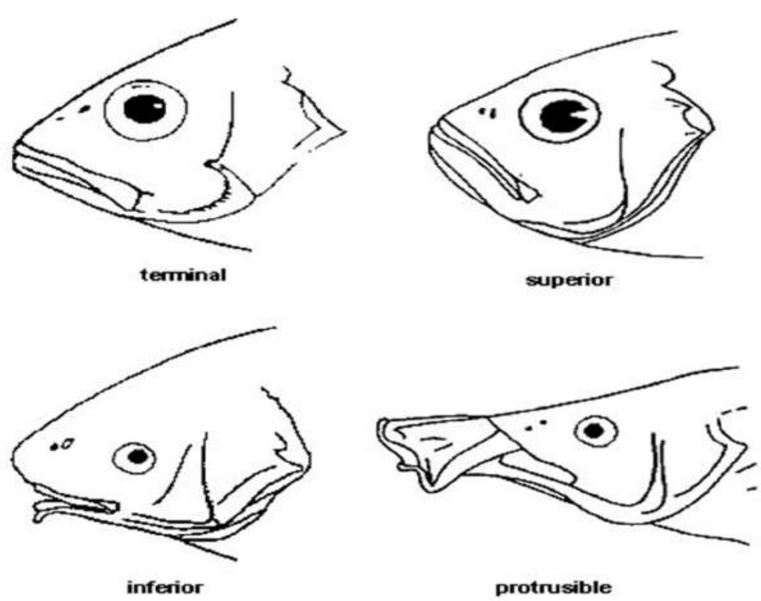
Mouth types:

Terminal: Fish with a terminal mouth position have a mouth in the middle, or centre of the head. These fish are mostly predators who either chase their food or feed on what is seen in front of them. The terminal mouth position is the "normal" position of mouth for most of the fishes inhabiting the middle levels of the water column of oceans or lakes.

Superior: This kind of fish has scoop-like mouth which is designed to feed on prey that swims above the fish (on the surface of the water), such as insects or plankton.

Inferior: Bottom feeding fish generally have inferior or sub-terminal mouths. Mouths located under the fishes head that are adapted for scavenging or grazing on algae, molluscs or bottom dwelling invertebrates.

Protrusible: Protrusible or protractile mouth in fish is a structural arrangement of the jaws that enables the animal to extend the mouth at will. When fully protruded, the cavity of the mouth is enlarged to form a funnel-like space facilitating the uptake of food. Fishes with feeds on small invertebrates in hidings has protrusible mouth.



Different mouth patterns (Source: Florida museum)

Teeth

These serve as a very important taxonomic character. Generally, five types of teeth are recognised in fish based on their cardiform, villiform, caniniform, incisiform and molariform.

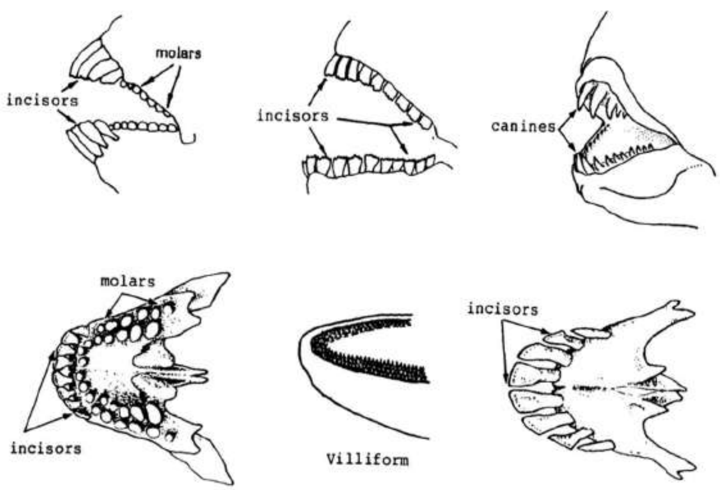
Teeth types: The following teeth patterns are encountered in the fishes mentioned in the book.

Canine teeth: They are sharp, highly pointed teeth seen in predatory fishes which are seen to attack and hold prey in their sharp teeth. The teeth are also used to tear of flesh from the prey. Sharks are best examples of fishes with canine teeth.

Incisor teeth: Incisors are used for cutting and they come in variety of shapes. These are flattened tooth with chisel like or saw edges.

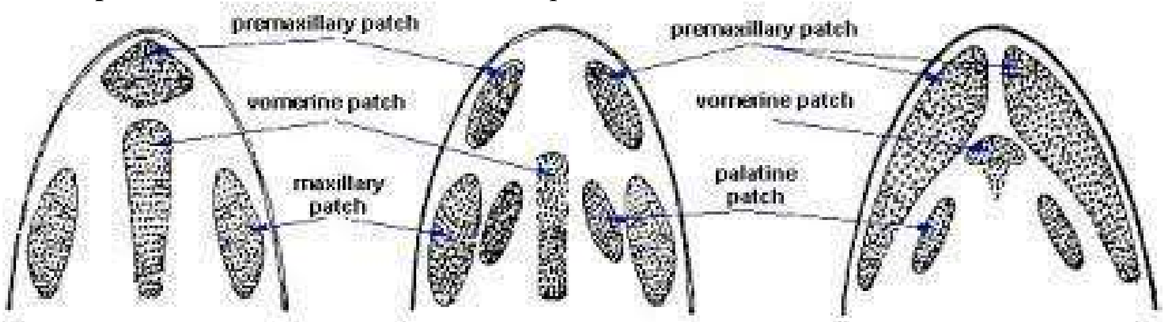
Molar teeth: These are blunt, rounded, broad tooth adapted for crushing and grinding shellfish. They are generally found in bottom dwelling fish.

Villiform teeth: Villiform teeth are elongated teeth they are very long, slender and crowded having the appearance of velvet or fine bristles of a brush. They are more common on deep see fishes used for stabbing and direction.



Common Teeth patterns (Source: Edwards et al. 2001)

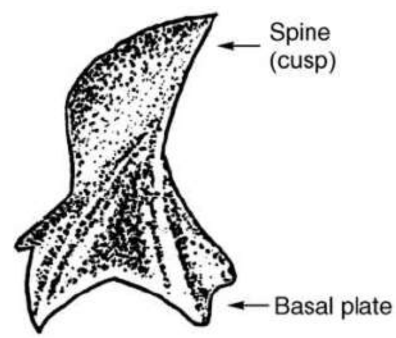
Dental plates: Teeth fused to form beak like plates.



Body Scales

Fish scales constitute the external covering of almost all fish species. The structure and configuration of scales can be used to determine the species from which they came. The type of scale will affect the behaviour of a fish--larger, heavier scales providing more protection but restricting movement, and smaller, lighter scales offering more freedom of movement but less protection. There are four different types of fish scale, each with their own characteristics and variations.

Placoid Scales: Placoid scales are formed of a rectangular base plate that is embedded within the skin of the fish and some of spine externally. The interior of the scale is a pulp that receives blood from the fish's vascular system, while the outside is made of an enamel-like substance called vitrodentine. The shape of the spines can vary greatly depending on species. However, almost all give the fish a rough texture. Sharks and rays are examples of fish with placoid scales.

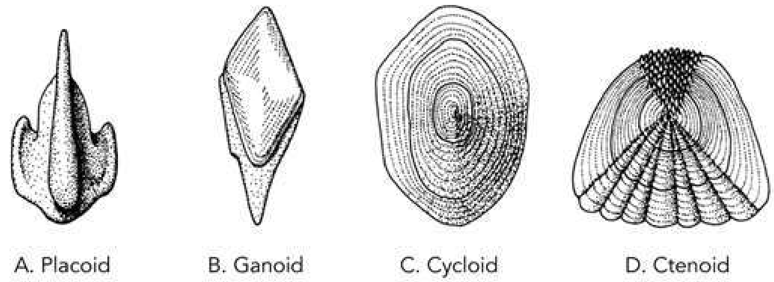


(Source: Diane Elliot, 2011)

Ganoid Scales: Ganoid scales have a bony base layer similar to that of cosmoid scales. and are modified cosmoid scales. However, they differ in that their outer layer is made of an inorganic bone salt called ganoine and that they are diamond-shaped and interconnected. Between ganoid scales are peg-and-socket joints that articulate. Ganoid scales are found on sturgeons, bowfish, paddlefishes and gars.

Cosmoid Scales: Cosmoid scales evolved from placoid scales fusing together. This is because cosmoid scales have two base plates and similar external spines composed of vitrodentine. The base plates are made from bone and new bone is added as the fish grows. Lungfishes and coelacanths have cosmoid scales.

Cycloid and Ctenoid Scales: Cycloid and ctenoid scales have different shapes but the same composition and positioning. Both are composed of collagen and calcium carbonate, rather than bone, and both are overlapping. This means that they are more flexible than the other types of scales. While the edges of cycloid scales are smooth, those of ctenoid scales have tiny teeth-like protrusions called ctenii, giving them a rougher texture. The majority of bony fish have cycloid or ctenoid scales.



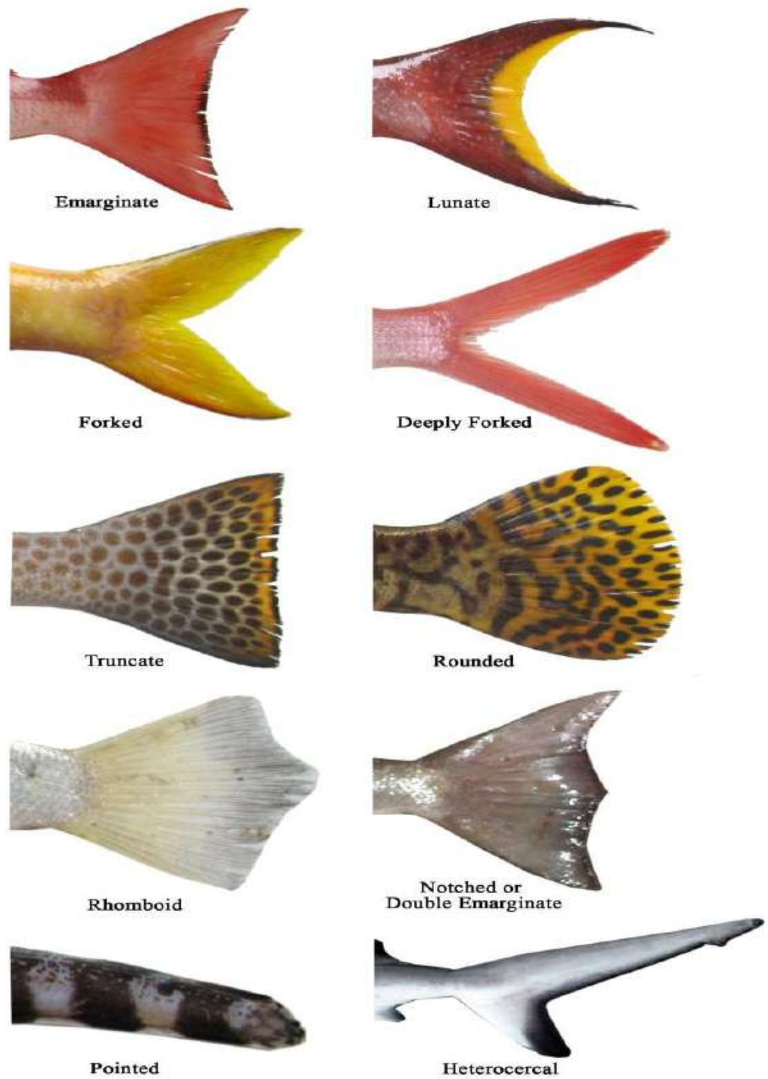
Different types of scale (Source Image from Living Ocean, CRDG, University of Hawaii at Manoa)

Caudal Fin types: The caudal fin is the tail fin, located at the end of the caudal peduncle and is used for propulsion. Types of Caudal fin in our collection.

Heterocercal: the vertebrae extend into the upper lobe of the tail, making it longer. Eg., sharks.

Homocercal: the vertebrae extend for a very short distance into the upper lobe of the fin, but the fin appears superficially symmetric. Most modern fishes are homocercal tailed fishes.

i. **Round:** ending in round shape
ii. **Truncate:** ending in vertical edge
iii. **Forked:** ending in two prolonged edges
iv. **Emarginate:** ending in a slight inward curve
v. **Lunate:** ending in crescent shape
vi. **Rhomboid:** ending in rhomboid shape.



Morphometrics: Measurements must be accurate, point to point and measured using digital vernier callipers in a straight line

(a) **Total length (TL)**: Distance measured from tip of snout to outer free tip of caudal fin. This measurement gives the total length attained by the fish.

(b) **Standard length (SL):** Distance from tip of snout or upper jaw tip (mouth should be in closed position) to the posterior margin of the hypural bone i.e. last vertebra. This measurement is used for all taxonomic calculations since the tip of the caudal rays are often damaged during collection.

(c) **Body depth (BD_1, BD_2):** The maximum girth of the body along the dorso-ventral axis is taken as body depth. In bony fishes, it is measured as the distance from the base of the first dorsal fin ray downwards in a straight line (BD_1). The second measurement for body depth is the distance from base of the first anal fin upwards on a perpendicular axis (BD_2).

(d) **Head length (HL):** The distance from tip of snout or upper jaw to the outer most tip of the operculum.

(e) **Eye diameter (ED):** The horizontal distance at the center of the orbit is taken from the bony anterior to the posterior orbit.

(f) **Jaw length**: Measurements of upper and lower jaw are taken.
Upper jaw length (UJL) is the distance from tip of premaxillary bone to the outermost end of maxillary bone.
Lower jaw length (LJC) is the length of lower jaw from tip of lower jaw to the end of the bone.

(g) **Dorsal fin length (DFL):** This is the maximum length of the dorsal fin when stretched. Measurements are taken at both the longest spine and at the soft dorsal tip.

(h) **Anal fin length (AFL):** The maximum length of the fin when stretched; this is measured at the soft rayed part.

(i) **Pectoral fin length (P_1FL):** This is the maximum length of the pelvic fin when stretched; measurements are taken at the extreme tip of the fin.

(j) **Pelvic fin length (V_1FL)**: This is the maximum length of the pelvic fin when stretched; measurements are taken at the extreme tip of the fin.

(k) **Caudal fin length (CFL)**: Taken as the distance from base of first caudal fin ray to the outermost tip of caudal region.

(l) **Dorsal fin base length (DFBL)**: The distance from base of first dorsal fin ray to the last fin ray in a straight line.

(m) **Anal fin base length (AFBL)**: The distance from base of first anal fin ray to the last fin ray in a straight line.

(n) **Pectoral fin base length (PFBL):** The distance from base of first pectoral fin ray to the last fin ray in a straight line.

(o) **Pelvic fin base length (V_1FB)**: The distance from base of first pelvic fin ray to the last fin ray in a straight line.

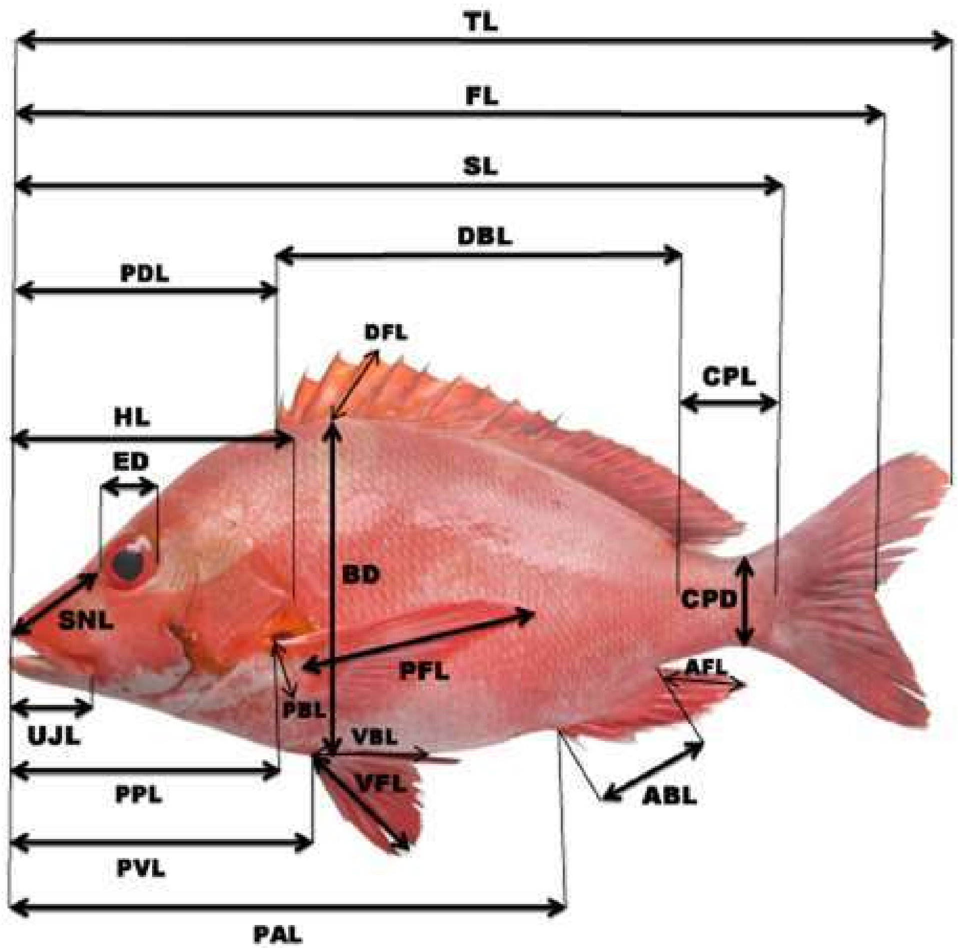
(p) **Caudal fin base length (CFB)**: The distance from base of first caudal fin ray to the last fin ray in a straight line.

(q) **Caudal peduncle length**: the distance from the base of the last dorsal ray to the origin of the caudal fin ray in a straight line.

(r) **Caudal peduncle base:** The vertical distance across base of the caudal fin.

(s) **Preorbital length (POL)**: Distance from tip of snout to anterior tip of the diameter of orbit.

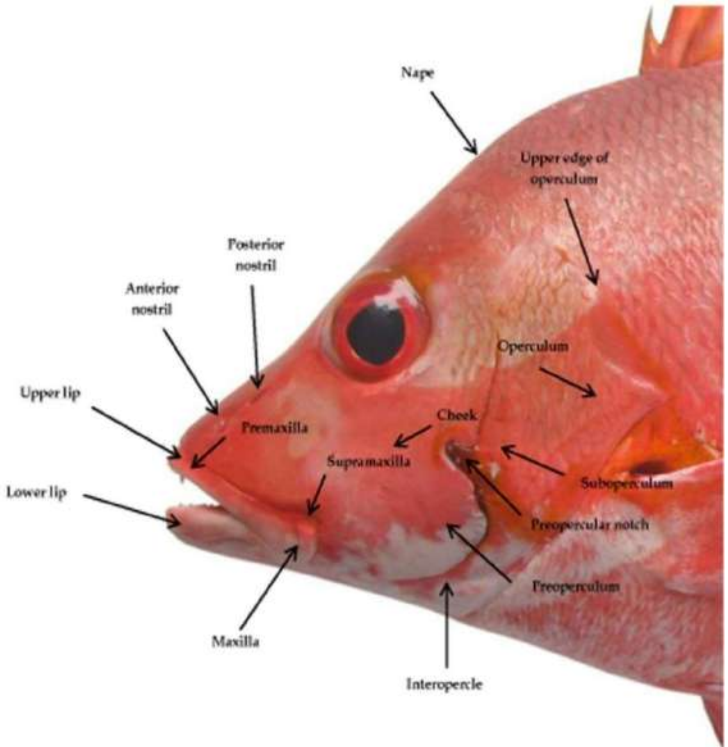
(t) **Post orbital length (PBL)**: Distance from posterior tip of orbit to outer free tip of operculum.



TL – Total Length
SL – Standard Length
FL – Fork Length
HL – Head Length
ED – Eye Diameter
SNL – Snout Length
UJL – Upper Jaw Length

BD – Body Depth
DFL – Dorsal Fin Length
DBL – Dorsal Base Length
PFL – Pectoral Fin Length
PBL – Pectoral Base Length
VFL – Ventral Fin Length
VBL – Ventral Base Length
AFL – Anal Fin Length

ABL – Anal Base Length
CPD – Caudal Peduncle Depth
CPL – Caudal Peduncle Length
PDL – Pre-dorsal Length
PPL – Pre-pectoral Length
PVL – Pre-ventral Length
PAL – Pre-anal Length



Parts of the head

Meristic Counts: Counts are generally taken on the left side of fish.

- **Finray/Spine counts**: Both spine and ray counts are taken on all fins. Dorsal fin counts are written in Roman numerals and rays counts in Arabic numerals eg. X, 6-8., if the spinous and soft-rayed portions of the fin are continuous, the counts are separated by a comma. If the fin is divided into two parts, a plus sign (+) separates the counts, eg. D IX + 4-6. If only a single fin ray is given instead of a range, the count is taken as usual with no variations.

- **Spines** are hardened, stiff, unsegmented, unpaired, unbranched fin rays. Spine counts are characteristic of the genus and does not normally vary between species of same genus.

- **Rays** are soft, flexible structures that may be branched or unbranched at the tips. The last ray of the dorsal and anal fins is sometimes branched at the base and is to be counted as one ray.

- **Scales**: Scales are calcified structures seen on the outer surface of the body of fish for its protection. Scales counts are variable and the range and average count is normally given in the description.

- **Lateral line scale count** is the number of pored scales in the lateral line. The count begins with the first scale at the outer upper end of operculum and ends with at the caudal fin base.

- **Lateral scale count** is taken as the number of scales from the lateral line to the base of the first spine of the dorsal fin excluding the lateral line scale.

- **Predorsal scale count** is the number of scales on the middle line from the origin of the first dorsal fin to the occiput.

Body shape:
The simplest way to identify fishes is by their physical shape and appearance. Different species have different profiles when viewed from the side, top or front. Some are slim and elongated others fat and rounded. Based on their lifestyle and feeding habitat their body shape differs.

Fusiform: Fusiform, or streamlined fish like the barracuda or jack are capable of swimming very fast. They usually live in open water.

Laterally compressed: Fish that are laterally compressed (flattened from side to side) usually do not swim rapidly (some schooling fish are an exception). However, they are exceptionally manoeuvrable. Many, like the angelfish, are found near coral reefs. Their shape allows them to move about in the cracks and crevices of the reef. A flounder is a laterally compressed fish that lies on its side on the bottom. Both eyes migrate to the left or right side early in development.

Depressed: Depressed fish (flattened from top to bottom), like stingrays, live on the bottom.

Eel-like: Eel-like fish have a snake-like body shape. The electric eel and moral eels are good examples of fish with this body shape.

Others: Many fish like the boxfish and porcupine fish do not fit into any of these categories. They are slow swimmers with special protective mechanisms.

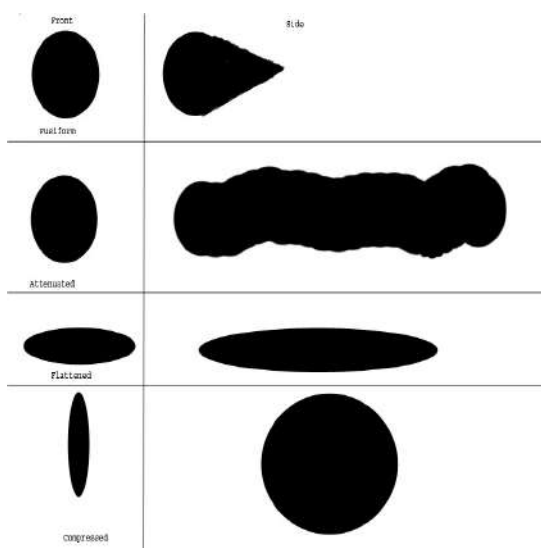
A) Eel-like, greatly elongated, attenuated

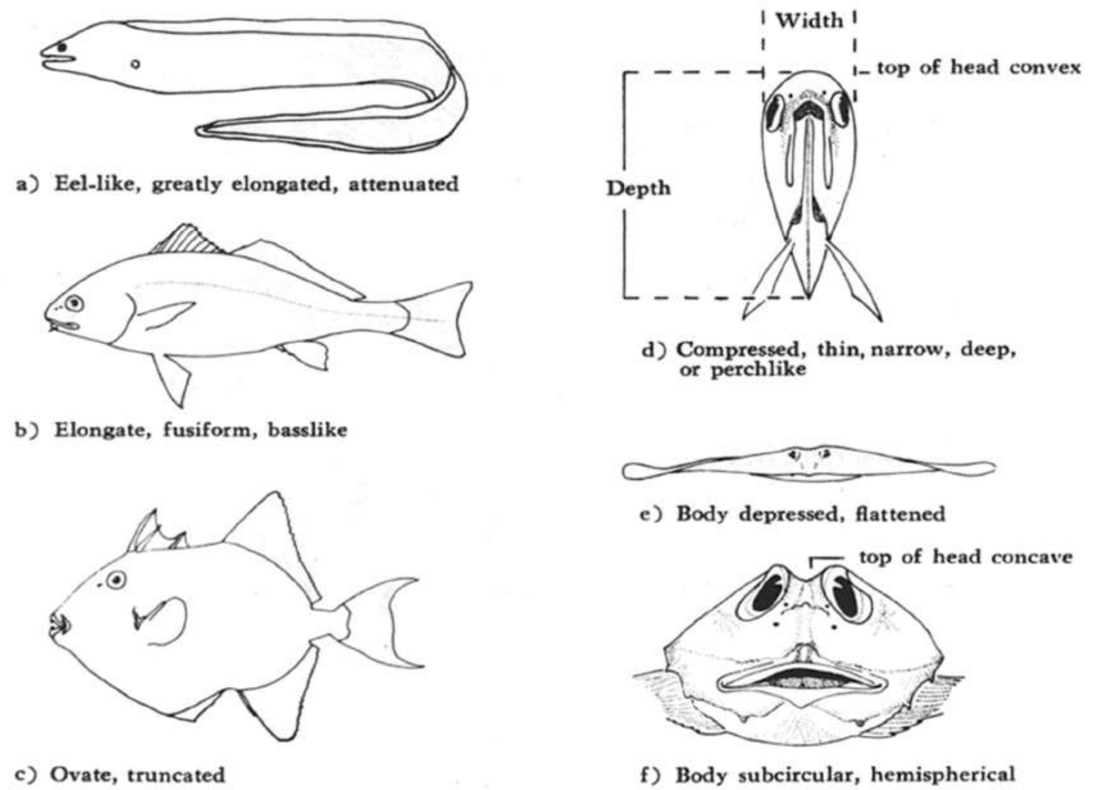
B) Elongated, Fusiform, basslike

C) Ovate, truncated

D) Body depressed, flattened

Body Shapes





Colour patterns: Reef fishes in particular have wide and varied colour patterns on their body which makes them highly suitable for life in reef habitats.

Red is a common colour in reef fish. However, most fish that have this coloration live in dark or deep water, or are nocturnal (active at night). In deep waters and in coralline areas, red light is filtered out quickly so red is a good camouflage. At night red-coloured objects appear grey. The squirrelfish has this kind of coloration.

Camouflage: Here, the fish takes on the appearance of the environment. This makes the fish invisible to other fish as well as other predators. This is achieved by

Disruptive: This is in the form of stripes, spots and helps the fish avoid being eaten by confusion. This is a form of camouflage. The patterns and lines break up the outline of the fish or help it to blend into the background. The brightly patterned fish of coral reefs blend in with the corals despite their brilliant colours. Eg. Moorish idol exhibits disruptive coloration.

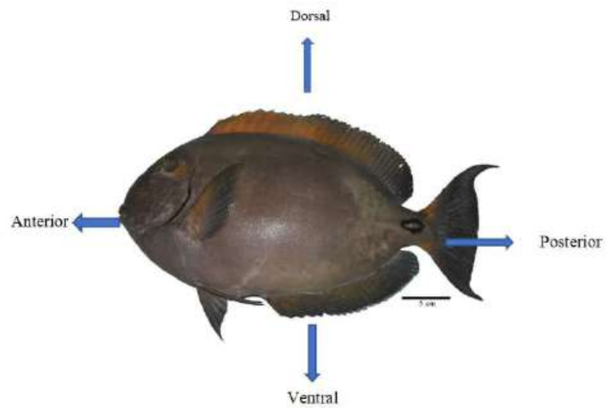
Counter Shading: This is primarily seen in marine fish where the top half of the fish is darker in colour than the bottom half.

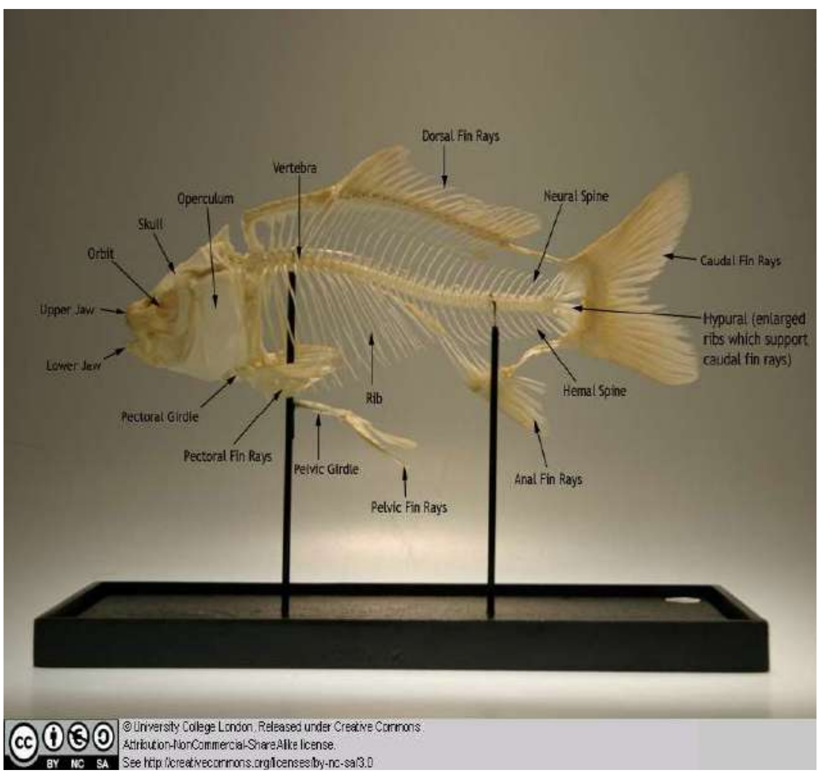
Poster Colouration: This is the most characteristic colouration pattern usually found in reef fish. The fish is characterized by different bright colors. This helps reduce predation on reefs and could be also used as a form of communication.

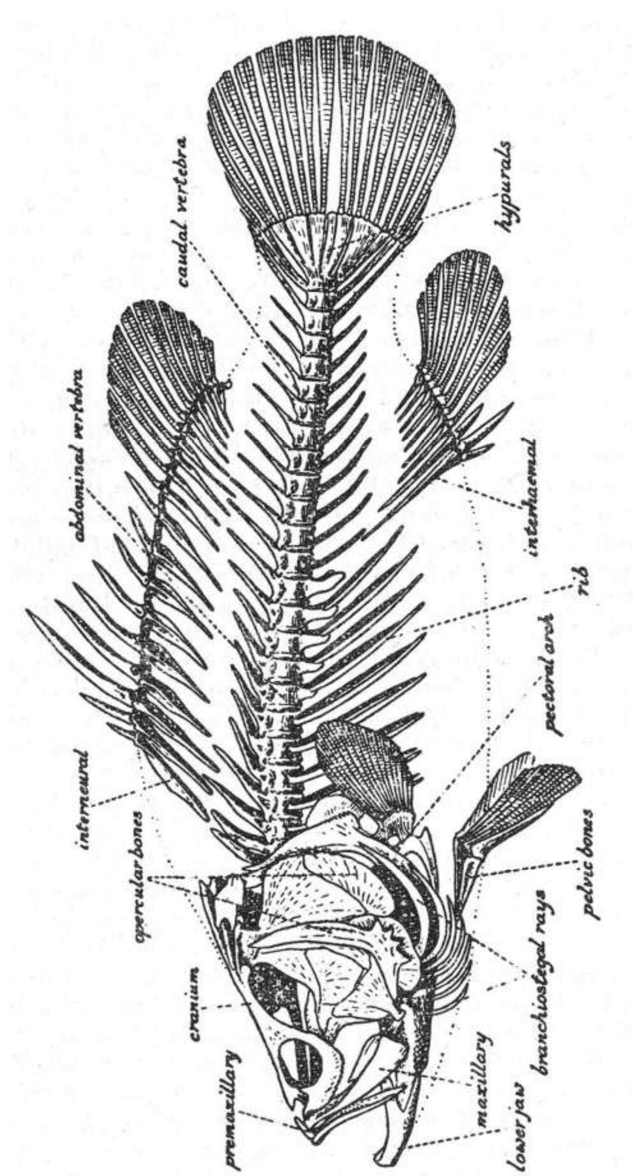
Warning Colouration: Many fish use bright colours to "advertise" the presence of poisonous spines or some other defensive mechanism. Eg. the Nave surgeonfish has two bright orange spots near the base of the tail that advertise the presence of razor sharp spines.

Mimicry: Here, nontoxic individuals mimic toxic individuals; non-aggressive fish look like aggressive species; predators can mimic prey species (ex. Sabertooth Blenny). Eye spots are a form of mimicry. The eye spot, usually found near the tail, draws attention away from the real eye which is a target that a predator might strike. The eye spot may cause the predator to attack the wrong end and allow the fish to escape alive.

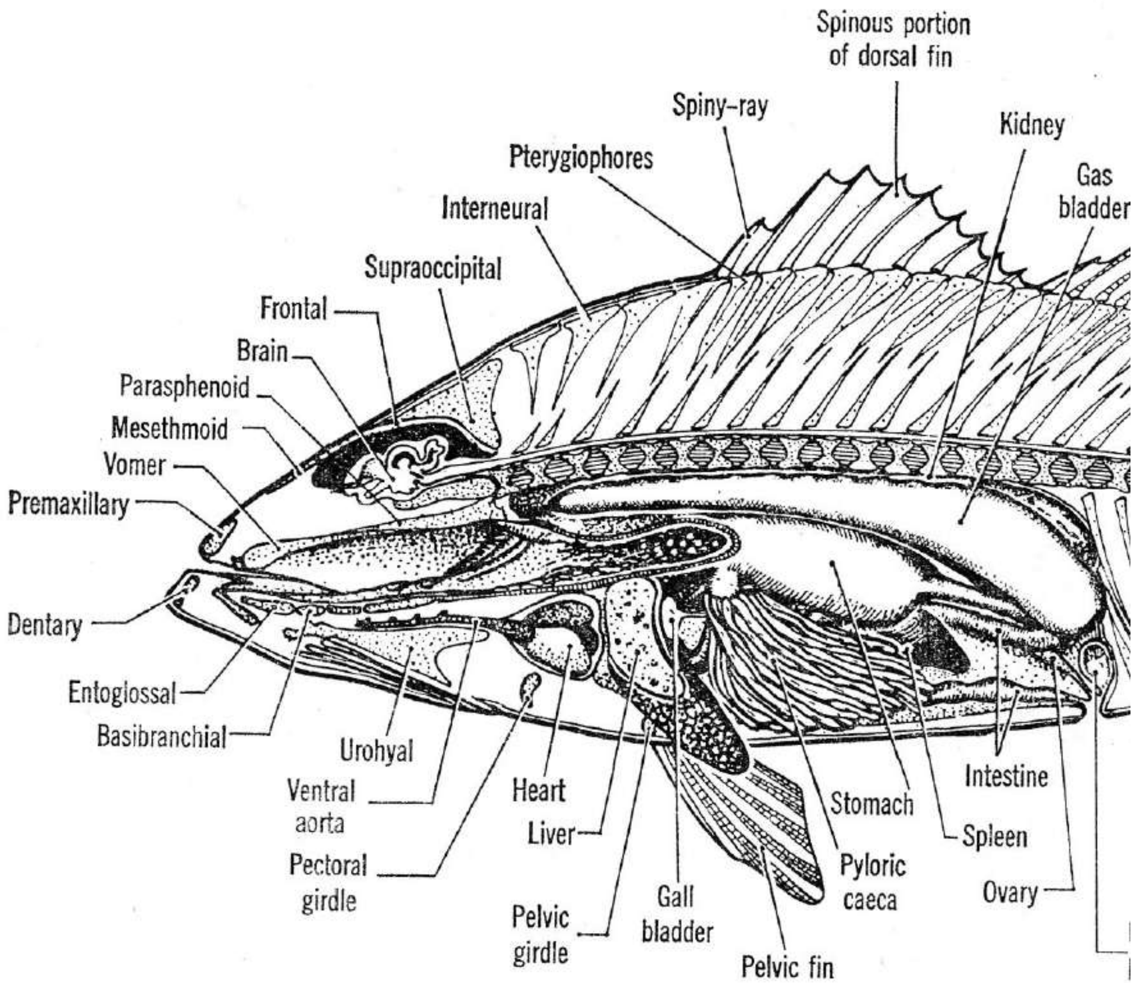
Typical parts of a Fish







Skeleton of a Nile Perch from Norman, 1947 Image



Source: Internal anatomical features of a Largemouth Bass, *Micropterus salmoides*. The image is from Lagler, Bardach & Miller (1964) - (Source: Lagler, 1954).

Further reading:

- Bone, Q., & Moore, R. (2008). Biology of fishes. Taylor & Francis.
- Gonzales, Benjamin. (2006). Basic taxonomy and biology of fishes.
- Jayaram, K. C. (2002). *Fundamentals of fish taxonomy*. Narendra publishing house.
- Lagler, K. F. (1977). *Ichthyology* (No. 597 LAGi).
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- Rathod, Sandeep. (2020). Fish Taxonomy.

CHAPTER 5

Basic Techniques in Fish Taxonomy

In the global context, approximately 36088 valid marine and freshwater species under 515 families and 5213 genera (Nelson, 2006; Fricke et al. 2021). A stable naming and indexing system is essential for global communication about organisms and this system is maintained by the International Code of Zoological Nomenclature. The species are named according to the protocol set by Linnaeus' binomial nomenclature system (Enghoff, 2009). The identification and description of fish species is important not only for taxonomy and systematics but also for natural history and ecology studies, fishery management, tracking the dispersal patterns of eggs and larvae, estimations of recruitment and spawn areas, and food product authentication (Anderson et al. 2007; Fischer, 2013).

Among other things, the science of taxonomy provides methods and manuals for identifying organisms. Taxonomical aids are tools that help us identify and classify organisms when studying taxonomy. The tools used to identify plants and animals are not the same. Plant taxonomy can be studied with the help of a herbarium and a botanical garden. Museums, Taxonomical Keys, and Zoological and Marine Parks are all traditional tools in animal studies. Field visits, surveys, identification, classification, preservation, and documentation are all important components of taxonomical tools. For taxonomical studies, a variety of tools are used; some of the most important tools are discussed below.

1) Expert authority

On-site taxonomist

A taxonomist is an expert who is familiar with a large number of species and has specialised knowledge in a specific group. They are well-versed in nomenclatural rules and morphometric methods for species identification, and they are aware of the precision with which their identifications are made. Individual taxonomists may have conceptual differences that limit the repeatability of certain identifications, but the accuracy should still be high.

Advantage

They can usually identify species quite fast, and expert judgements made on-site by taxonomists are ready to use. The use of a taxonomist is really convenient.

Disadvantage
Unavailability and scarcity of experts in a specific field, and if they are available, inaccessibility to the general public and high consultation fees. A taxonomist may specialise in one or more taxonomic groups or geographical areas.

Folk expert
Local fishermen and residents living near a river, a wetland or coastal waters would learn to identify fish at an early age. This is due to long-term observational knowledge and memory, as well as oral tradition passed down from elders. Many researchers have incorporated such traditional knowledge into modern ichthyology (Calamia, 1999; Drew, 2005; Stacey et al. 2008; MacLean et al. 2009; Ferreira et al. 2014), and the term for it is "traditional ecological knowledge" (TEK) (Berkes et al. 2000).

Advantages
It takes less time, no consultation charge

Disadvantages
Folk taxonomies do not follow scientifically established norms and classification. They lump together many biological species under a single name, or place species from several biological orders in the same group.

2) Local reference collection

Local reference collections are primarily found in research institutions and are geographically limited. Whole fish, otoliths, disarticulated bones, scales, pharyngeal bones, and other body parts preserved in reference collections are used in identification work. Local reference collections may be an adequate tool for identification work in a limited area, reducing the need for expert consultation, keys, field guides, and other methods. They are especially useful for smaller institutions in field-like situations, and they can also be used for ongoing staff training.

Advantages
Local collections have ready-to-use reference specimens that can be compared immediately to the organism for which identification is required. The skill required is relatively low and only a minimal amount of introductory training usually is sufficient for an operator.

Disadvantages
Transferability is limited because fauna differs throughout geographic regions and local collections typically only contain the fauna of the relevant geographical area.

3) Image recognition system

In this method, the user provides a photograph (image) of the fish as input, and the fish is identified to a taxonomic level using software (IRS). The identification process is based on computer vision techniques, such as image retrieval and/or classification approaches that use feature vectors and similarity functions to automatically characterise image visual properties (e.g. colour, texture, and shape).

Advantages
Desired identifications should be achieved with minimal effort, resulting in high and immediate usefulness as well as the highest level of reproducibility possible. A bit of training may be required to get started with the procedure. Software is easily available at free of cost.

Disadvantages
The transferability and resolution are somewhat limited because the fauna will differ between geographic regions, and, therefore, the characterization of fish image properties (e.g. colour, texture and shape) may vary for the same species from different regions.

4) Dichotomous keys

Diagnostic taxonomic keys are a common traditional method of identifying unknown specimens based on diagnostic (morphological) characters refer to measurable structures such as fin lengths, head lengths, eye diameters, or ratios between such measurements, and meristic characters that correspond to body segments such as countable structure including number of scales, gill rakers, cephalic pores, and so on, that leads to a reliable identification of an organism. A dichotomous key is a set of statements with two options that describe characteristics of unidentified organism's features. The user must decide which of the two statements best represents the unknown organism, based on that choice, then proceed to the following series of statements, ultimately ending in the identity of the unknown.

Advantages
Keys are logical choice systems that are easy to use by both unskilled and highly skilled individuals.

Disadvantages
If a single wrong decision is made at any juncture, a wrong identification will result.

As an example for identifying US Atlantic shark species using dichotomous key.

1a) Body flattened dorso-ventrally, skate-like in appearance.	 *Squatina dumeril* – Atlantic angel shark
1b) Body round in cross section.	Go to question 2

2a) Seven gill slits, single dorsal fin.	 *Heptranchias perlo* – sharpnose sevengill shark
2b) Six gill openings, single dorsal fin.	Go to question 3
2c) Five gill openings, two dorsal fins.	Go to question 4
3a) Snout short, blunt and broad; eye small; distance between rear base of dorsal fin and origin of caudal fin about 1.5 to 2 times length of dorsal fin base; lower jaw with six rows of teeth.	 *Hexanchus griseus* – bluntnose sixgill shark
3b) Snout more pointed and narrow; eye large; distance between rear base of dorsal fin and origin of caudal fin about 2.5 to 3 times length of dorsal fin base; lower jaw with five rows of teeth.	 *Hexanchus nakamurai* – bigeye sixgill shark

(Photo Source: Fishbase)

5) IPez (morphometric software)

IPez is a tool for taxonomic identification of fish that is based on machine learning techniques. It successfully recognises all new members of this species that aren't already in the database. The key morphometric features that have promoted or are promoting divergence among closely related species can be determined by this software. The software is available for download for free at http://www.ipez.es/index%20ingles.html. To learn how to operate the system, you'll need one day of training. A computer is necessary, and the time required for fish identification is usually less than five minutes, depending on the user's ability.

6) Biochemical taxonomy

Proteins are the building blocks of all biological processes. Each species is chemically made up of different proteins at varying levels. Proteomics is a large-scale examination of proteins in a biological system at a specific time. Proteomics encompasses not only the study of protein structure and function but also protein modifications, protein interactions, protein intracellular localization, and protein abundance quantification. Proteomics has been used to identify a variety of seafood species, including mussels (Lopez et al. 2002) and shrimps (Ortea et al. 2009); however, it has rarely been employed to authenticate Teleostei species.

Advantages
Helps to identify protein modification, intracellular localization and protein abundance quantification

Disadvantages
Not cost effective. Technologically demanding

7) Molecular method

Molecular taxonomy is the identification of specimens based on molecular rather than morphological characters. Molecular technique has become a major tool for systematics at the species level and above. Because all organisms contain DNA, RNA, and proteins but closely related organisms show a high degree of similarity in molecular structures, especially nuclear DNA and mitochondrial DNA have become increasingly useful at all levels of classification.

DNA-Based Methods for Species Identification
DNA based taxonomy system provides a new scaffold for the accumulated taxonomic knowledge and is a convenient tool for species identification and description. DNA polymorphisms, or genetic variations that emerge as a result of naturally occurring mutations in the genetic code, are used to identify genetic species (Liu and Cordes 2004). DNA is taken from the target organism and then the DNA fragment(s) of interest is amplified using PCR to discover species-specific genetic variations. The resulting PCR amplicons are then analysed to reveal the characteristic polymorphisms. Molecular markers can be categorized into two classes, nuclear DNA which includes random amplified polymorphic DNA (RAPDs), amplified fragment length polymorphisms (AFLPs), variable number of tandem repeats loci (VNTRs: minisatellites, microsatellites), and single nucleotide polymorphisms (SNPs) and mitochondrial DNA (mtDNA) markers includes Barcoding which is widely used today.

Barcoding

Barcoding is defined as the use of a standardized short region of DNA to verify species identity, which typically for fish is the CO1 region of mitochondrial DNA, with the generation of publicly accessible and highly comparable data. All publicly accessible data are available from one website (Barcode of Life Database), and information on specimen vouchers, photographs and other biological information are available from the same site. Cytochrome oxidase subunit I gene (COI) which has been proposed as a global bio-identification system for animals. Barcoding to be successful, within-species DNA sequences need to be more similar to each other than to sequences of different species. Successful barcoding will facilitate identification of fishes, linking larvae with adults, forensic identification of fish fillets and other items in commerce, and identification of stomach contents.

Advantages of molecular taxonomy
Molecular entities are strictly heritable. The description of molecular features is unambiguous. There is some regularity to the evolution of molecular traits. Molecular data are amenable to

quantitative treatment. Homology evaluation is less difficult than morphological characteristic evaluation. There is a plethora of molecular data available.

Disadvantages

Homoplasy is more prevalent in nucleotide sequences than in morphological features. Homology between characters is not always easy to determine, and require an intensive training time.

8) Integrated approach to fish taxonomy

Modern taxonomy in general is heading towards an integrated approach to taxonomy (Osterhage et al. 2016), especially in case where ambiguities are to be resolved among highly cryptic species. Integrated taxonomy compiles and analyse taxonomic information from all the available resources like classical taxonomy (morpho-meristic features) and modern tools (DNA based methods). The integrated approach most often provides a better resolution than the individual methods. Further, the classical approach to taxonomy itself has evolved substantially and provides much more insights than ever before. Classical taxonomy mostly revolves round the observation of external characters like major morphometric measurements or counts and subsequently on anatomical features like neurocranium, facial bones, caudal verterbrae, etc (Alexandre and Menezes, 2007). At present, in addition to these, even shapes of otolith and scales have been incorporated in species differentiation and description (Jawad and Al-Jufaili, 2007). The science of taxonomy also changed in the way the morphological data is being collected. Presently, several images based techniques like truss networks or fourier descriptors are used to objectively represent the morphometry and shape of the species (Pavlov, 2016; Renjith et al. 2014; Afanasyev et al. 2017; Gupta et al. 2018). These advancements in the classical approach to taxonomy and support extended by molecular science are given rise to an integrated approach to taxonomy, which is now being accepted as best practices in taxonomy.

9) Web-based fish identification and information resources

Experts and non-experts can find a lot of information and tools on the internet to help them identify fish. Web resources are especially useful for double-checking species information and confirming a first identification. Many other (typically local or regional) sources, such as FishBase (www.fishbase.org), SeaLife Base (www.sealifebase.org), FAO FishFinder online (www.fao.org/fishery/fishfinder/en), publications, and many others, offer descriptions of diagnostic features and distribution maps, as well as bio-ecological and fisheries data.

Another important use of web resources consists in confirming the validity of scientific names (in particular for older publications, field guides or keys). The Catalog of Fishes (http://research.calacademy.org/ichthyology/catalog), is the most authoritative site for taxonomic names of finfishes but FishBase and FishWisePro (www.fishwisepro.com), may be used if the name is not found in the CoF. SeaLifeBase, World Register of Marine Species (WoRMS) (www.marinespecies.org), Catalogue of Life (www.catalogueoflife.org), and the Integrated Taxonomic Information System (www.itis.gov), are good sources for taxonomic information on invertebrate aquatic species.

There are an increasing number of websites that can help you identify aquatic species. However, there is currently no generic platform that can route consumers to the optimal identifying tool for their needs.

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CHAPTER 6
Zoological Nomenclature

"Taxonomy is the theory and practice of classifying organisms" (Mayr).

Taxonomy can be described as an information system comprising of identification, description, nomenclature, and classification. It is the most basic activity in biology, dealing exclusively with the discovery, ordering and communication of patterns within, and relationships between, taxa. In combination with systematics, taxonomy paints a vivid picture of the existing biological diversity on the planet; helps reconstruct the tree of life, reveals evolutionary relationships, and provides names for all known organisms. Together, all of these buttress the various branches of biology.

Taxonomy is generally organised into three levels;

(i) Alpha (α) taxonomy is concerned with the identification, characterisation and naming of species.
(ii) Beta (β) taxonomy refers to the arrangement of the species into a natural system of hierarchical categories.
(iii) Gamma (Y) taxonomy is the analysis of intraspecific variation and evolutionary studies.

In practice, most taxonomic studies deal with alpha and beta taxonomy.

Nomenclature

Zoological nomenclature is the system of scientific names applied to taxonomic units of extant or extinct animals. Nomenclature refers to a set of mandatory rules and voluntary recommendations that determine the structure and formation of the names of organisms with the ultimate goal of providing stability in scientific communication. The three primary guiding principles of modern nomenclature are

(i) Stability: As a recognition symbol, names would lose much of their usefulness if they were changed frequently and arbitrarily.
(ii) Universality: Scientific communications based only on vernacular names would cause confusion due to the various names of taxa in different languages. To avoid this, zoologists have adopted, through international agreement, a single set of names for animals to be used on a worldwide basis.
(iii) Uniqueness: Every name has to be unique because it is the key to retrieving information relating to that species or higher taxon.

While systems for naming living things have existed earlier, the formal starting point in the history of zoological nomenclature is generally taken to be 1758, when the 10^{th} edition of Linnaeus's *Systema Naturae* was published. The first edition of the International Code of Zoological Nomenclature (ICZN) was published in 1961, with the fourth, and current, edition, which supersedes all previous editions published in 1999. The aim of the ICZN is to ensure that, with any given circumscription, position and rank a taxon can have one, and only one, name by which it is known. It also tries to reject or avoid the use of names that may create ambiguity or confusion.

Nomenclature is only a tool for designating names that follow taxonomy. The taxonomic identity of a name is determined by that of its type. In other words, the identity of a name relies only on its type, not on its description or diagnosis.

Types of Types

The ICZN has rules governing certain categories of types, also known as name bearing types.

(A) Types by Original Designation (fixed in an original publication)
- (i) Holotype: The single specimen on which a species-group taxon is based in the original description. Ideally, this should be an adult specimen, in a good state of preservation, exhibiting the characters which help distinguish the species.
- (ii) Paratype: The remaining specimens in the original type series.
- (iii) Syntypes: Specimens of a type series that collectively constitute a name bearing type. Syntypes are a feature of many older descriptions, but are not allowed now.

(B) Types by subsequent designation (not fixed in the original publication)
- (i) Lectotype: A single name-bearing type selected from amongst a lot of syntypes.
- (ii) Paralectotype: Remaining specimens from a syntype series after selection of a lectotype.
- (iii) Neotype: A single specimen designated as a name bearing type when no name-bearing type specimen is known to exist. Great care must be taken in choosing a neotype in order to prevent taxonomic instability. In addition, it is necessary to demonstrate the express need for designating a neotype.

Other "types" not regulated by the ICZN, and not possessing any nomenclatural status include:
- (i) Allotype: A designated specimen of opposite sex to the holotype.
- (ii) Genotype: Previously used to designate the type for a genus, now sometimes used to designate a DNA barcode generated from a type specimen.
- (iii) Topotype: A specimen originating from the same locality as a name bearing type.

Ruling principles of nomenclature
- (A) Synonymy: A taxon should have only one valid name. If a taxon is shown to have two or more names, all others except one are to be treated as synonyms based on certain criteria. If two or more names have been applied to the same type specimen, this is a case of objective or nomenclatural synonymy. If two or more names are applied to the same species, this is a case of subjective or taxonomic synonymy.
- (B) Homonymy: A species name must be unique from all other names in a given genus. Two genera cannot have the same.

(C) Priority: The oldest valid name takes precedence over all others. In the case of synonyms, the oldest name is valid and all others are junior synonyms. In the case of homonymy, the oldest name takes precedence and a replacement name must be assigned to the others.

Binomial nomenclature

All taxa in the rank of species possess a binomial name, consisting of a genus and species. Scientific names have traditionally been formed from Latin, and therefore follow the rules of Latin grammar. In order for a name or nomenclatural act to be considered valid, it must be published and be composed of any of the 26 letters in the Latin alphabet. Names can be derived from any language or an arbitrary combination of letters that can be used as a word. New names should be in Latin form; they should be euphonious and easily memorable, and should not be liable to confusion with those of other taxa of any rank, or with vernacular words.

Genus names are considered nouns and thus possess a gender. Words formed from Latin or Greek roots assume the gender of the root. Nouns from other European languages take the gender of that word in the native language. The gender of names formed from other languages must be specified by the author, or assume gender based on the type species or are assumed to be masculine.

Species names may be adjectives or nouns. The gender of an adjective must match the gender of the genus name. A noun need not agree in gender with the genus name. Species names formed from the name of a geographic location can be adjectives or nouns based on how they are formed. Names formed from non-Latin words whose gender is unknown are treated as nouns. Names formed from personal names are treated as genitive nouns and have suffixes indicating the gender. In general, a name based on a characteristic of the taxon is preferable to one based on a personal or place name.

Nomenclature is the language of zoology and the rules of nomenclature are its grammar. Since it is imperative to use properly assigned names for communication, it is, thus, essential that all zoologists familiarise themselves with the general principles of zoological nomenclature.

Reference:

https://www.iczn.org/the-code/the-code-online/

CHAPTER 7

International Code of Zoological Nomenclature (ICZN) & its Importance

Naming of objects including animals and plants is as old as mankind. It is the most succinct way of communication about an object. Man's dependency on animals and plants for food and also his innate quest for study of nature had paved way to name biotic organisms in a more scientific way for which rules and regulations were unorganizedly framed. Accordingly the system of naming animals and plants (living and extinct) with two names has been gradually emerged. With just two names (e.g. Cancer pagurus), a unique qualifier for each and every organism that shares the planet with us, together with its 'birth certificate'— the scholarly work and year in which it was first described can be communicated (in this case Linnaeus, 1758). Each name is unambiguous and unique: one organism, one name. Today we have about 1.5 million living animal species discovered and named. It is also reported that more than 80 per cent of life forms are yet to be discovered and named, excluding extinct forms which are not described.

This time-tested system (since 1758) has served all fields of human enterprise which in one way or another involved a living organism – zoology, taxonomy, phylogenetics, applied sciences, domestication and farming, nature cleaning, medicine, epidemiology, conservation, and genetics – for two-and-a-half centuries. The starting date of binominal nomenclature is fixed as 1^{st} January, 1758, the publication of 10^{th} edition of *Systemae naturae* by Carl Linnaeus. First International Congress of Zoology was held in 1889 in Paris, France. The first version of the code was adopted in the Vth International Congress of Zoology in Berlin in 1901. The XV^{th} session of the Congress held at London in 1958 updated the version and published by International Trust of Zoological Nomenclature in 1961 as second edition. The International Congress of Zoology elects a judicial body called International Commission on Zoological Nomenclature, established in 1895. The Commissioners, currently 25 senior scientists from 19 countries who are experts in different animal groups (and all of whom do this on their own time, with no pay) takes into account priority, prevailing usage, and other factors to help maintain nomenclatural stability to ensure that scientists and other users of names do not get confused. The major way these ends are achieved is the International Code of Zoological Nomenclature, now in its 4^{th} edition (1999), with a 2012 amendment on electronic publications, which is authored by the ICZN.

The ICZN does more than just ensure that names are unique: the Commission acts as the "Supreme Court" that manages and resolves disagreements pertaining to zoological nomenclature, some disagreements arising because strict application of the Code will create ambiguity or instability. Among these problems are some that have serious implications for business, commerce, and conservation. Commissioners discuss the cases, address concerns, listen to please and arguments from scientists, managers and public, and vote on the cases. Their votes are final and binding: once the Commission has made the decision, all biologists are obliged to follow the ruling for the names to be used. In some cases, there are legal consequences for ICZN decisions. Notable nomenclatural quandaries handled by the ICZN have included the names of the malarial parasites (the name Plasmodium as used today) and more recently, Drosophila (the ubiquitous laboratory fly). Even more challenging was the recent case of the highly endangered Giant Land Tortoise in Seychelles, its name now fixed as Geochelone (Aldabrachelys) gigantea. This Code has been adopted by the International Commission on Zoological Nomenclature and has been ratified by the Executive Committee of the International Union of Biological Sciences (IUBS) acting on behalf of the Union's General Assembly. IUBS, established in 1919, is a global platform for co-operation among scientists from various biology disciplines.

The code proper is described below. In addition to the Code itself, the present volume contains a Preface (by the present and preceding Presidents of the Commission) and an Introduction (by the Chairman of the Editorial Committee). There are Three Appendices; the first two of these have the status of Recommendations, and the third is the Constitution of the Commission.

History of ICZN:

Origin of ICZN - The origin of an internationally accepted Code of Rules for Zoological Nomenclature is a consequence of the confusion of names that occurred in the zoological literature of the early part of the 19th century. The publication of the 10^{th} edition of the Systema Naturae by Linnaeus in 1758, and the adoption of binominal names for species of animals had initiated overwhelming response to successfully include the new system for naming the animals. Thus the century witnessed that the new system expanded and developed in different places, and in different ways for different animal groups had created great confusion and instability. Moreover, the great explosion in known species, caused by the growth of science and by active exploration in countries outside Europe, resulted in a multiplicity of names; many of these were synonyms resulting from the work of scientists researching independently. By the second quarter of the 19th century disparate usages were common and it became critical to devise universally accepted methods for achieving universality in the scientific names of animals.

Different codes developed – British Association Code or the Stricklandian Code (1842): The rules proposed by Strickland and his colleagues developed Series of Propositions for Rendering the Nomenclature of Zoology Uniform and Permanent. Following its presentation at the British Association for the Advancement of Science in 1842, by a Committee that included such distinguished zoologists as Charles Darwin, Richard Owen and John Westwood, that Code was translated and circulated widely and had great influence. It was published in France, Italy and the United States of America.

Geologists and Naturalists code (1845): The American Society adopted the above code and the same was British Association for the Advancement of Science in 1846.

Douvillé Code (1881) : The above code revised and adopted internationally by geologists
American Ornithologists' Union Code (1886): the above adopted by American Ornithologists

Development of code - Rules for nomenclature in Zoology in a written form were available since 1830s. These rules are popularly known as Merton's Rules (Allen, 1878) and Strickland's Codes (Strickland, 1878). These rules paved way for the formation of rules for nomenclature purposes of animals. The first International Zoological Congress at Paris (1889) and the subsequent at Moscow (1892) emphasized the urgent need to establish commonly accepted international rules for all disciplines and countries to replace conventions and unwritten rules that varied across disciplines, countries, and languages. In agreement with this decision the first compilation of **"International Rules on Zoological Nomenclature"** was proposed at third International Congress of Zoology in 1895 in Leiden and was officially published in French by Blanchard *et al.* (1905) and the same was translated into English and German.

From this point onwards there were serious discussions on zoological nomenclature and resulted in different amendments and modifications in the existing rules. These modifications were accepted at subsequent Zoological congresses held at Boston in 1907; Graz in 1910; Monaco in 1913; Budapest in 1927; Padua in 1930; Paris in 1948; Copenhagen in 1953. The deliberations were recorded in English and its availability was restricted, but confusion increased. This was felt at the Copenhagen Congress itself. Considering the difficulty in getting the complete set of rules with amendments, the Zoological Congress appointed a new Editorial Committee for preparing a new compilation of the rules with amendments. This committee submitted a new compilation of rules at Zoological Congress at London in 1958 and were finally published as the first edition of the International Code of Zoological Nomenclature (*ICZN Code*) on 9th November, 1961. The second edition of the code (only weakly modified) came in 1963. The last zoological congress to deal with nomenclatural problems took place in Monte Carlo 1972, since by then the official zoological organs no longer derived power from zoological congresses. The International Commission on Zoological Nomenclature (ICZN) (established in 1895) acts as adviser and arbiter for the zoological community by generating and disseminating information on the correct use of the scientific names of animals. The ICZN is responsible for producing the International Code of Zoological Nomenclature - a set of rules for the naming of animals and the resolution of nomenclatural problems. The third edition of the code came out in 1985. The present edition is the 4th edition, effective since 2000 (ICZN, 1961, 1964, 1985, 1999). These editions are brought out by respective committees appointed by the International Commission on Zoological Nomenclature. The ICZN Commission takes its power from a general biological congress (IUBS, International Union of Biological Sciences.

As the commission may alter the code (by declarations and amendments) without issuing a new edition of the book, the current edition does not necessarily contain the actual provision that applies in a particular case. The Code consists of the original text of the fourth edition and Declaration 44. The code is published in an English and a French[15] version; both versions are official and equivalent in force, meaning, and authority.[16] This means that if something in the English code is unclear or its interpretation ambiguous, the French version is decisive, and if there is something unclear in the French code, the English version is decisive.

The Commission operates in two main ways:

- ICZN publishes the International Code of Zoological Nomenclature containing the rules universally accepted as governing the application of scientific names to all organisms which are treated as animals.
- ICZN provides rulings on individual nomenclatural problems brought to its attention, in order to achieve internationally acceptable solutions and stability. These rulings are published as 'Opinions' in the Bulletin of Zoological Nomenclature.

Editions of ICZN - First edition of the International Code of Zoological Nomenclature (*ICZN Code*) was published on 9th November, 1961. The second edition of the code (only weakly modified) came in 1963. To most zoologists at the time, the 17th International Congress of Zoology (Monaco, 1972) appeared likely to be the last general Congress of Zoology. Decisions were taken there to amend the second (1964) edition, and in addition, to ensure mechanisms for continuity and future up-dating, a decision was taken to transfer responsibility for future Codes (and the Commission) from the International Zoological Congresses to the International Union of Biological Sciences (IUBS).

Responsibility for the Code and the Commission was accepted by IUBS at the XVIII IUBS General Assembly (Ustaoset, Norway, 1973). In response to proposals for major and substantive changes to the Code, made by the community of zoologists at that time, and to eliminate ambiguities, a third edition of the Code was prepared and was approved by the Commission, with the authority of IUBS, late in 1983 and published in 1985. An account of the changes adopted in that edition, comments on proposals, and the Commission's voting, are given in the Introduction to the edition.

A more detailed account of the development of zoological nomenclature and the events leading to the modern Code are given by Richard Melville, former Secretary of the Commission, in the centenary history of the Commission which was published in 1995 entitled Towards stability in the names of animals.

The Code Proper:
The code comprises of a preamble, 90 articles (grouped under 18 chapters) and Glossary.
Preamble: This section provides an overall picture of ICZN. The provisions of the Code can be waived or modified in their application to a particular case when strict adherence would cause confusion, but this can only be done by the Commission, acting on behalf of all zoologists and using its plenary power (Articles 78 and 81), and never by an individual.
Chapter 1: Nomenclature (Articles 1, 2, 3)

Article 1: Definition, scope, exclusion and independence
Definition: Zoological nomenclature is the system of scientific names applied to taxonomic units (taxon – singular; taxa – plural) of extant and extinct animals (metazoan and protista).
Scope: The scientific names of extant or extinct animals include names based on domesticated animals, names based on fossils that are substitutions (replacements, impressions, moulds and casts) for the actual remains of animals, names based on the fossilized work of organisms (ichnotaxa), and names established for collective groups. The Code regulates the names of

taxa in the family group, genus group, and species group and also regulate names of taxa at ranks above the family group.

Exclusion: eg. Names for hybrids
Independence: The Code regulates the names of taxa in the family group, genus group, and species group. Articles 1-4, 7-10, 11.1-11.3, 14, 27, 28 and 32.5.2.5 also regulate names of taxa at ranks above the family group.

Article 2: Admissibility of certain names in zoological nomenclature
Two situations: Names of taxa later but not at first classified as animals; **names of taxa at some time but later classified as animals**

Article 3: Starting point
1st January 1758 is arbitrarily fixed in this Code as the date of the **starting point** of ICZN.
Two works are **deemed to have been published on 1 January 1758**: Linnaeus's Systema Naturae, 10th Edition; - Clerck's Aranei Svecici. Names in the latter have precedence over names in the former, but names in any other work published in 1758 are deemed to have been published after the 10th Edition of Systema Naturae.
No **name or nomenclatural** act **published before 1 January 1758** enters zoological nomenclature, but information (such as descriptions or illustrations) published before that date may be used.
Chapter 2: The number of words in the scientific names of animals (Articles 4, 5, 6)

Article 4: Names of taxa at ranks above the species group
The scientific name of a taxon of **higher rank than the species** group consists of one word (i.e. the name is uninominal); it must begin with an upper-case letter [Art. 28]
The scientific name of a **subgenus** must not be used as the first name in a binomen or trinomen unless it is being used at the rank of genus [Art. 6.1].

Article 5: Principle of Binominal Nomenclature
The **scientific name** of a species, and not of a taxon of any other rank, is a combination of two names (a binomen), the first being the generic name and the second being the specific name. The generic name must begin with an upper-case letter and the specific name must begin with a lower-case letter [Art. 28].
For the application of the article to the availability of genus-group names published without associated nominal species and of subspecific names published in trinominal see Article 11.4; and in the use of subgeneric names and names for aggregates of species and subspecies see Article 6.
The scientific name of a subspecies is a combination of three names (a trinomen, i.e. a binomen followed by a subspecific name) [Art. 11.4.2]. The subspecific name must begin with a lower-case letter [Art. 28].

A typographical sign such as ?, and an abbreviation such as aff., prox. or cf., when used to qualify the application of a scientific name, does not form part of the name of a taxon even when inserted between the components of a name.

Article 6. Interpolated names

The scientific name of a subgenus, when used with a binomen or trinomen, must be interpolated in parentheses between the generic name and the specific name; it is not counted as one of the words in the binomen or trinomen. It must begin with an upper-case letter.

A specific name may be added in parentheses after the genus-group name, or be interpolated in parentheses between the genus-group name and the specific name, to denote an aggregate of species within a genus-group taxon; and a subspecific name may be interpolated in parentheses between the specific and subspecific names to denote an aggregate of subspecies within a species; such names, which must always begin with a lower-case letter and be written in full, are not counted in the number of words in a binomen or trinomen. The Principle of Priority applies to such names [Art. 23.3.3]; for their availability see Article 11.9.3.5.

Chapter 3: Criteria of publication (Articles 7, 8, 9)

Article 7: Application

The provisions of this Chapter apply to the publication not only of a new scientific name, but also to that of any nomenclatural act or information likely to affect nomenclature.

Article 8: What constitutes published work

A work is to be regarded as published for the purposes of zoological nomenclature if it complies with the requirements of this Article and is not excluded by the provisions of Article 9.

A work must satisfy the following criteria: it must be issued for the purpose of providing a public and permanent scientific record; it must be obtainable, when first issued, free of charge or by purchase; it must have been produced in an edition containing simultaneously obtainable copies by a method that assures and numerous identical and durable copies (see Article 8.4), or widely accessible electronic copies with fixed content and layout. A few more subsections (up to 8.7) available in this article

Article 9: What does not constitute published work

Notwithstanding the provisions of Article 8, none of the following constitutes published work within the meaning of the Code: handwriting reproduced in facsimile by any process; works produced by hectographing or mimeographing and so on (refer 9.1 to 9.12)

Chapter 4: Criteria of availability (Articles 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20)

Article 10: Provisions conferring availability

A name or nomenclatural act becomes available only under the following conditions : **General conditions to be met; Availability of infrasubspecific names; Availability of names proposed for collective groups and ichnotaxa; Availability of names for divisions of genera; Availability of names of taxa later but not at first classified as animals; Effect of invalidity upon availability; Availability of names not listed in a relevant adopted Part of the** *List of Available Names in Zoology (refer 10.1 to 10.7).*

Article 11: Requirements

To be available, a name or, where relevant, a nomenclatural act must satisfy the following provisions: **Publication; Mandatory use of Latin alphabet; Derivation; Consistent**

application of binominal nomenclature; Names to be used as valid when proposed; Publication as a synonym; Family-group names; Genus-group names; Species-group names; Deliberate employment of misidentifications (refer 11.1 to 11.10)

Article 12: Names published before 1931
To be available, every new name published before 1931 must satisfy the provisions of Article 11 and must be accompanied by a description or a definition of the taxon that it denotes, or by an indication (refer 12.2, 12.2.1, 12.2.2, 12.2.3, 12.2.4, 12.2.5, 12.2.6, 12.2.7, 12.2.8) and exclusion (12.3) and exclusion.

Article 13: Names published after 1930
To be available, every new name published after 1930 must satisfy the provisions of Article 11 and must be accompanied by a description or definition that states in words characters that are purported to differentiate the taxon, or as contained in 13.1.2, 13.1.3.

Family-group names : To be available, every new family-group name published after 1930 must satisfy the provisions of Article 13.1 and must be formed from an available genus-group name then used as valid by the author in the family-group taxon [Arts. 11.7.1.1, 29] and 13.2.1.
Genus-group names : To be available, every new genus-group name published after 1930 (except those proposed for collective groups or ichnotaxa) must, in addition to satisfying the provisions of Article 13.1, be accompanied by the fixation of a type species in the original publication [Art. 68] or be expressly proposed as a new replacement name (nomen novum) [Art. 67.8] and also in 13.3.1, 13.3.2, 13.3.3.

Combined description of new genus-group taxon and new species, Combined description of new family-group taxon and new genus and exclusions as in 13.4, 13.5, 13.6, 13.6.1, 13.6.2.

Article 14: Anonymous authorship of names and nomenclatural acts
A new name or nomenclatural act published after 1950 with anonymous authorship [Art. 50.1] is not thereby made available; such publication before 1951 does not prevent availability. This Article does not apply to nomenclatural acts published by the Commission.

Article 15: Names and nomenclatural acts published after 1960
This article should be dealt as in 15.1, 15.2, 15.2.1

Article 16: Names published after 1999
Every new name published after 1999, including new replacement names (nomina nova), must be explicitly indicated as intentionally new (appropriate latin terms – 'fam.nov., sp. nov., g. nov, ssp. nov., or equivalent expression – new family, new genus, new species, new subspecies or n. fam, n.g., n. sp., n. ssp, nomen novum. Nom. Nov. should only be used to indicate a new replacement name. Similarly family groups names: type genus to be cited; genus-group names: ichnotaxa and collective groups; species-group names; fixation of name-bearing types to be explicit as per 16.2, 16.3, 16.4, 16.4.1, 16.4.2 respectively

Article 17: Names found to denote more than one taxon, or taxa of hybrid origin, or based on parts or stages of animals or on unusual specimens
The availability of a name should not be affected (as per 17.1, 17.2, 17.3)

Article 1: Inappropriate and tautonymous names
The availability of a name is not affected by inappropriateness or tautonymy [Art. 23.3.7].

Article 19. Status of emendations, incorrect spellings, and mandatory changes
Unjustified emendations and incorrect spellings, justified emendations, multiple original spelling (as per 19.1, 19.2, 19.3, 19.4) are to be corrected. The availability of a name is not affected by a mandatory change made under the provisions of Article 34.

Article 20 : Genus-group names ending in -its, -ytes, or -ithes given to fossils
Should be available only for the purpose of homonymy.

Chapter 5: Date of Publication (Articles 21, 22)

Article 21: Determination of date
Date to be adopted for a published work or nomenclature should be based on date of publication of a work. Date of incompletely specified (21.3), date incorrect (21.4), dates of work issued in parts (21.5), range of dates (21.6), dates not specified (21.7), advance distribution of separates and preprints (21.8) and work issued on paper or electronically (21.9) are to be followed as in subsections in brackets.

Article 22: Citation of date
When cited, the date of publication of a name follows the name of the author (see Article 51).
Chapter 6: Validity of dates and nomenclatural acts (Articles 23, 24)

Article 23: Principle of Priority
The valid name of a taxon is the oldest available name applied to it, unless that name has been invalidated or another name is given precedence by any provision of the Code or by any ruling of the Commission. For exclusions see 23.1.1, 23.1.2, 23.1.3, 23.1.4. The principle of priority is to be used to promote stability (23.2).

Application to Synonymy - The Principle of Priority requires that a taxon formed by bringing together into a single taxon at one rank two or more previously established nominal taxa within the family group, genus group or species group takes as its valid name the name determined in accordance with the Principle of Priority [Art. 23.1] and its Purpose [Art. 23.2], with change of suffix if required in the case of a family-group name [Art. 34]. Also follow subsections 23.3.1, 23.3.2, 23.3.2.1, 23.3.2.3, 23.3.3, 23.3.4, 23.3.5, 23.3.6, 23.3.7.

Application to Homonymy (23.4), application to spellings (23.5), Application to nomenclatural acts (23.6), application to collective groups and ichnotaxa (23.7), application to species- group names established on hybrids (23.8), reversal precedence (23.9), erroneous reversal of precedence (23.10), names rejected under former article 23b are to be addressed as in subsections mentioned against each.

Article 24: Precedence between simultaneously published names, spellings or acts
This act are to be addressed in Automatic determination of precedence of names and also determination by the first reviser as in 24.1, 24.2

Chapter 7: Formation and treatment of names (Article 25, 26, 27, 28, 29, 30, 31, 32, 33, 34)

Article 25: Formation and treatment of names
A scientific name must be formed and treated in accordance with the relevant provisions of Article 11 and Articles 26 to 34 (also see Appendix B, General Recommendations).

Article 26: Assumption of Greek or Latin in scientific names
If the spelling of a scientific name, or of the final component word of a compound name [Art. 31.1], is the same as a Greek or Latin word, that name or that component is deemed to be a word in the relevant language unless the author states otherwise when making the name available.

Article 27: Diacritic and other marks
No diacritic or other mark (such as an apostrophe), or ligature of the letters a and e (æ) or o and e (œ) is to be used in a scientific name; the hyphen is to be used only as specified in Article 32.5.2.4.3

Article 28: Initial letters
A family-group or genus-group name or the name of a taxon above the family group is always to begin with an upper-case initial letter, and a species-group name always with a lower-case initial letter, regardless of how they were originally published.

Article 29: Family-group names
A family-group name is formed by adding to the stem of the name [Art. 29.3] of the type genus, or to the entire name of the type genus [see Article 29.6], a suffix as specified in Article 29.2.

Suffixes for family-group names - The suffix -OIDEA is used for a superfamily name, -IDAE for a family name, -INAE for a subfamily name, -INI for the name of a tribe, and -INA for the name of a subtribe. These suffixes must not be used at other family-group ranks. The suffixes of names for taxa at other ranks in the family-group are not regulated.

Names in the genus and species groups which have endings identical with those of the suffixes of family-group names are not affected by this Article. E.g., genus *Ranoide,* species *Hyla mystocina* (Amphibia), *Collocalia terraereginae* (Aves).

Determination of stem in names of type genera (29.3), Acceptance of originally formed stem (29.4), Maintenance of current spellings (29.5), Avoidance of homonymy in family-group names (29.6) are as per subsection.

Article 30: Gender of genus-group names

Gender of names formed from Latin or Greek words - a genus-group name that is or ends in a Latin word takes the gender given for that word in standard Latin dictionaries; if it is a compound word formed from two or more components, the gender is given by the final component (in the case of a noun, the gender of that noun; in the case of any other component, such as a Latin suffix, the gender appropriate to that component). E.g., *Felis* and *Tuba* – Feminine; *Salmo, Passer, Ursus* and *Turdus* – masculine; *Argonauta* – masculine because noun nauta (a sailor) is masculine; *Lithodomus* where final part noun domus is feminine.

The exceptions are – If the word is a combination of letters and or a word of common or variable gender is to be treated as masculine unless the authors states the other way. Name ending in -ops is to be treated as masculine; the suffix -ites, -oides, -ides, -odes, or -istes is to be treated as masculine.

Gender of names formed from words that are neither Latin nor Greek as per 30.2.

Article 31: Species-group names

A species-group name formed from a personal name may be either a noun in the genitive case, or a noun in apposition (in the nominative case), or an adjective or participle [Art. 11.9.1] (ref.31.1.1, 31.1.2, 31.1.3) and agreement in gender (31.2).

Article 32: Original spellings

The "original spelling" of a name is the spelling used in the work in which the name was established. Corrections are to be done as per 32.2, 32.3, 32.4, 32.5

Article 33: Subsequent spellings

A subsequent spelling of a name, if different from the original spelling [Art. 32.1], is either an emendation [Art. 33.2], or an incorrect subsequent spelling [Art. 33.3], or a mandatory change [Art. 34].

Article 34: Mandatory changes in spelling consequent upon changes in rank or combination

This should be done as per subsections 34.1, 34.2, 34.2.1

Chapter 8: Family – group nominal taxa and their names (Articles 35, 36, 37, 38, 39, 40, 41)

Article 35: The family group

The family group encompasses all nominal taxa at the ranks of superfamily, family, subfamily, tribe, subtribe, and any other rank below superfamily and above genus that may be desired (see also Article 10.3 for collective groups and ichnotaxa).

Provisions applicable to all family-group nominal taxa and their names (35.2), Application of family-group names (35.3), Formation and treatment of family-group names (35.4), Precedence for names in use at higher rank (35.5) are dealt in the subsection mentioned against each.

Article 36: Principle of Coordination

Statement of the Principle of Coordination applied to family-group names : A name established for a taxon at any rank in the family group is deemed to have been simultaneously established for nominal taxa at all other ranks in the family group; all these taxa have the same type genus, and their names are formed from the stem of the name of the type genus [Art. 29.3] with appropriate change of suffix [Art. 34.1]. The name has the same authorship and date at every rank.

Type genus: When a nominal taxon is raised or lowered in rank in the family group its type genus remains the same [Art. 61.2.2].

Article 37: Nominotypical taxa

When a family-group taxon is subdivided, the subordinate taxon that contains the type genus of the superior taxon is denoted by the same name (except for suffix) with the same author and date [Art. 36.1]; this subordinate taxon is termed the "nominotypical taxon".

Effect of change of name on nominotypical taxa - If the name in use for a family-group taxon is unavailable or invalid it must be replaced by the name valid under Article 23.3.5; any subordinate taxa containing the type genus of the substitute nominal taxon (and therefore denoted by the valid family-group name, with appropriate suffixes) become nominotypical taxa.

Article 38: Homonymy between family-group names

For homonymy between family-group names, see Articles 39 and 55.

Article 39: Invalidity due to homonymy or suppression of the name of the type genus

The name of a family-group taxon is invalid if the name of its type genus is a junior homonym or has been totally or partially suppressed (see Articles 81.2.1 and 81.2.2) by the Commission. If that family-group name is in use it must be replaced either by the next oldest available name from among its synonyms [Art. 23.3.5], including the names of its subordinate family-group taxa, or, if there is no such synonym, by a new name based on the valid name (whether a synonym or a new replacement name (nomen novum)) of the former type genus.

Article 40: Synonymy of the type genus

Validity of family-group names not affected - When the name of a type genus of a nominal family-group taxon is considered to be a junior synonym of the name of another nominal genus, the family-group name is not to be replaced on that account alone.

Names replaced before 1961 - If, however, a family-group name was replaced before 1961 because of the synonymy of the type genus, the substitute name is to be maintained if it is in prevailing usage. A name maintained by virtue of this Article retains its own author but takes the priority of the replaced name, of which it is deemed to be the senior synonym.

Article 41: Misidentified type genera and overlooked type fixations
If stability and continuity in the meaning of a family-group name are threatened by the discovery that the type genus of the taxon is misidentified (i.e. interpreted in a sense other than that defined by its type species), or that the type genus was based on a misidentified type species, or that a valid fixation of type species for the type genus had been overlooked, see Article 65.2.

Chapter 9: Genus – group nominal taxa and their names (Articles 42, 43, 44)
Article 42: The genus group
The genus group, which is next below the family group and next above the species group in the hierarchy of classification, encompasses all nominal taxa at the ranks of genus and subgenus (see also Articles 10.3 and 10.4).

Provisions applicable to all genus-group nominal taxa and their names (42.2), application of genus-group names (42.3), Application of genus-group names (42.3), Formation and treatment of genus-group names (42.4)

Article 43: Principle of Coordination
When a nominal taxon in the genus group is raised or lowered in rank its type species remains the same [Art. 61.2.2] whether the type species was fixed originally or subsequently.

Article 44: Nominotypical taxa
When a genus is considered to contain subgenera, the subgenus that contains the type species of the nominal genus is denoted by the same name as the genus, with the same author and date [Art. 43.1]; this subgenus is termed the nominotypical subgenus. Change of nominotypical subgenus as per 44.2

Chapter 10: Species –group nominal taxa and their names (Articles 45, 46, 47, 48, 49)
Article 45: The species group
The species group encompasses all nominal taxa at the ranks of species and subspecies (see also Article 10.2). A species-group name is to be formed and treated in accordance with Article 11 and the relevant provisions of Articles 19, 20, 23 to 34.

Infrasubspecific names - it is excluded from the species group and is not regulated by the Code [Art. 1.3.4]. A fourth name published as an addition to a trinomen automatically denotes an infrasubspecific entity and authors used terms "variety" or "form".

The rank denoted by a species-group name following a binomen is subspecific.

Article 46: Principle of Coordination
When a nominal taxon is raised or lowered in rank in the species group its name-bearing type [Art. 72.1.2] remains the same [Art. 61.2.2] whether the name-bearing type was fixed originally or subsequently.

Article 47: Nominotypical taxa
When a species is considered to contain subspecies, the subspecies that contains the name-bearing type of the nominal species is denoted by the same species-group name as the species, with the same author and date [Art. 46.1]; this subspecies is termed the nominotypical subspecies.

Article 48: Change of generic assignment
An available species-group name, with change in gender ending if required [Art. 34.2], becomes part of another combination whenever it is combined with a different generic name.

Article 49: Use of species-group names wrongly applied through misidentification
A previously established specific or subspecific name wrongly applied to denote a species-group taxon because of misidentification cannot be used as an available name for that taxon (even if the taxon and the taxon to which the specific or subspecific name correctly applies are in, or are later assigned to, different genera), except when a previous misidentification is deliberately employed in fixing the type species of a new nominal genus or subgenus [Arts. 11.10, 67.13].

Chapter 11: Authorship (Articles 50, 51)

Article 50: Authors of names and nomenclatural acts
The author of a name or nomenclatural act is the person who first publishes it [Arts. 8, 11] in a way that satisfies the criteria of availability [Arts. 10 to 20] (but for certain names published in synonymy see Article 50.7). The provisions of this Chapter apply also to joint authors.
Authorship of names in reports of meetings (50.2), Authorship unaffected by changes in rank or combination (50.3), Authorship of justified emendations (50.4), Authorship of Authorship of a name published simultaneously by different authors (50.6), Authorship of names first published as junior synonyms (50.7)

Article 51: Citation of names of authors
The name of the author does not form part of the name of a taxon and its citation is optional, although customary and often advisable. The name of an author follows the name of the taxon without any intervening mark of punctuation, except in changed combinations as provided in Article 51.3.

The name of a subsequent user, if cited, is to be separated from the name of the taxon in some distinctive and explicit manner, but not by parentheses (cf. Article 51.3), unless an explanation is included. E.g., *Cancer pagurus* Linnaeus sensu Latreille.

Use of parentheses around authors' names (and dates) in changed combinations, e.g., *Taenia diminuta* Rudolphi when transferred to genus *Hymenolepis* is cited as *Hymenolepis diminuta* (Rudolphi).

Article 52: Principle of Homonymy
When two or more taxa are distinguished from each other they must not be denoted by the same name. When two or more names are homonyms, only the senior, as determined by the Principle of Priority (see Article 52.3), may be used as a valid name; for exceptions see Articles 23.2 and 23.9 (unused senior homonyms) and Article 59 (secondary homonyms in the species group).

Article 53: Definitions of homonymy in the family group, genus group and species group
In the family group, two or more available names having the same spelling or differing only in suffix [Art. 29.2] and denoting different nominal taxa are homonyms.

Article 54: Names that do not enter into homonymy
Name that is excluded from the provisions of the Code [Arts. 1.3, 8.3], unavailable names, suppressed names, incorrect spelling do not enter into homonymy.

Article 55: Family-group names
The Principle of Homonymy applies to all family-group names, including names of ichnotaxa at the family-group level. Even if the difference between two family-group names is only one letter, they are not homonyms.

Article 56: Genus-group names
The Principle of Homonymy applies to all genus-group names, including names of collective groups and of ichnotaxa at the genus-group level [Arts. 1.2, 23.7, 42.2]. Even if the difference between two genus-group names is only one letter, they are not homonyms. Of two homonymous genus-group names of identical date, one established for a genus and the other for a subgenus, the former takes precedence over the other [Art. 24.1].

Article 57: Species-group names
The Principle of Homonymy applies to species-group names that are or are deemed to be spelled identically [Art. 58] and are published originally or subsequently in combination with the same generic name [Art. 53.3], including names of collective groups and of ichnotaxa at genus-group level [Arts. 10.3 and 42.2.1].
Article 58: Variant spellings of species-group names deemed to be identical
Species-group names established for different nominal taxa that differ in spelling only in any of the following respects and that are of the same derivation and meaning are deemed to be homonyms when the nominal taxa they denote are included in the same genus or collective group: e.g., use of ae, oe or e (e.g. caeruleus, coeruleus, ceruleus);

Article 59: Validity of secondary homonyms
A species-group name while a junior secondary homonym must be treated as invalid by anyone who considers that the two species-group taxa in question are congeneric.

Secondary homonyms not replaced when no longer considered congeneric (59.2), Secondary homonyms replaced before 1961 but no longer considered congeneric (59.3) are to be discussed against subsection noted.

Article 60: Replacement of junior homonyms
Substitute names : A junior homonym [Art. 53] must be rejected and replaced either by an available and potentially valid synonym [Art. 23.3.5] or, for lack of such a name, by a new substitute name [Art. 60.3]. For unused senior homonyms see Article 23.9; for the replacement of homonymous family-group names see Articles 39 and 55.3; and for the replacement of secondary homonyms in the species group see Article 59.

Junior homonyms with synonyms (60.2), Junior homonyms without synonyms (60.3) interpretation as per subclauses.

Chapter 13: Type concept in nomenclature (Article 61)
Article 61: Principle of Typification
Statement of the Principle of Typification: Each nominal taxon in the family, genus or species groups has actually or potentially a name-bearing type. The fixation of the name-bearing type of a nominal taxon provides the objective standard of reference for the application of the name it bears (also take into consideration of 61.1.1, 61.1.2, 61.1.3).

Name-bearing types of nominotypical taxa (61.2), Name-bearing types and synonymy (61.3)
Chapter 14: Types in family group (Articles 62, 63, 64, 65)

Article 62: Application
The provisions of this Chapter apply equally to nominal family-group taxa at any rank (superfamily, family, subfamily, tribe, subtribe and at any other rank below superfamily and above genus) [Art. 35.1].

Article 63: Name-bearing types
The name-bearing type of a nominal family-group taxon is a nominal genus called the "type genus"; the family-group name is based upon that of the type genus [Art. 29]. (See also Articles 11.7, 35, 39 and 40). Coordinate nominal taxa of the family group have the same type genus [Arts. 36, 37, 61.2].

Article 64: Choice of type genus
An author who wishes to establish a new nominal family-group taxon may choose as type genus any included nominal genus the name of which he or she regards as valid [Art. 11.7.1], not necessarily that having the oldest name. The choice of type genus determines the stem of the name of the nominal family-group taxon [Art. 29.1].

Article 65: Identification of the type genus
It is to be assumed, unless there is clear evidence to the contrary, that an author who establishes a nominal family-group taxon has correctly identified its type genus. Misidentification or altered concept may be assumed as per subclauses 65.2

Chapter 15: Types in genus group (Article 66, 67, 68, 69, 70)

Article 66: Application

The provisions and recommendations of this Chapter apply equally to nominal genera and subgenera (including genus-group divisions deemed to be subgenera; see Article 10.4), but not to collective groups at the genus-group level, which have no type species [Arts. 13.3.2, 42.3.1, 67.14].
An ichnotaxon at the genus-group level proposed after 1999 must have a type species fixed for its name to be available. If established before 2000 it does not require a type species; however, one may have been, or may be, fixed in accordance with Article 69 (see also Article 13.3.3).

Article 67: General provisions

Name-bearing types: The name-bearing type of a nominal genus or subgenus is a nominal species called the "type species" [Art. 42.3]. 67.1.1. A nominal genus and its nominotypical subgenus [Art. 44.1] have the same type species [Art. 61.2]. 67.1.2. The name of a type species remains unchanged even when it is a junior synonym or homonym, or a suppressed name (see Article 81.2.1). The type species of a nominal genus or subgenus is fixed originally if fixed in the original publication [Art. 68], or subsequently if fixed after the nominal genus or subgenus was established [Art. 69]. A nominal genus-group taxon established after 1930 (or, in the case of an ichnotaxon, after 1999 [Art. 66.1]) must have its type species fixed in the original publication [Art. 13.3].

The subclauses given in brackets are to be made use of in: Species eligible for type fixation (originally included nominal species) (67.2), Admissibility of actions relevant to fixation (67.3), Fixations using incorrect spellings or unjustified emendations (67.6), **Status of incorrect citations (**67.7). **Type species of nominal genus-group taxa denoted by new replacement names (nomina nova) (67.8) Union of nominal genus-group taxa (67.10), Nominal species that are already type species (67.11).**

Article 68: Type species fixed in the original publication

Order of precedence in ways of fixation - If one (or more) species qualifies for fixation as the type species in more than one of the ways provided for in Articles 68.2-68.5, the valid fixation is that determined by reference to the following order of precedence: firstly, original designation [Art. 68.2], then monotypy [Art. 68.3], then absolute tautonymy [Art. 68.4], and lastly Linnaean tautonymy [Art. 68.5].

Type species by original designation - If one nominal species is explicitly designated [Art. 67.5] as the type species when a nominal genus-group taxon is established, that nominal species is the type species (type by original designation) unless the provisions of Article 70.3 apply. The expressions "gen. n., sp. n.", "new genus and species", or an equivalent, applied before 1931 to only one of two or more new nominal species originally included in a new nominal genus or subgenus, are deemed to be an original designation if no other type species was explicitly designated.

If, when a nominal genus-group taxon is established without explicit designation of a type species, one originally included new nominal species [Art. 67.2] is given the species-group name typicus, -a, -um or typus, that nominal species is deemed to be the type species by original designation.

Type species by monotypy (68.3), Type species by absolute tautonymy (68.4), Type species by "Linnaean tautonymy" (68.5), Fixation of type species with names cited as deliberately used misapplications or misidentifications by previous authors (68.9)

Article 69: Type species not fixed in the original publication
Type species by subsequent designation - If an author established a nominal genus or subgenus but did not fix its type species, the first author who subsequently designates one of the originally included nominal species [Art. 67.2] validly designates the type species of that nominal genus or subgenus (type by subsequent designation), and no later designation is valid.

In the absence of a prior type fixation for a nominal genus or subgenus, an author is deemed to have designated one of the originally included nominal species as type species, if he or she states (for whatever reason, right or wrong) that it is the type or type species, or uses an equivalent term, and if it is clear that that author accepts it as the type species.

A subsequent designation first made in a literature-recording publication is to be accepted, if valid in all other respects.

Eligibility of species for type fixation, Type species by subsequent monotypy, "Fixation by elimination" excluded where subclauses respectively 69.2, 69.3, 69.4 are to be followed.

Article 70: Identification of the type species
Correct identification assumed - It is to be assumed, in the absence of clear evidence to the contrary, that an author has identified the species correctly when he or she either includes a previously established nominal species in a new nominal genus or subgenus, or fixes such a species as the type species of a new or previously established nominal genus or subgenus.

Type fixation overlooked, Misidentified type species, Identification of type species by deliberate misapplication as per subclauses: 70.2, 70.3, 70.4 respectively.

Chapter 16: Types in the species group (Articles 71, 72, 73, 74, 75, 76)

Article 71: Application
The provisions of this Chapter apply equally to nominal species and subspecies, including taxa deemed to be subspecific [Art. 45.6].

Article 72: General provisions
Use of the term "type" relating to specimens - The term "type" forms part of many compound terms used by taxonomists to distinguish between particular kinds of specimens, only some of which are name-bearing types. For the purposes of the Code, three categories of specimens are regulated, namely, type series (72.1.1), name bearing types (72.1.2), other specimens (73.2.2, 74.1.3).

Fixation of name-bearing types from type series of nominal species-group taxa established before 2000 (72.2), Name-bearing types must be fixed originally for nominal species-group taxa established after 1999 (72.3), Type series (72.4), Eligibility as name-bearing types (72.5), Specimens that are already name-bearing types (72.6), Name-bearing types of nominal species-group taxa denoted by new replacement names (nomina nova) (72.7) Name-bearing types of nominotypical subspecies (72.8), Union of nominal species-group taxa (72.9) – details from subclauses in brackets.

Value of name-bearing types - Holotypes, syntypes, lectotypes and neotypes are the bearers of the scientific names of all nominal species-group taxa. The types, namely, holotype, syntype, lectotype and neotypes should be labeled in an unmistakable way – future recognition of the specimens, safely to be deposited and are to be made available for further study.

Article 73: Name-bearing types fixed in the original publication (holotypes and syntypes)

Holotypes - the single specimen upon which a new nominal species-group taxon is based in the original publication (for specimens eligible to be holotypes in colonial animals and protistans, see Articles 72.5.2, 72.5.4 and 73.3). The subclauses 73.1.1, 73.1.2, 73.1.3, 73.1.4, 73.1.5 are further clarification in this regard.

The designation of holotype will facilitate its subsequent recognition, it should have studied by the author. The data to be accompanied in the literature are : size (measurements of other parts), full locality and elevation from msl, depth in water if aquatic forms, date, sex if applicable, developmental stage, name of collector, register number if any, name of host if parasite. The author should not use cotype for syntype or paratype. Recommendations 73G-J should also be followed.

Syntypes are specimens of a type series that collectively constitute the name-bearing type. (see Article 73.2.1 for acceptable terms – “co-type” or “type”); for a nominal species-group taxon established before 2000 [Art. 72.3] all the specimens of the type series are automatically syntypes if neither a holotype [Art. 72.1] nor a lectotype [Art. 74] has been fixed. When a nominal species-group taxon has syntypes, all have equal status in nomenclature as components of the name-bearing type.

Hapantotypes consisting of one or more preparations or cultures may be designated when a nominal species-group taxon of extant protistans is established. This hapantotype is the holotype of the nominal taxon.

Article 74: Name-bearing types fixed subsequently from the type series (lectotypes from syntypes)

Lectotype may be designated from syntypes to become the unique bearer of the name of a nominal species-group taxon [Art. 73.3]). If it is demonstrated that a specimen designated as a lectotype was not a syntype, it loses its status of lectotype. For lectotype designation before 2000 follow rule 74.5; and for designation after 1999 rule 74.6 may be followed.

Article 75: Neotypes

Neotype is the name-bearing type of a nominal species-group taxon designated under conditions specified in this Article when no name-bearing type specimen (i.e. holotype, lectotype, syntype or prior neotype) is believed to be extant and an author considers that a name-bearing type is necessary to define the nominal taxon objectively. The continued existence of paratypes or paralectotypes does not in itself preclude the designation of a neotype. Circumstances excluded by 75.2, qualifying conditions by 75.3, priority by 75.4, replacement of unidentifiable name-bearing type by a neotype by 75.5, conservation of prevailing usage by a neotype by 75.6. Conservation of prevailing usage by a neotype by 75.6, status of neotype designated before 1961 by 75.7, status of rediscovered former name-bearer types by 75.8 subrules are to be followed.

Article 76: Type locality

The type locality of a nominal species-group taxon is the geographical (and, where relevant, stratigraphical) place of capture, collection or observation of the name-bearing type; if there are syntypes and no lectotype has been designated, the type locality encompasses the localities of all of them [Art. 73.2.3]. 76.1.1. If capture or collection occurred after transport by artificial means, the type locality is the place from which the name-bearing type, or its wild progenitor, began its unnatural journey.

Type locality determined by the lectotype (76.2), type locality determined by the neotype (76.3) as per subrules in brackets.

Chapter 17: International Commission on Zoological Nomenclature (Articles 77, 78, 79, 80, 81, 82, 83, 84)

Chapter 18: Regulations governing this code (Articles 85. 86. 88. 89. 90)

Appendices are: Code of Ethics (7 nos.) and General Recommendations (12 nos.)

All enquiries regarding the Code, or the application of its provisions to particular cases, should be addressed to: The Executive Secretary, I.C.Z.N., c/o Lee Kong Chian Museum of Natural History, National University of Singapore, 2 Conservatory Drive, Singapore 117377, Singapore (e-mail: iczn@nus.edu.sg)

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Further reading

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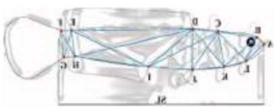
CHAPTER 8

Truss Networking: A Tool for Stock Structure Analysis



In fisheries management, the term 'stock' refers to a sub-set of a particular fish or shellfish species inhabiting a particular geographical area with the same growth and mortality parameters (Gulland, 1983). Stock structure means the contribution of stock units that represent the entire population. Fish stocks may be considered as subpopulations of a particular species of fish, for which intrinsic variables (growth, recruitment, mortality and fishing mortality) are the only significant factors in determining stock dynamics, while other factors, particularly immigration and emigration, are considered to have limited effect. Each population stocks usually characterized by the specific biological attributes (Secor, 2014). The differences can be seen through phenotype, genetic (Aini et al., 2020), or both simultaneously (Hollander and Butlin,2010). Stock identification is a field of fisheries science which aims to identify these sub-populations, based on a number of techniques involving an interdisciplinary approach (Cadrin et al., 2005).

Information on stock identity and spatial structure provide the basis for understanding fish population dynamics and enable reliable resource assessment for fisheries management (Reiss et al., 2009). Attempt to manage fisheries resources cannot be generalized in each region. Each stock may have unique demographic properties and responses or rebuilding capabilities when faced with exploitation. The biological attributes and productivity of the species may be affected if the stock structure considered by fisheries managers is erroneous (Smith et al*.,* 1991).

The major objective of stock assessment programs is to manage fishery resources by providing advice on the optimum exploitation (Sparre and Venema, 1998). Thorough knowledge of the stock structure of the target species in commercial fisheries forms the basis to formulate resource management strategies (Shaklee and Bentzen, 1998). If the stock structure is not considered while formulating plans for fisheries management, it can lead to the collapse of the population due to the changes in biological attributes and loss in productivity rates (Begg et al., 1999; Cadrin, 2005). Stock structure analysis is, therefore, a pre-requisite for developing fishery management plans to understand the existing levels of recruitment that may replenish the population (Cardrin et al., 2005).

A variety of body shapes developed because of variability in growth, development and maturation in individuals belonging to one or different populations of a species of fish (Cadrin, 2000). There are reports of multiple stock compositions in fish populations (Pepin and Carr, 1993; Serajuddin et al., 1998). Environmentally induced phenotypic variation provides rapid information on stock or subpopulation identity (Clayton, 1981). The study of morphometrics using truss network is a quantitative method to represent the complete shape of the fish (Strauss and Bookkstein 1982).

This representation is formed by interlinking the measurements between morphometric landmarks that give rise to a systematic pattern of connected cells covering the entire body structure (Turan 1999) which has been successfully used for population and taxonomic studies (Lin et al. 2005; Mevlut et al. 2006). Stock identification by truss network analysis is practically useful and an effective strategy for the description of the body shape in comparison to the traditional morphometric method (Cadrin 2005). It is effectively used to discriminate the stocks and differentiate between the population's shapes (Stratuss and Bookstein 1982).

A large number of studies using the box-truss network method gave better results in categorizing individuals accurately and classifying them to their intraspecific groups (Turan, 1999). In particular, the truss is a landmark-based technique that poses no restriction on the direction and localization of change in shape and is highly effective in capturing data on the shape of the organism (Cavalcanti et al., 1999). Phenotypic characters have been successfully used for stock differentiation in many shrimps, *Macrobrachium vollenhovenii* (Konan et al., 2010), *Macrobrachium nipponense* (P-C Chen et al., 2015) and fish species *viz*., *Decapterus russelli* (Sen et al., 2011), *Harpadon nehereus* (Pazhayamadom et al., 2015), *Sardinella longiceps* (Remya et al., 2015), and *Nemipterus japonicus* (Sreekanth et al., 2015) while homogeneity was reported in the population of *Farfantenaeus notialis* at Caribbean sea (Paramo and Saint-paul, 2010). Homogenous fish populations are often composed of discrete stocks which may have unique demographic properties and responses to exploitation, which should be managed separately to ensure sustainable fishery benefits and efficient conservation (Kinsey et al., 1994; Begg and Brown, 2000; Stransky et al., 2008; Neves et al., 2011).

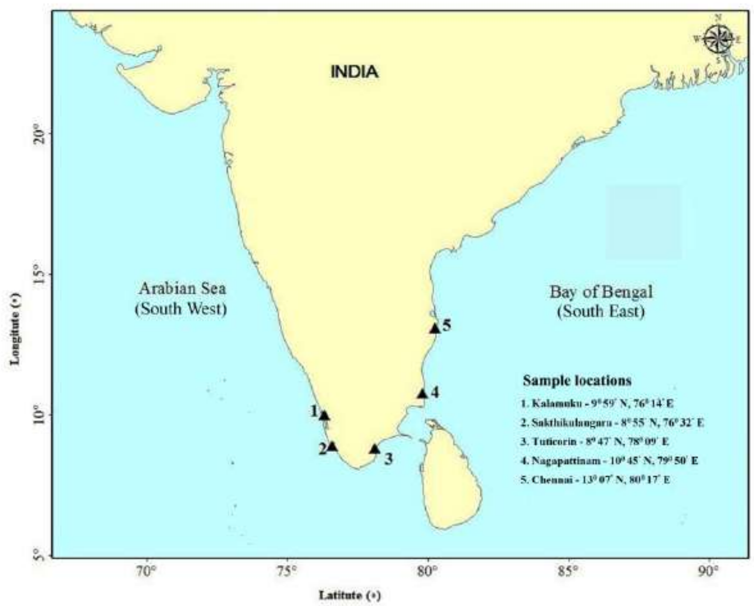
A Case Study: Deep-sea Shrimp: *Aristeus alcocki*- Penaeid shrimp

A. alcocki Ramadan, 1938 (Decapoda, Aristeidae), commonly known as Red Ring or Arabian red shrimp is distributed along the southern Indian coast at a depth range of 200-1000 m (Silas 1969; Suseelan 1989; Madhusoodana 2008; CMFRI 2015). It forms a commercial fishery confining only along the southeast and southwest coast, and it’s not recorded along the northern coast of India (Mohamed and Suseelan, 1973). The catch landed between 2008 and 2015 indicate that the *A. alcocki* is the prime species in order of biomass among the deep sea penaeid catch accounting to about 36% from the whole Indian coast and the trend in catch rates indicates a decline of these deep-sea shrimps (CMFRI 2008-2015). In this study we aim to investigate the effectiveness of the truss variables in differentiating the populations of *A.alcocki* along the Indian coast using truss morphometry, to provide management advisory for fisheries sustainability.

Sampling

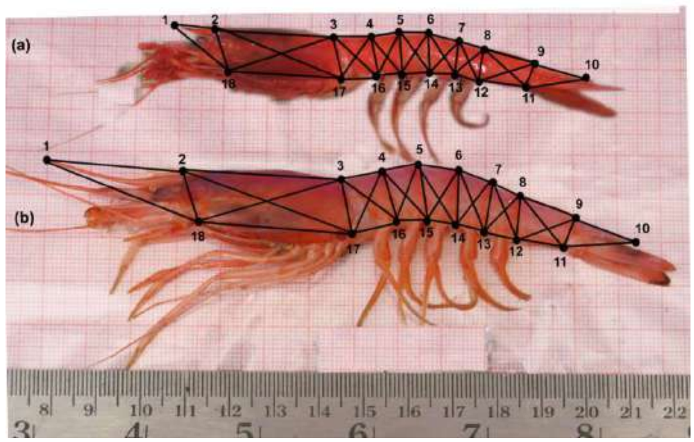
Samples of *A. alcocki* were collected from five different fishing harbors i.e., Tuticorin (SEN), Chennai (SEC), Nagapattianam (SEN) on the southeast, and Sakthikulangara (SWS), Kalamuku (SWK) on the southwest Indian coast (shown in figure below). The sampling sites were chosen such that they are distantly apart in latitudinal aspect to reduce the chances of mixing specimens from the same population. In total, 1842 specimens were collected from the selected sampling sites i.e., from commercial fishing harbors where the catch is landed by multiday trawlers along the southern coast during December 2014 and January 2015. The samples were collected during peak breeding season (November to January) to ensure that they represent to their parent population.

The matured specimens (carapace length: female>3.5 cm; male: >2.0 cm) were sorted from the samples collected from each fishing location and used for truss morphometric analysis. The species exhibit a high degree of sexual dimorphism where males were identified by the presence of petasma and females were sorted based on the presence of thelycum. Specimens showing physical damage *viz*., broken rostrum or any other body parts may distort the shape characteristics and hence they were not included in the samples for the study.



Digitization of specimens and fixing anatomical landmarks

Shrimp samples were first cleaned with running water, allowed the water to drain, wiped with tissue paper and finally placed on a graph paper (shown in figure below). Each specimen was placed on a flat platform with a graph paper over a thermofoam, appendages (pereiopods and pleopods) and telson were erected by positioning the rostrum portion towards the left side, telson on the right by assuming symmetry between left and right side of the shrimps and was labeled with a specific ID code. This helps us in identifying specimens if more landmarks are required to be fixed or if the morphometric measurements are to be repeated. Digital images of the specimens were captured using a camera (Canon G-15) which was fixed on a tripod stand directly above the specimen and the lens was adjusted so the margins of viewfinder align with margins of the graph paper in X-Y directions and each image included a scale to standardize the individual sizes and further scaling was applied in tpsdig utilizing the millimeter grid in graph paper. These images were used further in fixing the anatomical landmarks and measuring linear distances between them i.e., truss variables. In many previous studies, it has been found that differences in sex are likely to contribute to shape differences affecting total variance in morphometric distances (Reiss and Grothues, 2015; Sajina et al., 2011; Pazhayamadom et al., 2015). In the present analysis, both males and females were included to accommodate the effect of sex on their morphometry. The extraction of numeric truss distances from the digital images of specimens were carried out by using two software platforms, 1) tpsDig2 V2.1 for marking the landmark coordinates on the digital images (Rohlf, 2006 and 2) paleontological statistics (PAST) for extracting the values pertaining to the marked distances (Hammer et al., 2001). The data extracted by this method ensures stability, accuracy, and repeatability.



Analysis of truss morphometric data

MANCOVA was carried out in order to study the statistically significant differences among sex, location using log-transformed data and carapace length (CL) was incorporated into the models as a covariate. Data sets were standardized by log transformation and tested for normality by SAS PROC UNIVARIATE procedure for removing outliers. An allometric method was adopted to remove size-dependent variation in morphometric characters.

The normality and homogeneity variance assumptions were verified with the log-transformed data, using the SAS PROC UNIVARIATE procedure (SAS 2014), and the data rows with outliers (7-10%) were removed from each location, before proceeding further for analysis. MANCOVA was used to establish significant differences among sex, location using log-transformed data and carapace length (CL) was incorporated into the models as a covariate. Therefore, the whole truss measurements were transformed to size-independent shape variables using an allometric method as suggested by Reist (1985) in Equation 1.

$M_{trans} = \log M - \beta (\log CL - \log CL\ mean)$ Equation 1,

Where M_{trans} is the truss measurement after transformation, M is the original truss measurement, CL is the carapace length of the shrimp which is reported to be more reliable than using total length (TL) in the case of crustaceans (FAO 1974), CL mean is the overall mean carapace length, and β is the slope regressions of the log M against log CL.

Correlation coefficients were checked between each pair of variables before and after the size effect removal. In such analysis, the absolute values of correlation coefficients were expected to decrease after size effect removal (Murta, 2000). Mean (X), standard error (SE), standard deviation (SD), maximum and minimum of all measurements were recorded for each population. The percentage of coefficient of variation (CV%) was computed as CV% =

100×SD/X of morphometric variables in each population. Multivariate analysis used in this study consisted of principal component analysis (PCA), discriminant functions (DF) and hierarchical cluster analyses.

PCA was used to evaluate morphometric variation among specimens and identify variables contributing substantially to that variation. DF was run to test the effectiveness of variables in predicting different group locations (Tomovi´c and Dˇzuki´c 2003; Loy et al., 2008). The stepwise inclusion procedure was carried out to reduce the number of variables and identify the combination of variables that best separates the groups (Jain et al., 2000; Poulet et al., 2005, Hair et al. 1996). Hierarchical cluster analysis (HCA) based on Mahalanobis distances matrices determined with DF, was used to evaluate population relationships, as implemented by Slabova and Frynta (2007) and Ferrito et al. (2007). All the analysis in the present study was done by using Statistical Analysis System software (SAS 2014).

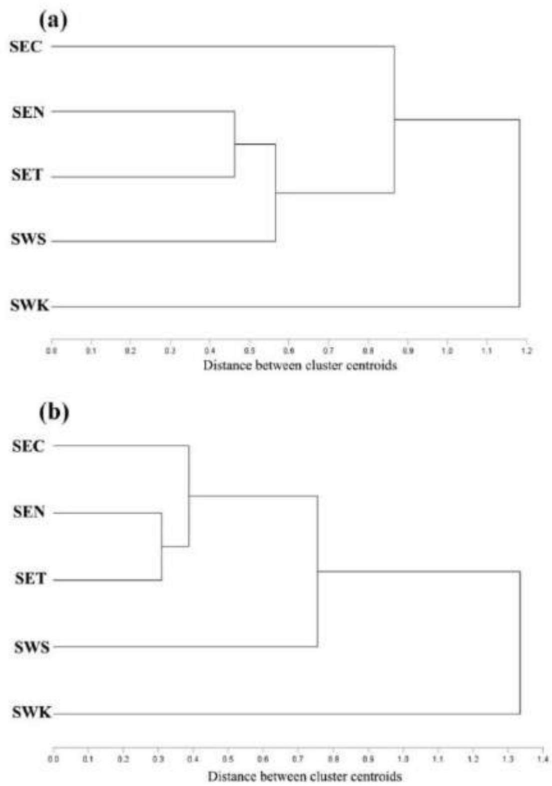
Results

Descriptive statistical results showed less coefficients of variation (CV) (<25%) in all the truss variables for both the sex at five different locations (Table 2). The range of CV for female varied from 7.6 to 20% and for male was 4.9 to 21.6%. The morphometric variability within populations was low for all the locations.

Correlation coefficients between the morphometric variables were estimated before and after the size effect removal. Before the size effect removal coefficient values were highly significant while it was reduced after the correction which suggested that the effects of size had been effectively removed from the morphometric data. The mean carapace length specifies that the males are much smaller than females, a significant difference on sex and location was observed.

The results of PCA analysis indicate that the first two components cumulatively explained >70% (female: 72.1%; male: 71.5%) of the total morphometric variation. A few truss distances loaded heavily on PC1 (1-2, 1-18, 2-18, 3-17, and 5-15) which alone explained >63% of the entire variance. The loadings of two variables i.e., the 1-2 distances that correspond to the rostral length and the 1-18 distances that connects the rostrum tip to the pterygostomian spine contributed a substantial proportion of the total variance. PC2 explained 8.21% of the total variation, and 3 distance variables (3-4, 15-16, and 4-17) corresponding to the abdominal region of the shrimp loaded heavily on this component. The distances with high loadings on both PC1 and PC2 characterize the rostrum and 2nd to 3rd abdominal segment portion of the shrimp and they all were found to be positive, signifying the positive correlation between the variables within a component i.e., these attributes grow in proportion with one another. A scatter plot between PC1 and PC2 resulted in the separation of SWK from other populations.

The results of hierarchical cluster analysis showed two distinct groups from five populations of both sexes. The group-I included SWK population and SWS, SET, SEN, SEC populations clustered in group-II. This analysis showed that SWK samples constituted phenotypically a separate population, while the morphometric resemblance between SWS, SET, SEN and SEC stocks were found to be high. The analysis of the present study revealed that the variables used in this study were capable to clearly differentiate SWK population from the other group.



Genetic Characterisation of the species

Genetic variation is considered to be an important feature of the population to reveal not only the short term fitness of individuals but also the long term survival of the population, through allowing adaptation to the changing environmental conditions. Information deduced from molecular markers can provide insight into genetic structure and geographical boundaries (*i.e.* breeding stock) and vulnerability (*i.e.* genetic diversity) of the species (Buchholz-Sørensen & Vella, 2016).

Molecular markers have been proved to be an effective indicator of genetic variation within and between fishery populations of shrimp species; *Aristeus antennatus* (Maggio et al., 2009; Cannas et al., 2012; Fernández et al., 2011b; Brutto et al., 2012), *Aristaeomorpha foliacea* (Fernández et al., 2011a), *Penaeus monodon* (Mandal et al., 2012; Sekar et al., 2014) and *Fenneropenaeus indicus* (Sajeela et al., 2015). Microsatellite markers are characterized as co-dominant and highly polymorphic in nature and addition to their abundance, even genomic distribution, small locus size, have quickly become useful molecular markers with great discriminatory power for the evaluation of genetic diversity in various species (Powell et al., 1996). Analyses of microsatellite nuclear markers were used to describe the differences and distribution patterns of natural populations of this species.

DNA extraction, amplification and genotyping of microsatellite loci

The total genomic DNA was extracted from the pleopod of the each individuals using DNeasy® Blood & Tissue Kit (Qiagen Inc.) according to the manufacturer's protocol. The cells were lysed by incubating at 56^0C for 2 hrs and all other steps were followed as per the protocol. The primers for nine nuclear microsatellite loci were taken from Cannas et al. (2008), were originally designed for the *Aristeus antennatus.* The microsatellite loci were optimised for genotyping by following the general protocols of Palumbi (1996), and Cannas et al. (2008). The amplification of microsatellite markers were performed in 25 µl reaction cocktails containing genomic DNA (0.5 µg μl^{-1}), *Taq* DNA polymerase (0.05 U μl^{-1}), 1X buffer, MgCl2 (1.5 mM), 10 pM μl^{-1} of each primer and dNTPs (200 µM). The PCR thermal profile used was 94^0C for 5 min for initial denaturation, followed by 35 cycles of 94^0C for 1 min, annealing at 52–54^0C for 1 min, extension at 72^0C for 1.5 min, and a final extension at 72^0C for 5 min (Table 1). Amplification of PCR products were confirmed by electrophoresis on a 1.5% agarose gel containing ethidium bromide and visualized under UV transilluminator (Lark, India). Analysis of fragment size was carried out by ABI prism genetic analyser (Applied Biosystems, USA) at AgriGenome Labs, Scigenom, Cochin, India.

Data analyses

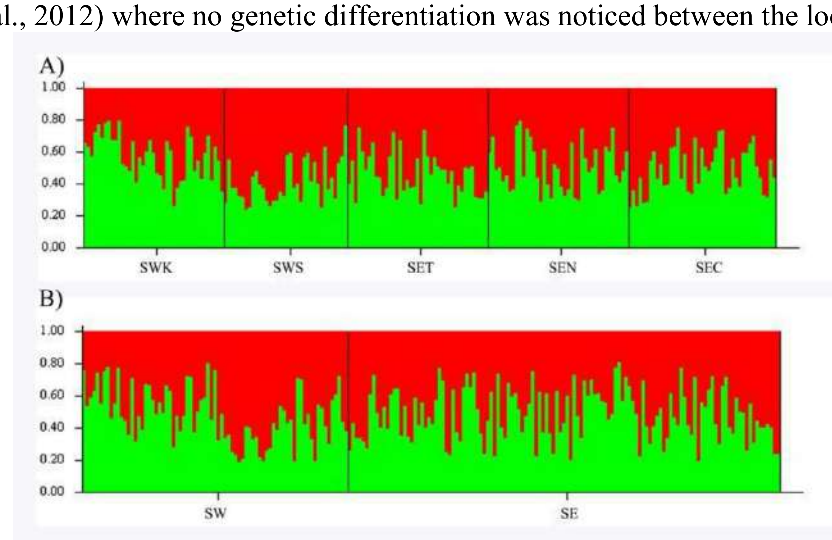
Allele frequency, the number of alleles (Na), observed (Ho), expected (He) heterozygosity and unbiased expected heterozygisity (UHe) per locus and locations were calculated with the computer program GenAlEx v. 6.41 (Peakall and Smouse, 2006). GENEPOP 4.0 package (Raymond and Rousset, 1995) was used to calculate deviations from Hardy-Weinberg equilibrium (HWE) for each locus and linkage disequilibrium between pairs of loci by using Fisher's exact test, under Markov Chain Monte Carlo (MCMC) algorithms (Guo and Thompson, 1992), with 1000 dememorizations, 100 batches (treatments per location) and 10000 iterations per batch. Significance levels for both determinations were adjusted with the Bonferroni test for multiple comparisons with a significance level of $p < 0.05$ (Rice, 1989). F_{IS} (Weir and Cockerham (1984) was calculated in GENEPOP 4.0 (Raymond and Rousset, 1995) with significance values for each locations. The presence of null alleles was tested with MICROCHECKER v 2.2.3 (Van Oosterhout et al., 2004). The F_{ST} values, relative to the null alleles and confidence intervals with and without correction were estimated with FREENA program (Chapuis and Estoup, 2007), if comparison of estimated F_{ST} values denoted significant difference, then any locus shows presence of null alleles in the sample should be

discarded. Polymorphism information content (PIC) for each locus and locations were calculated using PIC –Calc 0.6 software (Nagy et al., 2012). ANOVA F statistic was used to detect the differences among the locations with the means values of Ho and UHe.

To assess the genetic variation on among the populations and between the locations, pairwise Fst values were calculated and followed by statistical assessment of significance with 10,100 permutation steps for every comparison. Hierarchical analysis of molecular variance (AMOVA) was carried out using the program ARLEQUIN 3.5 (Excoffier & Lischer, 2010) to assess the presence of differential genetic structure. We performed a Bayesian cluster analysis to infer population structure and estimate the number of genetically distinct populations, using STRUCTURE v.2.2.3 (Pritchard, Stephens, & Donnelly, 2000) to determine the probabilistic assignments of samples based on genotypes to K sub populations. K estimation was completed using 20 independent simulations for K=1 to 5 with 100,000 MCMC iterations and 10,000 batches. The most probable estimation of groups in the current dataset was done by using the ad hoc statistic DK method proposed by Evanno et al. (2005) and the value of K best fitting the data was selected using the log posterior probability of the data for a given K, Ln Pr (XjK) (Pritchard & Wen, 2004).

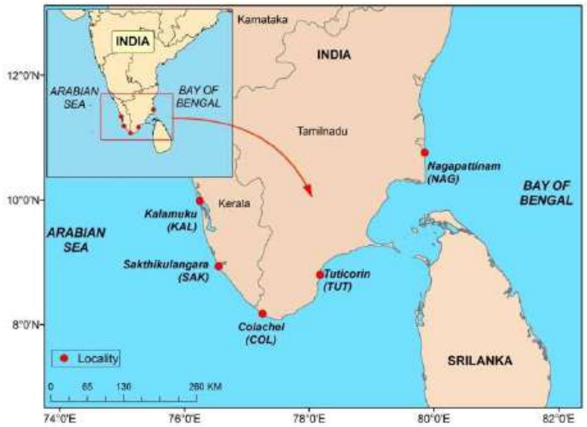
Molecular Results

The pairwise F_{ST}, Nei, and AMOVA values calculated from microsatellites indicated the absence of significant variation among the samples of *A. Alcocki* collected from the South west (Arabian Sea) and South east (Bay of Bengal) coast of India. Moreover the results of AMOVA also indicated the proportion of genetic variation was mainly associated to differences among the individuals (99.2%) with F_{st}=0.0078 which is further confirmed by the cluster analysis performed using STRUCTURE (shown in figure below) directed towards the presence of homogeneous groups due to the absence of specific allelic variation in the sampled localities. The present study was in agreement with the results reported in *A. Antennatus* (among individual difference 99.3%; Fst=0.0067) using same markers in the Mediterranean Sea (Cannas et al., 2012) where no genetic differentiation was noticed between the localities.

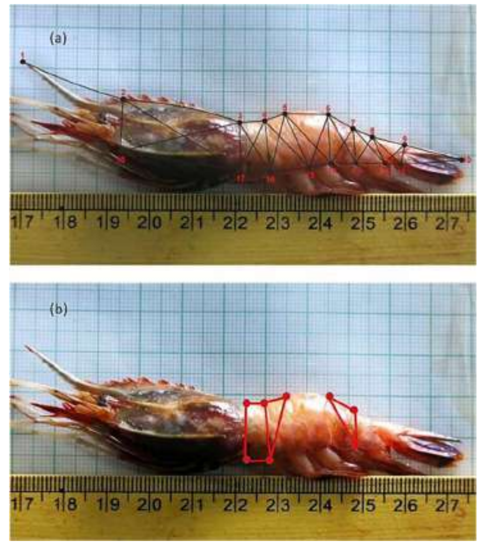


Case Study –II: *Heterocarpus chani*: A caridean deepsea shrimp

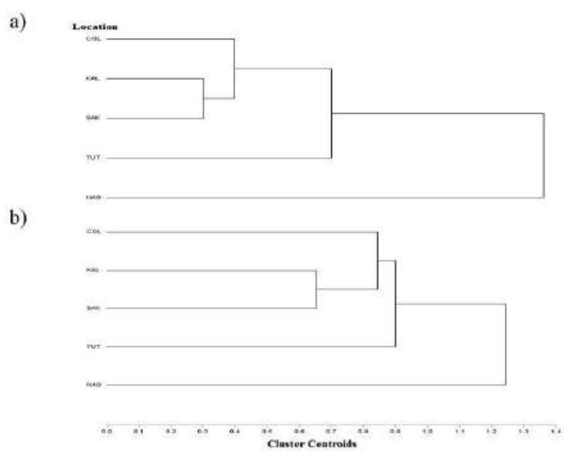
The samples of *H. chani* were collected from deepsea trawl shrimp catches obtained from five major fishing harbours along the southern coast of India. The sampling sites are Kalamuku (KAL), Sakthikulangara (SAK), Colachel (COL) on the southwest coast and Tuticorin (TUT), and Nagapattinam (NAG) on the southeast coast. Information on study sites, geographical coordinates, shrimp sex and the sample size from each location. A total of 1879 specimens of *H. chani* including 984 males and 895 female individuals were used in this study.



Digitisation of samples



The results of HCA showed three clear clusters from five populations of both sexes as shown below figure. The group-I included populations from NAG, group-II consisted of the TUT and group-III with SAK, KAL, and COL populations. Theinterpretation of resultsindicated that the samples obtained from the locations NAG and TUT represented a phenotypically distinct population while the morphometric resemblance between SAK, KAL, and COL stocks were observed to be high.



Conclusion

The truss morphometric characters in *A. alcocki* and *H.chani* can be efficiently used in the discrimination of populations as studied in other species of freshwater and marine environments. The major discriminating variable to differentiate the populations into two groups was attributed to the abdominal measurements, suggesting a need to adopt separate management strategies for the resource sustainability and policy regulations. Further, studies based on the genetic markers in *A. alcocki* indicated the presence of single population. However, in *H.chani* molecular studies can be used to validate the findings of this study.

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CHAPTER 9

Molecular Analytical Techniques to be used in Taxonomy

All organisms are characterized by biological characteristics driven by their inherent genetic variations that enhance their fitness and survival to their living environment. Taxonomy describes and classifies organisms in respect of their unique morphological, genetic as well as behavioural characteristics. It gives a basic knowledge of the components of biodiversity, which is required for the decision making for effective conservation and sustainable use.

Awareness of the evolutionary history, taxonomic position and ages of divergence (phylogeny) of an organism is indispensable and molecular taxonomy and population genetics gives a precise information on species diversity by detecting DNA level variations and thereby powerfully contribute to taxonomic and biodiversity research (Hajibabaei et al., 2007). DNA sequence level analyses changed the perspectives of conventional taxonomic methods which is based on the external morphological and meristic features that has its limitations for an accurate conclusion. A whole specimen itself may exhibit significant intraspecific variations and little interspecific variations in their morphology. Egg and larval stage identification is complicated than adult. These issues can be clearly resolved by DNA based techniques. As a commercially important commodity in the world market, incorrect labelling of fish causes risks in the quality and threat of adulteration in edible fish products. Molecular taxonomic techniques make fish identification possible even after cutting and processing of fishes (Fomina et al., 2020).

The molecular techniques

Genetically controlled markers/Molecular markers are used to assess the genetic variation at DNA level (DNA markers) or through phenotypic expression that can be a protein (Protein markers). The emergence of molecular methods of species identification was only in the second half of 20^{th} century. The very first technique used was based on the specific protein characterization using Electrophoresis (Isoelectric Focusing), capillary electrophoresis, HPLC and immunoassays (ELIZA). Rapid degradation, cross contaminations and differential expression in specific tissues etc are the limitations of using protein based techniques in a commercial system. The DNA based methods have been developed as an alternative only in the past two decades (Saritha et al., 2013). Compared to proteins, DNA is stable, have long life and found in all tissue types and secretions. Very small amount of sample is required for DNA extraction and DNA can be extracted even from processed, preserved and degraded samples. Also, DNA analysis is preferred due to larger variability of the genetic code. DNA markers are subdivided into Type I and Type II markers; Type I markers are associated with genes of known function and type II markers are associated with genes of unknown function.

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The genetic markers detect interspecies and intra-species differences based on their rate evolution owing to the mutation and recombination. Intra-specific differences reveal stock composition and genetic relatedness within a species. Inter specific differences focuses on the delineation and phylogenetics. (Sunnucks, 2000). Depending upon question to be answered, suitable markers need to be selected for the respective species. If a specimen is suspected to be new, voucher specimen preservation for future reference is mandatory.

Non-specific DNA markers
Random markers are used when we target a segment of DNA of unknown function. The widely used methods of amplifying unknown regions are RAPD (Random Amplified Polymorphic DNA), Restriction fragment length polymorphism (RFLP) and AFLP (Amplified Fragment Length Polymorphism) DNA. These are simple methods that does not require any sophisticated equipment or prior sequence information of species.

The **RFLP** detects interspecific variations and generates species –specific bands profiles through Restriction digestion of DNA using one or more Restriction endonucleases. The fragments are visualized using conventional agarose gel electrophoresis. The RFLP profile of each species is the result of the unique genomic distribution of recognition sites and distance between different sites. Main disadvantage of RFLP is incomplete digestion and the addition or deletion of restriction sites as a result of intra-specific variations. Previous sample analysis detail is required for identifying the REN to be used.

RAPD is Random PCR amplification of DNA using short primers (9-10p long) of arbitrary nucleotide sequence. RAPD profiles are generated by the random PCR amplification of DNA segments using of usually 9 or 10 nucleotides long (Williams et al., 1990). RAPD randomly scan the genome. The primers anneal to different regions in the genome at low annealing temperatures and amplified between two nearby annealed primers in proper orientation. Specific banding pattern will be generated for each species in an electrophoretic gel as a result of difference in genomic binding location of primer binding sites. RAPD is also called Arbitrarily primed PCR or APPCR. It can be executed in a speedy and simple manner. Major disadvantages include inconsistency in the results and highly susceptible to DNA quality and quantity.

AFLP uses restriction enzymes to cut genomic DNA, followed by ligation of adaptors to the sticky ends of the fragments and then amplified using primers complementary to the adaptor and part of the restriction site fragments. After final amplification, selectively amplified fragments are separated by gel electrophoresis. AFLP is a combination of RFLP and RAPD for increased sensitivity, reproducibility and resolution. AFLP has high diversity index to develop a fingerprint of an organism. This technique has been used barely for fish species identification and mainly used in population genetics to determine slight differences within populations. The technique is laborious and costly as it requires expensive software packages for analysis.

Specific Nuclear DNA markers
Species-specific PCR (polymerase chain reaction). is the most common diagnostic method. Knowledge of nucleotide sequence of the gene is the prerequisite in this method. Species-specific primers are designed from the vast genomic sequences available and used for identification here. After amplification, the fragment visualized by electrophoresis and a positive result may give an idea about presence of a particular species, but a negative result

gives no information about the origin of the sample. Species-specific PCR can lead to false positive or false negative results, which require inclusion of reference samples in each analysis.

A modified version of conventional PCR is the **Real-time PCR** in which specific DNA sequence in a sample is amplified along with a fluorescent reporter molecule that enables detection and quantification of the accumulated product by a fluorescence detector. Real-time PCR is the most common technology to use for species identification. Post PCR stages like electrophoresis and staining can be eliminated and risks of contamination can be reduced significantly.

PCR-RFLP method has become more accurate for species detection. Specific gene primers used for amplification and the product is cut with corresponding restriction enzymes to generate smaller fragments and analysed by gel electrophoresis. The PCR-RFLP is a robust and easy method to use for identification of fish species. But optimization and analysis affect the reliability of results.

DNA Barcoding is introduced by Hebert et al. (2003) that involves biological identification through a 650bp mitochondrial cytochrome c oxidase I (COI) gene as a marker DNA sequence to create the global system for animal bio-identification. It is linked with Sanger sequencing that reads the bases in a small fragment of genome. DNA barcoding have been proposed as a fast, efficient, and inexpensive technique to catalogue all biodiversity. The sequence of the COI gene that amplified using universal primers and compared with the barcode library and the specimen is identified based on its closely matched sequence. The method of DNA barcoding is simple and less time consuming and the online barcoding libraries such as NCBI-BLAST and Barcode of Life Database (BOLD) helps in fast conclusions.

DNA microarray consists of small glass microscope slides, silicon chip or nylon membranes with many immobilized DNA fragments arranged in a standard pattern. A DNA microarray can be utilized as a medium for matching a reporter probe of known sequence against the DNA isolated from the target sample which is of unknown origin. Species-specific DNA sequences could be incorporated to a DNA microarray and this could be used for identification purposes. DNA extracted from a target sample should be labelled with a specific fluorescent molecule and hybridized to the microarray DNA. When the hybridization is positive a fluorescent signal is detected with appropriate fluorescence scanning/imaging equipment. Identification of hundreds thousands of species can be possible from PCR mixtures by DNA microarrays if species-specific probes are available. It is a cost effective and accurate method of species identification.

Microsatellites/Short tandem repeats (STRs)/simple sequence repeats (SSRs) are tandemly repeating sequences of 2-6 bp. These species specific hypervariable markers are used mainly for population genetic analysis.

Next generation sequencing (NGS) is similar in concepts with Sanger sequencing and differs with the sequencing volume. NGS efficiently generates millions of reads of short fragments results in sequencing hundreds to thousands of genes at one time. It has greater discovery power to detect novel or rare variants with deep sequencing.

DNA analysis are the commonly used method for fish species identification in recent times along with the conventional taxonomic procedures. PCR-based methods are the most promising method that helps identifying different, even closely related fish species. Compared to all other methods, The DNA barcoding method with the use of NGS is the most promising but its high cost is the main disadvantage. Although DNA barcodes can significantly facilitate the process of species identification, comprehensive taxonomic analysis with several samples from the possible distribution ranges should be considered for validation of identification of a species, to avoid problems.

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CHAPTER 10

Museum Techniques in Preservation

When we search in the past about the preservation of natural history, it is nature that stands as the first museum as well as the curator. Nature did the first-ever clearing of massive fleshy creatures; stored specimens on various racks of the planet's crust, in rocky and icy jars; used inventive preservatives like amber that kept the specimens untainted for millions of years. Later, when people began digging for natural history at the dawn of modern science all the valuable collections that nature preserved over the vast geological time scale became the major tools for taxonomy and systematic studies as well as, recently, for species conservation measures. Modern science followed that path of nature to preserve specimens of organisms in a more sophisticated manner for the future. Thus numerous natural history museums were established over the last few centuries that now accommodate millions of specimens collected from across the planet.

The three major steps of museum techniques can be broadly named as collection, fixation and preservation. All these steps are equally important in which sloppiness in any of them will result in the loss of valuable collections. For those people who are involved in museum practices, it is important to understand the historical, scientific, cultural, aesthetic and conservational values of the specimens they handle and curate.

The process of collection

The process of sample preservation begins at the site of specimen collection. First of all, note the exact location from where the sample is being collected. Nowadays the location can be recorded to the most accurate point by using a GPS instrument, along with the name of the place if it is collected secondarily from the land. For marine specimens, most often, this is the case since the majority of samples has been collected from the shores or landing centres. For samples collected from the fish landing centres, we can get the most accurate location of the fishing grounds recorded in the GPS system of the fishing vessels, along with the depth up to which they operated the nets. This is of utmost importance if the collected species has certain taxonomical importance or conservation status. While in the case of specimens washed ashore, for eg. a seabird, we can only record the land location even though the species might have an original distribution somewhere else.

Multiple specimens should be collected if available instead of just one or two as a representative of the whole catch. In the case of some species which has only seasonal landings or are caught

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accidentally, specimens should be collected in such a quantity that is enough to serve taxonomical and biological analysis in the future. Specimens collected from the field can be temporarily kept in plastic bottles and carry bags. For comparatively big specimens, large containers or iceboxes should be needed for easier and better transportation. Specimens vulnerable to fast deterioration, e.g. jellyfishes or engraulid fishes like anchovies and herrings can be initially treated at least mildly with a fixative. Instead of putting the specimen directly on ice which could change the colour of the specimen at the points of contact with ice, ice boxes filled with ice-cold water is necessary for retaining the freshness of the samples (Motomura and Ishikawa, 2013).

If the specimen is intended for molecular taxonomy studies it is most appropriate to take tissue samples in alcohol from the collection site itself for better preservation of the genetic materials. In this process, utmost care should be taken to avoid contamination of the study sample by other specimens from the location. Prior to taking the tissue sample of a specimen from a trash landing, the specimen should be washed to clear any unwanted particles to avoid genetic contamination.

Specimens brought into the lab can be studied in detail to corroborate the species identity. After noting down the essential morpho-meristic characteristics of the samples they can be prepared for fixation and then preservation in the museum.

The process of fixation

Fixation is the process of stiffening or stabilizing ("chemically freezing") the cell contents of an organism into insoluble components through cross-linking proteins (Clyde et al., 1983; Martin, 2016). Specimens must be preserved as fast as possible after collecting the specimen to avoid any deterioration. Live specimens can be collected and narcotized by using anaesthetics such as MS-222 before fixation, which gives better results for long term preservation. Fixation increases the staining quality of the specimen by raising the refractive index (Martin, 2016). Different types of fixatives are used often selectively for different types of specimens based on their tissue characteristics. Generally, the fixatives are either aldehydes or alcohol.

Formalin: Formalin (40 per cent formaldehyde) is the most commonly used fixative in biological museums. It is found to be more efficient in maintaining the colour and shape of the specimen (Musial et al., 2016). The degree of concentration of formalin needed for fixation depends on the size of the specimens. Usually, a solution of one part formalin and nine-part seawater or distilled water is used for fixation. For small marine animals, a mild concentration of 5 per cent is enough for fixing. In the case of larger, bulky specimens, a maximum of 10 per cent of formalin is needed to inject into different parts of the body. The alimentary system of large fish can be removed or otherwise can be injected formalin. Large hypodermic needles must be required for safely injecting formalin into animals having tough skins like that of sharks. The fixed animal or tissue needs to be kept as such for 24 to 48 hours in the case of smaller animals while several days are required for sizeable specimens before washing out the excess formalin for further preservation.

Since it is highly toxic, safety precautions should be taken prior to using it. Face masks, safety glasses, gloves and proper ventilation is necessary while dealing with the formalin fixation process.

Bouin's Fixative: This is one of the best-known fixatives for whole animals as well as tissues. It is a combination of picric acid (150 ml), 40 per cent aqueous formalin (50ml) and glacial acetic acid (10ml). It has rapid penetration properties and will preserve well the soft and delicate structures of the animal. But it is not preferred for specimens having calcium structures owing to its high acidity. At least ten times the volume of Bouin's solution is required over the volume of the specimen for fixation and the specimen should be kept for 4 to 24 hours depending on the size of the sample (Clyde et al., 1983).

Alcohol: Although it is widely preferred for the long term storage of specimens, alcohol is not an ideal fixative especially for certain groups of animals such as cephalopods. Alcohol fixes the tissue by means of its hygroscopic activity which is well below the efficacy of formalin which is known for protein denaturation of the tissue. In addition, alcohol is very slow in action and has poor penetration makes the specimen brittle, so even if it is used as a fixative in the field in an emergency (the concentration must be 70 to 75 percentage), the specimen must be transferred later to buffered formalin for better fixation. At 70% concentration alcohol is an effective biocide, below which it is not. Above the 70% limit, it will dehydrate the sample.

Paraformaldehyde: Paraformaldehyde is a convenient and economical solution for the fixation of specimens. A 10 per cent solution (35 g of paraformaldehyde in 1.0 L of water) of paraformaldehyde is suitable for the fixation of fishes. A base (e.g. sodium hydroxide or sodium carbonate) should be added to the water and then boil it before adding paraformaldehyde to avoid precipitation and polymerisation.

The process of Preservation:

In contrast to fixatives, a preservative is used only to store the specimen without any degradation of the already fixed tissue. Thus fixatives should be milder and suitable in their chemical properties, otherwise, over time the preservative itself causes the eventual deterioration of the specimen. Moreover, the long term preservation in museums of the biological specimens, where they might be frequently used for academic and research needs, should be kept in non-toxic or less toxic preservatives.

The commonly used preservatives are alcohol (ethyl or isopropyl) and formalin. In some cases, alcohol is more suitable than formalin or any other preservative due to the tissue characteristics of the animals such as the cephalopods. However, alcohol has some serious disadvantages too as it might render the specimen brittle over time as a result of dehydration. Also, the chances of alcohol getting evaporated from poorly sealed containers demand careful and regular curatorial examinations and maintenance. Specimens having a high water content will drastically reduce the alcohol level. Compared to ethyl alcohol, isopropyl alcohol has some advantages of being more cost-effective, can be used in greater dilutions and is less volatile. Nonetheless, it is noxious and relatively unpleasant. The dilution of alcohol should be done carefully as impurities in the water cause precipitations in the preservation media and will damage the specimens.

Formalin is used widely as a preservative mainly because of its low cost. However, as mentioned earlier it is highly toxic to those who are continuously exposed to it. Thus, maintaining thousands of specimens preserved in formalin raises health risks to the workers or professionals in a museum. Importantly, it is also detrimental to valuable specimens due to the demerits already mentioned above. However, it is important to note that certain specimens need to be preserved in formalin, e.g. cephalopods because other preservatives are not efficient for their storage. Planktonic samples are also usually fixed and preserved in formalin. But there are studies that suggest the preservation of ichthyoplankton in 70% ethanol for valuable morphological, anatomical and molecular studies (Schnell et al., 2016). If the specimens are indented not for research purposes only but for displaying to the public also, preserving the natural colours is very much desirable. Studies suggest that alkaline fixatives and preservatives should be avoided and a pH between 6.3 to 7 is most appropriate for pigment retention (Taylor, 1981).

Glycerine can be used instead of formalin for the preservation of specimens since it gives the double benefit of not being toxic and preserving the morphology, flexibility and colour of the specimen. Glycerination thus enables the frequent handling of the specimens for academic purposes (Costa et al., 2021). Glycerin has antifungal and antibacterial properties. Costa et.al (2021) found that glycerine is most suitable for the preservation (after fixation with 4% formalin or 70% ethyl alcohol) of crustaceans samples as it maintains the in vivo states of colour and malleability of the animal.

Buffers: In biological specimen preservation buffer chemicals are inevitable in order to save the storage life of the valuable specimens. Fixation or preservation of samples using the two most widely used agents such as formalin and alcohol progressively develops a low pH in the medium as a result of interaction with the breakdown products like proteins and fatty acids from the specimen. The formation of formic acid due to the oxidation of formalin degenerates the calcified parts such as bones, carapace and cuttlebones of the organisms. Thus buffers such as calcium carbonate, sodium borate (borax) and hexamine can be used for efficient preservation. Marble chips or marble powder can be used as calcium carbonate buffer. Borax, which is easily soluble, is more used as a buffer in formalin preservation. However, care should be taken not to add excess borax as it causes the clearing of tissues. Hexamine or hexamethylenetetramine is more desirable than borax and calcium carbonate buffer in formalin media as it constantly maintains a pH near neutrality. It acts as a mild base, an anti-oxidant and a remover of acid in formalin solution.

Only labels make the sample in a collection useful. Without the details of its origin or date of collection, a sample is less attractive for research purposes. Ideally, a label must contain all the details such as the taxonomic position of the specimen, place, date and method of collection, name of the collector, the accession number exactly the same as those in the museum catalogue, date of deposition in the museum, if possible, as well as the medium of preservation. Labels can be fixed on a convenient part of the container for easy examination by anyone interested, and it will not mask the specimen inside. Tagging of the specimens with essential details is appropriate and beneficial and it must be done in the field itself if time and situations permit. This is especially important when collecting a particular species from various places in a single day. In such cases, a specific number of samples of a single species can be assigned as a lot tied together with a single label exhibiting their common field data.

The preservation, storage and regular maintenance of the specimens is a major aspect of museum techniques. It requires knowledge, skills as well as instinctive abilities while dealing with valuable specimens. Specimens can be stored in various types of containers according to availability, suitability and needs. Tough sealing of each container is indispensable since the contact with air will initiate physical, chemical and biological changes and processes in the specimens as well as the preservation media. Once a specimen is stored, periodic topping up or replacement of the preservative is essential to check pH alterations, remove breakdown products and retain the exact dilutions of the preservative. Systematic documentation of the techniques of fixation, preservation and maintenance of specimens, at least that of supreme importance, like an endangered species or of type specimens is imperative for future reference. Label the containers carrying information regarding the specimens along with the type of preservative used.

Topping up the preservative is most recommended than whole replacement as it can damage specimens and containers in addition to resulting in ill-health to those who are involved. Transferring of the specimen must be done in occasions of inescapable reasons such as the case of acidification of the preservative or inappropriate preservation technique, health and safety concerns, or for research and educational purposes.
(https://conservation.myspecies.info/node/33).

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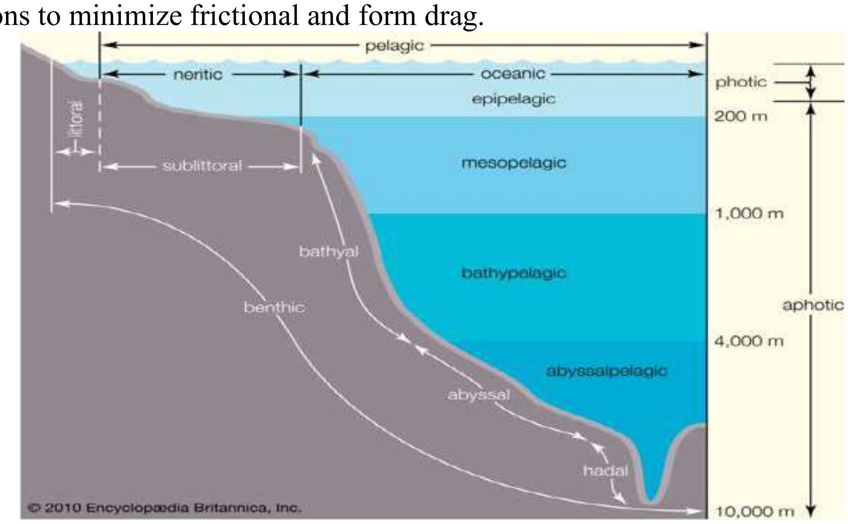
CHAPTER 11

Pelagic Fisheries of India: An Overview

Fishes that generally occupy the upper strata and columnar open waters in the oceans are referred to as pelagic fishes and range from small fishes (clupeoids) to the large sized fishes (tuna, billfishes and the whale sharks). The pelagic region in the ocean generally refers to open water region extending from the upper surface area to the deep waters. Pelagic fishes differ from other species in that they live in a three-dimensional environment without any discrete boundaries that impede their horizontal and vertical movements through the water column.

As these pelagic fishes live in open waters and not attached to any fixed structures for their feeding or as refugia, their body and physiology are suitably adapted for such a free living lifestyle. Most of them with some exceptions move in schools and swim continuously. The extent and degree to which they swim varies widely from minimal swimming in neutrally buoyant species (sunfish, whale sharks) to extensive swimming in negatively buoyant fishes (tunas, mackerels, barracudas, billfishes). These fast moving constantly swimming fishes have a streamlined body, a high aspect ratio caudal fin, narrow caudal peduncle and large pectoral fins, adaptations to minimize frictional and form drag.

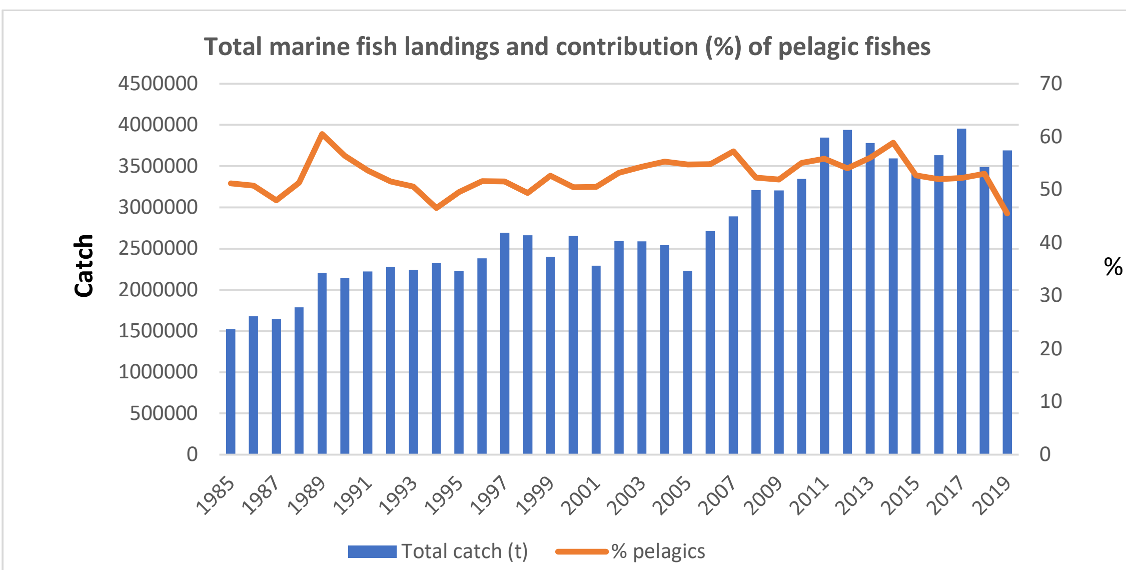


Source: Encyclopedia Britannica

India with a long coastline of 8129 km, continental shelf area of 0.5 million sq. km and of EEZ is 2.02 million sq. km is blessed with copious marine fauna and flora. The annual marine fishery potential of the EEZ is estimated at 5.31 million tonnes (excluding the non-conventional resources) of which the pelagic resources form more than 50% of the total marine fish landings of the country.

Pelagic fishes encompass an array of species residing in all realms of the pelagic region and include the small unicorn cod to the large billfishes, the planktivorous to the highly carnivorous fishes. The pelagic fishes therefore play a multi-faceted role in the food web of the marine system forming an important prey item of several larger fishes and as a predator of several other marine organisms. Further, their vast distributional range makes them vulnerable to exploitation by different categories of gears (seines, gillnets, lines and pelagic & mid-water trawls). The pelagic fishes have always played a pivotal role in dictating the general trend of the marine capture fisheries of the country through their sheer bulk catches. Clupeoids contribute to the food resources in two ways: directly, through actual consumption (fresh, frozen or processed) and indirectly, by providing products used for animal feeds and fertilisers or by serving as bait to catch other fishes. In addition, most of the pelagic fishes contribute significantly to the protein food basket providing the much needed comparatively cheaper protein source to the coastal fishers, considerable part of the marine domestic and export trade and supporting fishing industries (fishmeal, surimi and fish processing plants) and several ancillary industries. The larger fishes, mainly the scombroids, the billfishes and the carangids are valued as food fishes in the fresh as well processed forms, a valued in the sport fishery and play a significant role in maintaining the balance in the marine ecosystem.

A perusal of the marine fish landings of the country revealed the trends in landings of total fish as well as the pelagic group fluctuated over the years. However, the contribution of the pelagic fishes to the total catch was always more than 50% of the total catch.



The major groups / species comprising the pelagic fishes of the country include the clupeids, carangids, scombroids, ribbonfish, unicorn cods, Bombay duck, billfishes and barracudas. These major groups and its taxonomic classifications are briefly described for the purpose of this winter school.

Clupeoids

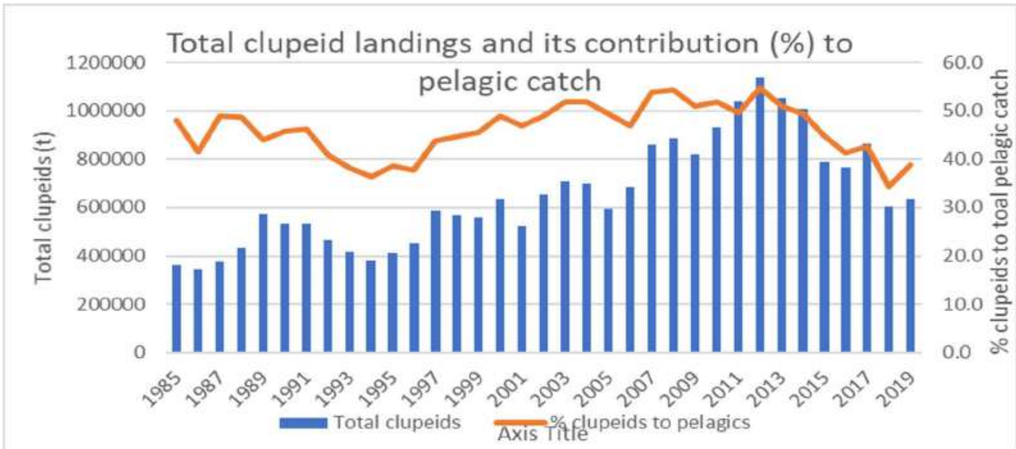
This is a large group consisting mostly small to moderate sized fishes belonging to several families, genera and species and accounts for more than quarter of the fish catch. The clupeid fishes are grouped under four families (Clupeidae, Engraulidae, Pristigasteridae and Chirocentridae) and seven subfamilies. The main groups included under these families include the sardines, anchovies, herrings, shads and sprats.

Clupeoid's species have a complete covering of easily shed cycloid scales on the body (except Chirocentridae) and can be easily identified in the field with the absence of spines in the fins, single short dorsal fin (11 to 23 finrays), situated usually near the midpoint of the body (except in *Chirocentrus*), small pelvic fins, short or moderate anal fins and a forked caudal fin (except rhomboid in *Coilia*). The body is usually fusiform, sometimes almost round in cross-section (*Dussumieria*, *Etrumeus*, also *Engraulis*), but more often compressed, sometimes highly compressed (Chirocentridae, some Pristigasteridae). Typically, there is a pelvic scute with ascending arms just in front of the pelvic fins (absent in Chirocentridae, W-shaped in the Dussumieriinae, and a series of similar scutes in front of the pelvic fins and behind them, but absent in the Dussumieriinae, some Pellonulinae, *Engraulis*. Mouth is either terminal or superior. Small conical teeth are typically present in the jaw s and on the vomer, palatines and endo-and ectopterygoids but some or all may be absent, or the jaws may bear canine teeth (Chirocentridae).

Table 1 General Classification Of Clupeids

FAMILY	SUBFAMILY	GENUS	DOMINANT SPECIES (INDIA)
Denticipitidae			
Engraulididae	Coiliinae	*Coilia*	*C.dussumieri*
		Lycothrissa	
		Papuengraulis	
		Pseudosetipinna	
		Setipinna	*S.breviceps*
		Thryssa	*Thryssa* spp. (5 spp.)
	Engraulinae	*Amazonsprattus*	
		Anchoa	

		Anchovia	
		Anchoviella	
		Cetengraulis	
		Encrasicholina	*E.punctifer, E.heteroloba*
		Engraulis	
		Jurengraulis	
		Lycengraulis	
		Pterengraulis	
Spratelloididae		*Stolephorus*	*S.indicus, S.commersonii,S.waitei*
Pristigasteridae	Pristigasterinae	*Chirocentrodon* *Ilisha* *Neoopisthopterus* *Odontognathus* *Opisthopterus* *Pellona* *Pliosteostoma* *Pristigaster* *Raconda*	*C.dorab* *I.melastoma* *O.tardoore* *P.ditchela* *R.russeliana*
Chirocentridae		*Chirocentrus*	*C. dorab, C.nudus*
Dussumieriidae		*Dussumieria* *Etrumeus* *Trollichthys*	*D.acuta*
Clupeidae	Clupeinae	*Amblygaster* *Clupea* *Clupeonella* *Escualosa* *Harengula* *Herklotsichthys* *Lile* *Opisthonema*	*A.sirm* *E.thoracata*
	Alosinae	*Alosa*	
		Brevoortia	
		Ethmalosa	
		Ethmidium	
		Gudusia	
		Hilsa	*H.kelee*
		Tenualosa	*T.ilisha, T.toli*



Carangids

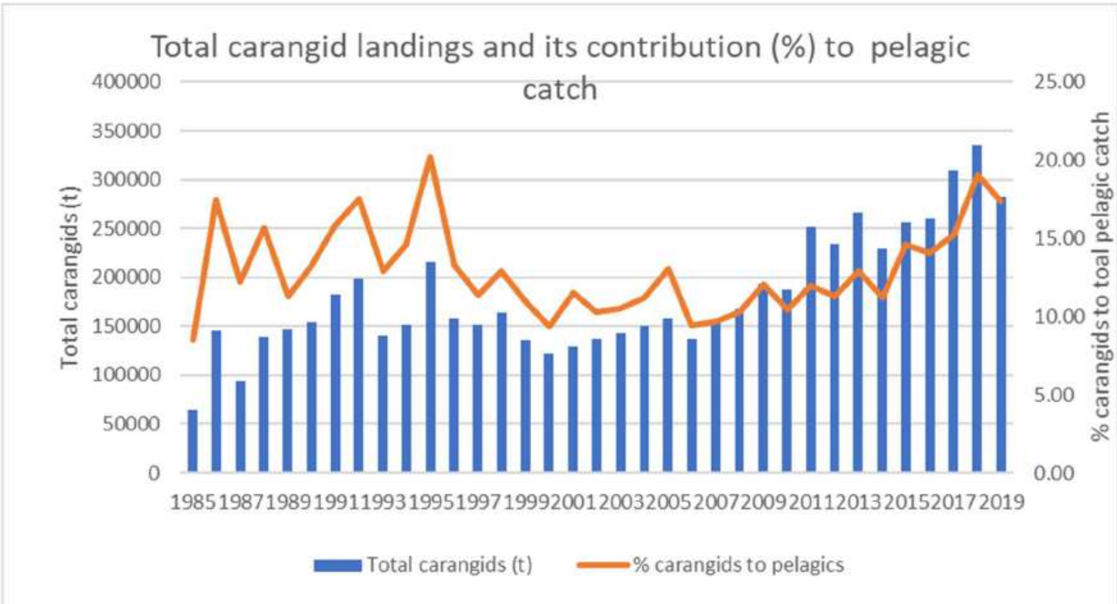
Carangids yet another vast group consisting of several families, several genera and species. Six families are included under Carangiformes and the family Carangidae is the largest of them and includes jacks, pompanos, jack mackerels, runners, scads. The import features used to identify carangids are the presence of two preanal spines, scutes on the body and scalation in the breast area. It forms an important fishery along the Indian coast with most of the species being commercially valuable and exploited by several gears. Some species are popular in sport fishing. Three species have been successfully bred and being cultured.

Table 2 General classification of Carangiformes

Family	**Subfamily**	**Genus**	**Dominant species (India)**
Nematistiidae		*Nematistius*	
Coryphaenidae		*Coryphaena*	*C.hippurus, S.equiselis*
Rachycentridae		*Rachycentron*	*R.canadum*
Echeneididae		*Echneis*	*E.naucrates*
		Phtheirichthys	
		Remora	*R.remora*
Carangidae	Trachinotinae	*Lichia*	
		Trachinotus	*T.mookalee, T. baillonii, T.blochii*
	Scomberoidinae	*Oligoplites*	
		Parona	
		Scomberoides	*S.commersonnianus, S.lysan, S.tala, S.tol*
	Naucratinae	*Campogramma*	
		Elagatis	*E. bipinnulata*
		Naucrates	*N. doctor*

		Seriola	*S.dumerili , S.fasciata S.lalandi, S rivoliana S.quinqueradiata S.nigrofasciata*
	Caranginae	*Alectis*	*A.ciliaris, A.indica*
		Alepis	*A.djedaba, A.kleinii A.melanoptera A.vari*
		Atropus	*A.atropos*
		Atule	*A.mate*
		Carangoides	*C.armatus, C.bajad, C.chrysophyrys, C.ciliarius, C.coeruleopinnatus, C.dinema, C.equula, C.ferdau, C.fulvoguttatus, C.gymnostethus, C.hedlandensis, C.malabaricus,C.oblongus, C.praeustus, C.talamparoides*
		Caranx	*C.heberi, C.ignobilis, C.melampygus, C.sexfasciatus, C.tille*
		Chloroscombrus	
		Decapterus	*D.kurroides, D.russelli, D.macrosoma, D.macarellus, D.tabl*
		Gnathodon	*G.speciosus*
		Hemicaranx	
		Megalaspsis	*M.cordyla*
		Pantolabus	
		Parastromateus	*P.niger*
		Pseudocaranx	
		Selar	*S.crumenopthalmus*
		Selaroides	*S.leptolepis*
		Selene	
		Trachurus	*T.trachurus*
			T.indicus
		Ulua	*U.mentalis*
		Uraspis	*U.uraspis*
Menidae		*Mene*	*M.maculata*

Coryphaenidae, Rachycentridae, and Echeneidae have been suggested to comprise a monophyletic grouping which has been recovered as a sister clade to the Carangidae.



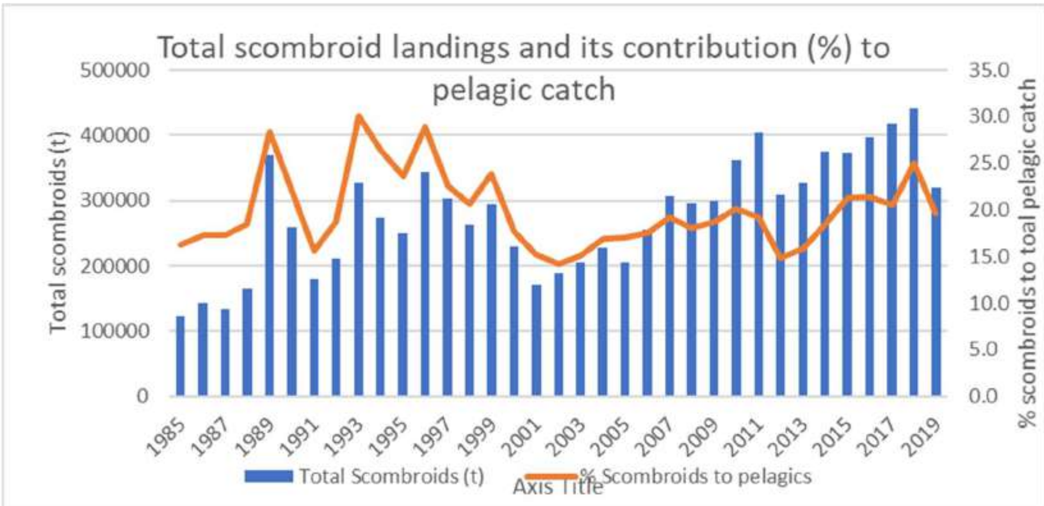
Scombriformes

This group includes different species of pelagic fish (the mackerels, tunas, bonotos) mostly from the family Scombridae, all being very important and favored food fishes with very high domestic as well as export demand. They are found in both temperate and tropical seas, mostly living along the coast or offshore in the oceanic environment.

Mackerel species typically have stream lined body, vertical stripes on their backs and deeply forked tails, two separate dorsal fins and finlets following the dorsal and anal fins. Forked caudal fin, with a slender ridged base. The first (spiny) dorsal fin and the pelvic fins are normally retracted into body grooves.

Fishes are medium to large sized; all undertake either short distance long distance migrations. Smaller mackerel are forage fish for larger predators, including larger mackerel Sport fishermen value the fighting abilities of the king mackerel.

Scombriformes is an order of bony fish containing nine families which were classified under the suborders Scombroidei and Stromateoidei.



General Classification of Scombriformes

Family	Subfamily	Tribe	Genus	Dominant species (India)
Gempylidae			*Diplospinus*	
			Epinnuli	
			Gempylus	
			Lepidocybium	
			Nealotus	
			Neopinnula	
			Nesiarchus	
			Paradiplospinus	
			Promethichthys	
			Rexea	
			Rexichthys	
			Ruvettus	
			Thyrsites	
			Thrsitoidesy	
			Thyrsitops	
Trichiuridae	Aphanopidinae		*Aphanopus*	
			Benthosesmus	
	Lepidopodinae		*Assurger*	
			Eupleurogrammus	
			Evoxymetopon	
			Lepidopus	
	Trichiurinae		*Daemissolinea*	
			Lepturacanthus	*L.savala*
			Tentoriceps	

			Trichiurus	*T.lepturus, T.auriga*
Scombridae	Gasterochismatinae		*Gasterochisma*	
	Scombrinae	Scombrini	*Rastrelliger*	*R.kanagurta R.brachysoma R.faughni*
			Scomber	*S.indicus S.japonicus*
		Scomberomorini	*Acanthocybium*	*A.solandri*
			Grammatorcynus	
			Orcynopsis	
			Scomberomorus	*S.commerson S.guttatus S.lineolatus*
		Sardini	Sarda	*S.orientalis*
			Cybiosarda	
			Gymnosarda	*G.unicolor*
		Thunnini	*Allothunnus*	
			Auxis	*A.rochei A.thazard*
			Euthynnus	*E.affinis*
			Katsuwonus	*K.pelamis*
			Thunnus	*T.albacares T.tonggol T.obesus*
Amarsipidae			*Amarsipus*	
Centrolophidae			*Centrolophus*	*C.niger*
			Hyperoglyphe	
			Icichthys	
			Psenopsis	*P.intermedia*
			Schedophilus	
			Seriolella	
			Tubbia	
Nomeidae			*Cubiceps*	*C.caeruleus*
			Nomeus	
			Psenes	*Psenes sp.*
Ariommatidae			*Arioma*	*A.indica*
Tetragonuridae			*Tetragonurus*	
Stromateidae			*Pampus*	*P.chinenesis, P.argentius*
			Peprilus	
			Stromateus	
Arripidae			*Arripis*	

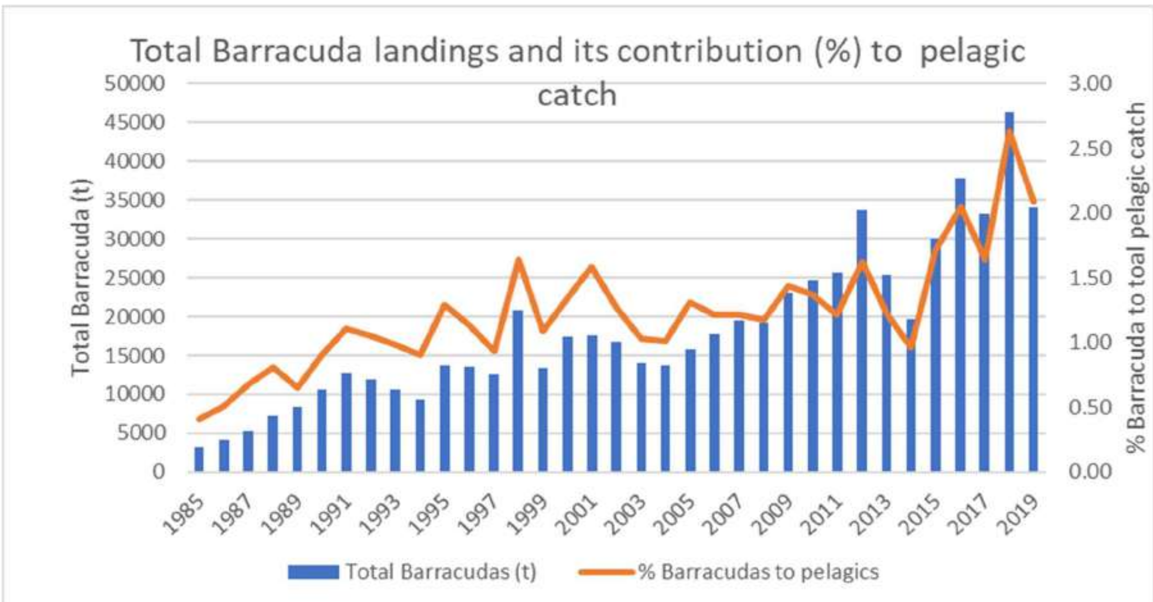
Bramidae			*Brama*	
			Eumegistus	
			Pteraclis	
			Pterycombus	
			Taractes	
			Taractichthys	*T.rubescens*
			Xenobrama	
Caristiidae			*Caristius*	
			Neocaristius	
			Paracaristius	
			Platyberyx	
Chiasmodontidae			*Chiasmodon*	
			Dysalotus	
			Kali	
			Pseudoscopelus	
Icosteidae			*Icosteus*	
Pomatomidae			*Pomatomus*	
Scombrolabracidae			*Scombrolabrax*	
Scombropidae			*Scombrops*	

Barracudas

The barracudas are considered as one of the most predatory fishes in the marine system. With a wide distribution in warm- temperate waters is represented by several species. Can be easily identified by the scaled slender body, two well-separated dorsal fins with the anterior fin having five spines, and the posterior fin having one spine and 9 soft rays. The posterior dorsal fin is similar in size to the anal fin and is situated above it. The lateral line is prominent and extends straight from head to tail. The spinous dorsal fin is placed above the pelvic fins and is normally retracted in a groove. The caudal peduncle is stout and the fin is moderately forked, a jutting lower jaw, and a large mouth with many large, sharp teeth.Their gill covers have no spines and are covered with small scales. They are popular as sport fishes, and also valued as food. *Sphyraena*, is the only genus in the family Sphyraenidae and included several species.

Colouration ranges from dark gray, dark green, white, or blue on the upper body, with silvery sides and a chalky-white belly. Coloration varies somewhat between species. For some species, irregular black spots or a row of darker cross-bars occur on each side. Their fins may be yellowish or dusky.

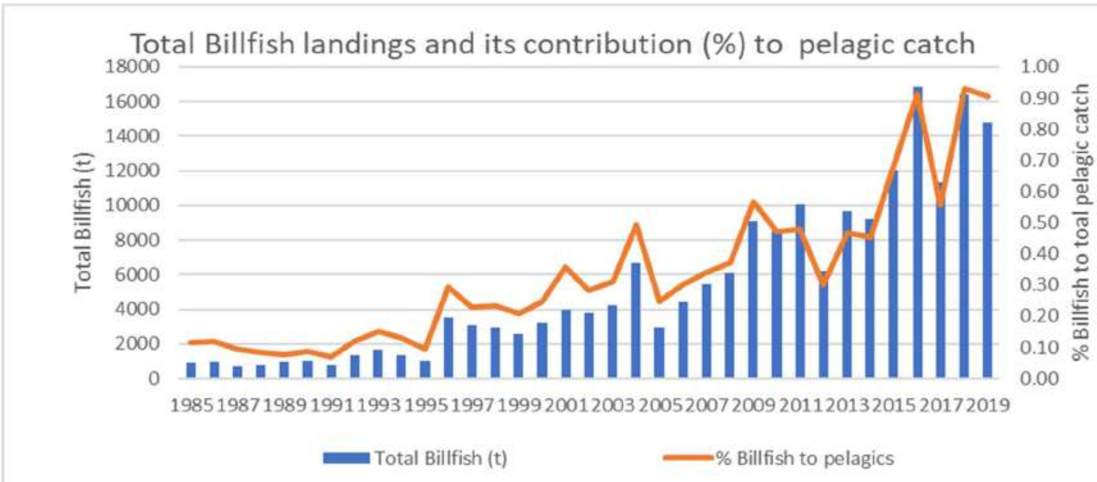
Family	Genus	Dominant species (India)
Sphyraenida	*Sphyraena*	*S. putnamae*, *S.obtusata*, *S. jello*, *S. forsteri*, *S.barracuda*, *S. arabiansis*



Istiophoriformes

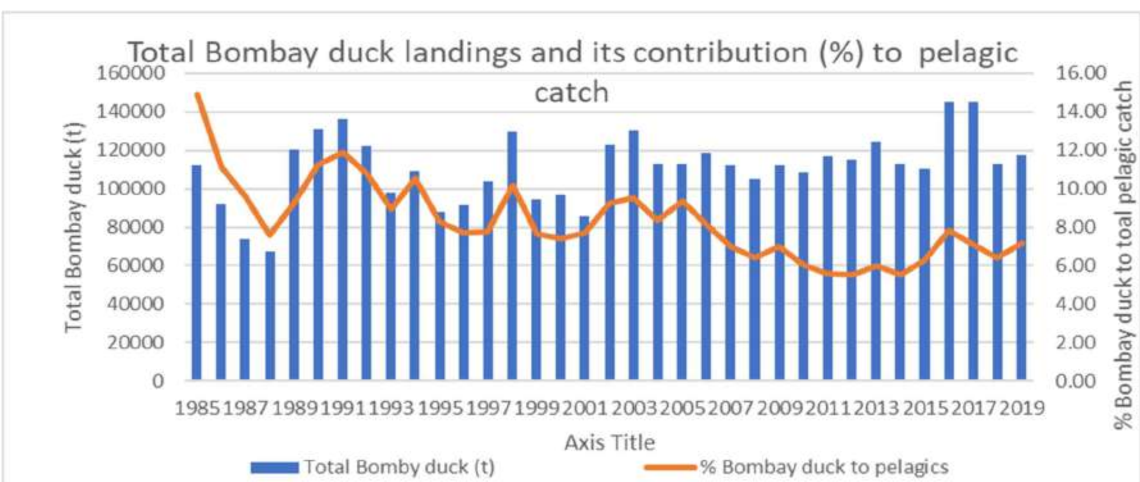
These are a group of highly migratory pelagic fishes characterised by prominent bills, or rostra and popularly referred to as billfishes. They are found in all oceans, although they usually inhabit tropical and subtropical waters and highly valued as gamefish by sports fishermen. They include sailfish and marlin, which make up the family Istiophoridae, and swordfish, sole member of the family Xiphiidae.

Family	Genus	Dominant species (India)
Istiophoridae	*Istiophorus*	*I.platypterus*
Xiphiidae	*Xiphias*	*X.gladius*



Bombay duck

The Bombay duck under the family Synodontidae is a benthopelagic ocenaodromous economically important pelagic fishery group of the country. It is characterized by it limited distribution along the northwest and north east region. Distinguishing characteristics of the Bombay duck are a compressed body with small eyes covered with adipose eyelid on anterior and posterior margins. Large mouth, gape tending obliquely and upper jaw not protractile.Teeth on palatines, vomer and tongue. Body naked except for a series of scales along lateral line and on to tail. *Harpodon nehereus* is the major species occurring along the Indian Coast.



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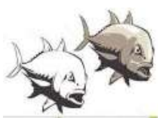

Macro-taxonomic Characters of Carangids (Family: Carangidae) for the Field Identification of Genera & Species

Introduction

Carangidae forms one of the largest families of bony fishes, enjoying wide distribution world over and is represented by about 140 species belonging to 32 genera. In the seas around Indian sub-continent, they are represented by 60 species, forming an assemblage of highly diverse group of fishes with size varying from very small to large having complex morphological and meristic characteristics, making their identification highly complicated. Carangids can be distinguished from other teleost groups by the presence of detached (free) anal spine(s), lateral line scutes, cutaneous fleshy lateral keels, dorsal and ventral grooves on caudal peduncle, adipose eyelids *etc*. Presence of one or a combination of the above different characters is used to distinguish them from other groups. Though many identification keys are available (Smith-Vaniz, 1984; Joshi *et. al*., 2011), their application in the field is difficult and confusing as they are based on several minute taxonomic characteristics. Moreover, many exhibit morphological changes with growth, exhibiting even sexual dimorphism and are often confused and misidentified as different species.

Considering the above points and importance of carangids in commercial fishery, a field identification key for genera and species has been prepared. This article is an illustrative guide for field identification of species using macro-taxonomic characters. The characters provided in this article is very distinct and striking even under field conditions.

Materials and methods

Carangid fishery along the Indian coast were monitored during 2004-'10 at weekly intervals covering all fishing regions. Samples covering all size groups were collected and colouration of body and fins were recorded afresh. Meristic counts and morphometric measurements were made following Hubbs and Lagler (1947) as well as Smith-Vaniz and Staiger (1973). Counts of fin-rays, spines, gillrakers, lateral line scutes, scales, branchiostegal rays and body measurements were taken from all size groups of each species, as far as possible. For all the abundant species, more than 30 specimens covering all the size groups were studied and for others according to availability.

Based on analysis of the data collected and published information (Smith-Vaniz, 1984, 1999 a&b, Smith-Vaniz, *et al*., 1999), a key was prepared for field identification of carangid species from Indian waters. Very distinct morphologic/meristic and colour features, which are observable with ease alone were made use of. Based on the morphology of first dorsal fin, they were grouped under three categories. They were further grouped under subcategories, genera and species based on the body squamation, morphology of fins, lateral line, scutes, gillrakers, presence of adipose eyelid as well as colourations of body, fins and mouth.

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Species diversity

Carangid resources in the Indian waters comprise 60 species belonging to 20 genera (Table 1).They include 13 species of scads belonging to six genera, 28 trevallies belonging to six genera, six leather jackets of single genus, six pompanos/darts of two genera and four jacks of two genera. Genera under other groups were represented by single species each.

Description of genera

No pelvic fin, (present in very small fishes and positioned anterior to pectoral origin); body including dorsal and anal fin covered with small deciduous scales……. Genus: *Parastromateus*.

Pelvic fin present; body superficially naked……. Genus: *Alectis*

Table 1. Major genera and species of the family Carangidae from the Indian seas

Group	Genus	Species
Scads	*Alepes*	*Alepes djedaba, A. kalla, A. melanoptera, A. vari.*
	Atule	*Atule mate*
	Selar	*Selar crumenophthalmus, Selar boops*
	Selaroides	*Selaroides leptolepis*
	Decapterus	*Decapterus kurroides, D. macarellus, D. macrosoma, D. tabl, D. russelli*
	Megalaspis	*Megalaspis cordyla*
Runners	*Elagatis*	*Elagatis bipinnulata*
Trevallies	*Atropus*	*Atropus atropus*
	Carangoides	*Carangoides armatus, C. bajad, C. chrysophrys, C. caeruleopinnatus, C. dinema, C. equula, C. ferdau, C. fulvoguttatus, C. gymnostethus, C. hedlandensis, C. malabaricus, C. praeustus, C. talamparoides, C. uii, C. plagiotaenia, C. oblongus*
	Caranx	*Caranx hippos, C. ignobilis, C. lugubris, C. melampygus, C. paupensis, C. sem, C. sexfasciatus, C. tille*
	Ulua	*Ulua mentalis*
	Gnathanodon	*Gnathanodon speciosus*
	Seriolina	*Seriolina nigrofasciata*
	Naucrates	*Naucrates ductor*
Pilot fishes	*Seriola*	*Seriola dumerili, S. rivoliana*
Jacks	*Uraspis*	*Uraspis helvola, U. uraspis*
Black pomfret	*Parastromateus*	*Parastromateus niger*
Queenfishes	*Scomberoides*	*Scomberoides commersonianus, S. lysan, S. tala, S. tol*
Pompanos and darts	*Alectis* *Trachinotus*	*Alectis ciliaris, A. indicus. Trachinotus baillonii, T. blochii, T. mookalee, T. russelli, T. coppingeri.*

Categorisation of carangids

Based on the morphology of first dorsal fins, carangids can be broadly grouped under three broad categories:

Category I : Superficially first dorsal fin absent.

Category II. : First dorsal fin modified in to short spines.

Category III : First dorsal fin entire and spinous.

Category I : Superficially first dorsal fin absent

Body deep and compressed, first dorsal fin absent, spine(s) occasionally visible in small juveniles. Members belonging to two genera *Parastromateus* and *Alectis* represented this category.

i. Genus: Parastromateus

Genus is represented by single species, *Parastromateus niger*

Description of species

Body deep, ovate and compressed, dorsal and ventral profile strongly and evenly convex; mouth terminal; body becomes slightly elongated with growth; body colouration dark brown in juveniles, uniform silvery gray to bluish brown in adults; fins with dark edges; young ones with 5 to 6 broad dark bands, which fades and disappears with age; lateral line with few (12-14) weak scutes; gillrakers on first gill arch, 26-27 total (8-9 upper, 17-19 lower) ……. *Parastromateus niger* (Bloch, 1795), Black pomfret (Fig. 1).

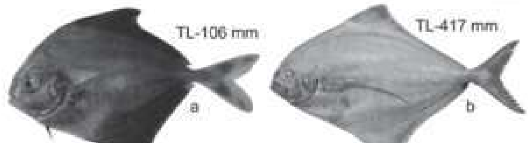


Fig. 1. *Parastromateus niger,* a) Juvenile; b) Adult

ii. Genus: Alectis

Dorsal profile more convex than ventral profile, body very deep and anterior soft rays of second dorsal, anal and pelvic fins extremely long and filamentous in young; undergo considerable morphological changes with growth, body elongates and filamentous rays shorten as the fish grows. Genus is represented by two species; *Alectis indicus* and *Alectis ciliaris.*

Description of species

Profile of head and nape angular; upper jaw ending just before the anterior margin of the eye; gillrakers on first gill arch 31 total (9 upper, 22 lower); lateral line with few weak (11-13) scutes……… *Alectis indicus* (Ruppell, 1830), Indian threadfish (Fig. 2).

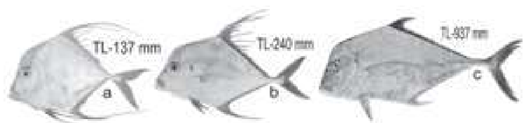


Fig. 2. *Alectis indicus* a) Juvenile; b) Sub-adult; c) Adult

Profiles of head and nape broadly rounded; upper jaw extends below beyond middle of the eye; gillrakers on first gill arch 19-20 total (5 upper, 14-15 lower); lateral line with 15-18 scutes................*Alectis ciliaris* (Bloch, 1788), African pompano (Fig. 3).

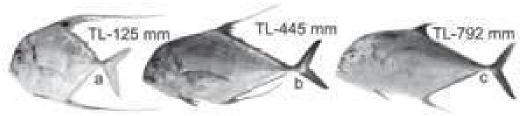


Fig. 3. *Alectis ciliaris* a) Juvenile; b) Sub-adult; c) Adult

Category II : First dorsal fin modified as short spines

Body elongate and compressed; first dorsal fin modified as free spines (Fig. 4) and occasionally with low membraneous inter-connection; no lateral line scutes. Members of three genera; *Scomberoides, Trachinotus* and *Naucrates* represented this category.

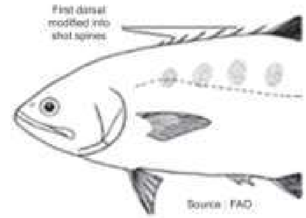


Fig. 4. Modification of first dorsal fin as free spines in Category II

Description of genera

Posterior part of soft dorsal and anal fins with several semi-detached finlets ……. *Genus: Scomberoides.*

No detached or semidetached finlets after second dorsal and anal fin ……. A

A. Body deep to ovate or sub-ovate, strongly compressed; first dorsal fin modified into 6 short spines; anterior lobes of second dorsal, anal and caudal fin falcate……… *Genus: Trachinotus*

Body elongate, shallow nearly rounded or sub-cylindrical; first dorsal modified into 4 or 5 spines; fins not falcate..................*Genus: Naucrates*

iii. Genus: Scomberoides

Body oblong to elliptical, dorsal profile more convex than ventral; first dorsal consists of 6 or 7 short spines, anal with two detached spines; upper jaw extends well beyond the posterior margin of the eye. Four species *viz., Scomberoides commersonianus, S. lysan, S. tala* and *S. tol* represent the genus.

Description of species

Two series of 6-8 round or vertically oblong blotches, one above and another below the lateral line; dorsal profile of head and nape concave; anal origin slightly behind second dorsal origin; distal half of second dorsal lobe pigmented black; gillrakers on first gill arch 25 total (8 upper, 17 lower)… *Scomberoides lysan* (Forsskal, 1775), Double spotted queen fish (Fig. 5).

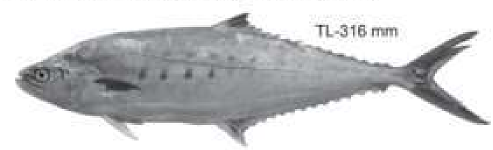


Fig. 5. *Scomberoides lysan*

Only single series of blotches along the sides … A

A. Single series of plumbeous round blotches above or touching lateral line, first one or two slightly intersect lateral line; snout pointed; dorsal profile of head and nape convex; anal origin in line with the second dorsal origin; gillrakers on first gill arch 13-15 total (3-5 upper, 10 lower)............*Scomberoides commersonianus* Lacepede, 1802 Talang queen fish (Fig. 6).

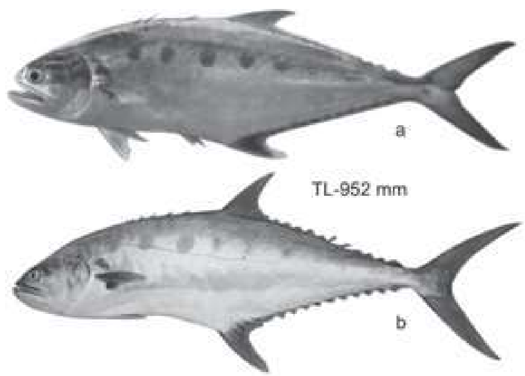


Fig. 6. *Scomberoides commersonianus* a. Sub-adult, b. Adult

Lateral blotches vertically elongate, ovate or oblong.... B

B. Blotches vertically elongate, plumbeous and intersects lateral line; dorsal profile of head and nape concave; anal origin slightly ahead of second dorsal origin; gillrakers on first gill arch 12 total (4 upper, 8 lower)............*Scomberoides tala* (Cuvier, 1832), Barred queenfish (Fig. 7).

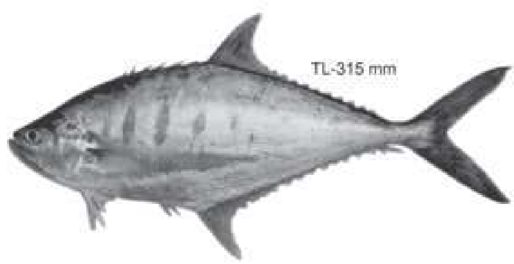


Fig. 7. *Scomberoides tala*

Blotches oval or vertically oblong, first 4-5 intersects lateral line and others just touches the lateral line; snout pointed; dorsal profile of head and nape concave; anal origin in line with the second origin; distal half of second dorsal lobe abruptly and heavily pigmented in small ones; gillrakers on first gill arch 23-24 total (6-7 upper, 17 lower).......*Scomberoides tol* (Cuvier, 1832), Needle scaled queenfish (Fig. 8).

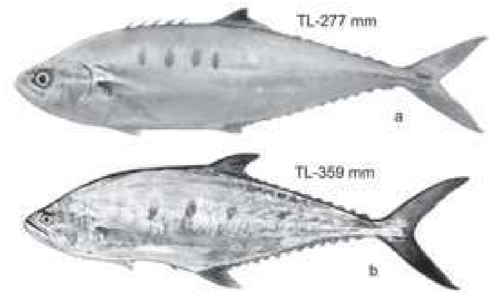


Fig. 8. *Scomberoides tol,* a) Juvenile; b Adult

iv. Genus : Trachinotus

Dorsal and ventral profile more or less equally convex or dorsal slightly more convex in some; anal with two detached spines. Five species; *Trachinotu baillonii, T. coppingeri, T. russelii, T. blochii* and *T. mookalee* represented the genus.

Description of species

No black spots or blotches on sides along lateral line.... A

A row of black spots or blotches on sides along lateral line ... B

A. Anterior margin of fin lobes brownish; second dorsal lobe longer than anal, lobe height decreases with age; gillrakers on first gill arch 14-15 total (6-7 upper, 8 lower) ....*Trachinotus blochii* (Lacepede, 1801), Snubnose pompano (Fig. 9).

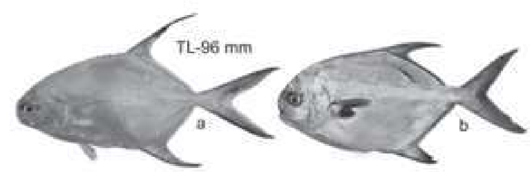


Fig. 9. *Trachinotus blochii* a) Sub-adult; b) Adult

Fin lobes without brownish anterior margin; lobe of second dorsal longer than anal; gillrakers on first gill arch, 15-18 total (7 upper, 8-10 lower) ....*Trachinotus mookalee* Cuvier, 1832, Indian pompano (Fig. 10).

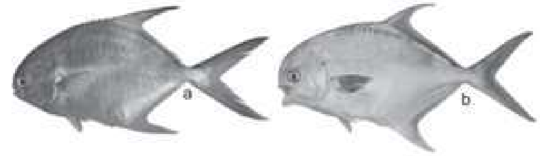


Fig. 10. *Trachinotus mookalee* a) Sub-adult; b) Adult

B. Black spots along the lateral line 2-5, smaller than eye diameter, middle ones being more sharp and relatively large; snout blunt; mouth terminal; caudal symmetrical; gillrakers on first gill arch 24-25 total (7-9 upper, 16-17 lower)………..*Trachinotus baillonii* (Lacepede, 1801), Small spotted dart (Fig. 11).

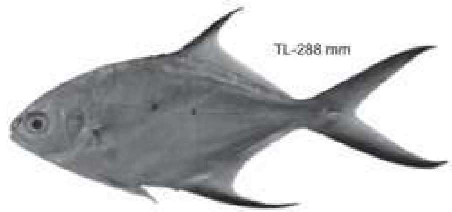


Fig. 11. *Trachinotus baillonii*

Black spots/blotches along the lateral line larger than eye diameter.............C

C. Lateral line spots 4 to 5, plumbeous, anterior ones larger, about $2/3^{rd}$ of the spot above lateral line; snout blunt; mouth terminal; second dorsal and anal lobe highly falcate, gillrakers on first gill arch 19-20 total (7 upper, 12-13 lower), soft anal with 19-21 rays.............. *Trachinotus russelli* Cuvier, 1832, Large spotted dart (Fig. 12).

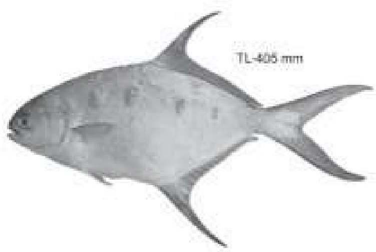


Fig. 12. *Trachinotus russelli*

Lateral line spots 5 to 7, oval/vertically elongate, anterior two above pectoral fin; 2^{nd} and 4^{th} larger, snout blunt; mouth terminal; lateral line irregular; gillrakers on first gill arch 20-21 total (6-8 upper, 13-14 lower), soft anal with 22-24 rays… *Trachinotus coppingeri* Cuvier, 1832, Large spotted dart (Fig. 13)

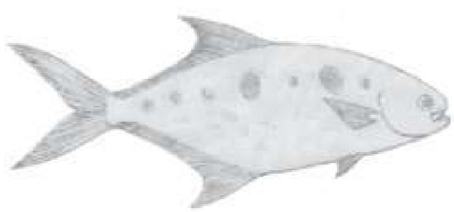


Fig. 13. *Trachinotus coppingeri*

v. Genus: Naucrates

Dorsal and ventral profile almost equal; upper jaw narrow towards posterior end; anal fin with only one detached spine; caudal peduncle with dorsal and ventral groove and lateral fleshy cutaneous keel. Genus is represented by a single species, *Naucrates ductor*.

Description of species

Head profile tapering sharply, snout blunt; upper jaw very narrow at end extending below to the level of anterior margin of the eye; pectoral short; gillrakers on first gill arch, 21 to 23 total (6 upper, 15-17 lower); body with 6-7 black bars against a light silvery background; tips of caudal, second dorsal and anal fin lobes white… ....*Naucrates ductor* (Linnaeus, 1758), Pilot fish (Fig. 14).

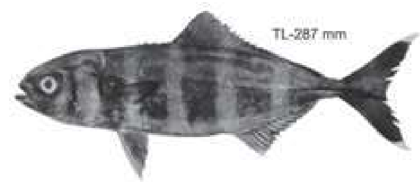


Fig. 14. *Naucrates ductor*

Category III : First dorsal fin entire (normal)

Possesses one or more detached or semidetached finlet(s) after second dorsal and anal fins..............I

No finlets after second dorsal and anal fins II

I. Several detached finlets after second dorsal and anal fin (7-9 and 8-10 respectively), chord of straight part of lateral line longer than the curved part and with broad prominent scutes; eyes covered completely with well-developed adipose eyelid; opercle with small black blotch ……Genus: *Megalaspis*

Only single detached finlet after second dorsal and anal fin..............A

A. Finlet double-rayed; no lateral line scutes; caudal peduncle with dorsal and ventral groove; no adipose eyelid; detached anal spines not visible externally in large specimens; no opercular blotch… Genus: *Elagatis*

Finlet single rayed; chord of the straight part of lateral line shorter than curved part and with very prominent scutes; no caudal peduncle grooves; eyes with well developed adipose eyelid; opercle with a small black blotch …….Genus: *Decapterus*

II. Straight part of lateral line without scutes; caudal peduncle with dorsal and ventral grooves; first dorsal very short, nearly 0.25 times or less of second dorsal height. ……….A

Straight part of lateral line with scutes, caudal peduncle without ventral grooves, first dorsal more than 0.25 times of second dorsal height ....B

A. Upper jaw narrow, broadly rounded at the end with moderately slender supramaxilla terminating below the posterior margin of the eye; caudal peduncle with lateral cutaneous keel; pelvic long, equal or slightly longer than second dorsal lobe; body elongate, shallow and sub-cylindrical; ……Genus: *Seriolina*

Upper jaw truncate, broad at the end, with broad supramaxilla terminating below the anterior margin of the pupil; caudal peduncle without lateral cutaneous keel; pelvic shorter than second dorsal lobe; body elongate, moderately deep and slightly compressed;… Genus: *Seriola*

B. Adipose eyelid totally absent or poorly developed …………. a

Adipose eyelid developed only towards posterior half of the eye .... b

Adipose eyelid fleshy, well-developed and covering entire eye; first dorsal as high as second dorsal.................c

a. Belly with deep median groove, conspicuously long jet black pelvic fin with white rays – fin extend up to the base of anal; body deep, strongly compressed and ovate ……. Genus: *Atropus*

Belly without deep median grove… i

i. Lower jaw very prominent with angle of chin projecting beyond the upper jaw; gillrakers of first gill arch long and more numerous (74-86) and projected into the mouth along the side of tongue, body deep, strongly compressed and ovate, second dorsal and anal falcate… Genus: *Ulua*

Lower jaw normal, not projecting significantly beyond the upper jaw… ii

ii. No detached anal spines; first dorsal relatively short with 8 spines; fin spines reduced or resorbed, tongue, roof and floor of the mouth whitish/creamy, the rest blue black; body oblong and compressed, dorsal more convex than ventral…….. Genus: *Uraspis*

Two detached anal spines…............ iii

iii. Lips and jaws fleshy (papillose), upper jaw strongly protractile, jaws without teeth (young fishes may have few feeble teeth on lower jaw)… Genus: *Gnathanodon*

Lips and jaws normal not fleshy and non-protractile, jaws with bands of fine teeth; body vary widely in shape - elongate/oblong/ovate/rhomboidal, dorsal and ventral profile convex ....Genus: *Carangoides*

b. Chord of curved part of the lateral line distinctly shorter than straight part, entire length of straight part with very prominent scutes/scales, body elongate and compressed, ventral more convex than dorsal; Genus: *Alepes*

Chord of curved part of the lateral line almost equal or slightly shorter than the straight part, straight part with relatively large and strong scutes and nil to few anterior scales; body mostly oblong and compressed, dorsal profile strongly convex to second dorsal, ventral almost straight or slightly concave to anal; upper jaw with an outer row of widely spaced strong conical or canine teeth. Genus: *Caranx*

Chord of curved part of the lateral line longer than the straight part, straight part with relatively small scutes; shoulder with a prominent black spot; mouth terminal with strongly protractile upper jaw, body oblong and compressed, dorsal and ventral profile evenly convex; ……….Genus: *Selaroides*

c. Terminal ray of second dorsal and anal fins, finlet like, slightly more separated and nearly twice in length than penultimate ray; second dorsal and anal fin without a basal sheath, body elongate and moderately compressed, dorsal and ventral profiles evenly convex, Genus: *Atule*

Terminal ray of second dorsal and anal fins as high as penultimate ray and not separated, body elongate, moderately compressed, ventral profile more convex than dorsal; eyes large and prominent;............. Genus: *Selar*

vi. Genus: *Megalaspis*

Only single species, *Megalaspis cordyla* represented the genus.

Description of species

Body elongate, sub-cylindrical and torpedo shaped; caudal peduncle with a medial keel; breast naked ventrally and laterally in triangular area; straight part of lateral line with 51-55 broad prominent scutes, gillrakers on first gill arch 28-30 total (10-12 upper, 18 lower) ……….. *Megalaspis cordyla* (Linnaeus, 1758), Torpedo scad (Fig. 15).

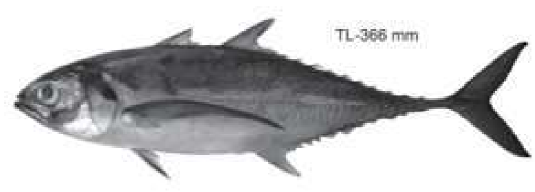


Fig. 15. *Megalaspis cordyla*

vii. Genus: *Elagatis*

Single species, *Elagatis bipinnulata* represented the genus

Description of species

Body elongate and fusiform, head and snout pointed; no adipose eyelid; first dorsal very short, nearly 0.33 times of second dorsal height, pectoral shorter than head. Body dark olive blue green above, white below, two narrow light blue or bluish white stripes along sides with a broad yellow stripe between them… *Elagatis bipinnulata* (Quoy and Gaimard, 1824), Rainbow runner (Fig. 16).

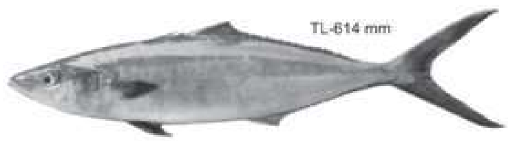


Fig. 16. *Elagatis bipinnulata*

viii. Genus: *Decapterus*

Five species represented the genera; *Decapterus macrosoma, D. macarellus, D. tabl, D. kurroides* and *D. russelli.*

Description of species

Pectoral shorter than head length, tip falling short of a vertical line from the posterior margin of first dorsal base; body very slender, elongate and somewhat circular in cross section .... A

Pectoral equal to or slightly longer than head length, tip extends beyond a vertical line from the origin of the second dorsal fin; body elongate, slender and slightly compressed; almost the entire straight part of the lateral line with scutes or prominent scales… C

A. Posterior upper opercular margin serrated (rough); caudal bright red, tips of soft dorsal fin rays fringed with red; except few anterior scales (4-10), entire straight part of the lateral line with (nearly 37) scutes; gillrakers on first gill arch 44 total (11 upper, 33 lower); .... *Decapterus tabl* Berry, 1968, Roughear scad (Fig. 17).

Fig. 17. *Decapterus tabl*

Posterior upper opercular margin not serrated… B

B. Posterior end of upper jaw (supramaxilla) concave above, rounded and produced below; posterior 2/3rd of the straight part of lateral line with relatively short scutes (33 nos.); gillrakers on first gill arch 44 total (10 upper, 34 lower). .... *Decapterus macrosoma* Bleeker, 1851, Shortfin scad (Fig. 18)

Fig. 18. a. *Decapterus macrosoma;* b. supramaxilla

Posterior end of upper jaw (supramaxilla) straight above, moderately rounded and slanted antero-ventrally; scutes only on posterior half of the straight part of lateral line (29-32 scutes); gillrakers on first gill arch 45-46 total (10-11 upper, 34-35 lower); caudal yellow green and occasionally have reddish tinge… *Decapterus macarellus* Cuvier, 1833, Mackerel scad (Fig. 19).

Fig. 19. a. *Decapterus macarellus;* b. supramaxilla

C. Entire stretch of straight part of the lateral line with prominent scutes (36-37 nos.), totally devoid of anterior scales; caudal bright red in fresh condition; gillrakers on first gill arch 43-44 total (11-12 upper, 32 lower); body with yellow mid-lateral stripe .... *Decapterus kurroides* Bleeker, 1855 (Redtail scad) (Fig. 20).

Fig. 20. *Decapterus kurroides*

Almost entire stretch of straight part of the lateral line with scutes (34-35 nos.), anterior scales if present, only few (0-4); caudal fin hyaline to yellowish; gillrakers on first gill arch 46-48 total (12 upper, 34-36 lower) .... *Decapterus russelli* (Ruppell, 1830), Indian scad (Fig. 21)

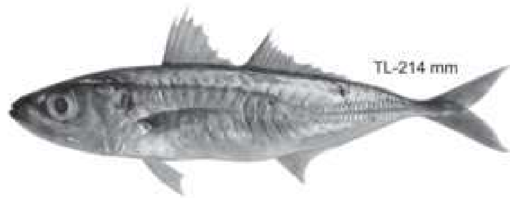


Fig. 21. *Decapterus russelli*

ix. Genus: *Seriolina*

Only single species, *Seriolina nigrofasciata* represented the genera.No detached anal spine (embedded under skin); first gill arch with only a single rudimentary gillraker; body dark grey to black dorsally, belly paler, young ones with 5-7 dark oblique bands on the body, more prominent dorsally and lobe tips of anal and second dorsal white.........*Seriolina nigrofasciata* (Ruppell, 1829), Black banded trevally (Fig. 22).

Fig. 22. *Seriolina nigrofasciata* a) Juvenile; b) Adult

x. Genus*: Seriola*

Two species, *Seriola rivoliana* and *S. dumerili* represented the genus.

Second dorsal and anal lobes longer than pectoral; first gill arch with well-developed gillrakers 25-27 total (7 upper, 18-20 lower), a conspicuous dark band extends backward from the upper jaw across the eye to the tip of the second dorsal lobe along the anterior margin (colour of the band fades with growth); anal margin fringed white; .... *Seriola rivoliana* Valenciennes, 1833, Almaco jack (Fig. 23).

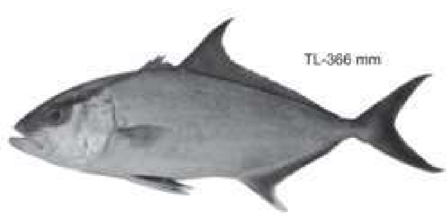


Fig. 23. *Seriolina rivoliana*

Second dorsal and anal lobe equal to or only slightly longer than pectoral; first gill arch with well developed gillrakers 25 total (including 3 rudiments) (8 upper, 17 lower); body dark grey to olivaceous green above, lighter below... ....*Seriola dumerili* (Risso, 1810), Greater amberjack (Fig. 24).

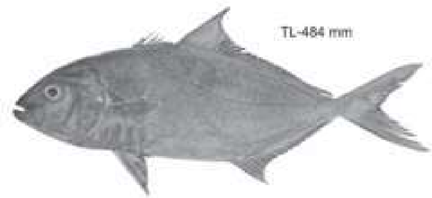


Fig. 24. *Seriola dumerili*

xi. Genus: Atropus

Only one species, *Atropus atropus* represented the genus.

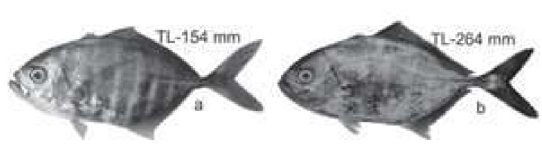
a. Breast naked ventrally and extend diagonally to the base of pectoral; chord of straight part of lateral line longer than curved part and its entire length with scutes (32-34 nos.); gillrakers on first gill arch 29 total (9 upper, 20 lower); opercular spot prominent; young ones with indistinct dark bands. Adults show sexual dimorphism with males having elongate and filamentous central soft ray of varying length in second dorsal fin... *Atropus atropus* (Schneider, 1801), Cleftbelly trevally (Fig. 25).

Fig. 25. *Atropus atropus*, a) female; b) male

xii. Genus: Uraspis

Two species, *Uraspis uraspis* and *Uraspis helvola* represented the genus.

a. Chord of straight part of lateral line distinctly shorter than curved part; almost the entire straight part of lateral line with small scutes (35); pectoral reach only up to the junction of straight and curved part; breast naked ventrally to the origin of pelvic fin and laterally extends to the naked base of pectoral fin; gillrakers on first gill arch 21 total (6 upper, 15 lower) .... *Uraspis uraspis* (Gunther, 1860) Whitemouth jack (Fig. 26).



Fig, 26. *Uraspis uraspis* a) Juvenile b) Adult

b. Chord of straight part of lateral line equal or longer than the curved part; pectoral extends beyond the junction of straight and curved part; straight part of lateral line with relatively narrow scutes (23-40) and few anterior scales; breast naked ventrally to the origin of pelvic fin, remain separated from naked base of pectoral; gillrakers on first gill arch 19-20 total (5 upper, 14-15 lower) .... *Uraspis helvola* (Forster, 1801), Whitetongue jack (Fig. 27).

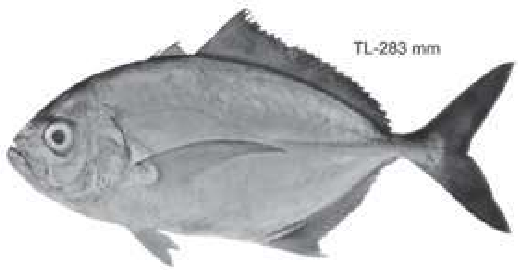


Fig. 27. *Uraspis helvola*

xiii. Genus: *Gnathanodon*

The genus consists of only one species, *Gnathanodon speciosus.*

Body golden yellow in young ones, alternate broad and narrow bands and one oblique band above the eye, caudal lobes tinged black, yellow colouration, darkness of bands and caudal tips fades and several irregular blotches appear with growth, blotches become large irregular with further growth; gillrakers on first gill arch 28 total (9 upper, 19 lower); posterior straight part of lateral line with 22 scutes.............*Gnathanodon speciousus* (Forsskal, 1775), Golden trevally (Fig. 28).

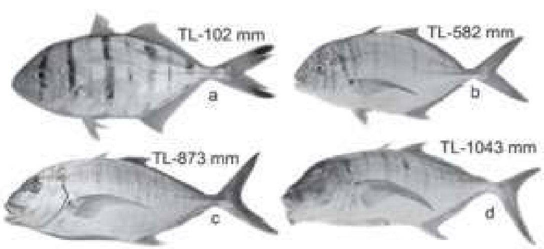


Fig. 28. *Gnathanodon speciosus,* a) Juvenile; b and c) Sub-adults; d) Adult

xiv. Genus: Ulua

Only single species, *Ulua mentalis* represented the genus.

a. Second dorsal and anal fin falcate, second dorsal lobe longer than head; gillrakers on first gill arch long and numerous, 77 total (23 upper, 54 lower); breast naked ventrally and extends laterally to the base of pectoral; straight part of lateral line with 32 small scutes *Ulua mentalis* (Cuvier, 1833), Longrakered trevally (Fig. 29).

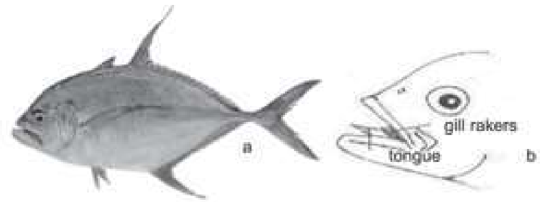


Fig. 29. a) *Ulua mentalis,* b) Gillrakers projected in to mouth

v. Genus: Carangoides

The genus is represented by 16 species.

Body elongate and compressed, dorsal and ventral profile equally convex; head profile nearly straight or slightly angular; lobe of second dorsal distinctly shorter than head length (in adults)… A

Body oblong (sub-ovate in young ones of some), compressed, head profile mostly convex or straight in some .... B

Body rhomboidal, very deep and strongly compressed, profile of snout and nape almost straight… H

Body ovate, very deep and strongly compressed profile of snout and nape convex… I

A. Lower jaw enlarged and projecting beyond upper jaw; first dorsal nearly 0.5 times of second dorsal lobe; breast completely scaled; straight part of lateral line with small scutes towards the posterior half, gillrakers on first gill arch 27-40 total (8-14 upper, 19-27 lower); young ones possess 5-6 dark bands across the body; large adults with small yellow spots on sides… .... *Carangoides plagiotaenia* Bleeker, 1857, Barcheek trevally (Fig. 30).

Fig. 30. *Carangoides plagiotaenia,* a) Juvenile; b) Adult

Mouth pointed with lower and upper jaw at the same level, first dorsal as high as second dorsal or slightly shorter; breast naked ventrally, with a small patch of pre-pelvic scales, remain separated from naked base of pectoral; almost entire straight part of lateral line with scutes (28-32); gillrakers on first gill arch 40-43 total (12-14 upper, 28-30 lower), distal half of second dorsal lobe abruptly black with a white margin wide anteriorly .... *Carangoides praeustus* (Bennett, 1830), Brownback trevally (Fig. 31).

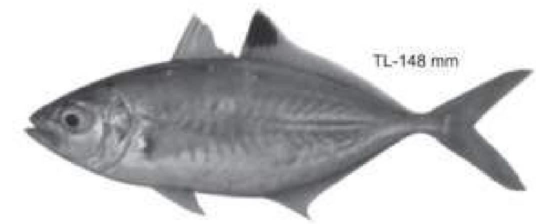


Fig. 31. *Carangoides praeustus*

A. Small dark blotches broader posteriorly on the back between the bases of dorsal fin rays; lobes of second dorsal and anal fin strongly falcate, lobe of second dorsal distinctly longer than head length; breast naked ventrally to behind the origin of pelvic and remain separated from the naked base of pectoral by a band of scales. C

No dark blotches on the back between the bases of dorsal fin rays, lobe of second dorsal distinctly shorter than head length in most; pattern of breast nakedness vary for species. ....D

C. Head profile convex, chord of curved part of the lateral line almost equal or slightly shorter than the straight part; pectoral extends only up to the junction of straight and curved part of lateral line or slightly beyond ………………. *Carangoides oblongus* (Cuvier, 1833), Coachwhip trevally (Fig. 32).

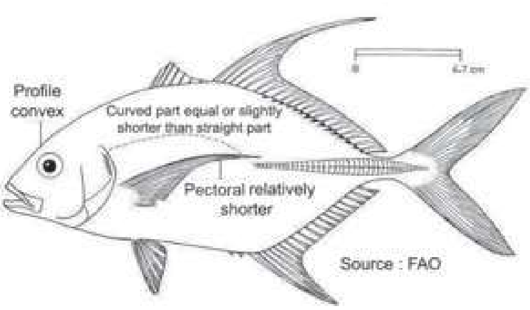


Fig. 32. *Carangoides oblongus*

Head profile nearly straight, chord of curved part of the lateral line longer than the straight part; pectoral relatively long and extends well beyond the junction between straight and curved part of lateral line; …… *Carangoides dinema* Bleeker, 1851, Shadow trevally, (Fig. 33).

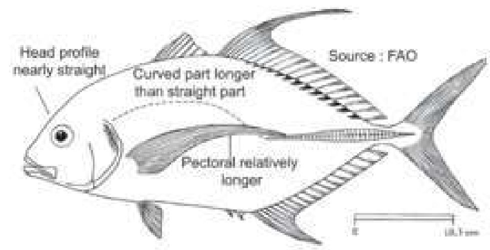


Fig. 33. *Carangoides dinema*

D. Dorsal and ventral evenly convex; first dorsal short, 0.25 times of second dorsal lobe or less; breast naked ventrally to the origin of pelvic fin and separated from the naked base of pectoral, snout bluntly rounded; body with 5-6 dark bands which fades with growth; numerous inconspicuous golden spots on sides above the level of pectoral; distal margin of anal fin whitish; gillrakers on first gill arch 22-25 total (7-8 upper, 15-17 lower); posterior half of straight part of lateral line with 29 (21-37) scutes.............*Carangoides ferdau* (Forsskal, 1775), Blue trevally (Fig. 34).

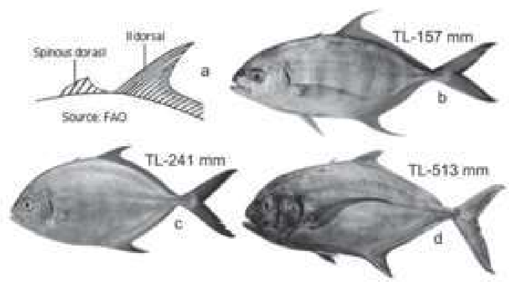


Fig. 34. *Carangoides ferdau*, a) dorsal fins; b) Juvenile; c) Sub-adult; d) Adult

Dorsal more convex than ventral; first dorsal nearly 0.5 times of second dorsal lobe ………… E

E. Breast completely scaled or with a narrow naked area antero-ventrally, mouth cleft distinctly below the level of eye; body sub-cylindrical, second dorsal and anal short, first dorsal as high as second dorsal or slightly shorter, numerous golden yellow spots on the body even below the level of pectoral fin, gillrakers on first gill arch 25-33 total (7-9 upper, 18-21 lower); scutes on straight part of lateral line 20-40 ……….*Carangoides bajad* (Forsskal, 1775), Orangespotted trevally (Fig. 35).

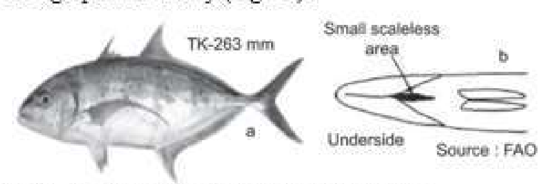


Fig 35. a *Carangoides bajad;* b) Scale-less area

Breast naked ventrally to behind the origin of pelvic and laterally extends to the naked base of pectoral F

F. Snout gently sloped, then abruptly vertical just above mouth cleft; body moderately deep, inter-radial membranes of second dorsal and anal fin dark and often with white spots basally in anal fin, gillrakers on first gill arch 23-24 total (7-8 upper, 16 lower), posterior half of straight part of lateral line with 26 (20-37) weak scutes ....*Carangoides chrysophrys* (Cuvier, 1833), Longnose trevally (Fig. 36).

Fig 36. *Carangoides chrysophrys*, a) Snout; b) Juvenile; c) Adult

Snout pointed above mouth cleft, several small golden or brassy spots in adults mainly above the mid-line .... G

G. Mouth cleft distinctly below the level of eye; body elongates with growth; head and nape convex, become steaper with age; gillrakers on first gill arch 26 total (7 upper, 19 lower); posterior half of the straight part of lateral line with 18 small scutes................*Carangoides fulvoguttatus* (Forsskal, 1775), Yellowspotted trevally (Fig. 37).

Fig. 37. *Carangoides fulvoguttatus*, a) Mouth position; b) Sub-adult; c) Adult

Mouth cleft in level with lower margin of the eye; last ray of second dorsal and anal fin longer than the penultimate ray; body sub-cylindrical, head and nape convex, gillrakers on first gill arch 22-23 total (8-9 upper, 14 lower), straight part of lateral line with 22-23 small scutes..............*Carangoides gymnostethus* (Cuvier, 1833) (Bludger) (Fig. 38).

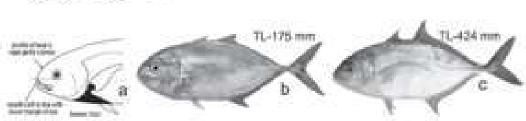


Fig. 38. *Carangoides gymnostethus*. a) Mouth position; b) Sub-adult; c) Adult

H. Breast completely scaled or with a narrow naked area antero-ventrally, second dorsal and anal fin with sub-marginal black to brown band, white distally; gillrakers on first gill arch 27-32 total (7-10 upper, 18-23 lower); almost entire length of straight part of lateral line with scutes (22-32 scutes and 0-6 scales); caudal, pectoral and pelvic yellowish to white...............*Carangoides equula* (Temminck & Schlegel, 1844), Whitefin trevally (Fig. 39).

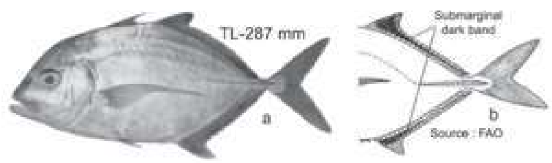


Fig. 39. a) *Carangoides equula;* b) Sub marginal fin band

Breast naked ventrally to behind the origin of pelvic and extends laterally to the naked base of pectoral, no submarginal black/brown band on second dorsal and anal fin, numerous small yellow spots on the body; opercle with small black blotch; gillrakers on first gill arch 24 total (7 upper, 17 lower); scutes on straight part of lateral line 35 ....*Carangoides caeruleopinnatus* (Ruppell, 1830), Coastal trevally (Fig. 40).

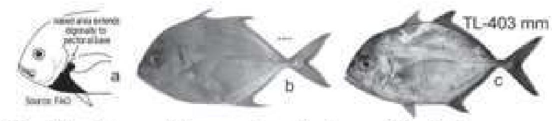


Fig. 40. *Carangoides caeruleopinnatus*, a) Scale-less area; b) Juvenile; c) Adult

I. Dorsal profile strongly convex than ventral; breast naked ventrally to behind the origin of pelvic and extends laterally to the naked base of pectoral fin and above, second dorsal and anal fin short, second dorsal height equal to or shorter than head length and distinctly shorter than anal fin lobe in adults (lobe moderately long in young, become short with age); first dorsal short, 0.5 times of second dorsal height or slightly more. J

Dorsal and ventral equally convex; breast naked ventrally to behind the origin of pelvic and extends laterally only to the naked base of pectoral, second dorsal and anal lobes longer than head length, elongates with growth and become filamentous; young ones possesses 5-6 broad dark vertical bands across the body, bands fades with growth... K

J. Tongue darker - grayish brown to brown; inter-radial membranes of soft anal fin often with white spots basally; gillrakers more numerous on first gill arch 35-36 total (13-14 upper, 22 lower); straight part of lateral line with 31 weak scutes.................. *Carangoides malabaricus* (Bloch & Schneider, 1801), Malabar trevally (Fig. 41).

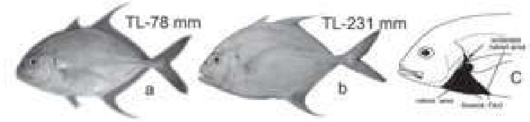


Fig. 41. *Carangoides malabaricus,* a) Juvenile; b) Adult; c) Scale-less area

Tongue paler - white to pale grey; base of inter-radial membrane of soft anal fin often with white spots; first gill arch with only few gillrakers, 28-29 total (7-8 upper, 21 lower); straight part of lateral line with 22-24 weak scutes ……………………*Carangoides talamparoides* Bleeker, 1852, Imposter trevally (Fig. 42).

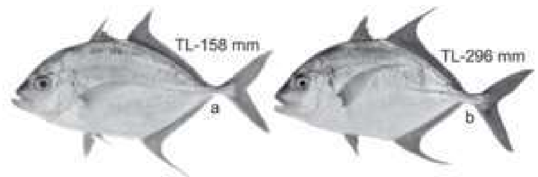


Fig. 42. *Carangoides talamparoides* a) Juvenile; b) Adult

K. Almost entire length of straight part of lateral line with scutes or prominent scales; mouth acutely pointed; second dorsal lobe distinctly longer than anal lobe in adults; eye diameter smaller than snout length; gillrakers on first gill arch few, only 23-24 total (6-7 upper, 17 lower); scutes on straight part of lateral line 15-16 …………….. *Carangoides uii* Wakiya, 1924, Onion trevally (Fig. 43).

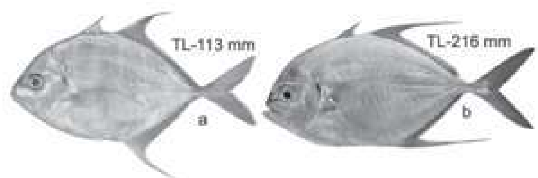


Fig. 43. *Carangoides uii a)* Juvenile; b) Adult

Posterior 2/3rd of straight part of lateral line possesses scutes or prominent scales, pelvic fins jet black with white rays in juveniles, darkness fades with growth; species exhibit sexual dimorphism - middle rays of second dorsal and anal fins elongate and filamentous with varying length in mature males ………..L

L. Head profile very steep, relatively straight from snout to nape without any break in contour (bump); eye diameter less than snout length; gillrakers on first gill arch 33-35 total (11-13 upper, 21-23 lower); pelvic fins long and reach almost anal origin in young ones ………..*Carangoides armatus* (Ruppell, 1830), Longfin trevally (Fig. 44).

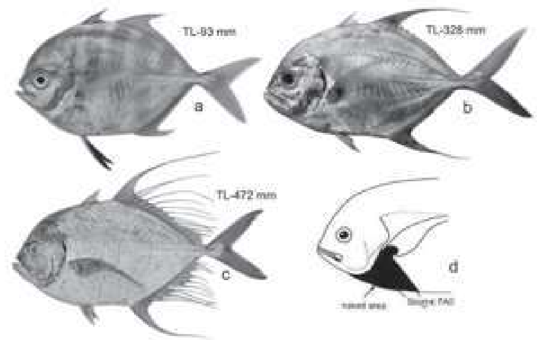


Fig. 44. *Carangoides armatus, a)* Juvenile; b) Female; c) Male; d) Scale-less area

Head profile steep, with a distinct break in contour (bump) in the inter orbital region (more pronounced in adults); eye diameter equal to or larger than snout length; gillrakers on first gill arch few, 24-25 total (9 upper, 15-16 lower); in young ones pelvic fins relatively short and reach only half way to anal origin or slightly beyond …………….*Carangoides hedlandensis* (Whitley, 1933), Bumpnose trevally (Fig. 45).

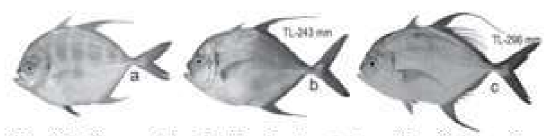


Fig. 45. *Carangoides hedlandensis, a)* Juvenile; b) Female; c) Male

xvi. Genus: Alepes

Five species represent the genus

Description of species

A. Body very deep and ovate, ventral distinctly more convex than dorsal profile, Dark bands on sides above - more prominent in small fishes; end of upper jaw broad and slightly concave posteriorly; caudal asymmetrical with long upper lobe; opercular spot large spreading to adjacent areas of shoulder; gillrakers on first gill arch 41-43 total (11-12 upper, 32 lower), lateral line with 42-43 scutes. ………..*Alepes kalla* Cuvier, 1833, Banded scad (Fig. 46).

Fig. 46. a. *Alepes kalla;* b) Upper jaw

Body oblong, dorsal and ventral profile almost equally convex...... B

B. Length of ultimate ray of second dorsal and anal fin almost equal to penultimate ray, inter radial membrane of first dorsal jet-black; snout bluntly rounded; end of upper jaw narrowly rounded; gillrakers on first gill arch 24-30 total (7-9 upper, 17-24 lower); straight part of lateral line with 49-69 relatively large scutes. ....*Alepes melanoptera* Swainson, 1839, Blackfin scad (Fig. 47).

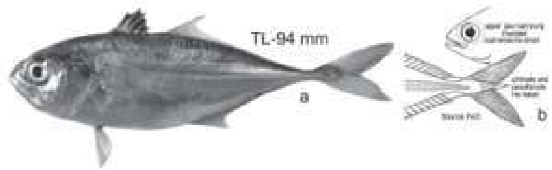


Fig. 47. a) *Alepes melanoptera;* b) Upper jaw and dorsal and anal details

Ultimate ray of second dorsal and anal fin longer than penultimate ray.............. C

C. Caudal asymmetrical with relatively long upper lobe; opercular spot bordered above by a small white spot; upper jaw broad and slightly concave posteriorly, gillrakers on first gill arch 39-40 total (11-12 upper, 28 lower), straight part of lateral line with 46-49 relatively large scutes.......... *Alepes djedaba* (Forsskal, 1775), Shrimp scad (Fig. 48).

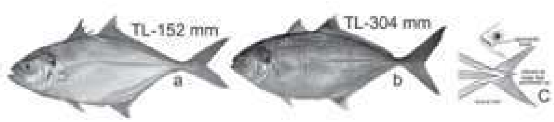


Fig. 48. *Alepes djedaba,* a) Juvenile; b) Adult; c) Upper jaw, dorsal and anal

D. Caudal symmetrical with relatively elongated lobes; end of upper jaw straight posteriorly and supramaxilla relatively large; gillrakers on first gill arch 36 total (12 upper, 24 lower); lateral line with relatively small, but more numerous (61) scutes than other species... ....*Alepes vari* (Cuvier, 1833), Herring scad (Fig. 49).

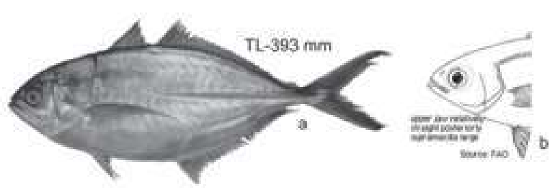


Fig. 49. a). *Alepes vari;* b) Upper jaw

xvii. Genus: Caranx

Members of the genus undergo considerable changes in morphology and colour with growth, body compressed, generally deep in young, become oblong and elongate in adults (Fig. 50).

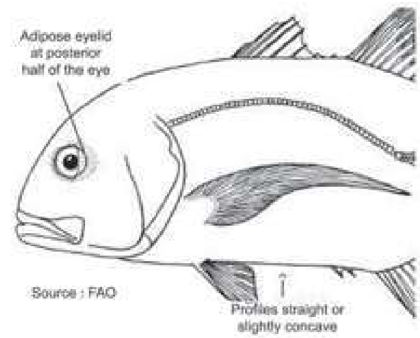


Fig. 50. Typical shape of *Caranx*

Eight species represented the genus in Indian waters

Description of species

Breast naked ventrally and typically with a small patch of pre-pelvic scales ..... A

Breast completely scaled... ......D

A. Upper jaw relatively short ending below, before the middle of the eye, a conspicuous white spot behind the postero-dorsal margin of opercle; small black spots scattered on the dorsal part of the body in larger fishes; lower lobe of caudal, pelvic and anal with a distinct narrow white margin; gillrakers on first gill arch 26 total (8 upper, 18 lower)............. *Caranx paupensis* Alleyne & Macleay, 1877, Brassy trevally (Fig. 51).

Fig. 51. *Caranx paupensis,* a) Supra maxilla; b) Sub-adult; c) Adult

End of upper jaw extends to the posterior border of pupil or only slightly beyond............ B

B. Opercle with black posterior margin; first dorsal fin black in young ones and possess 5-6 dark cross bars, fin become paler and bars disappear with growth; soft fins yellowish, lobes and leading edges of second dorsal and caudal pigmented black; body moderately deep; gillrakers on first gill arch 22-25 total (7-8 upper, 16-17 lower) ....*Caranx hippos* (Linnaeus, 1766)/*(Caranx carangus),* Blacktailed trevally (Fig. 52).

Fig. 52. *Caranx hippos,* a) Juvenile; b) Sub-adult

No opercular spot...............C

C. Body very deep; adults exhibit sexual dimorphism in colouration with males having darker body and fins than females; gillrakers on first gill arch 20-23 total (6-7 upper, 13-16 lower)… *Caranx ignobilis* (Forsskal, 1775), Giant trevally (Fig. 53).

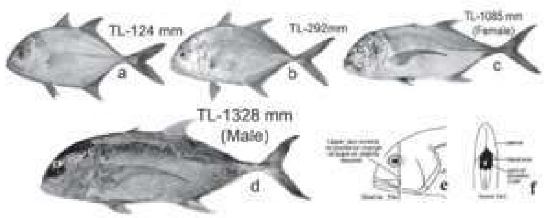


Fig . 53. *Caranx ignobilis,* a) Juvenile; b) Sub-adult; c) Adult female; d) Adult male; e) Supra maxilla; f) Ventral scaleless area

Body moderately deep; yellow green/bronze above; soft fins yellowish, upper lobe of caudal fin pigmented deep black; in juveniles distal margin of second dorsal lobe dark; gillrakers on first gill arch 23-26 total (7-8 upper, 15-18 lower)… *Caranx sem* Cuvier, 1833, Blacktip trevally (Fig. 54).

Fig. 54. *Carax sem,* a) Juvenile; b) Sub-adult; c) Adult

D. Upper jaw long, extends beyond the posterior margin of the eye… E

Upper jaw ends below or before the eye….........F

E. Head profile moderately steep in adults; opercular spot smaller than pupil diameter; second dorsal with a distinct white tip in large fishes, lateral line scutes dark to black; gillrakers on first gill arch 22-24 total (6-7 upper, 15-17 lower),……… *Caranxsex fasciatus* Quoy & Gaimard, 1824, Bigeye trevally (Fig. 55).

Fig. 55. *Caranxsex fasciatus,* a) Juvenile; b) Sub-adult; c) Adult

Head very steep in adults, opercular spot prominent and equal to pupil diameter; second dorsal without white tip, lateral line scutes grey, gillrakers on first gill arch 21-23 total (6 upper, 15-17 lower), ... *Caranx tille* Cuvier, 1833, Tille trevally (Fig. 56).

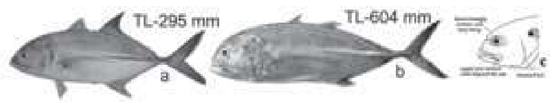


Fig. 56. *Caranx tille,* a) Juvenile; b) Adult; c) Supra maxilla

F. Upper jaw ends below middle of the eye, head steep, anterior part of the nape slightly concave above eye; opercular spot smaller than pupil; second dorsal and anal lobe falcate; body and fins uniform grey to brown, lateral line scutes usually dark brown to black; gillrakers on first gill arch 23-30 total (6-8 upper, 17-22 lower) .... *Caranx lugubris* Poey, 1860, Black jack (Fig. 57).

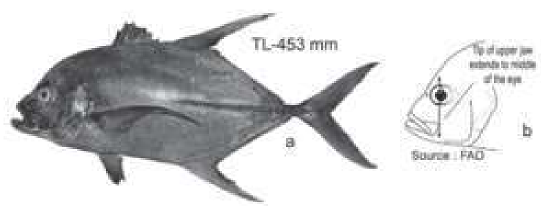


Fig. 57. a) *Caranx lugubris;* b) Upper jaw

Upper jaw ends below anterior margin of the eye; pectoral yellowish in young, colour changes with growth and soft fins become electric blue in adults, head and dorsal half of the body in adults brassy, suffused with blue and covered with blue black spots; gillrakers on first gill arch 26 total (7-9 upper, 17-19 lower)....................*Caranx melampygus* Cuvier, 1833, Bluefin trevally (Fig. 58).

Fig. 58. *Caranx melampygus* a) Juvenile; b) Adult; c) Upper jaw

xviii. Genus: Selaroides

Only one species under the genus; *Selaroides leptolepis*

a. Body with a broad yellow stripe from upper margin of eye to caudal peduncle, opercular spot encroaching to shoulder, pelvic white, other fins dusky yellow; eye diameter shorter than snout, upper jaw toothless; gillrakers on first gill arch 40-44 total (12 upper, 27-32 lower), straight part of lateral line with 25-26 small scutes ....*Selaroides leptolepis* (Cuvier, 1833), Yellow stripe scad (Fig. 59).

Fig. 59. a) *Selaroides leptolepis;* b) upper jaw

xix. Genus: *Atule*

Only one species under the genera; *Atule mate*

Chord of curved part of lateral line shorter than straight part; body with 9-10 dorso-ventral faint gray bars and prominent black opercular spot; eyes moderate; gillrakers on first gill arch 29-31 total (13 upper, 26-28 lower); lateral line with 41-43 scutes… *Atule mate* (Cuvier, 1833), Yellowtail scad (Fig. 60).

Fig. 60. *Atule mate,* a) Juvenile; b) Adult; c) Semi-detached finlet

xx. Genus: Selar

Upper jaw extends to below the middle of the pupil; a wide golden yellow stripe from opercle to upper part of caudal peduncle in fresh condition; pectoral fins falcate. The genus is represented by two species.

a. Straight part of lateral line longer than chord of curved part with very prominent 42-45 scutes, curved part with 22-24 scales, pectoral ends well beyond the junction between straight and curved part of lateral line, snout shorter than eye diameter. Body relatively deep (0.28 times of TL); eyes very large with prominent pupil; gillrakers on first gill arch 10-11 upper, 27- 29 lower ....*Selar boops* (Cuvier, 1833), Oxeye scad (Fig. 61).

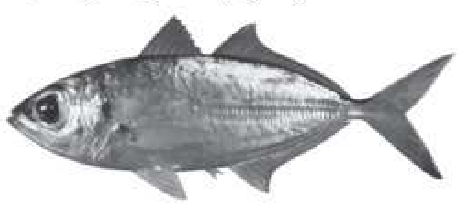


Fig. 61. *Selar boops*

b. Straight part of lateral line shorter than chord of curved part with 38-41 scutes, curved part with 50-56 scales, pectoral ends before the junction between straight and curved part of lateral line, snout equal or longer than eye diameter. Body less deep (0.25 times of TL); gillrakers on first gill arch 9-11 upper, 29-32 lower ....*Selar crumenophthalmus* (Bloch, 1793), Bigeye scad (Fig. 62).

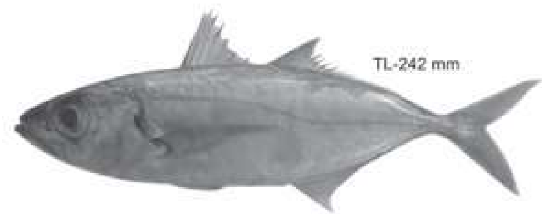
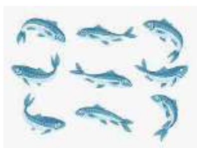


Fig. 62. *Selar crumenophthalmus*

Species identification catalogues report occurrence of several species of carangids in the Indian waters. But many were not represented in the fishery till recent past. With the recent expansion of fishing operations to previously unexploited grounds, some of them are appearing now in the landings in varying quantities. However, due to confusion on the identity many are not being documented properly. The present article will aid in identification of genera and species with ease in the field. Final confirmation can be made by conventional as well as molecular taxonomic tools.



CHAPTER 13
Taxonomy of Clupeoid Fishes

Introduction

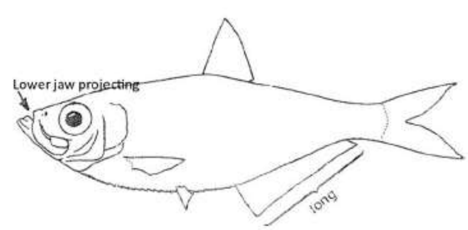
Clupeoids are fishes coming under the sub-order Clupeoidei of the order Clupeiformes whereas clupeids are fishes coming under the family Clupeidae. Clupeoids are moderate, small or very small fishes without spines in the fins; dorsal fin is single and short (11-23 fin rays) usually near midpoint of body; pelvic fin with 6-10 rays and anal fin usually short or moderate (10-36 fin rays), caudal fin forked. Body usually fusiform, sometimes almost round in cross section but more often compressed sometimes highly compressed. Mouth small. Small conical teeth typically present in jaws, and on vomer, palatines and endo- and ectopterygoids (roof of mouth). Swim bladder present, sometimes double chambered with pneumatic duct joined to oesophagus or stomach. Almost all species with complete covering of cycloid scales on body, scales frequently deciduous. No lateral line canal with pored scales along sides (occasionally one or two behind gill opening). A branching mainly cutaneous sensory canal system covering top and sides of head, supra occipital, infra orbital pre-opercular and pterotic canals all meet in the recessus lateralis, a special chamber characteristic of clupeiform fishes. They are mostly marine, coastal and schooling fishes which feed on small planktonic animals often form large schools at or near the surface. The clupeoid fishes are of prime importance to the fisheries. In 2018, it formed 17 % of the total capture fisheries landing in the world (FAO,2020). In India, it formed 18 % of the total marine capture fisheries landing in 2019 and among the pelagic finfish landing, its contribution was 42 %. Sardiines alone constituted 21 %. (CMFRI, 2019).

Classification

The classification is based on FAO Fisheries Synopsis No. 125 Vol.7. The sub-order clupeoidei contains four families namely Pristigasteridae, Chirocentridae , Engraulididae and Clupeidae.

Family: Pristigasteridae

Articulation of lower jaw under or just behind eye. Scutes present along belly. Body is oval or round in cross section. Anal fin base is long having more than 30 fin rays. Lower jaw is projecting with mouth directed more or less upward. Pelvic fin rays 7 though it is absent in *Opisthopterus* sp and *Raconda* sp.

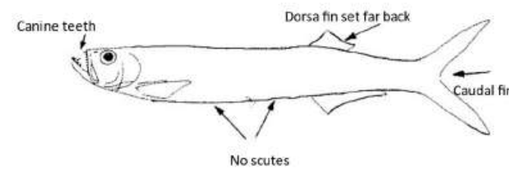


Until recently this family was included under clupeidae. But due to the following reasons, it is separated as a family:

Pre-dorsal bones either upright or inclined forward whereas it is inclined backward in all clupeids. There is no gap between the second and third hypural bones of the tail whereas upper and lower caudal fin rays are separated by a gap in clupeids.

Family: Chirocentridae

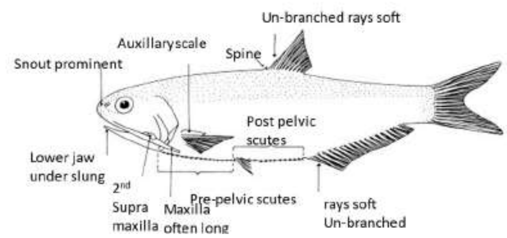
Articulation of lower jaw under or just behind eye. No scutes present all along body. Body is highly compressed and elongate. Canine teeth present. Dorsal fin origin is much nearer to caudal base than to the snout.



Family: Engraulididae

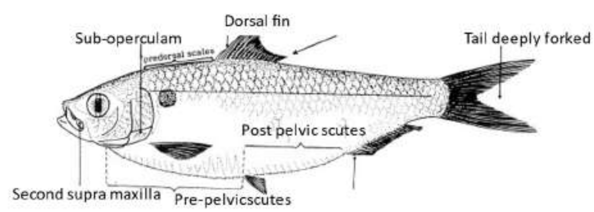
Articulation of lower jaw well behind eye. Scutes are present along the belly. Lower jaw usually slender and under slung. Snout is pig like and projecting. Pelvic fin rays 7.

The family name Engraulidae has been used in almost all previous literature and is still in use. But this is an incorrect derivation from Engraulis. The correct (but less euphonic) derivation is Engraulididae (Whitehead et al*.,* 1985).



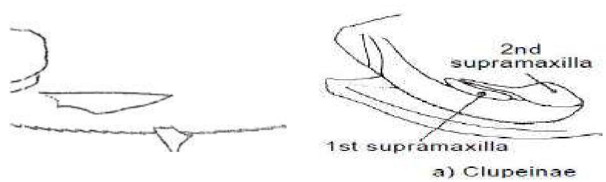
Family: Clupeidae

Articulation of lower jaw under or just behind eye. Mostly two supramaxillae present. Scutes present all along body in most of the genera. Body oval or round in cross section. Anal fin moderate and pelvic fin rays range from 7 to 9.

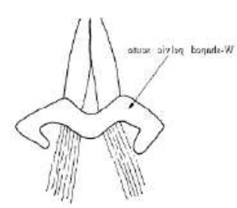


The family is divided into 5 sub-families as Clupeinae, Dussumieriinae, Pellonulinae, Dorosomatinae and Alosinae.

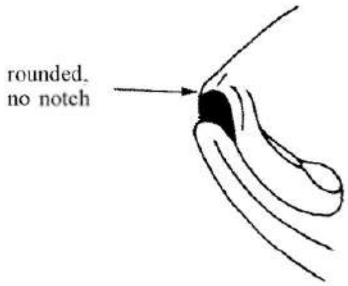
1. Cluepinae : Two supra maxillae. Abdominal scutes present

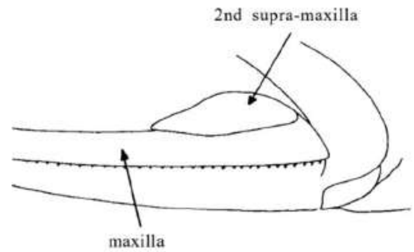


2. Dussumieriinae: Branchiostegal rays (B.S) 6 to 18. Pelvic scute W shaped. No other scutes on belly. Belly is smooth. Premaxilla is rectangular or triangular.
   This is further divided into 2 tribes:
   a. Dussumieriini: B.S rays numerous (11-18). Premaxilla rectangular
   b. Spratelloidini: B.S rays few (6-7). Premaxilla is triangular

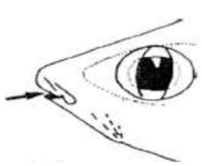


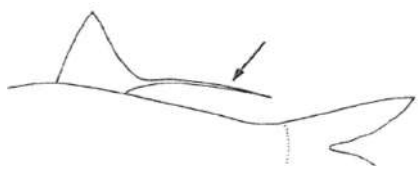
3. Pellonulinae: Mouth is terminal. Upper jaw without a median notch. Lower jaw not flared at corners. Only a single supra maxilla present. Last dorsal ray not filamentous.



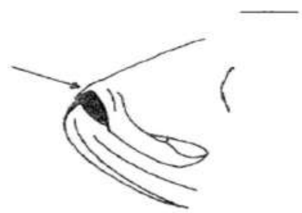


4. ***Dorosomatinae***: B.S rays 4 to 8. Scutes present. Anal fin is short with less than 30 rays. Lower jaw not prominent. Mouth is inferior and lower jaw is flared at corners. Last dorsal fin ray often filamentous.



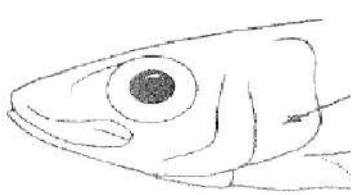


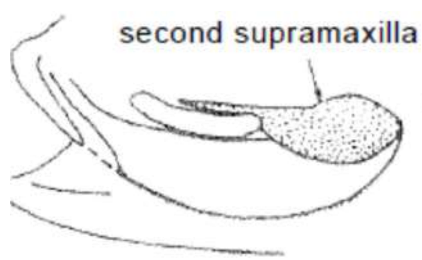
5. Alosinae: Mouth is terminal. Lower jaw not flared at corners. Upper jaw with a distinct notch at centre. Last dorsal ray not filamentous.

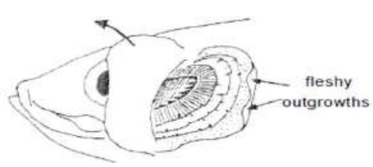


Key to genera
Family: Clupeidae
Sub-family: Clupeinae

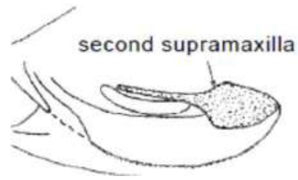
1. ***Herklotsichthys***
Opercle is smooth. Gill opening with two fleshy outgrowths. Fronto parietal striae on top of head is 3 to 8. Lower portion of paddle shaped, second supra maxilla is longer than upper. Pelvic fin rays 8 or 9. Back is blue or green

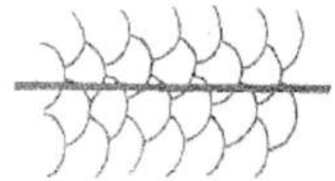






2. ***Sardinella***

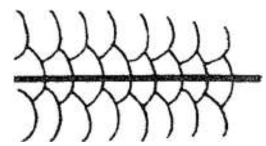




Opercle is smooth. Gill opening with two fleshy outgrowths. Fronto parietal striae on top of head is 3 to 8. Lower portion of paddle shaped second supra maxilla is equal to upper. Pelvic fin rays 8 or 9. Pre dorsal scales paired and overlapping in midline. Gill rakers more than 40. Back is blue or green

3. ***Amblygaster***

Opercle is smooth. Gill opening with two fleshy outgrowths. Fronto - parietal striae on top of head is 3 to 8. Pelvic fin rays 8 or 9. Gill rakers 26-43. Pre dorsal scales forming a well-defined single median row.

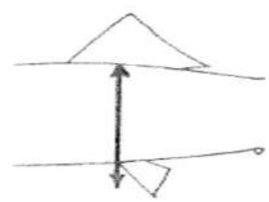


4. ***Escualosa***

Gill opening smoothly rounded. Pelvic fin rays 7. Body creamy white.

Sub-family : Dussumieriinae

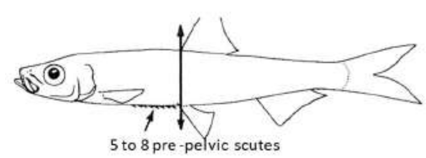
1. ***Dussumieria***
Pelvic fins under dorsal fin base. Pre maxilla is rectangular. B.S rays 11-18.



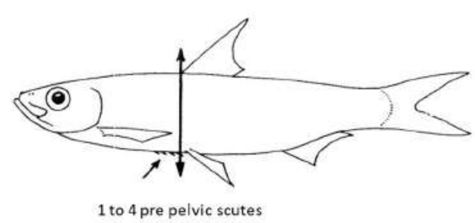
2. ***Spratelloides***
Pelvic fins behind dorsal fin base. Premaxilla is triangular. B.S rays few (6 or 7).

Sub-family: Pellonulinae

1. ***Ehirava***
One to 9 unkeeled pre pelvic scutes present. Pelvic fin base just before dorsal fin origin. Pre-pelvic scutes 5 to 8.

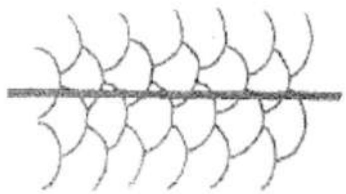
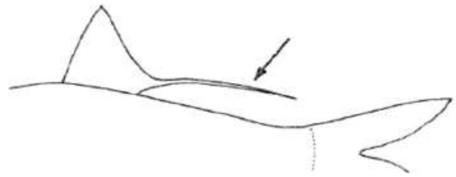


2. ***Dayella***
One to 9 unkeeled pre pelvic scutes present. Pelvic fin base just behind dorsal fin origin. Pre-pelvic scutes 1 to 4.

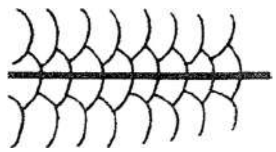


Sub-family: Dorosomatinae

1. ***Nematolosa***
Last dorsal fin ray is filamentous. Pre-dorsal scales paired and overlapping.

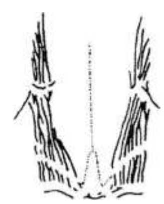
 

2. ***Anodontostoma***
   Last dorsal fin ray is normal. Pre-dorsal scales forming a single median row.

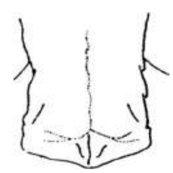


Sub-family: ***Alosinae***

1. ***Hilsa***
   Fronto-parietal striae on top of head many (8 to 14). Gill rakers on inner arches distinctly curved outward. Scales perforated.



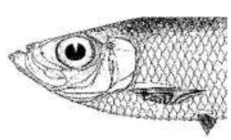
2. ***Tenualosa***
   Fronto-parietal striae on top of head weekly developed usually hidden by skin. Gill rakers on inner arches straight. Scales unperforated.



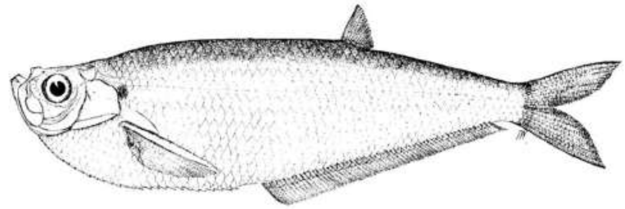
Family: ***Pristigasteridae***

1. ***Pellona***
   Toothed hypomaxilla. Pelvic fin present.

2. ***Ilisha***
   Hypomaxilla is not toothed. Pelvic fin is present. Anal fin rays 34-53.

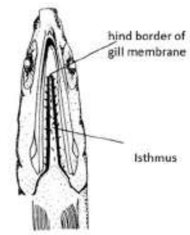
 

3. ***Opisthopterus***
Hypomaxilla not toothed. Pelvic fin absent. Anal fin base long with 51 to 65 fin rays. Scutes well developed.

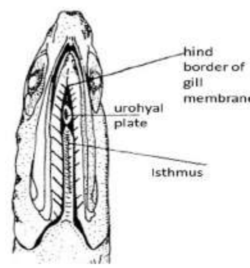


Family: *Chirocentrus*
A single genus ***Chirocentrus***
Family: ***Engraulididae***

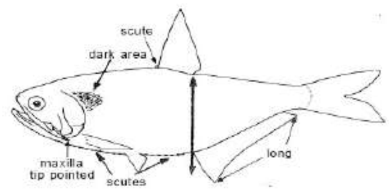
1. ***Stolephorus***
Isthmus muscle touch the hind border of gill membrane.



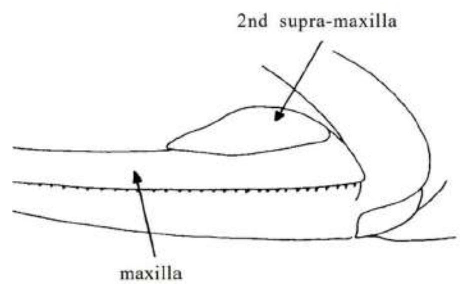
2. ***Encrasicholina***
Isthmus muscle is not touching the hind border of gill membrane. Urohyal is exposed



3. ***Thryssa***
Post pelvic scutes are strong and sharply keeled.



4. ***Setipinna***
Upper fin ray a filament. Single supra maxilla



5. ***Coilia***
Body tapering rat tailed caudal fin is small. Pectoral fin is filamentous.

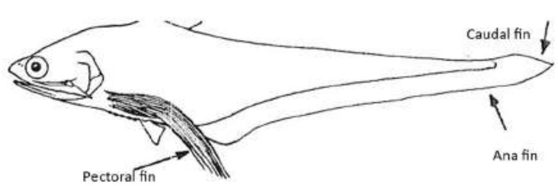


Table 1. List of common species of clupeoid recorded from Indian coasts.

Family	Ser.No.	Species name	Common name
Clupeidae	1	*Sardinella gibbosa* (Bleeker,1849)	Golden stripe sardinella
	2	*Sardinella albella* (Valenciennes,1847)	White sardinella
	3	*Sardinella brachysoma* Bleeker,1852	Deep body sardinella
	4	*Sardinella fimbriata* (Valenciennes,1847)	Fringe scale sardinella
	5	*Sardinella melanura* (Cuvier,1829)	Blacktip sardinella
	6	*Sardinella jessieui* (Valenciennes,1847)	Mauritician sardinella
	7	*Sardinella longiceps* Valenciennes,1847	Indian oil sardine
	8	*Amblygaster clupeoides* Bleeker, 1849	Bleekersmooth belly sardinella
	9	*Amblygaster leiogaster* (Valenciennes,1847)	Smooth belly sardinella
	10	*Amblygaster sirm* (Walbaum, 1792)	Spotted sardinella
	11	*Escualosa thoracata*(Valenciennes, 1847)	White sardine
	12	*Dussumiera acuta* Valenciennes, 1847	Rainbow sardine
	13	*Spratellides delicatulus* (Bennett, 1831)	Delicate round herring
	14	*Spratelloides gracilis* (Schlegel, 1846)	Silver stripe round herring
	15	*Ehirava fluviatilis* Deraniyagala, 1929.	Malabar sprat
	16	*Dayella malabarica* (Day, 1873)	Day's round herring
	17	*Nematalosa nasus* (Bloch, 1795)	Bloch's gizzard shad
	18	*Anodontostoma* chacunda (Ham.Buch., 1822)	Chacunda gizzard shad
	19	*Hilsa kelee* (Cuvier, 1829)	Kelee shad
	20	*Tenualosa ilisha* (Ham. Buch. , 1822)	Hilsa shad
	21	*Tenualosa toli* (Valenciennes, 1847)	Toli shad
Pristigasteridae	1	*Pellona ditchela* Valenciennes, 1847	Indian pellona
	2	*Ilisha megaloptera* (Swainson, 1839)	Bigeye ilisha
	3	*Opisthopterus tardoore* (Cuvier, 1829)	Tardoore
Chirocentridae	1	*Chirocentrus dorab* (Forsskal, 1775)	Dorab wolf herring
	2	*Chirocentrus nudus* (Swainson,1839)	Whitefin wolf herring
Engraulididae	1	*Thryssa balaema* (Forsskal,1775)	Baelema anchovy
	2	*Thryssa dussumieri* (Valenciennes, 1848)	Dussumier"s thryssa
	3	*Thryssa mystax* (Schneider,1801)	Moustached thryssa
	4	*Thryssa setirostri* (Broussonet,1782)	Longjaw thryssa
	5	*Thryssa vitriostris* (Gilchrist & Thompson,1906)	Orangemouth anchovy
	6	*Thryssa malabarica* (Bloch,1795)	Malabar thryssa
	7	*Coilia dussumieri* Valenciennes, 1848	Gold spotted granadier anchovy
	8	*Encrasicholina devisi* (Whitley,1940)	Devi's anchovy
	9	*Encrasicholina heteroloba* (Ruppel,1837)	Shorthead anchovy
	10	*Stolephorus commersonii* Lacepede,1803	Commerson's anchovy
	11	*Stolephorus waitei* Jordan & Seale,1926)	Spottyface anchovy
	12	*Stolephorus indicus* (van Hassell,1823)	Indian anchovy

Reference

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- Whitehead,P.J.P., G.J. Nelson and T.Wongratana (1985). FAO species catalogue Vol.7. Clupeoid fishes of the world Sub-Order Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines,pilchards, sprats, anchovies and wolf herrings. Part 2-Engraulididae. FAO Fish. Synop. (125) Vol.7, pt.2:305-579.

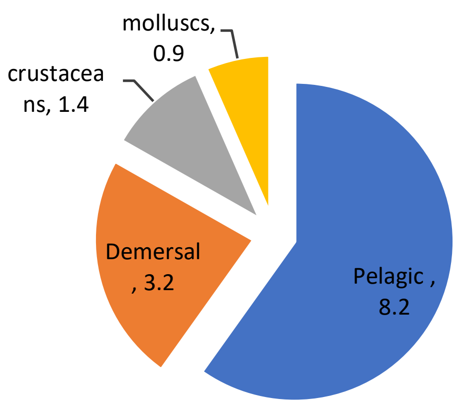
Line drawings-Courtesy to FAO Fish Synop. (125).

CHAPTER 14

Anchovies

INTRODUCTION

- Fisheries is an important sector in India. It provides employment to millions of people among the Asian countries, India ranks the third position in fisheries. World fish production reached 179 million tonnes in 2018(FAO).
- India has 8,118 km long coastline along 9 coastal states and 4 union territories producing 38,20,207 tonnes of fish catch from marine fisheries sector. The major catches come from the coast of Gujarat. Tamil Nadu. Kerala, West Bengal and Maharashtra.
- As per the data of CMFRI Annual report compared to 2018, marine fish landings during 2019 increased by 2.1% from 3.49 million tonnes to 3.56 million tonnes. In terms 12% is molluscs.



- *Clupeiformes* is the order of ray-finned fishes, with 5 families that includes the herrings family Clupeidae and anchovy family Engraulidae.
- Anchovies are small, thin silvery fishes that resemble miniature herrings. They feed planktonic organisms, travel in large shoals, near the shores and rarely found in depth greater than 60 meters.
- This group includes most of the world's numerous and commercially important fishes.
- This groups have silvery body with streamlined and spindle-shaped and they generally lack lateral lines.

- They filter food from water with their gill rakers.

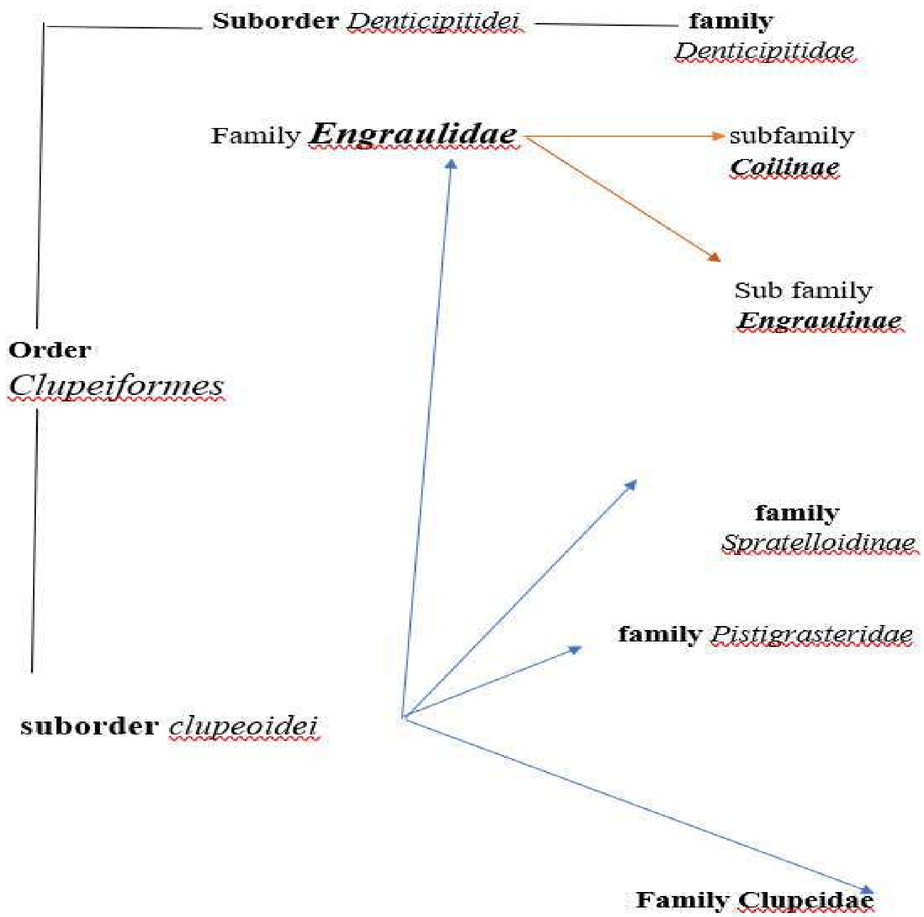
SCIENTIFIC CLASSIFICATION

Kingdom	: Animalia
Phylum	: Chordata
Class	: Clupeiformes
Sub order	: Clupeodei
Family	: Engraulidae

FAMILY-ENGRAULIDAE

- This family comprises of anchovies.
- Small silvery fishes, mostly 10 to 15 cm, usually with fusiform. Sub- cylindrical bodies but sometimes quite strongly compressed, body tapers to very slender tail in the rat-tailed anchovies (*Coilia*)
- Scutes are present along the belly, either needle-like or strongly keeled.
- Snout usually pig-like, strongly projecting, lower jaw characteristically unders lung.
- No spiny rays in fins.
- A single dorsal fin, usually short and midpoint of the body
- Pectoral fins set low on body, sometimes with (*setipinna*) or 4 to 19 (*coilia*) filamentous rays.
- Pelvic fins usually about midway between pectoral fin base and anal fin origin.
- Anal fin short, moderate or very long, caudal fin forked except in *coilia*.
- Scales always cycloid but often shed rather easily.
- No lateral line
- Color: Usually blue or green or brown or black, flanks wholly silver or with bright silver lateral stripe, darker marking include dark venulose area on shoulder (*Thryssa*) and dark pigmentation on all part of dorsal, pectoral, pelvic, anal and caudal fin.
- Anchovies are small fish having greenish-blue reflections due to a silver-colored longitudinal stripe that runs from the head to base of caudal tail.
- They are found in scattered areas throughout the world's oceans, but are concentrated in temperate waters and rare or absent in very cold warm seas.
- There are more than 28 species of anchovies reported in India.
- There are two fishing seasons, January to May and September to November, the latter period being the peak season for anchovy catches. Major contribution to the fishery is by the genera are *Stolephorus*, *Engraulis*, *Thryssa*, *Setipinna* and *Coilia*.

Phylogeny of *Clupeiformes* by Lavoue' et al., 2014



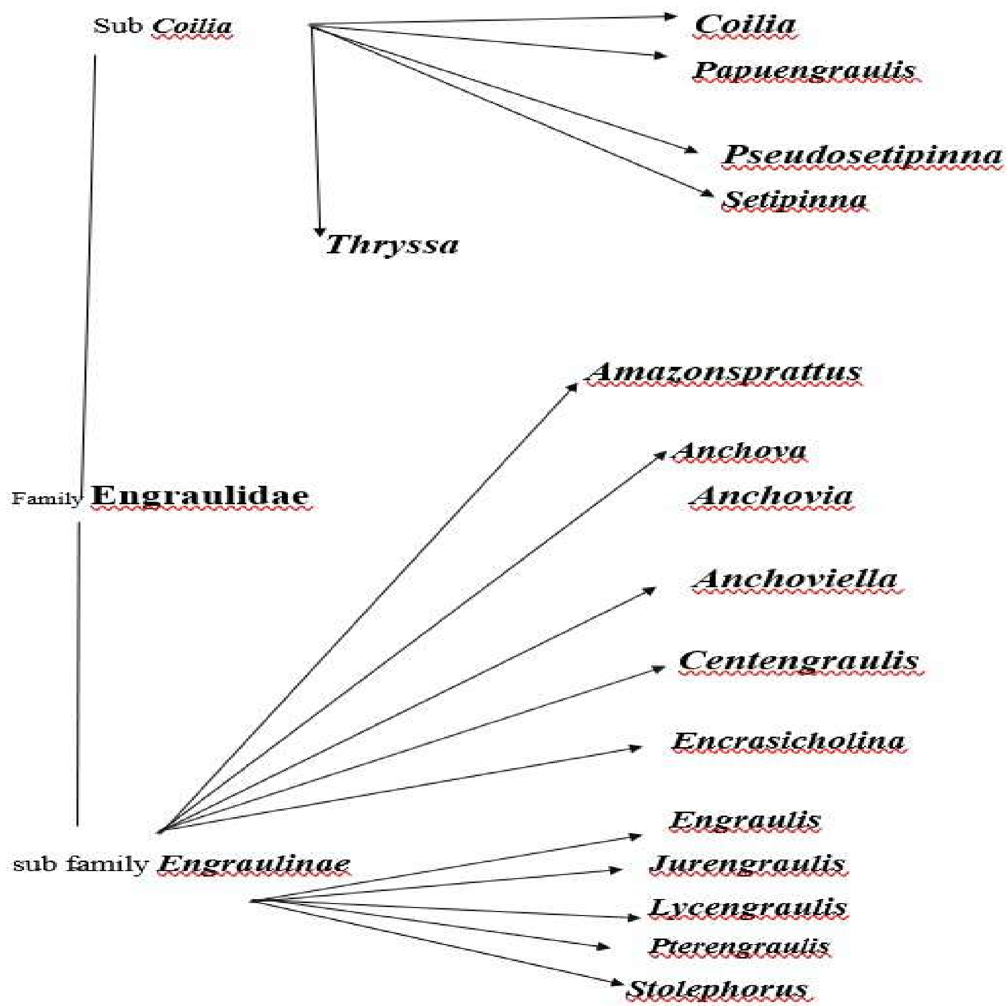
CRAFT AND GEARS

- Kerala and Karnataka coast: Ring seines (mesh size of 8mm).
- Maharashtra, Goa, Karnataka, Kerala coast: Purse seines (mesh size of 4-18mm).
- Andra Pradesh, Tamil Nadu and Kerala coast: Boat seines (10-20mm)
- Orissa and West Bengal: Bag net
- Kerala: Gill net.
- Maharashtra and Gujarat: Dol net (mesh size 5-25mm).

ECONOMIC IMPORTANCE OF ANCHOVIES

- Healthy heart
- Tissue and cell repair
- Eye health
- Skin health
- Weight loss
- Anchovies are rich in proteins, vitamins and minerals that help in maintaining good health.
- It contains Calcium, Magnesium, Iron, Potassium, Sodium, Zinc and phosphorus.

- Anchovies are a good source of vitamins such as Thiamin, Riboflavin, Niacin, Folate, Vitamin C, B-12, B-6, A, E, K.
- It contains fatty acid and cholesterol.



Subfamily: *Coilia*

- Body greatly elongates. Tail long and tapering. Caudal little or not forked. Lower portion continuous with long tail. Upper pectoral rays prolonged as slender filaments.
- There are 11 species were reported in the world, from those 5 species only found in India.

Coilia dussumieri (Valenciennes, 1848)

Common name: Gold spotted grenadier anchovy

- **Geographical distribution**: Thailand, Myanmar, Indian ocean.
- **Features**: Body elongated, compressed, snout prominent, conical, shorter than eye. Dorsal about twice nearer to snout than caudal. Six upper pectoral rays filiform and produced to about the middle of the length of the fish golden, with 2 or 3 rows of round golden spots along the lower half of the body.

C.grayii

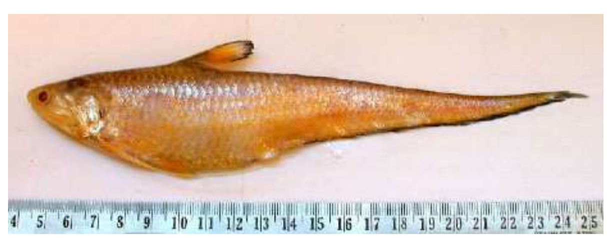
Common name: gray's grenadier anchovy

- **Distribution**: Indo-pacific, East and south China seas also Indian ocean (Kerala).
- **Features**: Body tapering belly rounded before pelvic fins with 12 to 15 plus 22 to 29 =36 to 44 keeled scutes from isthmus to anus. Maxilla long reaching to or beyond base of the first pectoral fin ray.

***C.neglecta* (Whitehead, 1968)**

- **Common name**: Neglected grenadier anchovy.
- **Features**: Maxilla almost or just reaching to edge of gill cover. Lower gill rakers 23 to 27.

C.regnaldi



- **Common name**: Reynald's grenadier anchovy
- **Features**: Maxilla short, not reaching to the edge of gill cover. Lower gill rakers 28 to 36. Pectoral fin with 10 to 13 long filaments and 6 or 7 branched fin rays, much shorter than those of pelvic fin later with 6 fin rays.

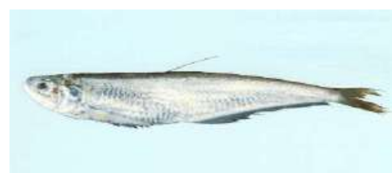
C.ramcarati

- **Diagnostic features**: Body tapering, belly rounded before pelvic fins with 6 plus 10 or 11=15 or 16 keeled scutes from just behind the pectoral fin base. Maxilla short, not reaching to edge of gill cover. Lower gill rakers 29 or 30. Pectoral fin with long filaments and or branched rays.

Genus Lycothrissa -Lycothrissa crocodilus

- **Common name**: Sabretoothed *Thryssa*
- **Distribution**: Asia, Thailand, Cambodia
- **Diagnostic features**: Rather elongated, not strongly compressed. Belly without scutes before the pectoral fin base, 7 or 8 (rarely 9) plus 9 or 10 (rarely 8 or 11) =16to 19 keeled scutes from pectoral fin base to anus. Maxilla short, tip reached to the edge of peroperculum.Enlarged canine like teeth. Lower gill rakers 8 to 19. It resembles to *T.baelama* and *T.encrasicholoides*.

Genus *Papuengraulis -P.micropinna*



- **Distribution**: Gulf of Papua and Arafura Sea
- **Characters**: belly with or needle like structure of scutes in front of pectoral fin base. Lower gill rakers 25 to 27. Pre pelvic scutes are reduced to 5 or 6 needle like scutes. Post pelvic scutes reduced to thin plates hidden by scales.

Genus ***Pseudosetipinna***

- Only one species is reported in this genus.
- *P.haizhouensis* and it is not reported in India.

Genus *Setipinna*

- Medium sized compressed anchovies
- Belly sharply keeled, 8 species found in world wide.
- Maxilla short, pectoral fin with first ray produced as a filament.

S.breviceps

- Pectoral fin with first ray produced as a filament that usually exceeds or well exceeds head length.
- Belly with 17 to 23 plus 9 to 11= 27 to 32 keeled scutes from isthmus to anus.
- Jaws slender.
- Lower gill raker 11 to 12, serrae enlarged.
- Pectoral filament long and reaching to base of 35^{th} to 41^{st} anal fin rays.

- Anal fin with 56 to 61 in number.

S.brevifilis

- Belly with 15 to 17 plus or 6 or 7 = 22 or 23 keeled scutes.
- Lower gill rakers 17
- Pectoral filament short
- Anal fin 65 to 72
- Very closed with *S.phasa*

S.phasa

- Belly with 15 plus or 7 = 21 or 22 keeled scutes from isthmus to anus.
- Pectoral filament long reaching to base of 15th to 39th anal fin ray
- 66 to 78 anal fin rays present in this species.

S.tali

- Body strongly compressed, belly with 20 to 29 plus 4 to 14 =32 to 40.
- Lower gill rakes 17 to 29.
- Anal fins 45 to 55.

Genus Thryssa

- Oblong or elongate, compressed
- Scales more or less deciduous
- Abdominal scutes well developed
- Origin of dorsal before that of anal which is long.
- Maxilla may be short, moderate, long or very long
- There are 24 species reported in worldwide, from those 15 species found in India

Subfamily *Engraulinae*

Genus *Amazonsprattus* (Robert 1984)

- **Habitat**: Fresh water
- Only One species was reported in the world.
- Maxilla short, reaching just to front of eye
- Gill rakers few in number 18 or 19

A.scintilla (Roberts, 1984)

- **Distribution**: Amazon
- Dwarf species with small mouth, toothless containing two supramaxilla.
- Dorsal fin origin well behind midpoint of body with 12 to 14 fin rays.

Genus *Anchoa*

- **Habitat**: Marine, Estuarine
- Small, snout fairly pointed, maxilla long reaching the margin of preoperculum, tip pointed.
- Gill rakers slender.
- Maxilla tip pointed, dorsal fin origin at about midpoint of the body.
- There are 35 species were reported in the world

Genus: ***Anchoviella***

- **Habitat**: Marine, Estuarine
- **Distribution**: Atlantic and Pacific coast
- Teeth on lower jaw small and evenly spaced or absent
- Lower gill rakers on first arch less than 45.
- Maxilla short, tip blunt, not reaching or just reaching anterior margin of preoperculum.

A.blackburni

- Anal fin origin slightly in advance of body midpoint.

A.brevirostris

- Anal fin origin posterior to body midpoint
- Snout very short, projecting only slightly beyond lower jaw, lower jaw symphysis almost at tip of snout.

A.gulanensis

- Snout longer, projecting beyond lower jaw, lower symphysis more posterior, not at tip of snout.
- Axillary scale of pectoral fin reaching only to about midpoint of fin.

A.cayennesis

- Axillary scale of pectoral fin reaching beyond midpoint but failing to reach tip of fin.
- Snout ½ eye diameter, lower gill rakers 29 to 35.

A.perfasciata

- Snout ¾ eye diameter
- Lower gill rakers 24 to 30.

A.elongata

- Axillary scale of pectoral fin about half as long as fin, body more moderately compressed, silver stripe, narrow, less than eye diameter through entire length.

A.lepidentostole

- Axillary scale of pectoral fin reaching beyond midpoint but failing to reaching tip of fin, body deeper, silver stripe wide, greater than eye diameter below about middle of dorsal fin.

Genus ***Engraulis***

- **Habitat**: Marine
- **Distribution**: Western Atlantic
- There are 9 species found in world wide.
- Anal fin origin equal with or posterior to vertical at dorsal fin origin, pectoral fin short, not reaching posteriorly beyond pelvic fin base.
- Teeth or lower jaw small and evenly spaced or absent.
- Lower gill rakers on first arch less than 45.
- Maxilla short, tip blunt, not reaching or just reaching anterior margin of preoperculum
- These are the species coming under this genus.

1. *E.albidus*
2. *E.anchoita*
3. *E.australis*
4. *E.capensis*
5. *E.encrasicolus*
6. *E.eurystole*
7. *E.mordax*
8. *E.japonicus*
9. *E.ringes*

Genus ***Cetengraulis***

- Two species were reported in this genus, *C.edentulus* and *C.mysticetus*
- Branchiostegal membrane broadly joined across isthmus.
- Lower gill rakers on first arch greater than or equal to 45.

Genus ***Encrasicholina*** (Fowler, 1938)

- **Distribution**: Indo-west pacific
- **Habitat**: marine
- They are 8 species found in the world, from those 4 species reported in India. These are *E.punctifer,E.devisi, E.intermedia, E.heteroloba*.
- Scales extremely deciduous, seldom with scales on body after catch, body semi-translucent with a silver mid lateral band.

- Body tinged grey after death with clear scale pattern on upper part of body, nodule- like expansion present on anterior part of isthmus, anal fin originating behind the dorsal fin base.

E.punctifer (fowler, 1938)

- Maxilla short not reaching to preopercle margin, its posterior end rounded

E.devisi (Whitely, 1940)

- Maxilla long extending to preopercle margin, its posterior end pointed.

Genus *Pterengraulis*

- Only one species reported in the world.

P.atherinoides

- Anal fin origin anterior to vertical at dorsal fin origin, pectoral fin reaching posteriorly beyond pelvic fin base.

Genus *Lycengraulis*

- Teeth on lower jaw enlarged and canine like
- Anal fin origin equal with or posterior to vertical at dorsal fin origin, pectoral fins short, not reaching posteriorly beyond pelvic fin base.

L.batesil

- Lower gill rakers 12 to 15.

L.grossidens

- Body depth 23 to 24.5% of SL, maxilla reaching margin of operculum, pelvic fin base, occasionally equidistant between these points, total gill rakers on first arch 30 to 36.

L.limnichthys

- Depth of body 21 to 23 % of SL (in specimen greater than 100m total length) maxilla not reaching margin of preoperculum, pelvic fin inserted nearer to pectoral fin base than to anal fin origin, total gill rakers on first arch 37 to 42.

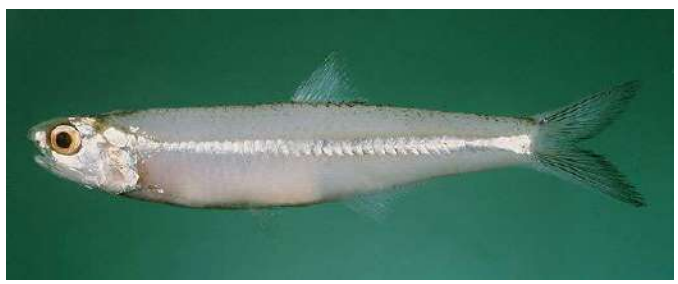
Genus *Stolephorus*

- **Distribution**: Indo-Pacific
- **Habitat**: Marine, pelagic and schooling.
- Body milky white after death without clear scale pattern on upper part of body, anal fin originating below the dorsal fin base
- Small and moderately compressed with 15cm SL.
- One to eight sharp needle-like pre pelvic scutes, no post pelvic scutes.
- Maxilla tip pointed and projecting beyond 2nd supramaxilla
- There are 18 species reported in the world from that 6 reported in India.

S.insularis

- Cross section of the body is round, caudal fin slightly dark.
- Body with 4 to 8 (usually 3 to 5, mostly 4) small needle-like prepelvic scutes, anal fin 14-17.
- Maxilla tip pointed, reaching to or only just beyond front border od preoperculum

S.commersonii



- Usually to and mostly or small needle like pre pelvic scutes.
- Maxilla tip pointed reaching to or a little beyond hind border of preoperculum
- 18 to 19 anal fin rays.

S.dubiosus

- Belly with 4 to 7 small needle like pre pelvic scutes.
- Maxilla tip pointed, reaching beyond the border of preoperculum.
- Gill rakers 25 to 31, anal fin rays 18 to 19.

S.andhraensis

- Caudal fin margins black, dorsal edge of body with indistinct black, scale pattern not arranged in a line.

Photos for the compilation have been adapted from Fishbase online

CHAPTER 15

Field Identification of Needlefishes From Indian Waters

Family Belonidae Bonaparte 1832

Needlefishes

The family Belonidae is comprised of 34 valid species under 10 genera, all over the world (Collette, 2003). Eight of the ten genera are monotypic or contain only two or three species. Highest numbers of species of the family are found in two genera, *Tylosurus* and *Strongylura* with 6 and 14 species, respectively while five species are polytypic containing a total of 17 subspecies. In India 8 valid species of needle fish under 4 genera were reported namely *Ablennes hians* (Valenciennes, 1846), *Platybelone argalus platyura* (Bennett, 1832), *Tylosurus crocodilus* (Péron & Lesueur, 1821), *T. acus melanotus* (Bleeker, 1850), *Strongylura strongylura* (van Hasselt, 1823), *S. leiura* (Bleeker, 1850), *S. incisa* (Valenciennes, 1846) and *Xenentodon cancila* (Hamilton, 1822).

Diagnostic characters (see Fig.1)**:** The needlefishes are relatively small family of beloniform fishes characterised by the following characters (Collette, 2003): Small to medium-sized (up to 2 m) fishes with elongate bodies. Head with both upper and the lower jaws extended into a long beaks filled with sharp teeth, third pair of upper pharyngeal bones are separated, finlets are absent behind dorsal and anal fins, nostrils lie in a pit anterior to the eyes, fins without spine, dorsal fin with 11–43 rays, anal fin with 12–39 rays, both dorsal and anal fins posterior in position, pelvic fins with 6 soft rays and abdominal in position, pectoral fins are short with 5–15 rays, lateral line runs down from the pectoral fin origin and then along the ventral margin of the body, scales are small (cycloid) and easily detached, precaudal vertebrae number 33–65, caudal vertebrae 19–41, and total vertebrae 52–97.

Colour: Body green or blue color on the back and silvery white on belly and lower sides, a dusky or dark blue stripe may be present along the sides of the body, green color of bones. The fleshy tip of the lower jaw is usually red or orange color in fresh.

Habitat, biology, and fisheries: Majority of the needlefish species found in marine waters but 12 species are found purely in fresh water. Many species of *Strongylura* are reported to move long distance into freshwater regions. Being a pelagic group, needlefishes are found at the

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surface of the water. Needlefishes are carnivorous in nature, mostly preying upon small pelagic fishes captured by their beaks in a sideways fashion. These fishes are one of the commercially important pelagic fishery resources, exploited globally due to its excellent flavour, mostly captured by casting or trolling surface or near-surface lures and in floating gill nets, marketed in fresh, frozen, and smoked condition (Collette, 2003). In India, these species are exploited all along the coastline including Lakshadweep and, Andaman and Nicobar Islands, mainly by hook and line, gill net, and trawl, and considered as one of the commercially important pelagic fishery resources throughout its ranges.

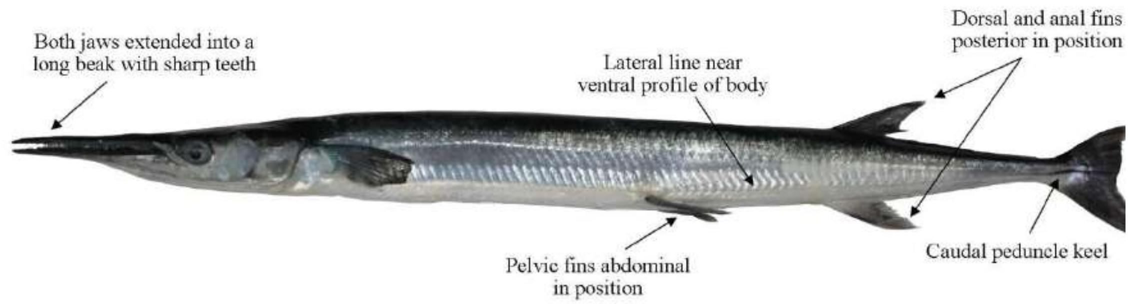

Fig. 1 General features of a typical needlefish species

Key to the species of needlefish occurring in the area
Adapted from Collette (1984, 1999), Roul *et al.* (2019a, 2019b) and the observation made during the present studies.
1a. Body strongly compressed laterally and marked with a series of vertical bars; anal-fin rays 24 to 28…………………………………………………… ***Ablennes hians* (Valenciennes, 1846).**

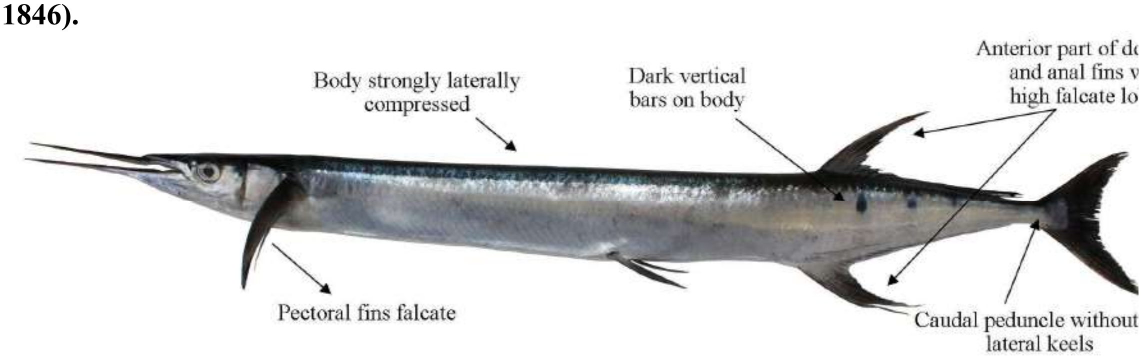

Fig. 2 Flat needlefish *Ablennes hians* (Valenciennes, 1846)
1b. Body rounded or squarish in cross-section; no vertical bars present; anal-fin rays 13 to 23 (rarely
24)………………………………………………………………………………..………. **2**.
2a. Caudal fin forked, lower and upper lobes of equal length; caudal peduncle strongly depressed (flattened dorsoventrally) with well-developed lateral keels, least depth of caudal peduncle about 1/2 the width; gill rakers present……………..... ***Platybelone argalus platyura* (Bennett, 1832).**

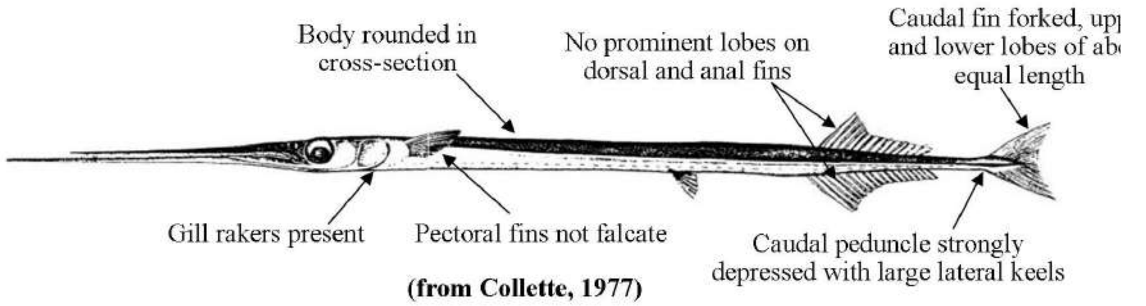

Fig. 3 Keeled needlefish *Platybelone argalus platyura* (Bennett 1832)

2b. Caudal fin forked or emarginated or rounded or truncated; caudal peduncle not strongly depressed, a small lateral keel on caudal peduncle or no keel at all, caudal peduncle deeper than wide; gill rakers absent ……………….. **3**.

3a. Caudal fin distinctly forked, with lower lobe longer than upper lobe; narrow raised dark lateral keel on each side of caudal peduncle; juveniles with an expanded black lobe in the posterior part of the dorsal fin; dorsal-fin rays 19 to 27…................... ***Tylosurus* Cocco 1833** **4**.

3b. Caudal fin emarginated, rounded or truncated; no keels on caudal peduncle; no posterior black dorsal-fin lobe at any size; dorsal-fin rays 12 to 21…………………………...………….. **5**.

4a. Dorsal-fin rays 24 to 27; anal-fin rays 22 to 24; conspicuous appendage present at tip of lower jaw in some specimens; air bladder with numerous air bubble; posterior part of anal fin rays usually blackish; lower part of upper lobe of caudal fin without elevation……………………………………...…***Tylosurus acus melanotus* (Bleeker, 1850).**

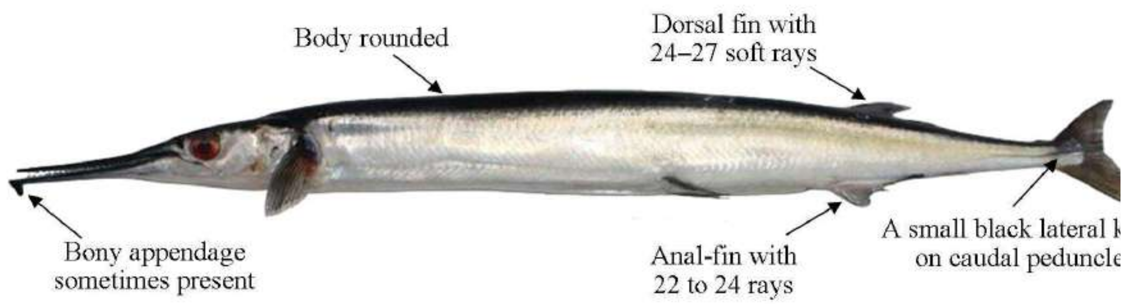

Fig. 4 Keel-jawed needle fish *Tylosurus acus melanotus* (Bleeker, 1850)

4b. Dorsal-fin rays 21 to 25 (usually 22 or 23); anal fin rays 19 to 22; conspicuous appendage absent at tip of lower jaw in all specimen; air bladder without air bubble; posterior part of anal fin rays usually transparent; lower part of upper lobe of caudal fin with an prominent elevation in adult but absent in juveniles……....................... ***Tylosurus crocodilus (*Péron & Lesueur, 1821).**

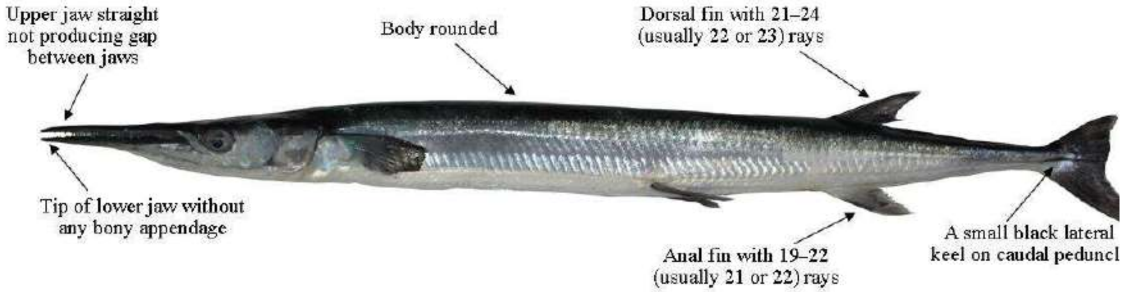

Fig. 5 Hound needlefish *Tylosurus crocodilus (*Péron & Lesueur, 1821)

5a. Dorsal and anal fin rays nearly opposite to each other; one pair of dentigerous upper pharyngeal……………………………………………...….. ***Xenentodon cancila*** **(Hamilton, 1822).**

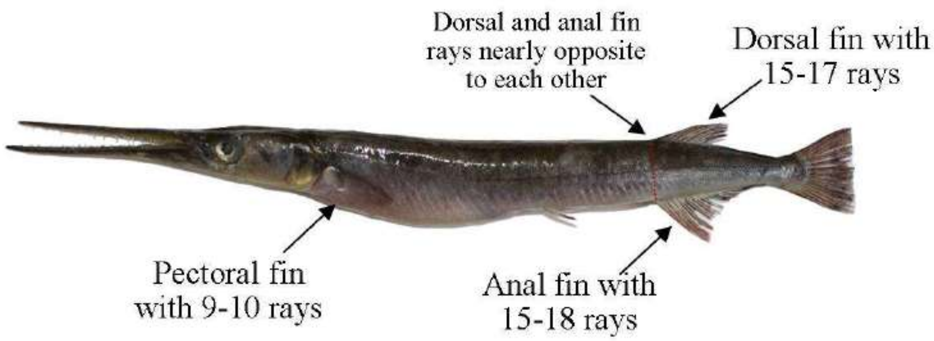

Fig. 6 Freshwater garfish *Xenentodon cancila* (Hamilton, 1822)

5b. Dorsal fin inserted behind anal fin origin; two or three pairs of dentigerous upper pharyngeal…………………………………………….... ***Strongylura van*** **Hasselt 1824** …..…**6**.

6a. Dorsal-fin rays 12 to 15; anal-fin rays 15 to 18; bases of dorsal and anal fins covered with scales, prominent black spot at base of caudal fin; caudal fin rounded or truncate; gonad bilobed .... ***Strongylura strongylura*** **(van Hasselt, 1823).**

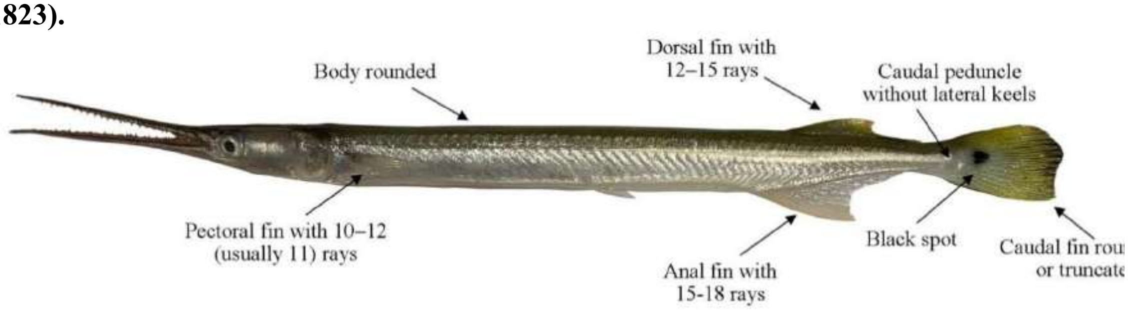

Fig. 7 Spottail needlefish *Strongylura strongylura* (van Hasselt, 1823)

6b. Dorsal-fin rays 17 to 21; anal-fin rays 21 to 27; bases of dorsal and anal fins without scales; caudal fin emarginated without black spot; gonad either single lobed or bilobed........................ **7**.

7a. Predorsal scales 100 to 125; dorsal-fin origin over anal-fin rays 4 to 6; prominent elongate spot on cheek between opercle and preopercle; pectoral fin with a yellowish tinge basally; dorsal and anal fin with yellowish rays with blackish tinge at the central region; caudal with yellowish tinge basally and greyish towards margin; gonad bilobed………………………………………….... ***Strongylura incisa* (Valenciennes, 1846).**

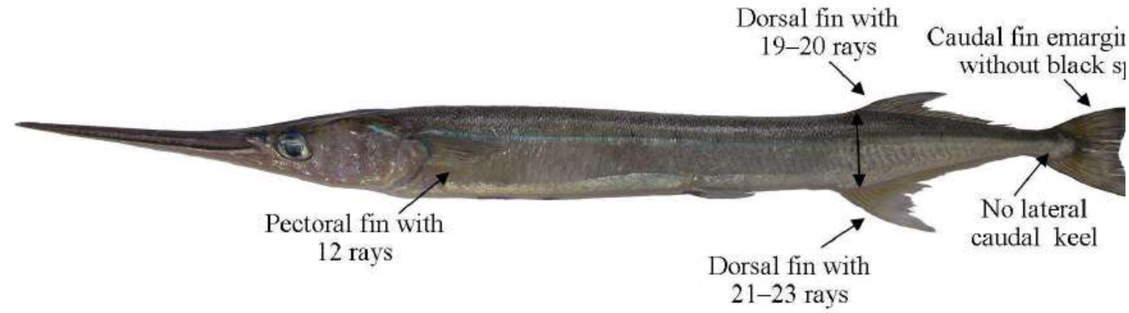

Fig. 8 Reef needlefish *Strongylura incisa* (Valenciennes, 1846)

7b. Predorsal scales 130 to 180; dorsal-fin origin over anal-fin rays 7 to 10; black bar on cheek between opercle and preopercle, and anterior pat of the body; pectoral fins with a distal dark spot, tip of fins yellow in fresh specimens; tip of dorsal and anal-fin lobes yellowish, caudal fin dark with a yellowish tinge on upper lobe; gonad single lobed………………………………...…………………… ***Strongylura leiura* (Bleeker, 1850).**

Fig. 9 Banded needlefish *Strongylura leiura* (Bleeker, 1850)

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CHAPTER 17
Taxonomy of Billfishes

Billfishes are one of the apex predators in the pelagic food chain, distributed worldwide in the epipelagic waters of tropical and subtropical oceans. These fishes can disperse widely throughout the world oceans and spawn over broad geographic regions during a protracted season (Nakamura 1985). Billfishes are commonly seen within 200 m of the ocean water layer above thermocline but the occurrence up to 800 m is also reported. They are characterized by a prolonged upper jaw forming a long rostrum called bill and using the long bill to attack and stun their prey by moving their heads in various directions to make the prey unconscious and form a hassle-free prey capture. Sexual dimorphism is reported in billfishes with large sized females.

General remarks on the taxonomy of billfishes

The term billfish is the common name given to large predatory marine fish comprising the families Istiophoridae and Xiphiidae of the Perciformes order (Collette et al., 2006). The order Perciformes is the most diverse order of ray-finned fishes such as Perches, basses, Tunas, Mackerels, Cichlids etc. The suborder Scombroidei typified the fishes that have an upper jaw that is not protrusible, with the premaxilla fixed as an adaptation to feeding upon larger fishes. The fastest swimming fish in the world include tuna, swordfish and sailfish are also members of the suborder Scombroidei (Nelson 2006). Nelson (2006) placed the two families of billfishes (Istiophoridae and Xiphiidae) under the suborder Scombroidei within the order Perciformes. Though billfishes are morphologically and genetically distinct from scombroids, Collete et al., (2006) placed the group in a separate suborder Xiphioidei. The suborder Xiphioidei are characterized by elongated premaxillary bill or rostrum in adults; dorsal-fin origin over the back of the head, first dorsal lacking true spiny rays, presence of two anal fins, low pectorals on the body, inferior mouth, pelvic fins with one spine and two rays or reduced, isthmus free gill membranes and 24-26 vertebrae. Nelson (2006) had recognized three genera under the family Istiophoridae; *Istiophorus* characterised by a sail-shaped dorsal fin which is taller than body depth and very long pelvic fins. *Tetrapturus* was noted by dorsal fin height higher than that of body depth and *Makaira* distinguished by the reduction in first dorsal fin height as not as high as the body depth. While Collette et al. (2006) and ITIS (2008) acclaimed Istophoridae be into five genera; *Istiophorus* (sailfish), *Istiompax* (Black marlin), *Makaira* (Blue marlin), *Tetrapturus* (spearfishes) and *Kajikia* (Striped marlin). The family Istiophoridae typified by a rounded bill or rostrum; embedded scales in the adult fishes; the presence of a determined lateral line throughout life; the presence of jaw teeth; elongate pelvic fins; very long dorsal fin base

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may be either sail-like or depressible into a groove; no. of vertebrae, 24 and presence of two keels on each side of the caudal peduncle.

The swordfish (*Xiphias gladius)* is the only member of Xiphiidae characterised by a depressed bill; absence of pelvic fins and girdle; lack of scales in the adult fishes; no. of vertebrae 26; toothless jaws in the adult fishes and a single medium keel on each side of the caudal peduncle.

Taxonomic Hierarchy

Kingdom :Animalia
Subkingdom :Bilateria
Infrakingdom :Deuterostomia
Phylum :Chordata
Subphylum :Vertebrata
Infraphylum :Gnathostomata
Superclass :Actinopterygii
Class :Teleostei
Superorder :Acanthopterygii
Order :Perciformes
Suborder :Xiphioidei
Family :Istiophoridae, Xiphidae
Genus :*Istiompax* Whitley, 1931 – black marlin
:*Istiophorus* Lacepède, 1801 – sailfish
:*Kajikia* Hirasaka and Nakamura, 1947
:*Makaira* Lacepède, 1802 – marlins, blue marlin
:*Tetrapturus* Rafinesque, 1810 – spearfishes
:*Xiphias*, 1758 - Linnaeus

The taxonomic studies recognized one extant species in the family Xiphidae and nine extant species in the five genera, in the family Istiophoridae with one species in *Istiophorus*, two species under *Kajikia*, four species in *Tetrapturus* and one species in *Makaira* and one under the genus *Istiompax*. Nelson et al., 2004 identified only one worldwide species in Istiophorus (*I.platypterus*), Collette et al. (2006) also support that there is no genetic evidence to support distinguishing two species of sailfish. Apart from this, (Collette et al., 2006) did the phylogenetic analysis of billfishes using nuclear and mitochondrial gene sequence showing that, *Makaira* is not monophyletic and that it might be better to either member of Istiophoridae into two genera with blue marlin grouped with the sailfish. ITIS (2008) likewise recognizes the five genera of family Istiophoridae, *Istiompax* (black marlin), *Istiophorus* (sailfish), *Kajikia, Makaira* (blue marlin, marlins), and *Tetrapturus* (spearfishes). ITIS (2008) also follows Collette et al. (2006) in placing Istiophoridae together with Xiphiidae in the suborder Xiphioidei.

The species distinguished under the suborder Xiphioidei are;

Family: Xiphiidae: *Xiphias gladius* Linnaeus, 1758 - Swordfish

Family: Istiophoridae

Istiophorus platypterus (Shaw in Shaw and Nodder, 1792)- Sailfish
Istiompax indica (Cuvier, 1832) -Black marlin
Makaira nigricans Lacépède, 1802 -Blue marlin

Kajikia albida (Poey, 1860) -White marlin
Kajikia audax (Philippi, 1887) -Striped marlin
Tetrapturus angustirostris Tanaka, 1915 -Shortbill spearfish

Tetrapturus belone Rafinesque, 1810 -Mediterranean spearfish
Tetrapturus georgii Lowe, 1841 -Roundscale spearfish
Tetrapturus pfluegeri Robins and de Sylva, 1963 -Longbill spearfish

There is no targeted fishery of billfishes along the Indian coast but it occurs as the bycatch of longlines, troll and oceanic drift gillnet fishery. In India, species of billfishes reported commonly are *Istiophorus platypterus* (Indo-Pacific Sail fish), *Tetrapturus audax* (Striped marlin), *Istiompax indica* (Black marlin), *Makaira nigricans* (Blue marlin) and *Xiphias gladius* (Sword fish). Rare landings of *T. angustirostis* was also reported.

General terms and measurements categorised for billfish taxonomy

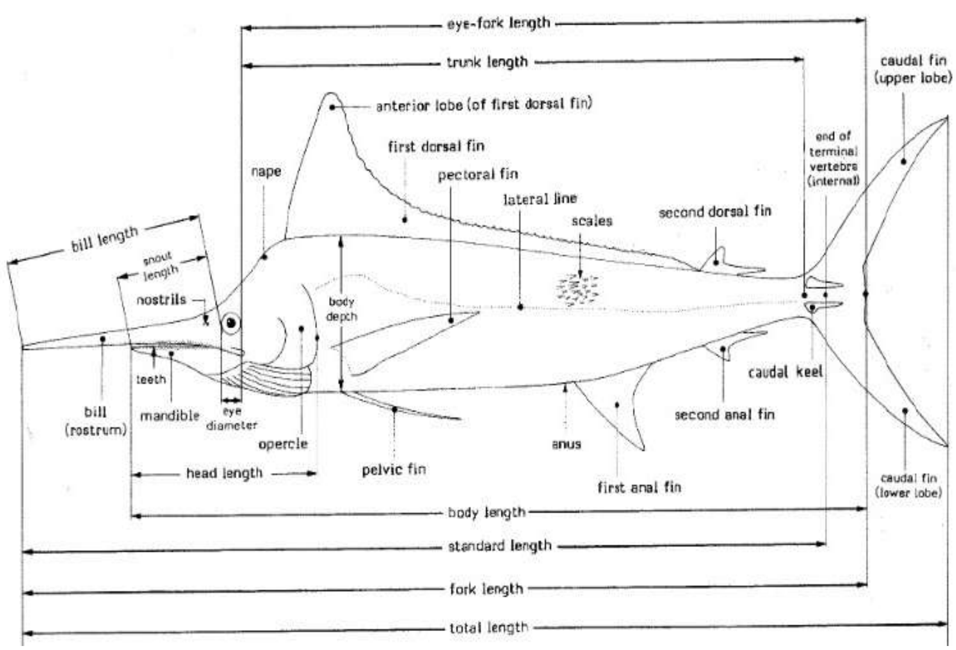

Fig 1. Schematic illustration of billfish with its measurable traits

Lower Jaw Fork Length (LJFL) or body length is the common measurement practised at the landing centre to collect the length-frequency data. Most of the billfishes landed with chopped upper jaw or bill. Figure 1, illustrated the morphometric measurements collected to generate the morphometric of the fish. The major measurements taken are Total length (TL), Fork Length(FL), Standard Length(SL), Body length or Lower Jaw Fork Length (BL, LJFL), Head Length(HL), Body Depth (BD), Snout Length(SL), Bill Length(BL), Eye Diameter(ED), Pre orbital length (PROL), Post orbital length (POL), Interorbital length(IOL), Lower jaw- Dorsal fin origin length (LJDF), Lower jaw- anal fin origin length(LJAF), Lower jaw- Pelvic fin length(LJPL), Lower Jaw- Pectoral fin length (LJPF), Lower Jaw – Caudal fin Length (LJCF), Length of pelvic fin (PVL), Length of Pectoral fin (PFL), First dorsal fin height(DH), Anal fin height(AH) and Caudal Fin length(CFL).

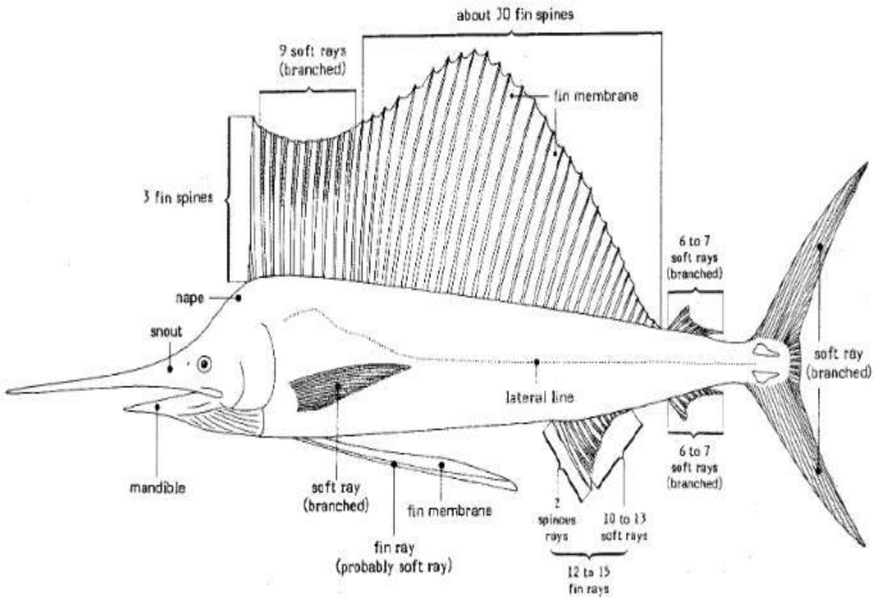

Fig. 2: Schematic illustration of Billfish with its countable traits

The major countable traits of billfishes are dorsal fin spines and rays, Pectoral fin rays, Pelvic fin rays, Anal fin spines and rays, Caudal fin rays and Branchiostegal rays. Gill rackers are absent in billfishes.

Specific body features of billfishes characterised for billfish identification

1. **Air bladder**: Single chambered air bladder in Swordfish while in Istiophorids the air bladder is made up of many bubble-shaped small chambers.
2. **Bill:** The bill is flat in Swordfish and round in Istiophorids
3. **Body length**: Usually following the dimension given by Rivas (1956). It is measured from the tip of the lower jaw to the posterior margin of the middle caudal rays (LJFL)
4. **Body width**: Body width at the origin of pectoral fins, pelvic fins and first anal fin may be used to find out the greatest body width. Body width will be compared with the length of the first dorsal fin to identify the different marlin species.
5. **Caudal keel**: The presence of a large median caudal keel in Xiphiidae and a pair of caudal keels in Istiophorids forms one of the major identifying characteristics of two families
6. **Caudal notch**: It is shallow and small in Istiophorids while it is rather large and deep in *Xiphias.*
7. **No. of caudal vertebrae**: The vertebrae which bear haemal spines ventral to the vertebral centrum and the caudal vertebrae lack pleural ribs. The number of haemal spines varies from species to species, it is 15 or 16 in *Xiphias*, 12 in *Istiophorus* and 13 in *Makaira* spp.

8. **Fin grooves**: In istiophorids, the first dorsal, first anal and pelvic fins fold down into grooves while it is not developed in *Xiphias gladius*
9. **Hypural plate**: The caudal fin rays are inserted distally on the expanded ends of the fan-like plate of hypural bones forms the hypural plate and it consists of four hypural bones in *Xiphias gladius* and five in Istiophorids
10. **Lateral apophyses**: the transverse flanges that extend laterally from the anterior part of each vertebral centrum. It varies from species to species. Figure 3 represent the variations in lateral apophyses of each billfish species
11. **Lateral line**: The lateral line appears looped or reticulate in marlins, single lateral line in other Istiophorids and *Xiphias* it appears as a single lateral line in juvenile stages and disappeared in the adult stages.

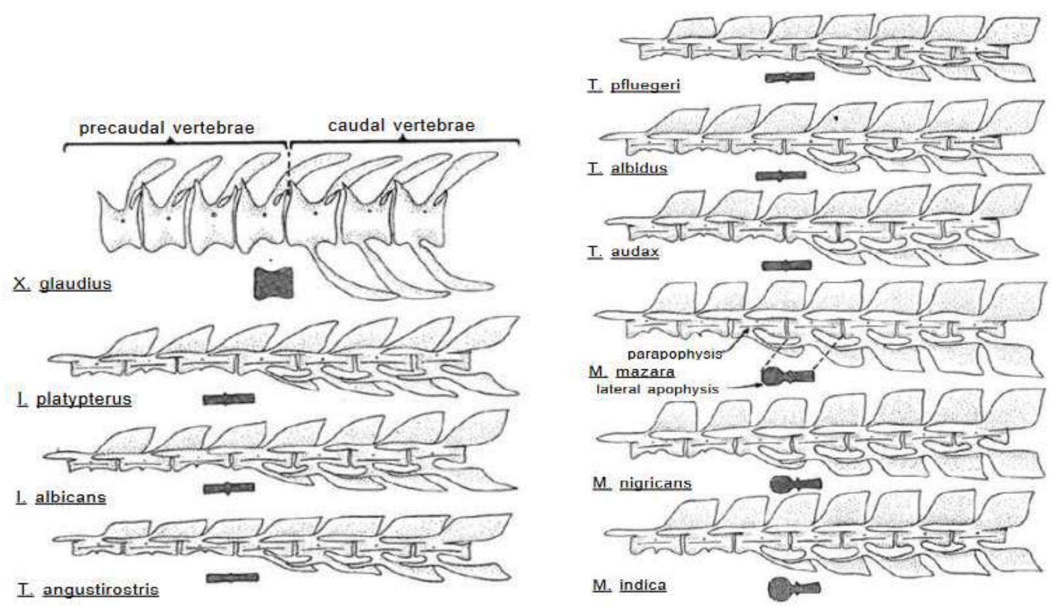

Fig.3 Lateral apophyses of different billfish species (Source FAO)

12. **Precaudal vertebrae**: the abdominal vertebrae which lack haemal bones called the precaudal vertebrae which are 10 or 11 in *Xiphias*, 12 in Istiophorids and *Tetrapturus* spp. and 11 in Marlins
13. **Scales**: The scales of billfishes are different from other Perciformes which are elongate, pungent with sharp posterior points. The arrangement and shape of the scales are useful characteristics for billfish identification. *Xiphias gladius* has no scales in the adult stage.
14. **Viscera**: Well developed internal organs in billfish. The intestine is coiled and, gonads are symmetrical in *Xiphias*, while in Istiophorids, the intestine is undulated and symmetrical gonads in *Istiophorus, Makaira* and apparently in *Tetrapturus* sp. In T. *angustirostris* and *T.pfluegeri* the gonads are asymmetrical and Y shaped.

Field identification characters of billfish species

Istiophorus platypterus (Indo-Pacific sailfish): Body laterally compressed, First dorsal fin tall, sail-like with 42-48 rays, marked with dark spots and remarkably higher than greatest body depth. Bill is long, slender and round in cross-section. Pelvic fins are very long, narrow and reach up to the anus. No gill rakers, small file like teeth on jaws and palatines and presence of two caudal keels. Second dorsal fin with 6-7 rays and origin before the second anal fin.

Fig.4: ***Istiophorus platypterus***

Istiompax indica (Black marlin): Body not strongly compressed, elevated nape, bill long, round in cross-section. Pectoral fins are rigid, sickle-shaped and not folding flat on the body. Pelvic fins are shorter than pectoral and depressible into ventral grooves. Two dorsal fins, first with 34-44 rays and height is half or less of the body depth. Second dorsal fin with 5-7 rays with its origin slightly in front of second anal fin. Presence of two strong caudal keels on each side and body densely covered with thick scales. No blotches or dark stripes on the body. The meat colour is white.

Fig.5: *Istiompax indica*

Makaira nigricans (Blue marlin) **(Fig. 6):** Body not very compressed, but with the elevated nape. Two dorsal fins, first dorsal fin height is equal to half or 3/4th of the body depth and with 39-43 rays. Pectoral fins are long, narrow and nearly straight folding flat on the body. Pelvic fins are shorter than pectoral fins. The lateral line forms a complicated pattern that looks like chicken wire and it is obvious in sub-adults and become obscure in adults. Second dorsal fin origin slightly behind second anal fin. Pelvic fins are shorter than

pectoral fins and presence of two strong caudal keels on each side. The presence of round spots or bars on the body is one another diagnosing characteristics of blue marlin. The meat colour is white.

Kajikia audax (Striped marlin): Body laterally compressed, thinner than black and blue marlin. Two dorsal fins, first dorsal height is greater than or equal to body depth and with 37-42 rays. Bill is long, sharp and round in cross-section. Long pelvic fins as long as pectoral fins. Second dorsal fin origin slightly backward of second anal fin. Two strong caudal keels on each side. Body with rows of round dots stripes and densely covered with elongate scales.

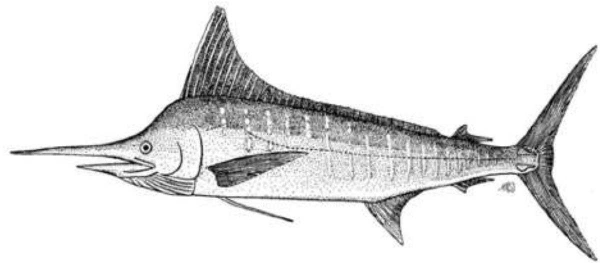

Fig.7: *Kajikia audax* (Source FAO)

Tetrapturus angustirostris (Shortbill spearfish): Body laterally compressed, long and slender with an elongated dorsal fin. Bill is very short and round in cross-section. Head profile between the pre-orbital and origin of first dorsal fin flat. First dorsal fin with 45-50 rays with pointed anterior lobe and its height greater than that of body depth. The anal opening is far anterior to the first anal-fin origin. The second dorsal fin position is far beyond the second anal-fin origin. Pectorals are short and narrow. Pelvic fins are slender and twice the length of pectoral fins. Caudal peduncle with two strong keels on each side. Single visible lateral line and dense bony scales on the body.

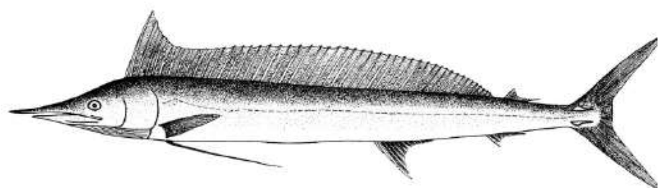

Fig.8: *Tetrapturus angustirostris* (Source FAO)

Xiphias gladius (Swordfish): Single species belongs to the family Xiphidae, easily distinguished from the istiophorids by its extremely flattened long bill, elongate cylindrical body, very large eyes, low pectoral-fin insertion and absence of pelvic fins. Scales, jaw teeth absent in adults. Narrow based falcate first dorsal fin in adults well separated from the second dorsal fin. Presence of single large median caudal keel on both sides.

Fig.9: *Xiphias gladius*

***Kajikia albida* (Poey, 1860):** Anterior lobe of the first dorsal fin is higher than that of the remainder of the fin, the distance between the anal opening and first anal fin is smaller than that of the first anal fin height.

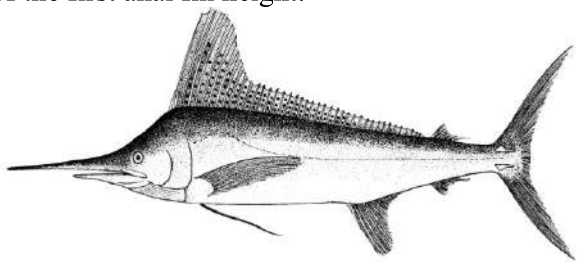

Fig.10: *Kajikia albida* (Source FAO)

***Tetrapturus belone* Rafinesque, 1810:** Bills are very short, forms only 18% of body length, pectoral fins narrow and short, which is 15% of body length. The distance between anal-fin origin and anus is equal to anal-fin height.

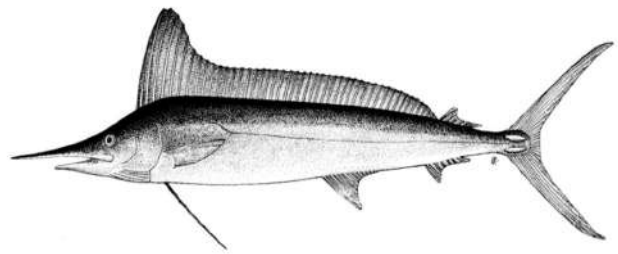

Fig 11: *Tetrapturus belone* (Source FAO)

***Tetrapturus georgi* Lowe, 1841:** Tip of first dorsal and anal fin rounded and first dorsal fin unspotted. The distance between the anal opening and anal fin origin is nearly equal to half of the anal fin height. The scales on the mid-body is soft and round

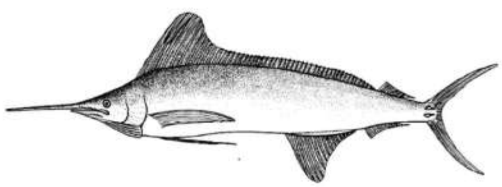

Fig.12: *Tetrapturus georgi* (Source FAO)

Tetrapturus pfluegeri Robins & de Sylva, 1963: Bill is long and it is equal to or more than head length. Pectoral fins are wide, long and rounded, which is 18% longer than body length. The anal opening is far anterior to the first anal-fin origin and the distance is equal to anal-fin height.

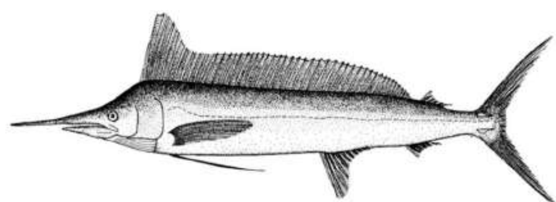

Fig.13: *Tetrapturus pfluegeri* (Source FAO)

Conclusion

A comprehensive insight on the taxonomy of billfishes revealed that billfishes under the suborder Xiphioidei comprise two families Xiphidae and Istiophoridae with ten extant species. One extant species in Xiphiidae and nine in Istiophoridae apportioned under five genera. Billfishes are distinct genetically and morphologically to be placed in a separate suborder,

Xiphioidei. The two families identified under the suborder Xiphioidei are easily distinguished with their family characteristics.
The family Xiphiidae differs from the Istiophorids by the presence of a single median keel, sword-like bill, lack of pelvic fins, well separated dorsal fin and single large swimbladder. The recent phylogenetic study of billfishes identified two major clades: first clade as blue marlin+ Sailfish and second clade - all the rest (as *Tetrapturus*). Within the first clade; Blue marlin (*Makaira*) separated from Sailfish (*Istiophorus*) and in the second clade; Black marlin (*Istiompax*), Striped and white marlin (*Kajikia*) and four spearfishes (*Tetrapturus*) were identified. So altogether five genera were recognised under the family Istiophoridae. There is always controversy over the Atlantic and Indo-pacific populations of Sailfishes and marlins, whether same species or not. Even though some morphometric variations were reported between the sailfish population at Atlantic and Indo-Pacific oceans, there is no genetic evidence in the sailfish mtDNA control region to indicate that, both are separate species. Earlier studies had separated Atlantic blue marlin (*Makaira nigricans*) from Indo-Pacific blue marlin (*Makaira mazara*) based on the reticulate lateral line pattern in Atlantic blue marlin and a simple loop pattern in the latter one. However, the mtDNA genotypes study can't provide enough evidence to separate them as different species. There are several Regional Fisheries Management Organisations (RFMOs) establishes to conserve and manage tuna and billfish stocks all over the oceans due to its worldwide distributions and prevalent economic values.

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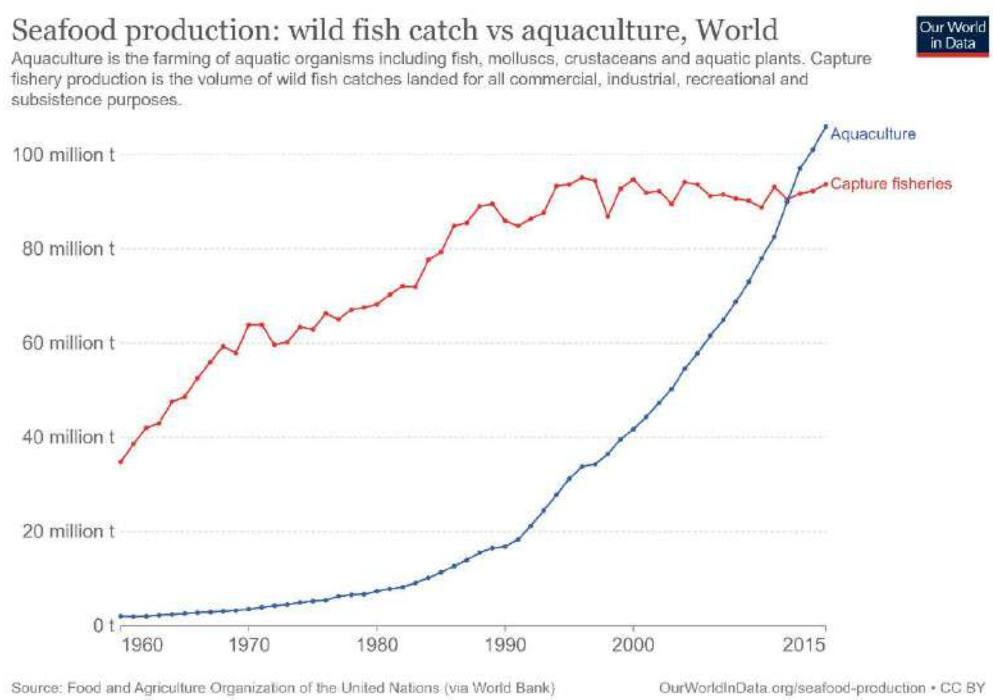
CHAPTER 18

Demersal Fishes

Production of seafood has quadrupled over the last 50 years. With the seafood consumption nearly doubling in the last 50 years there has been increased pressure on fish stocks across the world. Globally, the share of fish stocks which are overexploited are also increasing and sustainability of resources is being attempted at a faster rate since current levels of wild fish catch are unsustainable. Globally, the percentage of fish stocks that are within biologically sustainable levels have decreased from 90 percent in 1974 to 65.8 percent in 2017 (SOFIA, 2020). The volume of global fish production amounted to 177.8 million metric tons in 2019, which rose up by 29.7 t from 148.1 million metric tons in 2010. In the Western Indian Ocean, total landings continued to increase and reached 5.3 million tonnes in 2017. The 2017 assessment estimated that 66.7 percent of the assessed stocks in the Western Indian Ocean were fished within biologically sustainable levels, while 33.3 percent were at biologically unsustainable levels. The Eastern Indian Ocean continues to show a steady increase in catches, reaching an all-time high of 7 million tonnes in 2017. Since 1961, average per capita fish consumption has been increasing in Asia at an annual rate of 2 percent.



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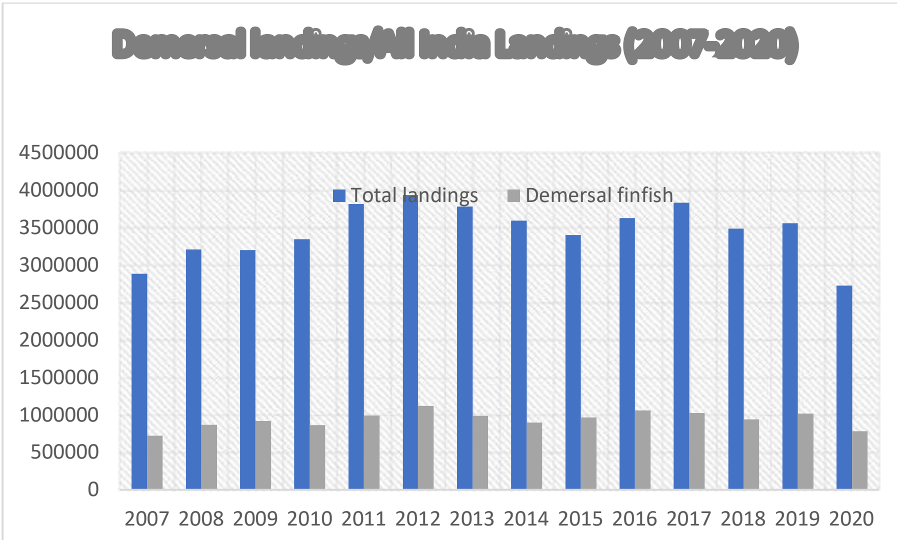
In the Indian scenario, the contribution of demersal raliies around 26 -29 percent of the total fish catch of the country with the last two years the catch contributing to 29 percent of the All India landing.



(Source: CMFRI, 2021)

What is Demersal?

Taking the definition from the UN Atlas of Oceans "demersal, or seafloor perspective, the deep-sea region consists of the continental slopes (starting at the shelf break and corresponding to the mesopelagic and bathypelagic zones) the continental rise which extends down to the abyssal plane at around 6000m, and the trenches. The deep-sea is the largest habitat on earth. The area over 4 000m in depth covers 53% of the sea's surface, which in turn covers 71% of the world's surface! The continental slopes alone occupy 8.8% of the world's surface, compared to 7.5% for the continental shelf and shallow seas. It is a predominately dark and cold environment with much lower productivity than shallower ones."

The seamounts stand out of the abyssal plain.

The continental shelf of Indian EEZ extending upto 200 m depth and is a rich abode of a variety of demersal finfish resources contributing substantially to the total marine fish production in the country. The major demersal fin fish resources are the sharks, rays, guitar fishes, groupers, snappers, sciaenids. catfishes, threadfin breams, silverbellies, lizardfishes, pomfrets ,bulls eye, flatfishes, goatfish and white fish. On the flip side we have several issues adversely affecting the increase in production of the resources such as growth overfishing, recruitment overfishing, increased operation of units through multiday fishing, scraping the benthic biota etc

Major Groups of Demersals

Order: Anguilliformes (Apodes)

The Order Anguilliformes, or true eels, contains 20 families and about 820 species. Species are usually elongate and slender, with single dorsal and anal fins that are continuous with the caudal fin (if present) in most species. All species lack fins and skeleton while some groups lack pectoral fins. Scales are usually absent, or if present, are cycloid and embedded in skin. All have leptocephalus larvae.Most true eels are predators and belong toone of three families Congridae (Conger eels), Muraenidae (Moray Eels) and Ophichthidae (snake eels and worm eels). Some species are excellent food fish and form the basis of very important commercial fisheries.

Order Aulopiformes

Suborder Chlorophthalmoidei -includes 5 families

Family Chlorophthalmidae-Greeneyes

Large eye with teardrop-shaped pupil and distinctive lensless space anteriorly. A hermaphroditic species. Species recorded from India

- *Chlorophthalmus agassizi*-Shortnose greeneye
- *Chlorophthalmus bicornis*-Spiny jaw greeneye

Family Ipnopidae-Deepsea tripod fishes

The family Ipnopidae includes five genera

Bathymicrops, Bathypterois, Bathytyphlops, Discoverichthys and Ipnops and 29 species of slender deep-sea fishes (Nelson, 2006) distributed worldwide demersally in tropical and temperate seas, at depths between 476 and 6000 m (McEachran & Fechhelm 1998). Eyes minute or plate like, directed dorsally.

Family Synodontidae-Lizardfishes

These are generally small with a slender cylindrical body and head that superficially resemble those of lizards. They have a dioecious mode of reproduction. Worldwide, four genera with about 57 species have been recorded.

In India 22 species have been reported in three genera-*Harpadon, Saurida, Trachinocephalus and Synodus*

Family Evermannellidae (Sabertooth Fishes)

Three genera, *Coccorella, Evermannella and Odontostomps* with seven species Family Alepisauridae (Lancetfishes)

Slender elongated body with a large mouth and strong teeth. Two genera, *Alepisaurus* and *Omosudis* reported worldwide (Nelson 2006). However as per Eschmeyer (2015), only one genus *Alepisaurus* has been recorded,

Order Batrachoidiformes

Family Batrachoididae (Toadfishes)

Species recorded from India

- *Allenbatrachus grunniens* (native) Frog fish, Grunting toadfish
- *Austrobatrachus dussumieri* (native) Flat toadfish

Order Beryciformes

The Order has 7 families with 29 genera and 144 species. All species are marine. Four families represented in Indian waters.

Family Berycidae (Alfonsinos)

Dorsal fin without notch, with 4-7 spines increasing in length from first to last, and 12-20 soft rays. 2 genera with about 9 species.

Family Holocentridae (Squirrelfishes, soldierfishes)

Species with a long dorsal fin with spiny portion and soft rayed portion divided by a notch. Holocentrids (squirrelfish and soldierfish) are vocal reef fishes whose calls and sound-producing mechanisms have been studied in some species only. Worldwide, eight genera with 78 species has been reported. In India, 18 species in 4 genera have been recorded.

Elasmobranchs

Sharks are the most diverse and largest group of cartilaginous fishes, comprising eight families, 51 genera, and at least 337 described species.Habitat wise there are pelagic dwelling and demersal dwelling species. The pelagic proportion is largely comprised of those Carcharhiniformes species, nine Lamniformes, and four Myliobatiformes. India, is reportedly the largest shark fishing nation in the ASR and second largest in the world (Dent and Clarke, 2015), contributes 74,000 metric tons of an estimated 831,460 metric tons of global chondrichthyan exports annually (FAO Yearbook, 2020). Chondrichthyan exports from India thus account for ∼ 9% of global and ∼ 93% of ASR exports of the species. While the FAO reports a 20% decline in global recorded landings of sharks and rays since 2003 (FAO, 2021).

As apex predators, sharks play an important role in the ecosystem by maintaining the species below them in the food chain and serving as an indicator for ocean health. •10 species protected as WLP 1972 •sawfishes - listed in the Appendix I •sharks and rays are listed in the Appendix II •Five species of sharks (oceanic whitetip shark, the porbeagle shark, scalloped, smooth and great hammerhead sharks), and great and reef manta rays were added to Appendix II at Bangkok (Thailand), CITES at the 16th Meeting of the Conference of the Parties (CoP16), in 2013. •In 2016, silky shark, all the thresher sharks and all the devil rays were also added to the CITES lis

Family Lutjanidae

The family Lutjanidae collectively known as snappers, contains 17 genera and 105 species, which are mainly confined to tropical and subtropical marine waters, with few occurring in estuaries (Allen, 1985; Eschmeyer 2012; Anderson, 2003a). •49 species in 10 genera as reliable records and presently known snappers from the Indian Waters (Nair et al., 2014)

Family Serranidae - are mostly marine in habitat with widespread occurrence from tropical and temperate seas. Fishes are characterised by an opercle with three spines with the main spine in centre and one each above and below. •Three subfamilies, Anthiadinae, Epinephelinae and Serraninae are recognized with about 72 genera and 579 species (Parenti and Randall 2020).

Order Pleuronectiformes -Flatfishes

62 species have been reported from India (Nair, 2011)Flounders, Halibut and Soles are the main three groups in India. Major landings are from Kerala and West Bengal. The fishes are mainly landed by trawlers. *Cynoglossus macrostomus* is the major species with size range of 65 -190 mm.

Family Nemipteridae (Threadfin breams, Whiptail breams)

Six species of threadfin breams are known from the seas around India. And form a major fishery along the coastline. Spawning in *N. japonicus* takes place during October-April with a peak during October- December along Gujarat. In Kerala, *N. japonicus and N. randalli* spawn during monsoon and post monsoon periods with peaks during monsoon in the former and during post monsoon in the latter species. The fish is mainly landed by trawlers on the west coast

Catfishes are important demersal resources which have wide distributional range in the IndoPacific region. They are distributed all along the Indian coastal waters upto the middle shelf with preferential concentration on muddy grounds of 30-70 m depths.The fishery had once showed a drastic decline but now is on a path of improvement. They migrate both vertically (diurnal migration) and horizontally (seasonal) in small schools to large shoals in response to seasonal climatic / hydrographic variations. Marine catfishes (family Ariidae – genera Tachysurus (21 species), Osteogeneiosus (1 species), Netuna, and Batrachocephalus (1 species) in Indian waters) of which 11 appear in the commercial fisheries. West coast landed 70% of the total catfish catch and the east coast 30%; north west coast landed

Scaienids:

A major resource landed all along the coast with specific fishery fir its air bladder along the NE coast supported by the *Protonibea diacanthus*. Fishery is present throughout the coast, however taxonomic ambiquities are high. Exploited by trawlers. Major landings in Maharashtra, Gujarat and Andhra Pradesh.

Whitefish

Although distributed all along the coastline, the resource had high landings along the southwest and southeast regions. *Lactarius lactarius* is the only species available in this family. Whitefish production in India shows wide fluctuation along the coast now with catches fluctuating badly along east coast.

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CHAPTER 19

Taxonomy of the fishes of the family Leiognathidae (Pisces, Teleostei) from the West Coast of India

Abstract

A total of 16 species of the family Leiognathidae have been collected from the commercial landings from Cochin and Neendakara on the western coast of India from 1998–2000. Detailed morphometric data have been collected and all 16 species are redescribed with live color photographs here. Various relationships in the morphometric characteristics have been studied and regression equations fitted to enable comparison of the populations of these species from Kerala with those from other regions. Of the 16 species collected and described in the present work, five species*, Nuchequula nuchalis, Equulites absconditus, Equulites leuciscus, Aurigequula longispina*, and *Gazza achlamys,* are reported for the first time from the entire western coast of India.

Introduction

Fisheries are one of the most important renewable resources. With increasing fishing pressure, the only option left for the sustainability of fisheries is their rational management. Proper management is possible with a thorough knowledge of the dynamics of the fish stocks. For a meaningful study of the dynamics, knowledge of natural his- tory of the species is necessary and this in turn can be acquired by the correct identification of fish species. This assumes greater importance in tropical seas where, a multitude of closely related and morphologically similar species occur. The role of taxonomy and proper identification cannot be overstressed in studies of population dynamics. The study is also a step towards understanding the bewildering biodiversity that characterizes the tropical seas. In regard to the taxonomy of the family Leiognathidae from the Indian waters, Day (1878), described 14 species. Munro (1955) described twelve species of ponyfish (as members of this family are often called, they are also called silverbellies and slipmouths) from neighboring Sri Lanka. Recently Chakrabarty et al. (2008) redescribed the ponyfishes of Sri Lanka and resurrected *Aurigequula* Fowler, 1918. James (1969), Rani Singh and Talwar (1978a, 1978b), Jayabalan (1985) and James and Badrudeen (1990), added seven species to the known ponyfish species of India of which four were new to science and three were first reports from India. The most thorough and only comprehensive revision of the family Leiognathidae from the Indian seas was that of James (1975). Jayabalan and Ramamoorthi (1977) gave a synoptic key to the genera of Leiognathidae

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of Porto Novo and Talwar and Kacker (1984) described 15 species. James (1984) also described 17 species of ponyfish from the Western Indian Ocean including India.

The survey of literature on taxonomy of silverbellies from India clearly reveals that most of the work was carried out from the eastern and southeastern coasts. In the backwaters of Kerala, Shetty (1963) reported 6 species and Kurup and Samuel (1983) reported nine species which brought the total known species from Kerala to 11. Only two species *L. equulus* and *L. brevirostris* (now recognized as a junior synonym of *Photopectoralis bindus* that was long been misidentified as a member of *Nuchequula* – see Chakrabarty and Sparks, 2007) were reported to be abundant. Adequate biometric data is lacking for marine species from the west coast of India. The literature on species distribution in different regions in India suggests a great deal of variation in the distribution and abundance of species (James, 1975; Jayabalan and Ramamoorthi, 1977). The distribution of species along the west coast needs to be better understood. Therfore, we felt it necessary to study the taxonomy of the one of the most abundant and mis- identified marine taxa found in the sea off Kerala. The taxonomy of silverbellies has changed a great deal in recent years. Several new genera have been established, resurrected, or raised in taxonomic status such as *Eubleekeria* Fowler, 1904 by Chakrabarty and Sparks, 2005, Kimura et al., 2008; *Karalla* Chakrabarty and Sparks, 2008, *Photopectoralis* by Sparks, Dunlap and Smith, 2005; *Nuchequula* Whitley, 1932 by Chakrabarty and Sparks, 2007; *Aurigequula* Fowler, 1918 and *Equulites* Fowler, 1904 elevated to generic rank by Chakrabarty and Sparks, 2008.

Material and methods

Specimens for the study were collected from the fish landing centers at Cochin and Neendakara, at regular intervals from 1998-2000. After noting the fresh color and pigmentation of the specimens they were injected with 5 % formalin. The specimens were then stored in 5 % formalin. After taking biometric data, the belly was cut open to note the sex. In most species, 30 specimens were examined for describing the species. However in certain species, which are rare in the catches, the descriptions were based on fewer specimens. In taking meristic and morphometric data, the methodology of Hubbs and Lagler (1947) was followed. All the linear measurements were made in the median longitudinal axis. Counts of pectoral rays, pelvic rays and lateral line scales were made on the left side of the specimens. Height of dorsal and anal fins, eye diameter, snout length, head height and height of body were taken using vernier calipers. Counts of lateral line scales and fin rays were made under a binocular stereozoom microscope.

The relationship between certain body length and standard length and between certain dimensions in the head and head length were calculated after ascertaining the type of relationship through a scatter diagram, following the least squares method (Snedecor and Cochran, 1967). Certain body proportions for each species, are expressed as percentages of standard length and certain proportions in the head expressed as percentages of head length are given in the descriptions; the means are given in parentheses following the range for each proportion (the expressions used are predorsal for predorsal length, preanal for preanal length, dorsal base for length of the base of dorsal fin, anal base for length of the base of the anal fin, head for head length, dorsal height for height of the dorsal fin , anal height for height of the anal fin, pectoral for length of the pectoral fin, depth for depth of the body, preorbital for preorbital length and eye for horizontal eye diameter). These measurements useful in comparing and differentiating between morphologically similar species (e.g. Murty, 1978) and comparison of the stocks of the same species from different localities (Lachner and Jenkins, 1971). Since the body proportions are known to vary with growth i.e., the rate of growth of a body part changes with increase in length, a study like this assumes greater importance. Understanding such variations in growth (allometric growth) will help in understanding the intraspecific variations in each species. The frequency distribution of the various meristic characters for each species is given along with the calculated standard deviation and standard error in the Tables. The classification and nomenclature used by Sparks et al. (2005); Chakrabarty and Sparks (2007) and Chakrabarty et al. (2010) was adopted.

Results

A total of 20 species of Leiognathidae known from the seas around India are listed below; the species collected in this work are shown by one and two asterisks, those marked with ** are the first reports from Kerala coast.

1. *Eubleekeria splendens** (Cuvier, 1829)
2. *Eubleekeria jonesi* James, 1969
3. *Nuchequula mannusella** Chakrabarty and Sparks, 2007
4. *Nuchequula nuchalis* ** (Temminck and Schlegel, 1845)
5. *Leiognathus equulus** (Forsskal, 1775)
6. *Leiognathus striatus* James and Badruddin, 1990
7. *Leiognathus rapsoni* Munro, 1964
8. *Karalla dussumieri* * (Valenciennes, 1835)
9. *Karalla daura** (Cuvier, 1829)
10. *Photopectoralis bindus**(Valenciennes, 1835)
11. *Photopectoralis aureus** (Abe and Haneda, 1972)
12. *Equulites absconditus*** Chakrabarty and Sparks, 2010
13. *Equulites leuciscus*** (Günther, 1860)
14. *Aurigequula fasciata** (Lacepède, 1803)
15. *Aurigequula longispina*** (Valenciennes, 1835)
16. *Secutor insidiator* * (Bloch, 1787)
17. *Secutor ruconius** (Hamilton, 1822)
18. *Gazza minuta** (Bloch, 1797)
19. *Gazza achlamys*** Jordan and Starks, 1917
20. *Gazza shettyi* Jayabalan, 1985

Description of species

***Eubleekeria* Fowler 1904**

(Type species: *Eubleekeria splendens* (Cuvier, 1829))

***Eubleekeria splendens* (Cuvier, 1829)**
(Plate I, Fig. 1; Tables 1–3)

Leiognathus splendens Cuvier, 1829, *Regne Anim, dit*., 2a, 2: 212

Material examined. 30 specimens (10 females, 14 males, 6 indeterminates) of 41–108 mm TL (Cochin and Neendakara, Kerala) .
Description. D.VIII – IX, 16; P. ii, 13–14, i – ii; V. I, 5; A. III – 14–15; C. 15–16; Ll. 45–57.
As percent of standard length: Total length 135.06–142.86 (138.64); fork length 116.07–123.33 (118.85); pre- dorsal 33.33–40.51 (36.35); preanal 44.44–54.55 (51.25); dorsal base 51.85–70.51 (58.63); anal base 40.00–48.15 (43.56); head 31.34–34.62 (33.21); dorsal height 18.18–24.64 (22.14); anal height 15.69–21.28 (18.74); pectoral 20.90–27.27 (23.66); depth 40.85–55.36 (52.29) .
As percent of head length: Snout 22.22–31.58 (26.26); eye 33.33–44.44 (39.11); head height 77.78–95.24 (87.79).
Body compressed and deep. Anterior part of dorsal profile more strongly convex than anterior part of ventral profile. Dorsal profile with a notch above eye. Snout blunt and shorter than eye diameter. Gape of mouth below ventral border of eye. Mandibles slightly concave. Minute villiform teeth in each jaw. Ventral margin of preoperculum finely serrated. Lateral line prominent and convex from the beginning, but less convex than the dorsal pro- file. It extends beyond the end of soft dorsal and anal fins, but stops just short of the base of caudal fin. Ventral fin with an axially scale and reaches very near the origin of the anal fin.

Color. Body silvery, abdomen more silvery than back. Back grayish silvery with faint gray wavy vertical lines descending from the dorsum to a little below lateral line. Tip of snout dotted black. Pectoral axil black. Membrane between the second and sixth dorsal spines jet black and the membrane between the following spines, soft dorsal, anal spines, soft anal fin, and the caudal lobes, faint yellow. Tip of caudal lobes dusky.

Distribution. Most widely distributed along the Indian coast, contributing to the fishery, along with other species, especially along the west coast of India. It is known from Veraval, Mangalore, Calicut, Cochin, Mandapam, Porto Novo, Madras, Visakhapatnam and Kakinada.

***Nuchequula* Whitley, 1932**
(Type species: *Equula blochii* Valenciennes in Cuvier and Valenciennes, 1835)

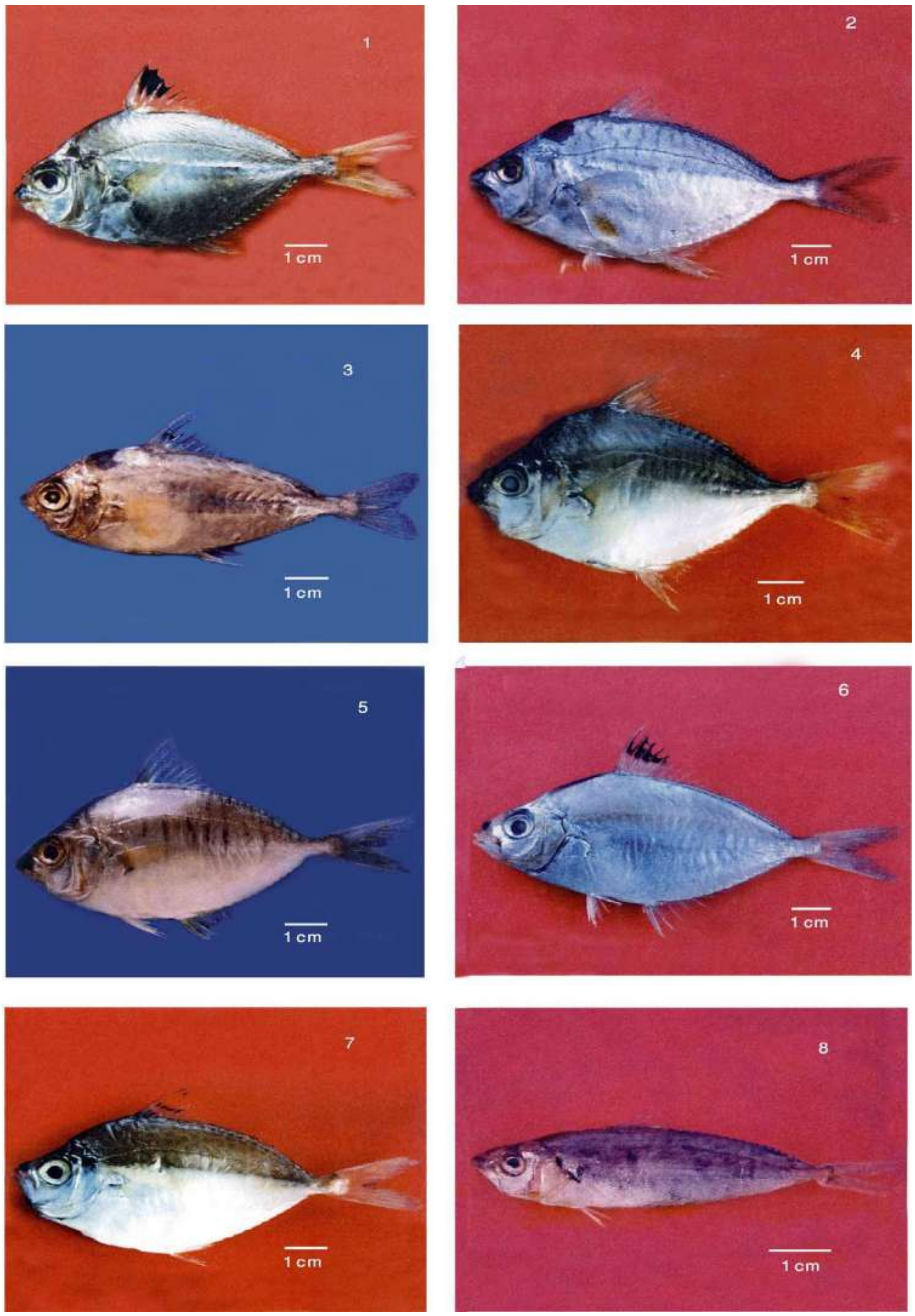

PLATE I. 1. *Eubleekeria splendens* (Cuvier, 1829); 2. *Nuchequula mannusella* Chakrabarty and Sparks, 2007; 3. *Nuchequula nuchalis* (Temminck and Schlegel, 1845); 4. *Leiognathus equulus* (Forsskal, 1775); 5. *Karalla dussumieri* (Valenciennes, 1835); 6. *Karalla daura* (Cuvier, 1829); 7. *Photopectoralis bindus* (Valenciennes, 1835); 8. *Photopectoralis aureus* (Abe and Haneda, 1972).

***Nuchequula mannusella* Chakrabarty and Sparks, 2007**
(Plate I, Fig. 2; Tables 1–3)

Equula brevirostris Valenciennes in Cuvier and Valenciennes, 1835, *Hist. Nat. poiss*., 10 :83.

Material examined. 30 specimens (14 females, 13 males, 3 indeterminates) of 82–114mm TL (Cochin, Neendakara).

Description. D.VIII, 16–17; P. ii, 13–15, i – iii; V. I, 5; A. III – 14; C. 15; Ll. 52–64.
As percent of standard length: Total length 131.82–137.31 (134.97); fork length 114.06–118.46 (115.81) ; pre- dorsal 35.53–40.48 (37.66) ; preanal 47.69–52.38 (49.95) ; dorsal base 40.63–57.97 (55.47) ; anal base 38.81– 45.21 (43.42) ; head 29.85–33.33 (31.37) ; dorsal height 15.56–26.56 (22.70) ; anal height 15.56–20.00 (18.07) ; pectoral 16.42–20.90 (18.87) ; depth 43.75–50.00 (46.19) .
As percent of head length: Snout 26.32–35.71 (30.46) ; eye 30.00–36.84 (32.73) ; head height 81.82–91.30 (86.22).

Body oval and compressed. Dorsal and abdominal profiles equally convex. Mouth when protracted forms a tube directed downward. Gape of mouth immediately below or opposite to the ventral margin of the eye. The ven- tral margin of the lower jaw very concave. Teeth small and numerous in a single row in each jaw. Two small spines on dorsal aspect of head opposite the anterior border of eye. The lower margin of the pre-operculum finely serrated. Anterior part of the lateral line concave, ventrally it runs less convex to the dorsal profile extending posteriorly up to the base of the caudal fin. Ventrals with axillary scales and reaches two thirds of the way to the anal fin. Caudal fin deeply forked.

Color. Belly silvery, dorsal body with dark wavy vertical lines extending down to about or slightly ventral to the lateral line, anteriorly to below the origin of dorsal fin and posteriorly to the end of the soft dorsal. A brown blotch on the nape, which becomes diffuse on preservation in formalin. A conspicuous golden yellow patch on belly, about midway between the pelvis and the anal fin origin. Tip of snout, dotted black. The pectoral axil dotted black. Spinous part of the dorsal fin golden at mid height.

Distribution. Occurs along Mangalore, Cochin, Palk Bay, Gulf of Mannar (Mandapam), Kakinada and Goda- vari estuary. It has also been reported from Vembanad Lake off Cochin. It is abundant in the Rameswaram region.

TABLE 1. Frequency distribution of pectoral fin rays in the silverbellies collected off Kerala coast.

Species	Pectoral fin rays (Branched + Unbranched)									
	15	16	17	18	19	20	21	N	$\bar{x}$	SD	SE
E. splendens	-	-	29	1	-	-	-	30	17.03	± 0.18	± 0.03
N.mannusella	-	-	1	24	5	-	-	30	18.13	± 0.43	± 0.08
P.bindus	9	19	2	-	-	-	-	30	15.77	± 0.57	± 0.10
L.equulus	-	-	-	-	5	20	5	30	20.00	± 0.59	± 0.11
K.dussumieri	-	-	-	13	16	1	-	30	17.97	± 3.24	± 0.59
K.daura	-	-	-	1	8	1	-	10	19.00	± 0.47	± 0.15
N.nuchalis	-	-	23	7	-	-	-	30	17.23	± 0.43	± 0.08
E.absconditus	-	10	-	-	-	-	-	10	16.00	-	-
E.leuciscus	-	-	-	9	1	-	-	10	18.10	± 0.32	± 0.10
A .fasciata	-	-	-	1	1	1	-	3	19.00	± 1	± 0.58
A.longispina	-	-	-	-	-	-	1	1	-	-	-
P. aureus	-	2	-	-	-	-	-	2	14.00	-	-
S.insidiator	-	-	14	16	-	-	-	30	17.53	± 0.51	± 0.09
S.ruconius	-	-	11	19	-	-	-	30	17.63	± 0.49	± 0.09
G.minuta	-	1	20	9	-	-	-	30	17.27	± 0.52	± 0.10
G.achlamys	-	-	5	-	-	-	-	5	17.00	-	-

1. *Nuchequula nuchalis* (Temminck and Schlegel, 1845)
(Plate I, Fig. 3; Tables 1–3)

Equula blochii Valenciennes, in Cuvier and Valenciennes, 1835, *Hist. Nat. poiss.*, 10: 84.

Material examined. 30 specimens (11 females, 10 males, 9 indeterminate) of 71– 94 mm TL (Cochin, Neenda- kara).
Description. D.VIII, 15–16; P. ii, 12–14, i–iii; V. I, 5; A. II, 14; C. 15. Ll. 49–57.

As percent of standard length: Total length 131.34–136.54 (133.74); fork length 112.96–118.75 (115.78); pre- dorsal 34.55–38.89 (36.78); preanal 46.55–52.24 (49.74); dorsal base 55.07–58.18 (56.17); anal base 40.30–44.62(43.10); head 27.59–31.03 (29.28); dorsal height 19.70–24.07 (21.93); anal height 17.91–21.74 (19.57); pectoral17.91–23.08 (20.45); depth 36.21–42.59 (39.72).
As percent of head length: Snout 22.22–30.00 (25.98); eye 27.78–37.50 (32.58); head height 80.00–88.89 (84.24).

Body oval, compressed, rather elongate. Dorsal and ventral profiles almost equally convex, the former evenly curved from tip of snout to origin of dorsal fin. Snout pointed. Mouth small, lips narrow and thin. Mouth when pro- tracted forms a tube directed downwards. Gape of mouth opposite lower third of eye. Lower jaw strongly concave. Teeth small, numerous, villiform, in each jaw. Two small spines on top of the head opposite front border of the eye. Pre-opercle with a finely serrated lower margin. First part of the lateral line shows concavity, later running less con- vex to the dorsal profile, extending posteriorly to the base of the caudal fin. Ventrals not reaching half way to the anals and with axillary scales. Caudal deeply forked.

Color. Abdomen more silvery than back, with black irregular bands extending to about half level. Light brown blotch on nape, which covers an area from about the posterior half of the nuchal spine to the origin of the dorsal fin. Membrane from above the half level to the tip of spines between the second to the seventh dorsal spines black. Tip of snout dotted black. Fine black dots on ventral half of the body. Inner side of the pectoral, posteriorly dark coloured. Gill opening area covered by the lower half of the operculum also dotted black.

Distribution. Known from off Cochin, Quilon, Madras, Kakinada, and Calcutta and in Sunder bans and Chalk Lake.

***Leiognathus* Lacepède, 1803**

(Type species: *Leiognathus argenteus* Lacepède, 1803) (= *Scomber eduntulus* Bloch, 1785)

***2. Leiognathus equulus* (Forsskål, 1775)**
(Plate I, Fig. 4; Tables 1–3)

Scomber equula Forsskål, 1775, *Descr. Animal*, p.75

Material examined. 30 specimens (6 females, 23 males, 1 indeterminate) of 79–126 mm TL (Cochin, Neenda- kara).
Description. D.VIII, 16–17; P. ii, 15–17, i – iii; V. I, 5; A. III, 13–14; C. 15; Ll. 54–64.
As percent of standard length: Total length 134.88–142.68 (137.73); fork length 115.12–120.73 (117.40); pre- dorsal 37.21–43.75 (40.17); preanal 48.84–54.88 (51.45); dorsal base 50.72–56.18 (53.54); anal base 40.00–45.00 (42.58); head 31.40–35.94 (33.50); dorsal height 22.09–27.78 (24.70); anal height 18.99–22.22 (20.48); pectoral 20.00–26.09 (23.22); depth 53.45–60.00 (56.80).
As percent of head length: Snout 28.57–35.71 (32.18); eye 31.25–37.93 (35.20); head height 88.89–104.35 (95.21).

TABLE 2. Frequency distribution of Dorsal Fin Spines, Dorsal Fin Rays , Anal Fin Rays and Caudal Fin Rays in the silverbellies collected off Kerala coast

Species	Dorsal fin spines						Dorsal fin rays							Anal fin rays							Caudal fin rays						
	8	9	N	$\bar{X}$	SD	SE	15	16	17	N	$\bar{X}$	SD	SE	13	14	15	N	$\bar{X}$	SD	SE	14	15	16	N	$\bar{X}$	SD	SE
E. splendens	29	1	30	8.03	0.18	0.03	-	30	-	30	16.00	-	-	-	29	1	30	14.03	0.18	0.03	-	28	2	30	15.07	0.25	0.046
N.mannusella	30	-	30	8.00	-	-	-	29	1	30	16.03	0.18	0.03	-	30	-	30	14.00	-	-	-	30	-	30	15.00	-	-
P.bindus	30	-	30	8.00	-	-	-	29	1	30	16.03	0.18	0.03	-	29	1	30	14.03	0.18	0.03	1	29	-	30	14.97	18	3.286
L.equulus	30	-	30	8.00	-	-	1	27	2	30	16.03	0.32	0.06	2	28	-	30	13.93	0.25	0.05	-	30	-	30	15.00	-	-
K.dussumieri	30	-	30	8.00	-	-	-	30	-	30	16.00	-	-	-	30	-	30	14.00	-	-	-	30	-	30	15.00	-	-
K.daura	10	-	10	8.00	-	-	-	10	-	10	16.00	-	-	-	10	-	10	14.00	-	-	-	10	-	10	15.00	-	-
N.nuchalis	30	-	30	8.00	-	-	1	29	-	30	15.97	0.18	0.03	-	30	-	30	14.00	-	-	-	30	-	30	15.00	-	-
E.absconditus	10	-	10	8.00	-	-	-	10	-	10	16.00	-	-	-	10	-	10	14.00	-	-	-	10	-	10	15.00	-	-
E.leuciscus	10	-	10	8.00	-	-	-	10	-	10	16.00	-	-	-	10	-	10	14.00	-	-	-	10	-	10	15.00	-	-
A .fasciata	3	-	3	8.00	-	-	-	3	-	3	16.00	-	-	-	3	-	3	14.00	-	-	-	3	-	3	15.00	-	-
A.longispina	1	-	1	8.00	-	-	-	1	-	1	16.00	-	-	-	1	-	1	14.00	-	-	-	1	-	1	15.00	-	-
P. aureus	2	-	2	8.00	-	-	-	2	-	2	16.00	-	-	-	2	-	2	14.00	-	-	-	2	-	2	15.00	-	-
S.insidiator	30	-	30	8.00	-	-	-	30	-	30	16.00	-	-	-	30	-	30	14.00	-	-	-	30	-	30	15.00	-	-
S.ruconius	30	-	30	8.00	-	-	-	30	-	30	16.00	-	-	-	30	-	30	14.00	-	-	-	30	-	30	15.00	-	-
G.minuta	30	-	30	8.00	-	-	2	28	-	30	15.93	0.25	0.05	1	29	-	30	13.97	0.18	0.03	-	30	-	30	15.00	-	-
G.achlamys	5	-	5	8.00	-	-	-	5	-	5	16.00	-	-	-	5	-	5	14.00	-	-	-	5	-	5	15.00	-	-

Body oblong, deep and compressed. Dorsal profile more convex than the ventral profile; gently elevated from the occipital region to form a strongly humped back. Snout blunt. Mouth with thick lips. Mouth pointing downwards when protracted. Commencement of gape of mouth below lower border of eye. Lower margin of lower jaw strongly concave. Teeth small, numerous, villiform, in each jaw. Two small spines on top of the head, opposite front border of the eye. Preopercle with its lower margin slightly concave and serrated. Lateral line, conspicuous, concave at first, later on becomes convex, but less convex than the dorsal profile, and extends almost up to the base of the caudal fin. Ventrals do not reach the origin of the anal fin and has a prominent axillary scale, and a strong spine. Caudal fin not deeply forked and with rounded lobes.

Color. Body silvery, back grayish. Close set fine vertical bands descend from back to about mid height, clearly seen in fresh specimens, but fade on preservation in formalin. Membrane between anal spines yellowish. Snout dotted black. Pectoral fin axil faintly dusky. Posterior margin of caudal lobes pale yellow and dusky.

Distribution. Along Bombay, Mangalore, Calicut, Cochin, Quilon, Cape Comorin, Mandapam, Rameswaram, Kilakarai, Pamban, Madras, Porto Novo, Visakhapatnam, Kakinada. Also found in Godavary estuary and Chilka Lake.

TABLE 3. Frequency distribution of lateral line scales in the silverbellies collected off Kerala coast.

TABLE 3. Frequency distribution of lateral line scales in the silverbellies collected off Kerala coast.

Species	Lateral Line Scales															
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
E. splendens	1	-	2	4	2	1	5	4	4	4	1	1	1	-	-	-
N.mannusella	-	-	-	-	-	-	-	1	1	-	3	2	6	2	5	3
L. equulus	-	-	-	-	-	-	-	-	-	2	-	4	5	7	3	4
K. dussumieri	-	-	-	-	-	-	1	-	-	1	4	6	8	3	5	2
K. daura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N. nuchalis		-	-	-	1	1	-	1	-	1	2	10	14	-	-	-
E. leuciscus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. fasciata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A.longispina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. minuta	-	-	-	-	-	-	-	-	-	-	-	-	3	23	4	-

continued.

Species	Lateral Line Scales									
	61	62	64	66	67	69	N	$\bar{x}$	SD	SE
E. splendens	-	-	-	-	-	-	30	51.27	2.900	0.529
N.mannusella	4	2	1	-	-	-	30	58.23	2.760	0.504
L. equulus	2	2	1	-	-	-	30	58.33	2.310	0.422
K. dussumieri	-	-	-	-	-	-	30	56.87	1.925	0.351
K. daura	-	-	1	4	4	1	10	66.50	1.269	0.401
N. nuchalis	-	-	-	-	-	-	30	55.77	2.029	0.370
E. leuciscus	5	-	5	-	-	-	10	62.50	1.581	0.500
A. fasciata	-	3	-	-		-	3	62.00	-	-
A.longispina	1	-	-	-	-	-	1	61.00	-	-
G. minuta	-	-	-	-	-	-	30	58.03	0.490	0.089

***Karalla* Chakrabarty and Sparks, 2008**
Type species: *Karalla daura* Cuvier, 1829)

3. *Karalla dussumieri* (Valenciennes, 1835)
(Plate I, Fig. 5; Tables 1–3)

Equula dussumieri Valenciennes 1835, in Cuvier & Valenciennes, *Hist. Nat. Poiss*., 10: 77.

Material examined. 30 specimens (8 females, 13 males, 9 indeterminate) of 71–130 mm TL (Cochin, Neendakara).
Description. D.VIII, 16; P. ii, 14–15, i – iii; V. I, 5; A. III, 14; C. 15; Ll. 51–60.
As percent of standard length: Total length 131.31–137.84 (134.70); fork length 115.05–118.97 (116.58); pre- dorsal 35.71–38.46 (37.14); preanal 46.43–53.54 (50.27); dorsal base 55.26–58.21 (56.81); anal base 40.40–45.61 (43.37); head 29.82–34.21 (31.74); dorsal height 17.54–26.87 (23.65); anal height 14.55–20.55 (18.00); pectoral 19.18–23.29 (20.91); depth 43.21–49.49 (46.97).
As percent of head length: Snout 23.53–34.48 (29.49); eye 30.77–40.91 (34.07); head height 76.92–88.24 (81.01).

Body oblong, moderately compressed, dorsal and ventral profiles equally convex. Dorsal profile elevated and curved behind occipital profile and separated from it by a gentle concavity. Snout blunt. Mouth small and when protracted directed downwards. Commencement of gape of mouth below lower margin of eye. Mandibles slightly concave inferiorly. Teeth small, numerous, villiform, in each jaw. Two small spines on top of the head, opposite the front border of the eye. Pre-opercle with its lower margins finely serrated. Lateral line begins with a concavity and runs less convex than the dorsal profile, extending beyond the end of the soft dorsal and anal fins, but stops just short of the base of the caudal fin. Ventrals do not quite reach the anals, stopping just short. Ventrals with a strong spine and a large axillary scale. Caudal forked with rounded lobes.

Color. Abdomen silvery, back brownish. Sides of body with dark, narrow, wavy vertical lines descending from the back to a little beyond lateral line, often fading on keeping in formalin. An elongate yellow spot on belly below pectoral fin. Base of pectoral fin dark.

Distribution. It is known from off Cochin, Quilon, Tuticorin, Pamban, Mandapam, Kakinada, and Visakhapatnam. It is most dominant in southern Tamilnadu, in the Gulf of Mannar off Mandapam, Tuticorin and Pamban.

***Photopectoralis* Sparks, Dunlap and Smith, 2005**
(Type species: *Leiognathus aureus* Abe and Haneda, 1972

4. *Photopectoralis bindus* (Valenciennes, 1835)
(Plate I, Fig. 7; Tables 1–2)

Equula bindus Valenciennes 1835, in Cuvier & Valenciennes, *Hist. Nat. Poiss*., 10: 78.

Material examined. 30 specimens (6 females, 9 males, 15 indeterminates) of 50–106 mm TL (Cochin and Neendakara).
Description. D.VIII, 16; P. ii, 11–13, ii – iii; V. I, 5; A. III – 14; C. 14–15.
As percent of standard length: Total length 128.95–139.66 (135.80); fork length 112.33–117.24 (114.72); pre- dorsal 31.25–37.25 (34.61); preanal 42.31–48.65 (46.45); dorsal base 56.86–61.70 (59.35); anal base 44.74–50.91(47.28); head 26.92–30.99 (29.11); dorsal height 15.69–21.43 (18.53); anal height 12.50–17.91 (15.17); pectoral17.65–22.97 (20.89); depth 48.65–57.14 (54.24).
As percent of head length: Snout 18.18–26.67 (23.28); eye 35.00–45.00 (39.94); head height 90.91–110.53
(102.58).
Body deep oval and strongly compressed, particularly in the lower part. Ventral profile of the body more markedly convex than the dorsal profile. Abdomen before anal more strongly convex. Occipital profile shows a slight concavity and gradually rises to the dorsal profile. Protracted mouth parts point forward to slightly downward. Commencement of the gape of mouth somewhat above level of lower border of eye. Mandible slightly concave. Teeth small, numerous, in both the jaws. Two small spines on top of the head, opposite the front border of the eye. Pre-opercle with its lower margin finely serrate. First part of the lateral line straight, later running less convex to the dorsal profile and ending below the middle of the soft dorsal, posteriorly lateral line becoming obsolete. Ventrals short, their tips scarcely reaching half way to the anals. Ventral fin with a long axillary scale. Caudal fin deeply forked with spreading pointed lobes. Dorsolateral lobes of light organs hypertrophied about pectoral-axil window.

Color. Body silvery, abdomen more silvery than back. Dark irregular, somewhat vermiculate or semicircular markings in a zigzag pattern, commencing immediately behind head and extending to the end of the soft dorsal, laterally extending down to less than half height. In males with flank patch in the region behind the pectoral fin is translucent, whereas in females it is covered in silvery white as in the remainder of the body. Spinous part of dorsal fin, black at half height, above which the membrane between the second and fifth spines bears a bright orange blotch which turns yellow on preservation in formalin. Tip of snout and ventral half of body with grey dots. Pectoral axil dotted black. Faint yellow colour on basal part of spinous anal fin membrane. Caudal especially its posterior margins are dusky.

Distribution. Widely distributed along both the coasts, along Veraval, Mangalore, Calicut, Cochin, Palk bay, Gulf of Mannar, Madras, Kakinada, Visakhapatnam and West Bengal. It forms a significant part of silverbelly fishery in Gujarat, Tamilnadu.

5. *Photopectoralis aureus* (Abe and Haneda, 1972)
(Plate I, Fig. 8; Tables 1–2)

Equula elongata Günther, 1874, *Ann. Mag. Nat. Hist*., 4(14):369.
Material examined. 2 specimens (both indeterminates) of 71–77 mm TL (Neendakara).
Description. D.VIII, 16; P. ii, 12, ii; V. I, 5; A. III, 14; C. 15.
As percent of standard length: Total length 126.23–126.79 (126.51); fork length 113.11–114.29 (113.70); pre- dorsal 37.50–37.70 (37.60); preanal 52.46–53.57 (53.02); dorsal base 55.74–57.14 (56.44); anal base 40.98–41.07(41.03); head 29.51–30.36 (29.93); dorsal height (12.50); anal height 7.14–8.20 (7.67); pectoral 14.29–16.39(15.34); depth 21.43–24.59 (23.01).
As percent of head length: Snout 27.78–29.41 (28.59); eye 27.78–29.41 (28.59); head height 52.94–61.11 (57.03).

Body elongate, slender and moderately compressed. Dorsal and ventral profiles, almost evenly curved and tapering gently to the very short caudal peduncle. Upper surface of head weakly convex. Snout sharp, pointed. Pro- tracted mouth parts point downwards. Narrow band of small teeth in each jaw. Mandibular slightly concave. Lateral line conspicuous at the beginning, but could not be clearly traced thereafter, for the lateral line scales to be counted. Caudal fin deeply forked. Ventrals reaching halfway to the anals. The light organs of males is twenty times longer than conspecific females of similar SL.

Color. Body silvery, back and sides marked with a number of irregular, dark, brownish spots and vermiculations. Underside of pectoral fin with minute dark dots. A black spot at the base of each dorsal and anal ray. Anal fin between second and third spines yellow, as also the margin of the anterior part of the fin. Lower half of the body covered with fine black dots on the sides, the dots on the upper half of the body minute, but just as numerous. Edge of the gill opening on the lower side, covered by the opercular flap also dotted black.

Distribution. Occurs only in stray catches along the coast.

***Equulites* Fowler, 1904**

(Type species: *Leiognathus vermiculatus* Fowler, 1904)

6. *Equulites absconditus* Chakrabarty and Sparks, 2010
(Plate II, Fig. 1; Tables 1–2)

Equula lineolata Valenciennes in Cuvier and Valenciennes, 1835, *Hist. nat. Poiss.,* 10: 86.

Material examined. 10 specimens (2 females, 4 males, 4 indeterminates) of 54–76 mm TL (Cochin, Neendakara).
Description. D.VIII, 16; P. ii, 11–12, ii; V. I, 5; A. III, 14; C. 15.
As percent of standard length: Total length 128.81–132.00 (130.48); fork length 112.77–116.07 (114.52); pre- dorsal 35.42–37.50 (36.49); preanal 46.67–50.00 (48.67); dorsal base 55.36–59.57 (57.04); anal base 42.55–45.83 (44.18); head 26.67–29.17 (27.87); dorsal height 15.56–18.00 (17.06); anal height 12.20–14.58 (13.13); pectoral 16.67–18.00 (17.29); depth 31.71–40.00 (36.97).
As percent of head length: Snout 21.43–31.25 (26.62); eye 31.25–38.46 (34.00); head height 71.43–81.82 (76.17).

Body oblong, compressed and elongate, dorsal and ventral profiles equally convex. A slight concavity over occiput. Snout pointed. Mouth small, lips narrow and thick. Mouth when protracted forms a tube directed down- wards. Commencement of gape of mouth over lower one third of eye. Inferior edge of mandibles slightly concave. Teeth small, numerous, on the jaws. A pair of spines on top of the head, over the anterior third of the orbit. Pre-opercle with its lower margin straight and finely serrated. First part of lateral line with a concavity, later running less convex to the dorsal profile, and cannot be traced forward from somewhere between the middle to the end of the dorsal fin, posteriorly. Ventrals with axillary scale and their tips do not quite reach the origin of the anals. Caudal fin deeply forked. In males, an expansive triangular translucent patch in the shape of an equilateral triangle is present in the midflank.

Color. Belly silvery, back brownish with relatively sparse vertical zigzag lines or grey irregular vermiculations from behind head to caudal base, laterally extending down to a little below the lateral line. Ventral half of the body with fine black dots. Tip of snout dotted black. Inner side of pectoral base also dotted black, as also the lower edge of the gill opening covered by the opercular flap.

Distribution. Along Cochin, Quilon, Palk Bay and Gulf of Mannar, Madras, and Kakinada.

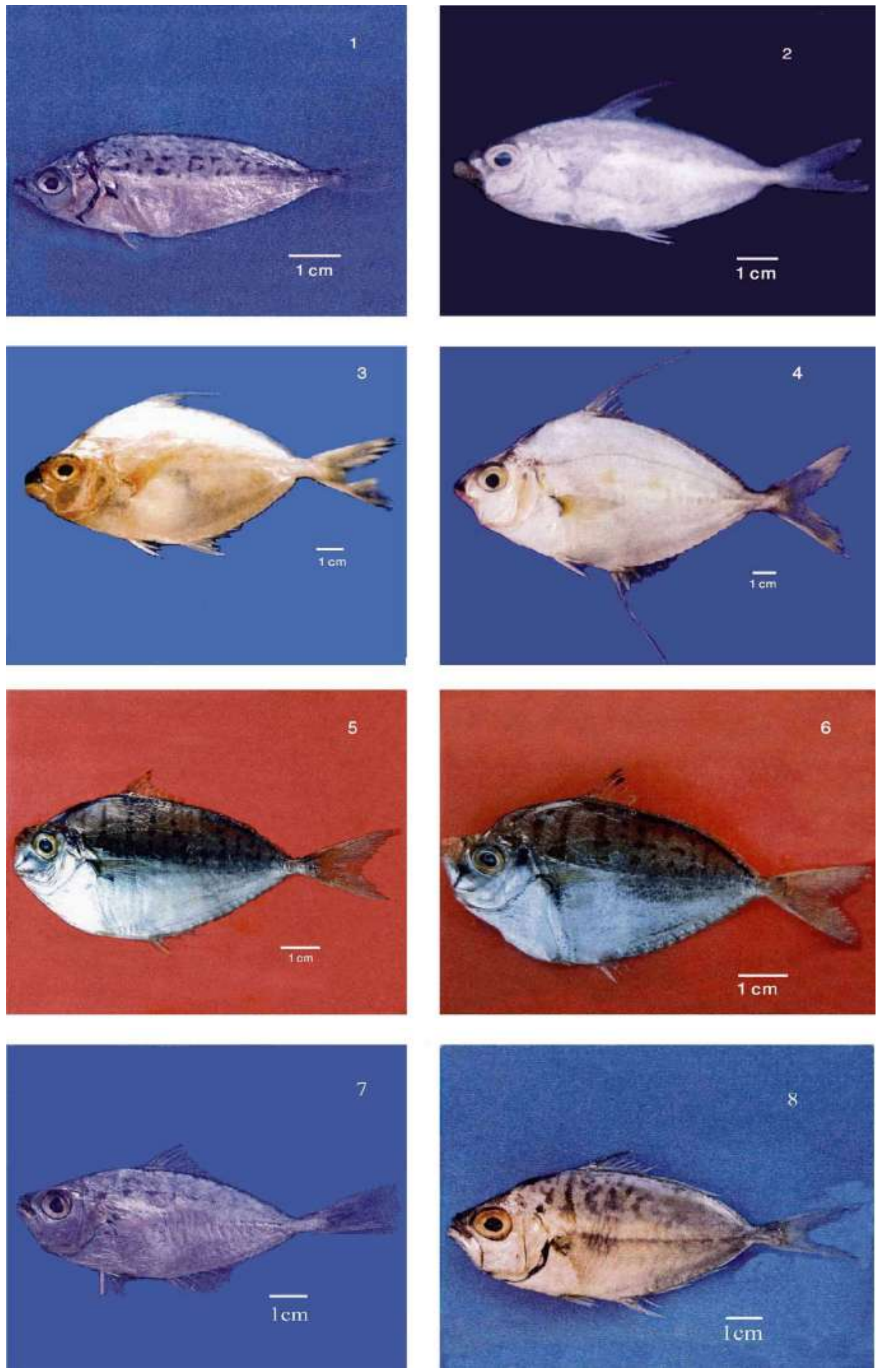

PLATE II. 1. *Equulites absconditus* Chakrabarty and Sparks, 2010; 2. *Equulites leuciscus* (Günther, 1860); 3. *Aurigequula fas- ciata* (Lacepède, 1803); 4. *Aurigequula longispina* (Valenciennes, 1835); 5. *Secutor insidiator* (Bloch, 1787); 6. *Secutor ruco-nius* (Hamilton, 1822); 7. *Gazza minuta* (Bloch, 1797); 8. *Gazza achlamys* Jordan and Starks, 1917.

7. *Equulites leuciscus* (Günther, 1860)
(Plate II, Fig. 2; Tables 1–3)

Equula leuciscus Günther, 1860. *Cat. Brit. Mus*., 2: 503.

Material examined. 10 specimens (5 females, 4 males, I in determinant) of 77–134 mm (Cochin, Neendakara).
Description. D.VIII, 16; P. ii, 13–14, iii; V. I, 5; A. III, 14; C. 15; Ll. 61–64.
As percent of standard length: Total length 128.77–135.09 (131.37); fork length 113.04– 116.28 (114.40); pre-
dorsal 36.23–38.46 (37.37); preanal 49.12–55.77 (50.92); dorsal base 54.10–58.14 (55.88); anal base 38.46–44.26 (42.24); head 26.25–28.85 (27.87); dorsal height 21.05–27.54 (24.72); anal height 15.79–20.51 (17.52); pectoral 15.94–17.91 (16.71); depth 36.07–41.86 (39.06).
As percent of head length: Snout 28.57–33.33 (30.41); eye 29.17–37.50 (32.58); head height 76.19–85.71 (79.78).

Body compressed and elongate. Dorsal profile somewhat more convex than the ventral. Upper profile of head rises back with a little concavity. Snout pointed. Mouth small pointing downwards when protracted. Cleft of mouth opposite middle to lower third of eye. Mandibular profile slightly concave. Two spines on the supraorbital edge of the eye. Villiform teeth present in each jaw. Lateral line extends beyond soft dorsal and anal fins, up to the base of the caudal fin. Second dorsal spine elongated and filiform, upper half of which is flexible. The second dorsal spine when flexed backwards extends up to the second to the fourth dorsal ray (only 3 specimens examined for this char- acter, since in all the others the second dorsal spine was broken), i.e. well in front of the middle of the soft dorsal. The third dorsal spine is only about half the length of the preceding. The anal fin commences vertically below the eighth dorsal spine. Ventral fins reaching only to about two-thirds of the distance to the anal fin origin. Caudal forked. Dorsolateral lobes of light organs hypertrophied, extend posteriorly into gas bladder.

Color. Body silvery, back and sides marked with a number of irregular semicircular and undulated, dark, gray– brown spots and vermiculations. Yellow spots below lateral line on large specimens, fading almost completely on preservation in formalin. Pectoral axil, black with minute dots. Membrane between dorsal fin spines soft yellow at mid height, edge of soft part of dorsal fin also yellow. Posterior part of caudal fin also yellowish.

Distribution. Distributed off Cochin, Quilon, Palk Bay, Gulf of Mannar and Madras.

Aurigequula **Fowler, 1918**

(Type species: *Clupea fasciata* Lacepède, 1803)

8. *Aurigequula fasciata* (Lacepède, 1803)
(Plate II, Fig. 3; Table 1–3)

Clupea fasciata Lacepède, 1803, *Hist. Nat. Poiss*., 5: 460,463

Material examined. 3 specimens (2 males, 1 indeterminate) of 111 mm–129 mm SL (Cochin, Neendakara).
Description. D.VIII, 16; P. ii, 14–16, ii; V. I, 5; A. III, 14; C. 15. Ll. 62.
As percent of standard length: Total length 134.48–136.04 (135.26); fork length 113.79–115.32; predorsal 38.76–39.64 (39.06); preanal 49.61–52.59 (51.48); dorsal base 55.17–55.86 (55.61); anal base 41.38–44.96 (43.19); head 31.01–32.43 (31.49); dorsal height 39.66; anal height (20.93); pectoral 22.41–22.52 (22.47); depth 54.95–56.59 (55.57).
As percent of head length: Snout 33.33–35.00 (33.89); eye 35.00–36.11; head height 86.11–91.67 (88.43).

Body compressed, ovate and deep. Back more strongly arched than anterior part of belly. Mouth horizontal and when protracted forming a tube with downward direction. Gape of mouth when closed opposite and below the lower margin of the eye. Mandible slightly concave inferiorly. Narrow band of villiform teeth in each jaw. A pair of spines above the anterior superior angle of the orbit. Pre-opercular with its lower margin finely serrated. Lateral line, very slightly concave at commencement and convex thereafter, but less so when compared to the dorsal pro- file, and extends up to a little distance short of the base of the caudal fin. Second dorsal spine filiform, its tip extending up to the origin of the eighth dorsal ray, when flexed backward (only one specimen examined for this character). Second anal spine somewhat elongate, but not as long as the second dorsal. Ventrals with prominent axillary scale (its tip reaching the tip of the innermost rays). Ventrals does not reach the origin of the anal. Caudal deeply forked. This species bears moderately enlarged light organs. No sexually dimorphic with respect to internal or external features of the LOS.

Color. Abdomen and back silvery. Upper half with indistinct gray-brown vertical bands descending up to a little beyond the lateral line, numbering ten to fifteen. In between lateral line and median line of the body a few big oval yellow blotches are present in addition to a few smaller ones of the same hue. Inner side of pectoral base dot- ted black. Spinous anal fin with faint yellow colouring, continued marginally along the rays. Caudal fin dusky.

Distribution. Along Cochin, Quilon, Gulf of Mannar and Palk Bay. It does not form a fishery of any importance anywhere along the coast.

9. ***Aurigequula longispina* (Valenciennes, 1835)**
(Plate II, Fig. 4; Tables 1–3)

Leiognathus longispina Valenciennes, 1835, *Proc. Linn. Soc. N. S. Wales* (2) 1: 11.Body oval and compressed. Anterior part of the dorsal profile more strongly arched than anterior part of the ventral profile. The upper profile of the head with a gentle concavity. Snout blunt. Mouth small and pointing downward when protracted. Cleft of mouth above lower edge of eye. Mandibles inferiorly slightly concave. Teeth small, numerous and villiform. Two small spines above the anterior superior angle of the orbit. Pre-operculum with its lower margin distinctly and finely serrated. Lateral line strongly convex, extends beyond end of soft dorsal and anal, but stops a short distance in front of the caudal fin. Second spines of dorsal and anal fin greatly elongated. The second dorsal spine reaches up to the sixth dorsal ray and the ventral spine up to the fifth dorsal ray (only one specimen examined).

Color. Abdomen more silvery than back, which shows a few, faint, unevenly spaced horizontally elongate grey brown streaks or blotches. Variable number of yellow blotches along the flank below the lateral line. Soft anal and margin of soft dorsal fin yellow. Underside of the pectoral fin base dotted black. Tip of snout gray. Margin of caudal lobes dusky.

Distribution. Only stray catches are reported from Palk Bay and Kakinada. Reported from Cochin for the first time, in the present work.

***Secutor* Gistel, 1848**

(Type species: *Zeus insidiator* Bloch, 1787)

10. ***Secutor insidiator* (Bloch, 1787)**
(Plate II, Fig. 5; Tables 1–2)

Zeus insidiator Bloch 1787, *Ausl. Fische*, 3: 41, pl. 192, fig.2–3.

Material examined. 30 specimens (14 females, 12 males, 4 indeterminates) of 47–106 mm TL (Cochin, Neenda- kara).
Description. D.VIII, 16; P. ii, 13–15, i–iii; V. I, 5; A. III, 14; C. 15.
As percent of standard length: Total length 127.94–134.48 (131.96); fork length 111.54–117.14 (113.89); pre-dorsal 35.71–38.89 (37.03); preanal 42.50–46.91 (45.25); dorsal base 52.78–58.93 (56.30); anal base 46.05–51.43 (48.07); head 26.23–28.57 (27.24); dorsal height 13.89–18.18 (16.39); anal height 8.75–12.50 (10.86); pectoral 19.44–23.08 (21.48); depth 41.67–50.72 (47.48).
As percent of head length: Snout 20.00–28.57 (25.04); eye 29.41–40.00 (33.59); head height 110.00–122.73 (117.62).

Body oval, deep, elongated and compressed. Dorsal profile less convex than the ventral profile and the dorsal profile strongly concave in the occipital region. Snout pointed. Mouth small and oblique, when protracted forms a tube directed upwards. Gape of mouth opposite about middle of eye. Mouth small, lips broad and thin. Lower lip broader and smaller than the upper lip, which is like a loop over the lower. When mouth is closed, the mandible is almost vertical. Lower margin of the mandible slightly concave. Teeth minute, numerous and villiform. One small spine on head, immediately above the eye and opposite its front border. Lateral line shows a slight concavity at first, later running less convex to the dorsal profile extending posteriorly almost to the base of the caudal. Ventrals with axillary scales, their tips reaching only halfway to the origin of the anals. Caudal fin deeply forked. Ventro-lateral lobes of light organ hypertrophied.

Color. Silvery, back with about ten or so black, vertical bands, formed of patches, from behind head to end of soft dorsal, laterally extending to a little below the lateral line. Abdomen with black pigment spots. Spinous dorsal fin with the membranes between the second to the sixth spines black at the upper one third portion. A black curved band from the lower margin of the eye to the posterior angle of the lower jaw. Inner side of pectoral base dotted black. Caudal fin yellowish and posterior margin of the lobes are dusky.

Distribution. Along Mangalore, Cochin, Quilon, Mandapam, Madras, Visakhapatnam and Kakinada. It forms the dominant fishery at Mangalore and contributes heavily at Madras, Kakinada and Cochin.

11. *Secutor ruconius* (Hamilton-Buchanan, 1822)

(Plate II, Fig. 6; Tables 1–2)

Chanda ruconius Hamilton-Buchanan, 1822, *Fish. Ganges*, P. 106, 371, pl.126, fig.35.

Material examined. 30 specimens (7 females, 9 males, 14 indeterminates) of 42–83 mm TL (Cochin, Neenda- kara).

Description. D.VIII, 16; P. ii, 12–14, i–ii; V. I, 5; A. III, 14; C. 15.

As percent of standard length: Total length 130.77–140.00 (135.19); fork length 110.26–118.75 (115.28); pre- dorsal 35.48–40.91 (38.28); preanal 40.63–47.17 (43.92); dorsal base 52.27–57.41 (54.87); anal base 46.81–51.85 (49.61); head 26.42–30.77 (28.93); dorsal height 15.63–20.37 (17.47); anal height 10.34–13.95 (12.19);pectoral 20.93–25.00 (22.68); depth 56.41–62.75 (59.57).

As percent of head length: Snout 18.18–28.57 (24.28); eye 30.00–42.86 (37.15); head height 125.00–144.44 (134.66).

Body oval, strongly compressed and deep. Ventral profile, much more convex than the dorsal profile. Rostro- occipital line of the head concave. Mouth small, oblique, lips broad and thin, lower lip smaller and broader than the upper. Mouth when protracted forms a tube directed upwards. Gape of mouth opposite middle level of the eye. Lower margin of lower jaw slightly concave and at right angles to the mouth slit. Teeth minute, numerous and in a villiform band. One small spine on head. Pre-opercle with its lower margin finely serrate. Lateral line convex from the beginning later runs less convex to the dorsal profile, often indistinct from the middle of the soft dorsal. Ventrals with axillary scales and do not reach even half way to the anals.

Caudal deeply incised, lobes pointed. Ventro-lateral lobes of light organs hypertrophied.

Color. Body silvery with about ten or so black or gray vertical bands on the back, extending to a little below the lateral line, anteriorly commencing below tip of the nuchal spine and posteriorly extending up to the end of the soft dorsal, and often the lines are in continuous patches. Membrane between the second and fifth dorsal spines black in the upper one third portion. A prominent curved black band running from lower margin of eye to beyond posterior angle of lower jaw. Abdomen silvery, dotted with black pigment dots. Pectoral axil dotted black.

Distribution. Along Goa, Cochin, Quilon, Gulf of Mannar, Palk Bay, Chilka lake, Porto Novo and Godavari estuary. Among these places it is more abundant at Visakhapatnam and Kakinada.

***Gazza* Rüppel, 1835**

(Type species *Gazza equulaeformis* Rüppell, 1835
= *Scomber minutus* Bloch, 1797)

12. *Gazza minuta* Bloch, 1797
(Plate II, Fig. 7; Tables 1–3)

Scomber minutus Bloch, 1797, S*ystema Ichthylogiae*, p. 110, tab. 429, fig. 2.

Material examined. 30 specimens of 83–123 mm
Description. D.VIII, 15–16; P. ii, 13–14, i–ii; V. I, 5; A. III, 13–14; C. 15; 57–59.
As percent of standard length: Total length 129.89–134.72 (131.59); fork length 113.24–117.81 (115.20); pre- dorsal 38.71–42.86 (40.32); preanal 49.25–54.95 (51.63); dorsal base 51.28–54.84 (53.22); anal base 39.08–44.44 (41.86); head 30.30–34.07 (31.87); dorsal height 15.15–20.83 (17.81); anal height 13.64–16.44 (15.05); pectoral 15.79–19.48 (17.55); depth 38.71–45.05 (42.00).
As percent of head length: Snout 23.81–29.17 (26.36); eye 33.33–40 (36.52); head height 84–100 (91.68).
Body oval, compressed and moderately deep. Dorsal and ventral profiles equally convex. Snout pointed.
Mouth large, lips thick and broad. Mouth when protracted forms a horizontal tube. Gape of mouth oblique and near the middle of eye. Mandible at an angle of about 45^{o} with the horizontal. A single series of small sharp teeth on the upper jaw, with a big and curved canine tooth on each side of the symphysis. In the lower jaw a series of curved pointed teeth are present, becoming larger anteriorly, with a pair of symphysial canines, with a notch between them to receive the upper canines. Pre-operculum with an obtuse angle, its lower margin finely serrated. Two small spines on top of the head immediately above the eye and opposite its front margin. Lateral line convex from the ori- gin and is parallel to the dorsal profile extending posteriorly, but getting obsolete near to the end of the soft dorsal fin. Ventrals with axillary scales. Tip of the ventrals not reaching the origin of anals. Caudal deeply forked. Ventro- lateral lobes of light organs hypertrophied.

Color. Silvery, back grayish, upper half of the body with grayish, irregular marks, or vertical wavy lines or faint irregular blotches, extending to below lateral line. Membrane of spinous dorsal, black at the edge. Snout mar- gin dotted black. Inner side of pectoral base with black dots. About seven grey irregular blotches along the lateral line. Front part of anal fin yellowish. Edge of the gill opening on the lower side, covered by the opercular flap also dotted black. A black narrow line along the base of the dorsal fin. Posterior edges of the caudal fin dusky. Black minute dots all over the ventral half of the body.

Distribution. Though it does not form a fishery by itself or dominate the catch at any particular locality, it con- tributes substantially to the silverbelly catch along both coasts of the country. It is distributed off Cochin, Cape Comorin, Quilon, Tuticorin, Pamban, Mandapam, Madras, Porto Novo, Visakhapatnam and Kakinada and especially abundant at Tuticorin, Pamban and Mandapam.

13. *Gazza achlamys* Jordan and Starks , 1917
(Plate II, Fig. 8; Tables 1–2)

Gazza achlamys Jordan & Starks, 1917, *Ann. Car. Mus.,* 11: 446, pl.45.

Material examined. 5 specimens of 82–110 mm
Description. D.VIII, 16; P. ii, 13, ii; V. I, 5; A. III, 14; C. 15. Ll. 59–61.
As percent of standard length: Total length 129.55–134.18 (131.70); fork length 115.12–120.25 (117.09); pre- dorsal 39.77–41.98 (40.64); preanal 50.62–52.33 (51.30); dorsal base 51.16–54.43 (52.33); anal base 39.77–44.30 (41.91); head 31.82–34.18; dorsal height 20.78; anal height 17.05–20.93 (19.18); pectoral 18.18–19.77 (18.73); depth 46.59–49.37 (47.71).
As percent of head length: Snout 24.00–28.57 (25.88); eye 35.71–39.29 (37.01); head height 95.59–100.00 (94.89).

Body oval, somewhat compressed and deep. Dorsal and ventral profiles equally convex. The dorsal profile shows a slight concavity over the front border of the eye. Snout pointed. Mouth large, lips broad and thick. Mouth when protracted forms a horizontal tube. Gape of mouth oblique and opposite the middle of the eye. Mandibles almost straight, ascending with an angle of about 50–60^{o}.
A band of small villiform teeth on each side and a pair of symphysial canines on the upper jaw, lower jaw having a series of teeth on the sides, getting bigger when going for- ward, with a pair of large canine teeth at the symphysis, with a gap between them to receive the upper canines. Two small supraorbital spines present opposite the front border of eye. Pre-operculum with its lower margin finely ser- rated. Lateral line convex from the origin and runs parallel to the dorsal profile extending posteriorly up to the base of the caudal fin. Ventrals with axillary scales and tip of the ventrals do not reach the origin of the anals. Caudal deeply forked. Ventro-lateral lobes of light organs hypertrophied.

Color. Body silvery, back grayish, with daVentrork irregular marks or circles, extending to little beyond lateral line, which often disappear on preservation. Membrane of the spinous dorsal black in its distal portion. Snout tip dotted gray. Edge of soft dorsal also gray. Inner side of the pectoral fin dotted black and dark pigment spots present along the edge of the ventral half of the gill opening, covered by the opercular flap. Caudal dusky at its posterior margin. Minute black dots all over the ventral half of the body.

Distribution. Very rare in Indian waters with only stray specimens reported. It is reported from the Great Nico- bar Island (Rani Singh and Talwar 1978b) and known to occur off southern India. It is reported from off Cochin for the first time in the present study.

GENERAL KEY TO LEIOGNATHIDAE

(1) Mouth protracts dorsally, extremely laterally compressed………………………………...2
(1b) Mouth protracts ventrally or anteriorly…………….…………………….………………..…3
(2) Dorsal flank pigmentation composed of about 10 vertical bars…………..…*Secutor ruconius*
(2b) Dorsal flank pigmentation composed of large spots and dashes……………*Secutor insidiator*
(3) Mouth with large caniniform teeth………………………………………….…………...…4
(3b) Mouth with small, inconspicuous teeth……………………………………………………5
(4) Elongate to rhomboid shaped (BD < 47 % of SL)…….……………………………*Gazza minuta*
(4b) Deep bodied (BD > 50% of SL).…...……….………………………………………*Gazza achlamys*
(5) Deep bodied (BD > 50% of SL)……………………………………………..……..…..9
(5b) Elongate bodied (BD < 45 % of SL)……..……………….…………………..…………….6
(6) Large lips, prominent black markings on dorsal fin……………………………*Karalla daura*
(6b) No black markings on dorsal fin…………………………………………….…………..…7
(7) Greenish-yellow tint to body with dark vertical vermiculate lines present on the dorsal flank ….……………………...…………..…………………*Karalla dussumieri*
(7b) No prominent vermiculate lines or greenish pigmentation……..………………………...8
(8) Prominent black nuchal marking……………………………………………*Nuchequula* sp.
(8b) Body silvery-white, males with a large trapezium or cornucopia shaped translucent patch ……………………………………..…………..…*Equulites laterofenestra*

(9) Large adult body size (typically reaching >120 mm SL)…………..…………………..…....10
(9b) Small adult body size (typically less than 100 mm SL)………..………………………..12
(10) No broad yellow markings on dorsal flank…………..………………....*Leiognathus equulus*
(10b) Prominent yellow vertical lines present on dorsal flank, markedly long dorsal fin spine…11
(11) Large nuchal hump, broad unbroken yellow bands on dorsal flank……………*L. striatus*
(11b) Broad yellow bands become rounded dashes along the midline……. *Aurigequula fasciata*
(12) Dorsal-fin membrane with bright orange pigmentation…………....*Photopectoralis bindus*
(12b) Dorsal-fin membrane with black pigmentation, lateral line scales yellow-orange ....*Equulites splendens*

(Adapted from Chakraborty et al., (2008))

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CHAPTER 20

Taxonomy Identification of Pigfacebreams

Pigface breams belong to the family Lethrinidae. They are tropical marine perciforms found entirely in the Indo-Pacific, except one species that occurs only in the eastern Atlantic. They belong to the suborder Percoidei, a diverse group containing many families whose relationships are poorly understood. Lethrinids are included under the superfamily Sparoidea, which also contains the families Sparidae (porgies), Centracanthidae and Nemipteridae (threadfin bream). Among percoids, sparoicis appear most closely related to the Lutjanoidea (includes the snappers or Lutjanidae and, fusiliers or Caesionidae) and the Haemuloidea (includes the grunts or Haemulidae and Inermiidae). There has been much confusion concerning the familial allocation of the genera and species amongst these groups.

Pigface breams or emperor breams are mostly reef fishes but their preferred habitat is sandy or rubble substrate. The reefs which they frequent can be shallow, coralline reefs or deep, rocky reefs. One species frequents the outer edges of the continental shelf and is caught to depths of 200 m. Lethrinids can be solitary or schooling and do not appear to be territorial. They often form large aggregations while spawning

Lethrinids are bottom-feeding, carnivorous, coastal fishes, ranging primarily on or near reefs. They generally possess large, strong jaws and food preference is correlated with the type of lateral jaw teeth and to a certain extent, the length and angle of the snout found in a particular species. For example, the humpnose big-eye bream, *Monotaxis grandoculis*, has large, well-developed molars, and a short, blunt snout. It consumes molluscs, sea urchins and other hard-shell invertebrates. At the other extreme, the longface emperor, *Lethrinus olivaceus*, has conical lateral teeth, and an elongate, gradually sloping snout. It feeds mainly on fishes and crustaceans. Between these extremes, species exhibit many intermediate lateral teeth types, from molar through rounded to conical, and snout shape also varies widely. Diet concomitantly varies between the extremes from primarily hard-shell invertebrates, to soft-shell invertebrates,

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to fishes, with combinations of these food items found in many species. There is also a great deal of selectivity for particular food items.

The problems previously encountered in identification of lethrinids are primarily due to the fact that many of the characters traditionally used to differentiate fishes are relatively constant among certain species of lethrinids. When they are live or still fresh, colour can be very helpful for species determination. Body colours and markings also add to the confusion because they can change substantially according to the time of day, the emotional state of the fish, geographic locality, and state of freshness. Despite these problems, previous researchers have contributed to our understanding of the taxonomy of lethrinids and have revealed a number of characters that help differentiate species. For example, Sato (1978) found that the pattern of dark pigment cells, or melanophores, on the membranes of the pelvic fin, help differentiate some species which were previously difficult to separate.

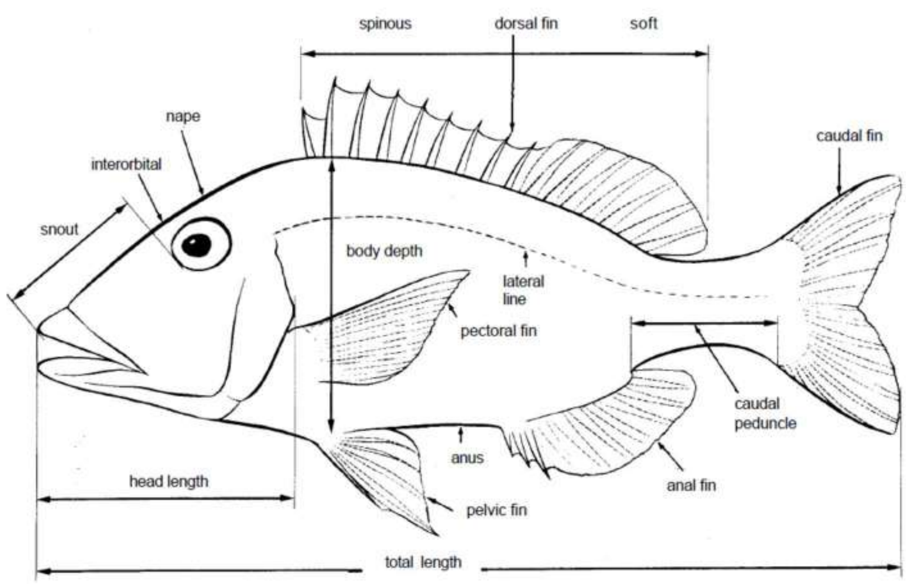
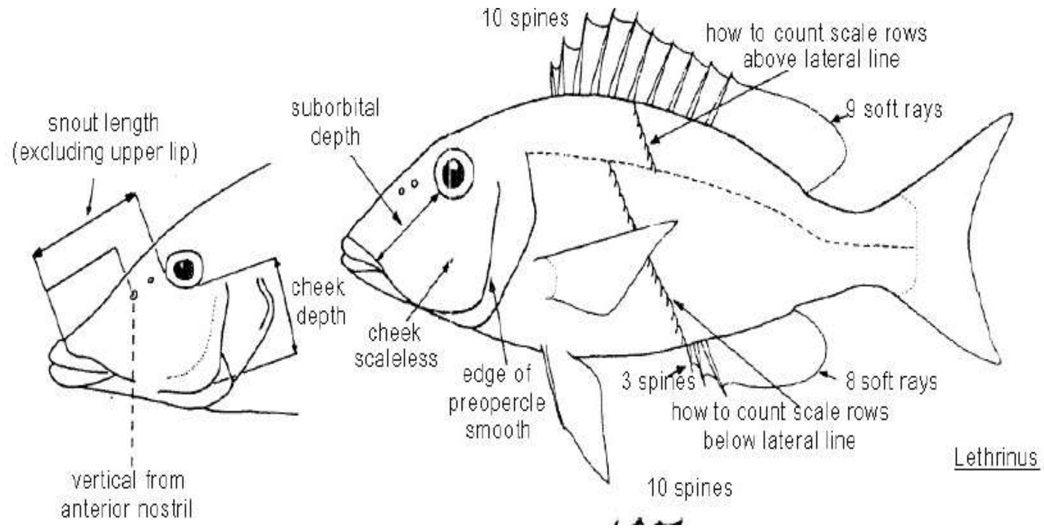
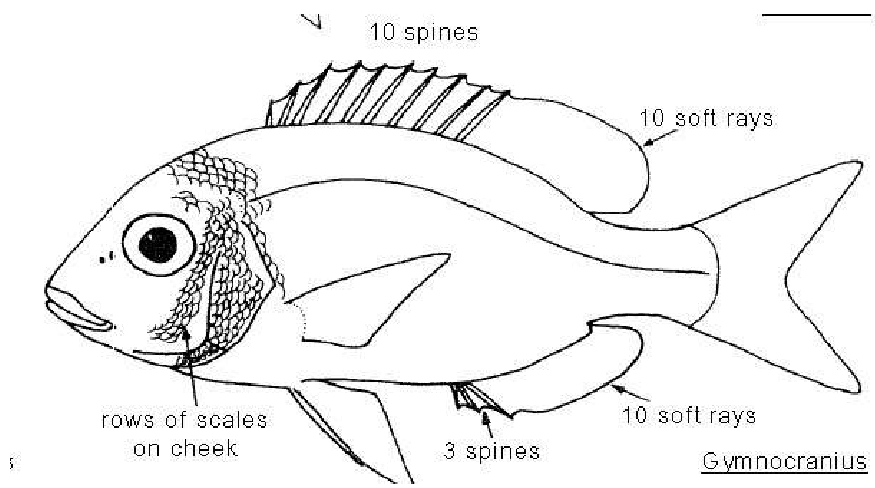


Fig. 1. External morphology measurements of Lethrinids

General characteristics of Lethrinidae

- Perch-like fishes with a large head: lips often thick and Fleshy; maxilla concealed, without supplementary bone, mostly slipping below infraorbiital bones, but overlapping the premaxilla anteriorly;
- A single, continuous dorsal fin with 10 spines and 9 or 10 branched (soft) rays,
- Cheeks, upper surface of head and preorbital area scaleless in *Lethrinus*, but scales present on cheek in the other genera.





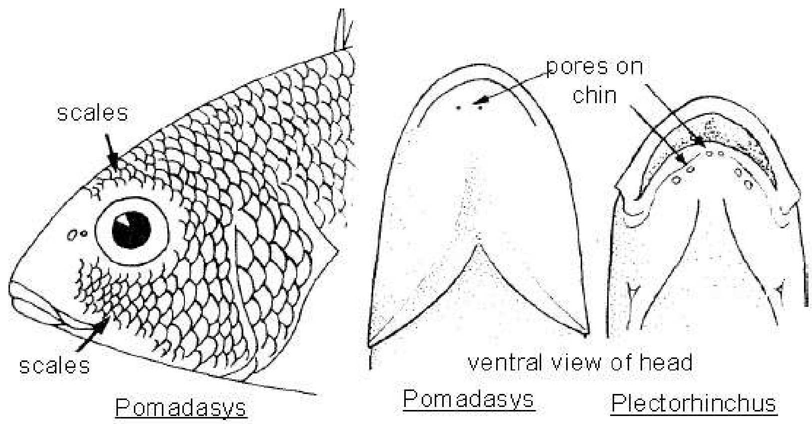
Similar families existing in the area

Lutjanidae (Lutjanus)

- cheek always scaled (naked in Lethrinus)
- a preopercular notch and an interopercular knob often present;

Haemulidae

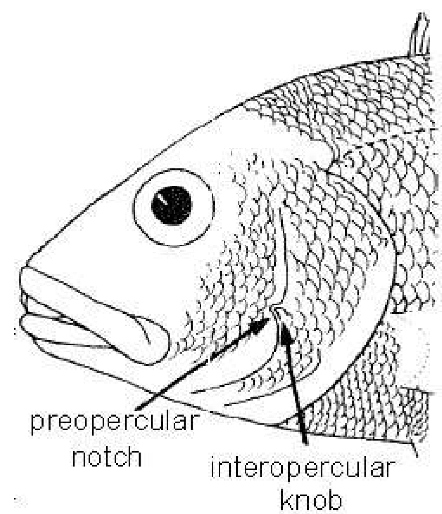
- scales always present between eye and
- mouth (absent in that area in Lethrinidae); 2 or
- more pores present on chin;

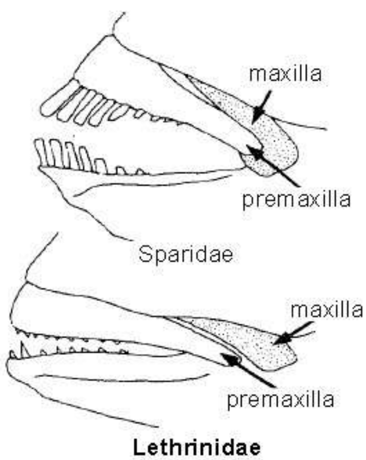


Haemulidae

Sparidae:

- posterior tip of premaxilla overlapping
- maxilla at hind end of mouth (maxilla overlapping
- premaxilla in Lethrinidae); usually more
- than 10 dorsal fin spines





Key to the identification of major species of lethrinidae

1a. Cheek with 4 to 6 vertical rows of scales; 10 soft rays in dorsal fin; 9 or 10 soft rays in anal fin

2a. 9 soft rays in anal fin
Profile of head in front of eye strongly convex (Fig.2); pectoral fin with 14 soft rays, inner surface of pectoral fin base scaled. No longitudinal stripes on body --------- *Monotaxis grandoculis*

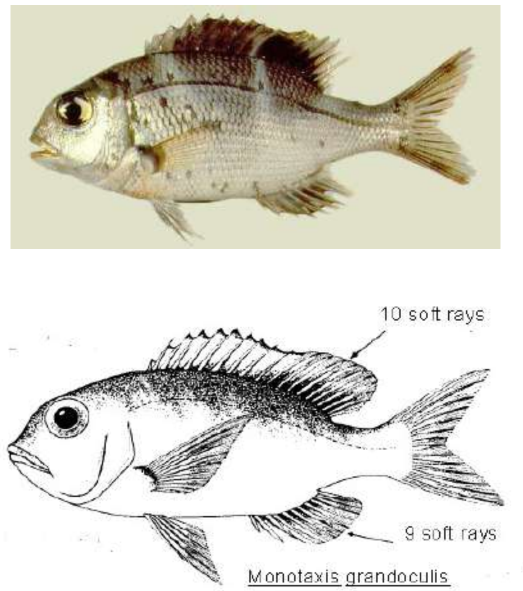


Fig. 2. *Monotaxis grandoculis (Photo courtesy* http://www.fishbase.org.)

Profile of head in front of eye slightly convex or straight; pectoral fin with 15 soft rays; inner surface of pectoral fin base scaleless . yellow longitudinal stripes on body (Fig. 3) ……………………………………………………………………… *Gnathodentex aurolineatus*

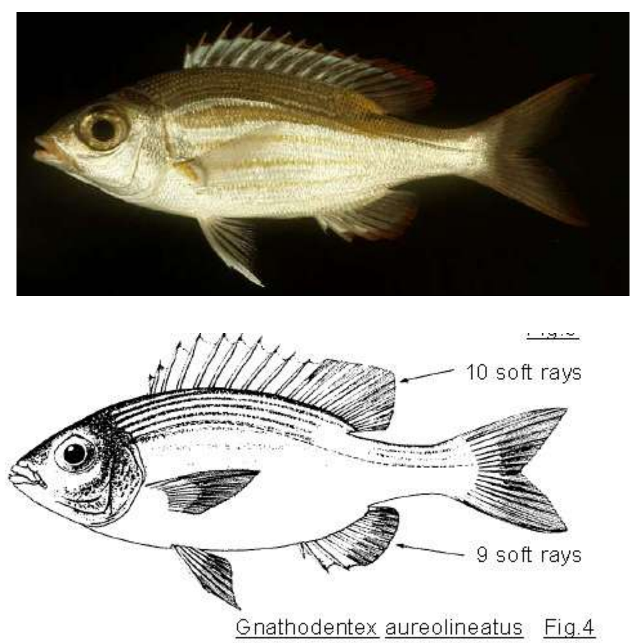
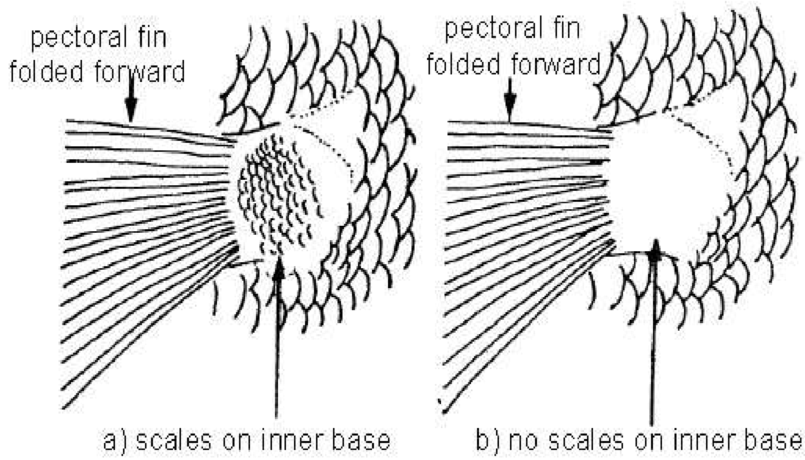


Fig. 3. *Gnathodentex aurolineatus* (Photo courtesy Randall, 1997)



2b. 10 soft rays in anal fin
4a. Maxilla with a strong denticulated longitudinal ridge. caudal fin lobes rounded; body 2.2 times or less in standard length (Fig. 4) .... *Wattsia mossambica*

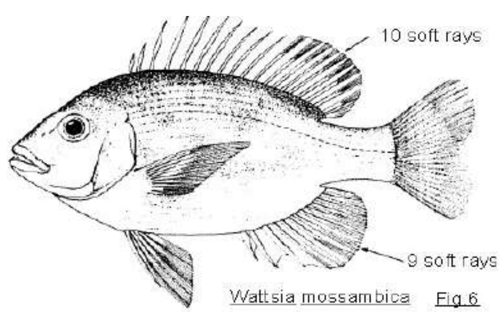
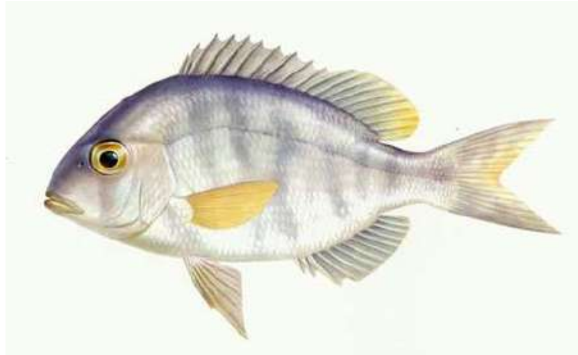


Fig. 4. *Wattsia mossambica (Photo courtesy* Randall, 1997)

4b. Maxilla surface smooth; caudal fin lobes pointed; body not as deep, 2.3 to 2.8 times in standard length (adults) 5a. Anal-fin base 2.1 to 2.5 times longer than longest soft anal-fin ray; no wavy blue lines on cheek, snout or opercle (Fig.5) .... *Gymnocranius griseus*



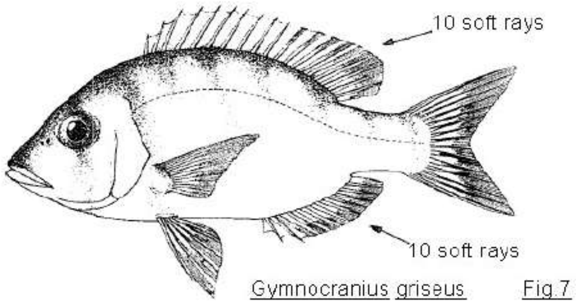
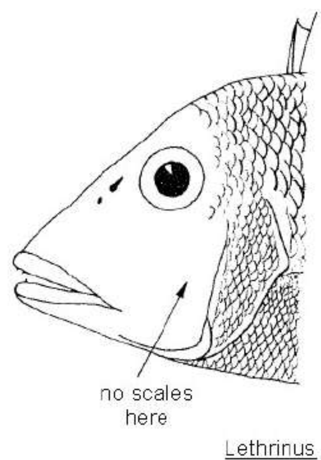


Fig.5. *Gymnocranius griseus* (Photo courtesy http://www.fishbase.org.)

1b. Cheek naked; 9 soft rays in dorsal fin; 8 soft rays in anal fin
6a. Snout and head elongate; body depth less than head length, inner surface of pectoral fin base scaleless,



7a. Upper margin of eye almost on dorsal profile; interorbital space concave, flat or only slightly convex
8a. No red coloration to opercle or pectoral fin base
9a. Posterior nostrils much closer to anterior nostril than to anterior margins of eye..... *Lethrinus variegatus*
9b. Posterior nostril about halfway between anterior nostril and anterior margin of eye ....….. *Lethrinus semicinctus*
8b. Bright red coloration to opercle and/or pectoral fin base
10a. One or 2 red spots on pectoral fin base; opercular margin red (Fig.6) ....… *Lethrinus xanthochilus*

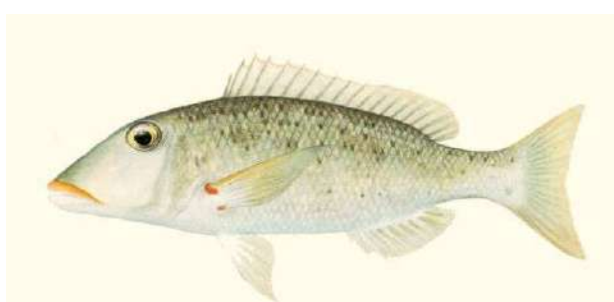


Fig. 6. *Lethrinus xanthochilus (Photo courtesy* FAO, 1989)
10b. No red spot on pectoral fin base; a conspicuous red spot on opercular edge (Fig.7) ....….. *Lethrinus rubrioperculatus*

Fig.7. Spotcheek emperor *Lethrinus rubrioperculatus*

7b. Upper margin of eye well separated from dorsal profile; interorbital space moderately to strongly convex
11a. No red coloration present; oblique bluish lines from eye to snout tip, and a few broken streaks connecting eyes on top of head (Fig. 8)....…….. *Lethrinus microdon (L elongatus)*

Fig. 8. Smalltooth emperor, *Lethrinus microdon (L elongatus)* (Photo courtesy Randall, 1997)

11b. Red coloration present on lips, pectoral fin base or opercular edge
12a. A single, bright red blotch above pectoral fin base; opercular edge and pectoral fir, base also red; lips large arid bright red; profile of snout concave, snout bulbous (Fig. 9) .... *Lethrinus conchyliatus*

Fig. 9. Redaxil emperor, *Lethrinus conchyliatus* (Photo courtesy FAO, 1989)
12b. No red coloration on and above pectoral firs base or opercular edge; a red line sometimes present above and below lips; often 2 or 3 blackish streaks radiating from eye; profile of snout straight.............. *Lethrinus elongatus (L microdon)*

6b. Snout not elongate; body depth greater than head length

13a. A characteristic series of bright blue lines radiating across cheek from eye; centres of scales with white spots; often longitudinal yellowish streaks on body (Fig.10) .. .. *Lethrinus nebulosus*

13b. No blue radiating lines on head 14a. A persistent, oblong blotch present or, sides, usually encircled with a golden rim (Fig.11)

Fig. 10. Spangled emperor, *Lethrinus nebulosus (Photo courtesy* Randall, 1997)

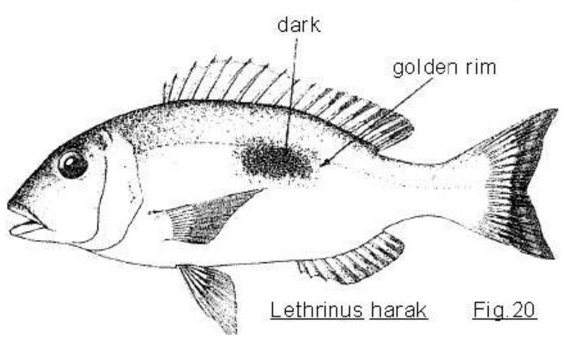


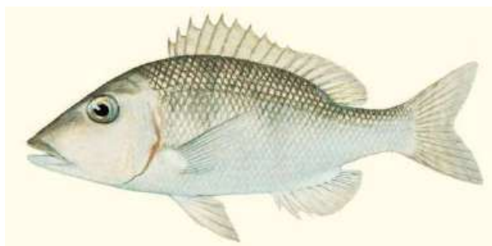
Fig. 11. Thumbprint emperor, *Lethrinus harak (Photo courtesy* Randall, 1997)

14b. No obvious large dark blotch present on sides of body

15a. Small orange spots on sides of head (Fig.12) ....*Lethrinus kallopterus* (*Lethrinus erythracanthus*)

Fig. 12. Orange-spotted emperor, *Lethrinus kallopterus* *(Photo courtesy* Randall, 1997)

15b. No orange spots on head 18a. red spot on opercular margin and on pectoral fin base; no conspicuous yellow stripes on body (Fig. 13) .... *Lethrinus lentjan*



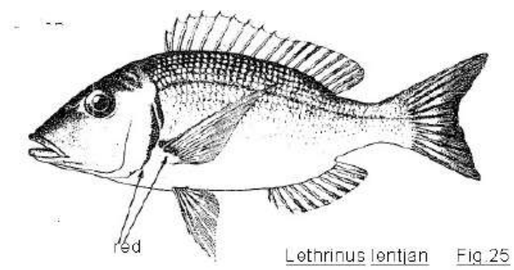


Fig. 13. *Lethrinus lentjan* (Photo courtesy FAO, 1989)

17b. Snout length (excluding upper lip) equal to, or less than cheek depth (Fig.24b)

19a. Several prominent bright orange stripes present on body; opercular and preopercular margins bright red (Fig.14) .... *Lethrinus ornatus*

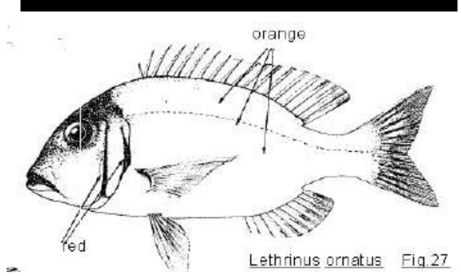


Fig. 14. Ornate emperor, *Lethrinus ornatus (Photo courtesy* Randall, 1997)

19b. No bright orange stripes on body; no red colour on preopercle

20a. Six scale rows between lateral line and median dorsal fin spines .... *Lethrinus mahsenoides (L. lentjan)*

20b. Less than 6 scale rows between lateral line and median dorsal fin spines; opercular margin not red

21a. Four scale rows between lateral line and median dorsal fir, spines (excluding the very small scales at base of dorsal fin) (Fig.15).......…………………... *Lethrinus mahsena*

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Fig. 15. Sky emperor *Lethrinus mahsena (Photo courtesy* FAO, 1989)

21b. Five scale rows between lateral line and median dorsal fin spires (excluding the very small scales at base of dorsal fin) (Fig. 16) ....……..... *Lethrinus crocineus*

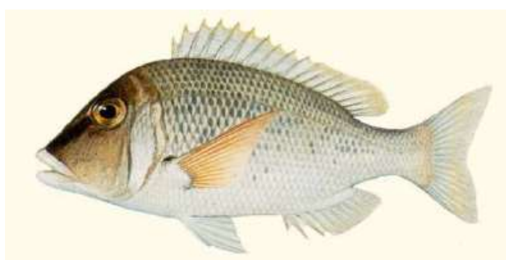


Fig.16 . Yellowtail emperor, *Lethrinus crocineus (Photo courtesy* FAO, 1989)

CHAPTER 21

Identification of Groupers and Snappers Available in Indian Waters

Family Serranidae - Sea basses

Sea basses are mostly marine in habitat with widespread occurrence from tropical and temperate seas. Fishes are characterised by an opercle with three spines with the main spine in centre and one each above and below. Body scales are generally ctenoid with cycloid scales also reported. Lateral line is continuous, not extending onto caudal fin. Single continuous dorsal fin, in some with notches, 7- 13 spines. Anal fin with 3 spines; caudal fin usually rounded, truncate, or lunate. Tip of maxilla exposed, pelvic fin with one spine and five soft rays; seven branchiostegal rays usually present. Colour patterns are helpful for identification of species, but variations are common based on ground of capture. Colour changes have also been noticed when the fish are brought to the shore. Red List assessments show that 20 species (12%) risk extinction if current trends continue, and an additional 22 species (13%) are considered to be Near Threatened.

Three subfamilies Serraninae, Anthinae and Epinephelinae are recognized worldwide with about 64 genera and 529 species (Fraser and Pauly online).

Family Serranidae - Sea basses

Subfamily Serraninae

Synchronous hermaphroditism, with both sexes functional at the same time in a single individual, is characteristic of most species in the Subfamily Serraninae. Although these synchronous hermaphrodites can fertilize their own eggs, they normally spawn in pairs and alternate the release of eggs or sperm in order to have their eggs fertilized by the other fish.

The subfamily includes 13 genera *Acanthistius,* *Bullisichthys, Centropristis, Chelidoperca, Cratinus, Diplectrum,* *Dules,* *Hypoplectrus*, *Paralabrax, Parasphyraenops, Schultzea, Serraniculus* and *Serranus* with 86 valid species.

Subfamily Anthinae

Includes around 21 genera, *Acanthistius, Anthias, Caesioperca, Caprodon*, *Epinephelides, Giganthias, Hemanthias, Holanthias, Hypoplectrodes, Lepidoperca, Luzonichthys,*

Rekha J Nair, Vishnupriya K M, Sangeetha A T and Mahesh V *ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala*

Plectranthias, Pronotogrammus, Pseudanthias, Rabaulichthys, Sacura, Serranocirrhitus, Stigmatonotus, Tosana, Tosanoides, and Trachypoma, with about 214 species and is mostly being Indo-West Pacific in distribution.

Subfamily Epinephelinae

The tribe Epinephelini is one of the most speciose percoid assemblages, with hypothesized monophyly comprising 167 species.

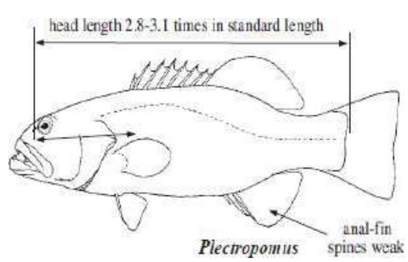
The subfamily includes around 30 genera *Aethaloperca, Alphestes, Anyperodon, Cephalopholis, Cromileptes, Dermatolepis, Epinephelus, Gonioplectrus, Gracilia, Mycteroperca, Paranthias, Plectropomus, Saloptia, Triso, Variola, Aulacocephalus, Belonoperca, Diploprion, Bathyanthias, Liopropoma, Rainfordia, Aporops, Grammistops, Jeboehlkia, Pogonoperca, Pseudogramma, Rypticus, Suttonia* and *Niphon.*

Key to the genera of Serranidae

Less than 1/2 of upper border of opercle joined to body by skin; dorsal-fin spines VIIto XI .... (tribe Epinephelini)- **1a**

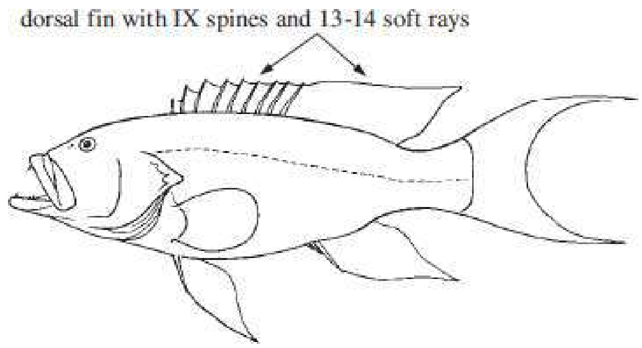
1a. Dorsal-fin spines VII or VIII; lower edge of preopercle with 1 to 3 enlarged spines (usually hidden by skin, but these spines can be detected by running a finger or probe along preopercle edge).
Anal-fin spines weak, the first and second covered by skin; preorbital depth 0.7 to2 times eye diameter; head length 2.8 to 3.1 times in standard length . . . .
Plectropomus

1b. Dorsal-fin spines IX to XI; lower edge of preopercle smooth except for a few species of *Epinephelus* with 1 to 4 enlarged serrae...................................... **2**



Plectropomus areolatus

2a. Caudal fin deeply lunate or forked; dorsal-fin spines IX.........***Variola***



2b. Caudal fin rounded, truncate, or concave; dorsal-fin spines 9-11 .... **3**

3a. No teeth on palatines; body and head elongate and markedly compressed, the greatest body width 11 to 15% of standard length and more than 3 times in head length …… ***Anyperodon leucogrammicus***

3b. Palatines with teeth; body compressed in some species, but its width only 1.8 to 3times in head length.. **4**

4a. Dorsal profile of head markedly concave; dorsal-fin spines X; rear nostrils of adults a long vertical slit . .
. . . . . . ***Cromileptes altivelis***

4b. Dorsal profile of head straight, convex or slightly concave; dorsal-fin spines IX orXI. **5**

5a. Pectoral fins distinctly asymmetric, the fifth or sixth rays longest; dorsal fin with IX spines and 17 or18 soft rays; caudal fin truncate . .
. . . . ***Aethaloperca rogaa***

5b. Pectoral fins symmetric or nearly so, the middle rays longest; dorsal fin with IX toXI spines and 12 to 21 soft rays; caudal fin rounded, truncate, or emarginate
....
18

6a**.** Dorsal-fin spines 9 .... ***19***

6b**.** Dorsal-fin spines 11 .... ***20***

19a**.** Caudal fin rounded; dorsal-fin membranes distinctly incised between spines. . . . . ***Cephalopholis***

19b. Body depth 2.4 to 4.1 times in standard length, usually less than head length; dorsal fin with XI spines and 12 to 19 soft rays, the base of soft-rayed part shorter than or equal to that of spinous part............***Epinephelus***

Key to the species of *Cephalopholis* occurring in the area

1. Caudal fin rounded; head length 2.2 to 2.7 times in standard length; colour patternnot of alternating stripes of blue and orange-yellow.. ***2***

2a. Anal-fin rays usually 8; colour generally brown to dark brown **3**

2b. Anal-fin rays 9 (rarely 10); colour generally red, orange, or yellow...........**8**

3a. Small dark spots or dark-edged pale blue spots on head and/or body **4**

3b. No small dark spots or blue ocelli on head or body.............**5**

4a. Dorsal-fin rays 15 to 17; lateral scale series 92 to 106; pectoral-fin length 1.5 to 1.8 times in head length; blue ocelli on head, body, and basally on median fins; juveniles greenish grey, the median fins yellow……………***Cephalopholis cyanostigma***

4b. Pectoral fins short, their length 1.5 to 1.8 times in head length; colour generally brown or yellowish brown, with dark blue lines on head, body, and fins; black spot between upper. 2 opercular spines .....***Cephalopholis formosa***

5a. Body brown, with 7 to 8 more or less distinct dark bars; fins dark brown, with paleblue line caudal fin corner.... ***Cephalopholis boenak***

5b. Dorsal-fin rays 15 to 17; lower limb of first gill arch with 17 to 19 gill rakers; colour dark brown, covered with small dark-edged blue ocelli; 6 pale bars often visible onrear half of body ***Cephalopholis argus***

6. Dorsal-fin rays usually 14 or 15; lower limb of first gill arch with 13 to 16 gillrakers; no auxiliary scales on body scales; colour not as above . **7**

7a. Lateral-line scales 66 to 80 colour generally red to reddish brown with widely scattered whitish blotches (Indian Ocean) or generally brownish, covered withsmall dark red to reddish brown spots and irregular white blotches. . . . . . ………………………………………………***Cephalopholis sonnerati***

7b. Lateral-line scales 45 to 68; colour not as above............**8**

8a. Lateral-line scales 54 to 68; caudal fin blackish red, with red pectoral fins. . . . . . . **…………………………………………………*Cephalopholis urodeta***

8b. Lateral-line scales 45 to 56; colour not as above.............**9**

9a. Lateral scale series 79 to 90; head length 2.2 to 2.4 times in standard length; dark brown saddle spot on caudal peduncle, followed by a smaller spot; submarginal dark streak at corners of caudal fin............ ***Cephalopholis leopardus***

11b. Lateral scale series 90 to 121; head length 2.3 to 2.6 times in standard length; colour not as above **12**

12a. Head, body, and fins covered with small blue ocelli **13**

12b. No blue spots on head, body, or fins............ **14**

13a. Body with 4 or 5 dark blotches along base of dorsal fin, a faint blotch on nape and 2 smaller ones on peduncle (blotches sometimes merging with or being replaced by dark red vertical bars); most specimens with dark-edged blue lines radiating from eyes............ ***Cephalopholis sexmaculata***

13b. No dark blotches on body or blue lines radiating from eyes . . . .***Cephalopholis miniata***

14a. Edge of subopercle and interopercle distinctly serrate; pelvic fins usually reaching anus, their length 1.6 to 2 times in head length; colour generally orange-yellow toorange-red or golden, with red to orange dots on head and dorsally on body . . . ………………………………………Ce***phalopholis aurantia***

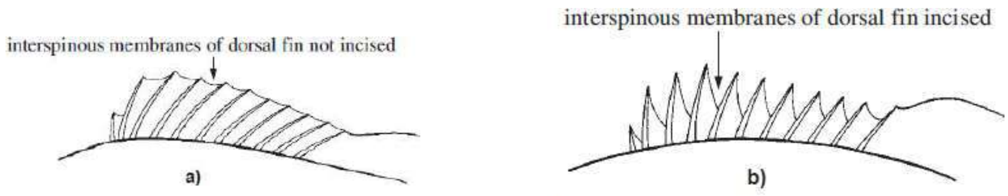
Key to the species of *Epinephelus* occurring in Indian waters

1a**.** Caudal fin of adults emarginate to truncate (slightly rounded on some *E. bleekeri* and juveniles, and convex if broadly spread in adults) ***2***

1b**.** Caudal fin rounded (truncate on some *E. fasciatus* from Oceania) ***12***

2a**.** Interspinous membranes of dorsal fin not incised............ ***3***

2b**.** Interspinous membranes of dorsal fin incised ***6***



3a. Gill rakers elongate, no rudiments, 20 to 23 rakers on lower limb of first gill arch; dorsal-fin rays 17 to 19; colour purplish to brownish grey with yellowish brown dots on head and longitudinal brown lines on dorsal part of body (lines usually lost on large adults)........... ***Epinephelus undulosus***

3b. Gill rakers not elongate and rudiments often present, 13 to 18 rakers on lower limb of first gill arch; dorsal-fin rays 15 to 17; colour not as above ***4***

4a. Second dorsal-fin spine of adults elongated, its length 1.8 to 2.4 times in head length; total gill rakers on first gill arch 20 to 23; body depth 2.7 to 3.2 times in standard length; body reddish brown with a white dot on each scale; broad dark red margin on spinous portion of dorsal fin.............***Epinephelus irroratus***

4b. Second dorsal-fin spine not elongate (third or fourth spines longest); total gill rakers on first gill arch 24 to 28; body depth 2.3 to 2.9 times in standard length ***5***

5a. Body dark purplish grey with scattered irregular whitish blotches; body depth 2.6to 2.9 times in standard length........***Epinephelus multinotatus***

5b. Head, body, and fins bluish grey with numerous blackish dots; large adults with scattered irregular blackish spots and blotches, most smaller than pupil; body depth 2.4 to 2.7 times in standard length .... ***Epinephelus cyanopodus***

6a. Lateral-line scales 48 to 54; head and at least front of body with small spots, either yellow (pale in preservative) or brown ***7***

6b. Lateral-line scales 56 to 76; spots on head and body dark brown or absent.........***10***

7a. Caudal fin truncate to slightly rounded; body depth 3.0 to 3.5 times in standard length; head, body, dorsal fin, and upper third of caudal fin with small orange-yellow spots, the lower two-thirds of caudal fin dark grey; anal and paired fins dusky, without spots .... ***Epinephelus bleekeri***

7b. Caudal fin slightly emarginate (truncate on some *E. chlorostigma*); body depth 2.7 to 3.4 times in standard length; spots on head, body, and fins yellow or yellowish brown to dark brown; anal fin with spots ***8***

8b. Head, body, and fins covered with small, close-set, yellowish brown to dark brown spots (dark in preservative). ***9***

9a. Dorsal-fin rays 15 to 17; anal fin of adults rounded to slightly angular, the longest soft ray 2.0 to 2.6 times in head length; 14 to 16 gill rakers on lower limb of first gill arch; pyloric caeca 11 to 17; dark spots on body of adults about equal to pupil . . . .***Epinephelus areolatus***

9b. Dorsal-fin rays 16 to 18; anal fin of adults angular or pointed, the longest soft ray 1.9 to 2.3 times in head length; 15 to 18 gill rakers on lower limb of first gill arch; pyloric caeca 26 to 52; dark spots on body of adults distinctly smaller than pupil . . . .***Epinephelus chlorostigma***

12a. Anal-fin rays 9 (rarely 10); body with 5 dark bars below dorsal fin, the last 2 bars as broad as preceding bars; 2 pale interspaces below soft dorsal fin . . . .
Epinephelus octofasciatus
12b. Anal-fin rays 8 (rarely 7 or 9); colour not as above.......... ***13***

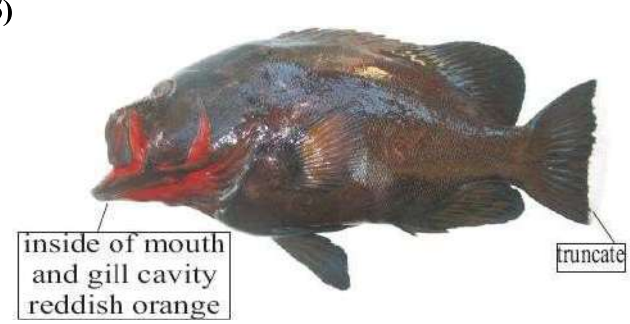
13. Lateral-line scales 56 to 65; lateral body scales smooth; rear nostrils and anterior nostrils subequal; juveniles with 2 broad, longitudinal, black-edged whitish bands that disappear in adults, the dark edges breaking into dashes and spots, which may be lost in large adults ....***Epinephelus latifasciatus***

14. Lateral-line scales with branched tubules; eye small, its diameter about 1/8 head length for specimens of 20 cm length, about 1/9 head length at 35 cm, and 1/13 head length at 145 cm standard length; interorbital wide, the width more than 1/5 head length for specimens of 23 to 153 cm standard length; maximum length about 270 cm; juveniles yellow, with 3 broad black bars on body and irregular black bands on head............***Epinephelus lanceolatus***

Some common species

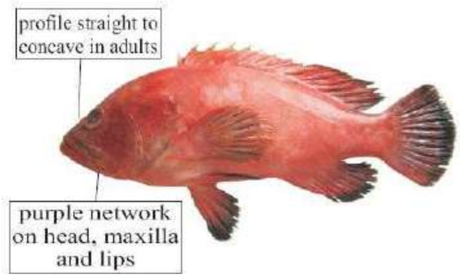
Aethaloperca rogaa **(Forsskal, 1775)**

Redmouth grouper



D IX, 17; A III, 8; P 17-18; V I, 5.
Body rounded its depth greater than head length; mouth slightly superior; dorsal profile of head steeply sloped; small hump on nape; pre-operculum finely serrated; operculum with 3 undeveloped spines; pelvic fins equal to pectorals, reaching the level of anus or beyond; caudal fin truncate.
Body uniformly dark brown to black; reddish inside the mouth, gill cavity and upper jaw membrane; soft-rayed part of dorsal fin and caudal fin margin white white.

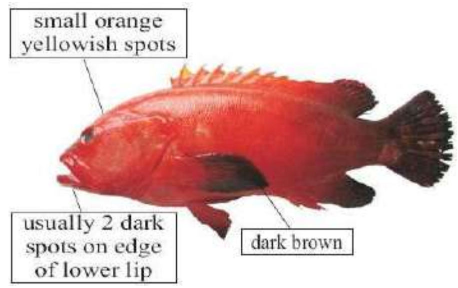
***Cephalopholis sonnerati* (Valenciennes, 1828)**



Tomato hind

D IX, 15; A III, 9; P 17-18; V I, 5; Gr 14 to 16. Body depth, greater than or equal to head length; dorsal profile of head near eye and nape strongly convex; mouth small, slightly superior; maxilla reaches posterior of eye; pre-operculum rounded; **operculum spines very small, poorly developed**; Body bright orange to red, with scattered bluish-white spots; head purplish to red with numerous close-set orange-red spots; opercular flaps dark reddish; all fins reddish, the membranes of soft dorsal, caudal, anal, pectoral and pelvic fins dark red to dusky.

Cephalopholis urodeta



Similar to *C. sonnerati*, but differs in the absence of the reticulate pattern in *C. sonnerati*

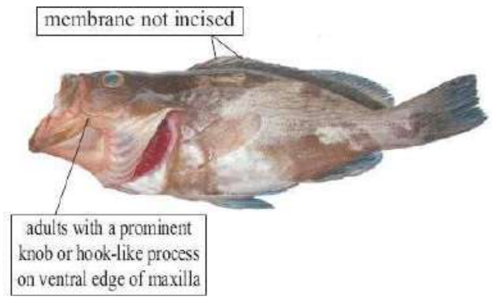
***Epinephelus polyphekadion* (Bleeker 1849)**

Camouflage grouper

D XI, 15; A III, 8; P 16; V I, 5; LL 47 to 52; Gr (8-10) + (15-17).

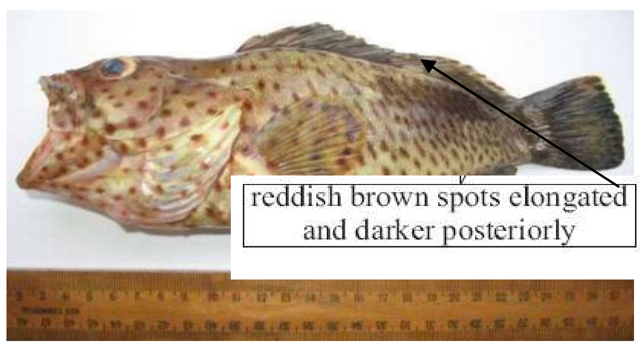
Dorsal profile of head evenly convex; maxilla reaches rear edge of eye; pre operculum rounded, the serrae at corner slightly enlarged; two undeveloped spines in operculum; inter spinous membranes moderately incised; caudal fin rounded; body scales ctenoid. Body pale brownish covered with numerous small dark brown spots; some irregular dark blotches superimposed with the spots scattered in head and body; **a prominent black blotch on caudal peduncle**; dark spots extend all over head, including lower jaw, lips and inside of mouth; numerous small white spots on fins and a few on head and body.

***Epinephelus undulosus* (Quoy & Gaimard 1824)**
Wavy-lined grouper
D XI, 20; A III, 8; P 18; V I, 5; LL 70 to 75.



Eyes small; mouth superior to slightly protractile; pre-operculum highly serrated at the angle; operculum notched with 2 undeveloped spines; **dorsal fin membrane not notched** between the spines; body scales ctenoid, except on belly; caudal fin truncate to slightly concave. Body generally brownish to purplish grey, usually with golden brown to yellowish spots on head and upper body, which becomes wavy longitudinal lines in mid body; median fins and pelvic fin black to brown in base and bluish in the tip; preserved specimen becomes brownish with dark spots and lines.

***Epinephelus longispinis* (Kner 1864)**
Longspine grouper
D XI, 16; A III, 8; P 18; V I, 5; LL 49 to 53; Gr (8 to 11) + (15 to 17).



Body deep, upper edge of operculum straight or slightly convex, with 3 undeveloped spines; the third or fourth spine longest, its length contained 2.1 to 2.6 times in head length; caudal fin rounded, convex. Body pale to brownish and grey laterally; reddish to dark brown spots all over the body, which is round in head and slightly elongated in sides; some dark spots or blotches at dorsal fin base; median and paired fins with dark brown spots; tip of the fins slightly yellowish; preserved specimen becomes brownish with dark spots.

***Plectropomus leopardus* (Lacepede 1802)**
Leopard coral grouper
D VII, 12; A III, 8; P 16; V I, 5; LL 89 to 99; Gr (1-3) + (6-10).

Body elongate, robust; Head comparatively small, 2.7 to 3.1 times in standard length; dorsal profile of the head slightly slopped, with a concave insertion near nape; eyes slightly prominent; mouth oblique, slightly superior;preoperculum rounded, with 3 large, spines along lower half; operculum with 3 flat spines, the upper and lower spines covered by skin;

pectoral fins subequal to pelvic fins; caudal peduncle broad; caudal fin emarginated.

Body brownish to orange-red, with numerous small dark-edged, blue spots on head and body (except ventrally) and fins; spots slightly elongated near mid body; pectoral fins reddish with darker rays; a indistinct dark band at rear margin of caudal fin.

***Variola albimarginata* (Baissac 1953)**
White-edged lyretail
D IX, 14; A III, 8; P 18; V I, 5; LL 120-130; Gr (7-9) + (13-16).
Body elongated, moderately deep; dorsal profile of head gently sloped; eyes small;mouth oblique, terminal; jaws with sharp canine teeth; maxilla reaches beyond the eye; pre-operculum finely serrate; operculum spinesnot well developed; soft rays tips of fins slightly elongated; caudal fin crescentic, the upper and lower rays elongate.

Brownish orange to reddish with numerous irregular, small whitish to pink or lavender spots to streaks; fins colour same as body except pectoral fin and caudal fin rear margin; rear margin of caudal fin dusky with a narrow white edge; pectorals yellowish; preserved specimens changes complete brownish white.

***Epinephelus coeruleopunctatus* (Bloch, 1790)**
White Spotted grouper
D XI, 15; A III, 8; P 18; V I, 5; LL 52-62; Gr 10+14-17.

Body moderately elongated; dorsal profile of the head nearly straight; head pointed; Body depth more or less equal to head length; pre-operculum rounded, serrated; eyes big, prominent; dorsal and anal fin soft rays, pectoral and caudal fins rounded.
Body brownish gray to black with numerous large white spots including fins; dark blotches below dorsal fin and caudal peduncle; prominent black streak on maxillary groove.
***Cephalophalis miniata* (Forsskål, 1775)**
Coral hind
D XI, 14; A III, 8; P 17; V I, 5; LL 47-56; Gr 7-9+14-16.

Body moderately deep; dorsal profile of the head straight, with convex above eye; maxilla big, crossing the rear edge of eye; eyes small; pre-operculum rounded; soft rays of dorsal and anal fin, pectoral and caudal fins rounded.

Body orange to reddish brown, with small blue spots all over the body including fins; Margin of soft rays of dorsal and anal and caudal fins bluish.

Anyperodon leucogrammicus **(Valenciennes, 1828)**
Slender grouper
D XI, 14; A III, 8; P 15; V I, 5; LL 61-72; Gr 7-9+14-17.

Body elongated, slightly compressed; head elongated, its length greater than body depth; dorsal profile of the head slightly slopped to straight; eyes moderate; mouth large terminal; pre-operculum slightly serrated, rounded; interfin membrane of soft rays transparent; soft rays of dorsal and anal fin, pectoral and caudal fins rounded. Body greenish brown to gray with numerous reddish spots including head and fins; spots in head small; 3 to 4 longitudinal white bands running from mouth to caudal peduncle.

Cephalopholis argus **(Schneider, 1801)**
Peacock hind
D XI, 16; A III, 9; P 16; V I, 5; LL 46-51; Gr 9-11+17-19.

Body deep; head big, its length 2.4 to 2.7 times in standard length; eyes small; mouth big, terminal to slightly superior;
maxilla extends beyond to the level of eye; pectoral fin fleshy; dorsal and anal fin soft rays, pectoral and caudal fins rounded. Body dark brown with numerous blue to white spots with dark margin; 5 to 6 pale vertical bars on the rear part of body; dorsal fin spines with orange margin; posterior margin of median fins darker with a narrow white tip; pectoral fin with dark brownish to purplish red posterior edge.

Cephalopholis formosa **(Shaw, 1812)**
Bluelined Hind
D IX, 18; A III, 8; P 15; V I, 5; LL 47-51; Gr 6+15.

Body moderately, deep; dorsal profile of the head slopped with convex inter-orbital; eyes small; maxilla ends at posterior end of the eye; dorsal and anal fin soft rays, pectoral and caudal finsrounded; body scales ctenoid.
Body dark yellowish brown, fins darker; wavy longitudinal blue lines all over body including head and fins; blue spots on the snout, lower part of head and thorax.

Epinephelus lanceolatus **(Bloch 1790)**
Giant grouper

D XI, 14; A III, 8; P 16; V I, 5; LL 46-51; Gr (9-11)+(17-19).

Body robust in adult and slightly deep in juveniles; dorsal profile of the head slightly convex; eyes small; mouth moderately big, terminal to superior; maxilla reaching rear edge of eye; pre-operculum finely serrated in edges; inter fin membrane of spines notched; soft rays of dorsaland anal fin, pectoral and caudal fins rounded. Body greyish yellow above,grayish white below and sides with numerous uneven black blotches all over the body; head darker; fins yellowish with black blotches; juveniles with 3 irregular black bars in body, large adults dark brown to grey.This is a protected species under Wild Life (Protection) act, 1972 of India.

Cephalopholis cyanostigma **(Valenciennes, 1828)**

Blue spotted hind

D IX, 15; A III, 8; P 15; V I, 5; LL 46 to 50; Gr 7-9+14-18

Body moderately compressed, deep; dorsal profile of head convex above eye; eyes small slightly projected; mouth large terminal to superior; maxilla vertically reaching the rear edge of the eye; pre-operculum rounded; body scales ctenoid; soft rays of the dorsal and anal fin, pectoral and caudal fin rounded.

Body brown to brownish red, head darker; with numerous black edgedbluish spots all over the body including fins; spots in head, chest and belly comparatively big with spots in fins and posterior body; sides with 4 to 5 dark chain like bars; median fins darker than body colour; pectoral fin darker or with black margin at the free tip.

Epinephelus ongus **(Bloch, 1790)**
White streaked grouper
D XI, 14; A III, 8; P 15; V I, 5; LL 48 to 53; Gr 8-10+15-18.
Body comparatively deep; dorsal profile of head steeply sloped, slightly convex aboveeye; eyes big projected; mouth moderately small; maxilla vertically reaching middle of

the eye; head slightly pointed; pre operculum rounded; soft rays of dorsal and anal fins, pectoral and caudal fin rounded. Body brownish with numerous small white spots all over the body which sometimes forms wavy lines; head darker with less white spots; median fins with small white spots, posterior margin darker with white tip; paired fins greyish brown.

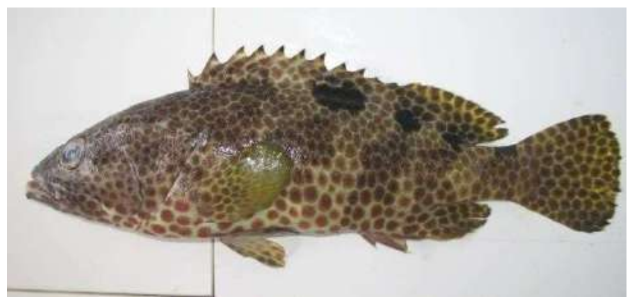
Epinephelus merra **(Bloch, 1793)**
Honeycomb grouper
D XI, 17; A III, 8; P 17; V I, 5.

Body robust, slightly compressed, elongated; mouth superior, large, maxilla exposed, slightly protractile; small, slender teeth on jaws, vomer and palatine; some small canines on front; eyes prominent; dorsal profile ofthe head sloped; pre-operculum serrated; one flat spine on operculum; small ctenoid scales; pectoral fin like an hand fan; caudal fin rounded.
Body grey above and lighter below; brown to black spots all over the body, hexagonal anteriorly, rounded posterior; fins rays of dorsal and caudal fin yellowish; pectoral and pelvic fins dark brown to black.

Epinephelus flavocaeruleus **(Lacepède, 1802)**
Blue-and-yellow grouper
D XI, 8; A III, 5; P 16; V I, 5; LL 61-74; GR (9-10) + (15-17)

Body deep; dorsal profile convex; eyes small, head length 2.5 in SL; BD 2.5 in SL; nostril top of the eye; mouth inferior;
teeth canine; operculum with undeveloped spines; pre-operculum serrated; interfin membrane of dorsal fin deeply notched; caudal fin truncate; caudal peduncle thick and short. In fresh condition body colour blackish with bright yellow dorsal, anal and caudal fins; outer tip of caudal blackish; in formalin preserved specimens fins are whitish; black tip of caudal fin is retained.

Epinephelus spilotoceps **(Schultz, 1953)**
Four saddle grouper
D XI,17;A III,8;P 17;I,5;LL 60-69;GR (7-8)+(15-18)



Body elongated; pre dorsal profile is slightly convex; eyes small; head length 2.5 in SL; BD 2.5 in SL; mouth inferior; maxillary ends at the middle of the eye; teeth canine; operculum with one developed pine; pre-operculum

serrated; pectoral fin origin in front of the pelvic fins; dorsal fin spinous interfin membrane deeplynotched; caudal fin truncate; caudal peduncle thick and short.
In fresh condition the body colour is yellowish brown with spot all over the body; in formalin preserved specimens the black spots are light black.

Epinephelus diacanthus **(Valenciennes, 1828)**
Thornycheek grouper
D XI, 15-17; A III, 8-9; P 18-20; VI, 5; Ll 105-120.

Body depth contained 2.8 to 3.2 times in standard length. Pre-opercle border forming nearly a right angle, with 1 to 3 enlarged serrae at the angle; sides of lower jaw with 2 rows of small subequal teeth; anterior nostrils tubular, with a large flap posteriorly extending over rear nostril; lower gillrakers 14 to 16. caudal fin rounded to almost truncate. Pored lateral line scales 53 to 60. Body generally buff, with 5 more or less distinct, vertical dark bars;

4 bars below dorsal fin and 5th on caudal peduncle. Ventral part of head and body reddish. Some specimens with a black streak across cheek at upper

edge of maxilla. Dark bars on body sometimes absent.

Epinephelus malabaricus **(Schneider, 1801)**

Malabar grouper

D XI, 14-16; A III, 8; P 18-20; VI, 5; Ll 98-114.

Body depth contained 3.0 to 3.6 times in standard length. Pre-opercle finely serrate,with a shallow notch, the serrae enlarged at the angle; rear nostrils not more than

twice the size of anterior nostrils; lower gillrakers 13 to 16; mid lateral part of lower jaw with 2 rows of teeth. Midlateral body scales distinctly ctenoid withminute auxiliary scales.

Head and body generally pale greyish brown covered with small orange, golden brown, or dark brown spots. Five more or less distinct, slightly oblique, irregular, broad, dark bars on body; these bars are darker dorsally and the last 3 are usually bifurcate ventrally; the first 4 bars usually continued onto the dorsal fin, the last bar covers most of the caudal peduncle; usually 3 dark blotches on interopercle, the first 2sometimes merging to one blotch; small, irregularly shaped and spaced, white spots visible on head and body of some fish; soft dorsal, caudal, anal and pectoral fins brownish-black with small dark spots on basal half of fins.

FIELD IDENTIFICATION OF SNAPPERS

Family Lutjanidae – SNAPPERS

Body deep, mouth large, protrusible, anterior part of head without scales; some rowsof scales on cheek, pre-opercle and on gill cover.

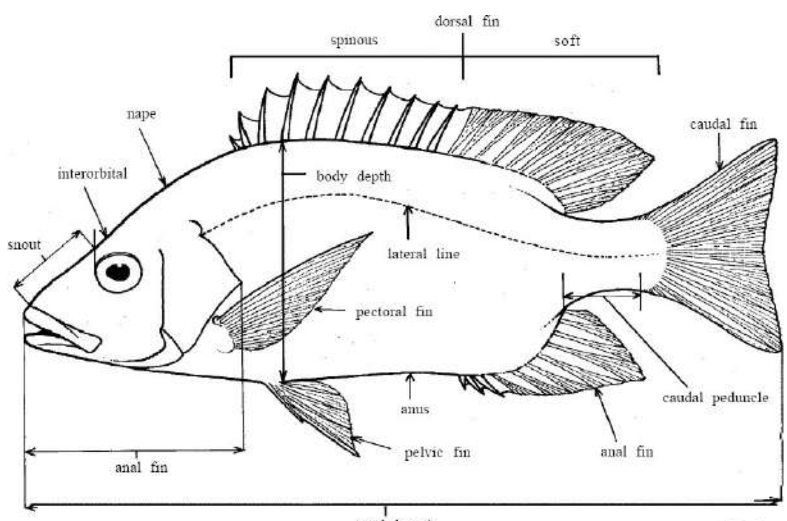
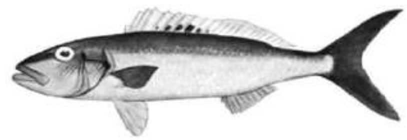


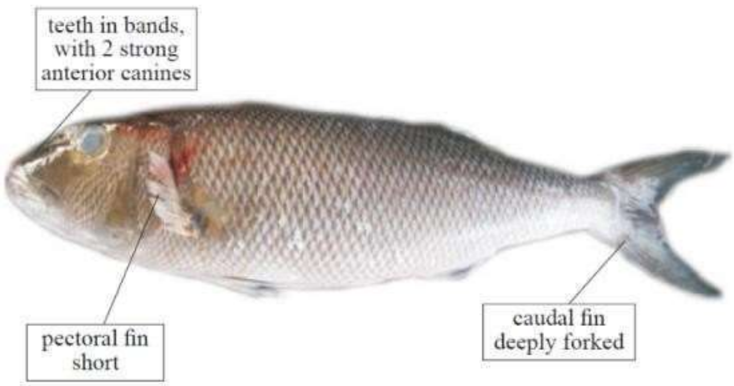
Fig 4

The Main genera

Aprion



Aprion virescens



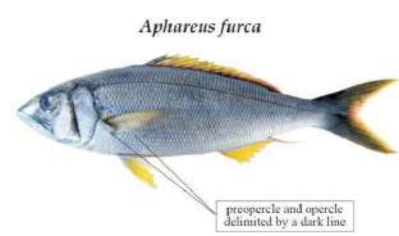
Green jobfish

D X, 11; A III, 8; Gr 14 -15 (lower limb); P 17; Ll 48 -50
Elongate fish with rounded body; clear horizontal groove in front of eye; teeth in both jaws in bands, with 2 strong canines anteriorly; vomerine tooth patch crescent-shaped.Pectoral fins short, rounded, about equal to snout length; caudal fin deeply forked, lobes pointed; scales absent on dorsal and anal fins. Moderate-sized scales, on lateral line; scale rows on back parallel with lateral line. Body colour dark green to bluish or blue-grey.

Genus Aphaerus

Medium-sized snappers; minute teeth in jaws, canines, vomerine absent; premaxillae not protractile; gill openings extending well forward to front of eye; interorbital space flattened. Continuous dorsal fin, not incised near junction of spinous and soft portions, with 10 spines and 11 soft rays; anal fin with 3 spines and 8 soft rays; pectoral fins long, slightly shorter than head, with 15 - 16 rays; dorsal and anal fins scaleless; caudal fin forked. Scales small, about 65 - 75 in lateral line. Body bluish grey,sometimes with a silvery sheen on lower sides and belly.

Species: ***Aphareus furca*** **(Lacepède 1801)-** Small toothed jobfish D X, 11; A III, 8, P 15 -16, Ll65 -75; Gr 16 -18
Elongate compressed body, with lower jaw protruding; maxilla extending to below middle of eye; interorbital space flattened;
teeth in jaws small, disappearing with age; roof of mouth toothless; scale rows onback parallel with

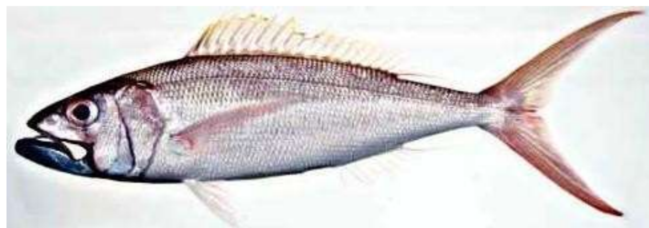


lateral line.

Colour: Back and upper sides purplish-brown; blue-grey on sides; a silvery sheenon head and lower sides; edges of pre-opercle and opercle outlined with black; fins whitish to yellow-brown.

***Aphareus rutilans* -** Rusty jobfish

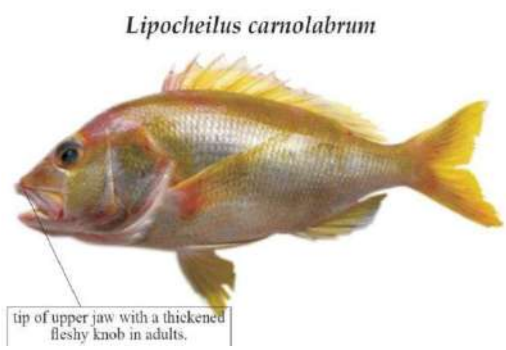
D X, 11; A III, 8, P 15 -16, Ll 70 - 73; Gr 15 - 16



Elongate compressed body, with lower jaw protruding; maxilla extending to below middle of eye; interorbital space flattened; **teeth small, forming narrow uniform band in each jaw**; roof of mouth toothless; gill rakers on lower limb (including rudiments) 30 to 34; scale rows on back parallel with lateral line. Body colour blue- greyish reddish; fins yellowish red, pelvics and anal fin sometimes whitish; margin of maxilla black.

Lipocheilus carnolabrum

D X, 10; A III, 8, P 15 -16, Ll65 -75; Gr 16 -18



Mouth large, adults with a thick, fleshy protrusion at anterior end of upper lip. Vomerine tooth patch V-shaped, without a medial posterior extension; no teethon tongue. Maxilla scaleless. Interorbital space flattened to convex. Dorsal and anal fins scaleless. Last dorsal and anal soft rays not produced. Pectoral fins long, reaching beyond level of anus.
Scale rows on back parallel to lateral line. Upper part of head brown; yellowish or pinkish on sides; a silvery sheen on ventral portion of body.

Upper lip with a median fleshy protrusion, well developed in adults spines of dorsal and anal fins strong, very robust in large adults....... ***Lipocheilus carnolabrum***

Genus Lutjanus

Small oblong, slender and fusiform sized snappers with relatively deep bodies. Mouth large, protractile; with pointed, conical teeth in jaws arranged in one or more rows, with an outer series of canine teeth, some of which, particularly those at front of jaws, are generally enlarged and fanglike; vomerine tooth patch V- shaped or crescentic, with or without a medial posterior extension, or diamond-shaped; interorbital space convex; pre-opercle serrate, its lower margin with a shallow to deep notch, and opposite portion of interopercle sometimes with a bony knob, most strongly developed in species with a deep pre opercular notch. Dorsal fin continuous, often with a slight notch between the spinous and soft portions, with 10 or 11 spines and, 11 to 16 soft rays; anal fin with 3 spines and 7 to 10soft rays; pectoral fins with 15 to 18 rays; dorsal and anal fins scaled; caudal fin truncate or emarginate, rarely forked.

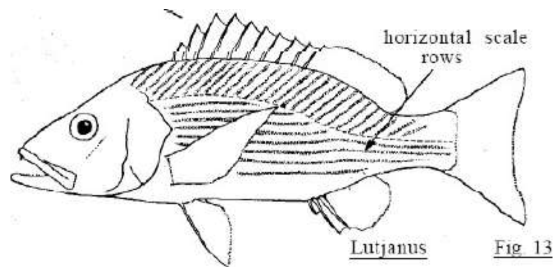


Fig. 13

Colour: Extremely variable, but often consisting of a reddish, yellow, grey, or brown background and a pattern of darker stripes or bars; frequently with a large blackish spot on upper sides below anterior dorsal soft rays.

Key to the genera of Lutjanidae occurring in the area (adapted and modified from FAO)

Notes: Species names are given when a genus includes a single species. Counts of gillrakers include rudiments, if present.

1a**.** Dorsal and anal fins without scales; dorsal fin with X spines and 10 or 11 soft rays ***. 2***
1b**.** Soft dorsal and anal fins with scales or sheathed with scales basally; dorsal fin withX to XII spines and 11 to 19 soft rays ***10***
2a. Maxilla with scales.............***3***
2b**.** Maxilla without scales ***5***
3a**.** Spinous portion of dorsal fin deeply incised at its junction with soft portion; dorsalfin with X spines and 11 (very infrequently 10) soft rays...***Etelis***
3b**.** Spinous portion of dorsal fin not deeply incised at its junction with soft portion; dorsal fin with X spines and 10 soft rays..............***4***

4a**.** Last soft ray of both dorsal and anal fins shorter than next to last soft ray ***. . . . . . . Paracaesio***

5a**.** Premaxillae essentially not protrusible, attached to snout at symphysis by a frenum ***6***

5b. Premaxillae protrusible, not attached to snout by frenum ***7***

6a. Vomer without teeth (small juveniles may have minute teeth on vomer); teeth in jaws very small, no caniniform teeth; pectoral fins somewhat shorter than head; lateral surface of maxilla smooth ....***Aphareus***

7a. Dorsal fin with X spines and 11 (rarely 10) soft rays; last soft ray of both dorsaland anal fins longer than next to last soft ray......***8***

7b. Dorsal fin with X spines and 10 soft rays; last soft ray of both dorsal and anal finsshorter than next to last soft ray ***9***

8a. Groove present on snout below nostrils; pectoral fins less than 1/2 length of head **. . . . .** ***Aprion virescens***

8b. No groove on snout; pectoral fins a little shorter than head to somewhat longerthan head.......***Pristipomoides***

9a. Upper lip with a median fleshy protrusion, well developed in adults spines ofdorsal and anal fins strong, very robust in large adults ....***Lipochei lus carnolabrum***

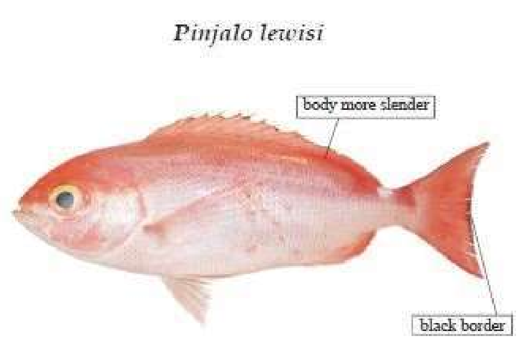
9b. Upper lip without a median fleshy protrusion .... ***Paracaesio***

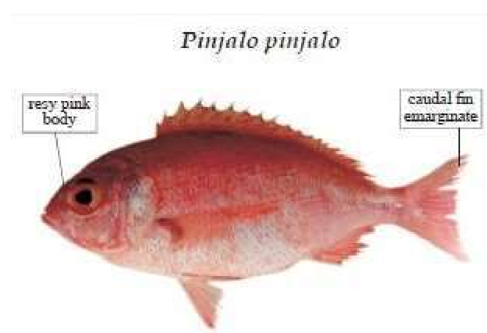
10.Vomer with teeth; dorsal fin with X to XII spines and 11 to 16 soft rays; none of anterior soft dorsal-fin rays produced as filaments............. ***11***

11a. First gill arch with 60 or more gill rakers on lower limb ***Macolor***

11b. First gill arch with 20 or fewer gill rakers on lower limb ***12***

12a. Upper and lower profiles of head equally rounded; eye set toward middle of head; mouth rather small, somewhat upturned; no fang-like canines at anterior ends of jaws .... ***Pinjalo***





12b. Upper and lower profiles of head not equally rounded, upper profile evenly rounded to steeply sloped, and lower profile flattened; eye closer to upper profile of head than to lower; mouth larger, usually not upturned; some fang-likecanines usually present at anterior ends of jaws ....***Lutjanus***

Key to the species of *Aphareus* occurring in Indian waters

Remark on key character: counts of gill rakers include rudiments, if present.

1a. First gill arch with 6 to 12 gill rakers on upper limb and 15 to 18 on lower limb (total 22 to28); colour of body varying from steel blue to purplish brown . . . .
Aphareus furca

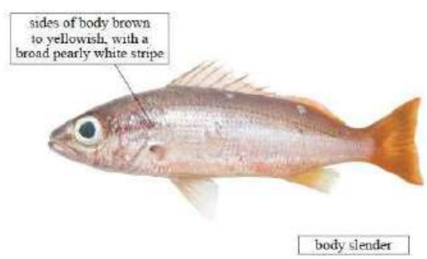
1b. First gill arch with 16 to 19 gill rakers on upper limb and 32 to 35 on lower limb(total 49 to 52); colour of body varying from blue-grey or mauve to . . . . . .
Aphareus rutilans

Key to the species of *Etelis* occurring in Indian waters

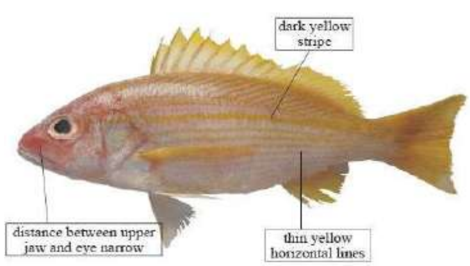
1a. Total gill rakers on first gill arch 17 to 22 ....***Etelis carbunculus***
1b. Total gill rakers on first gill arch 23 to 36 upper lobe of caudal fin longer.............***2***

Key to the Indo-Pacific species of *Lutjanus (modified from FAO)*

l. Pre-orbital space (distance between upper jaw and eye) very narrow, body slender, dorsal spines usually 11, soft dorsal rays 12.



Body depth 3.5 to 3.8 times in standard length; tongue without teeth; a dark band from snout to caudal fin base and two pearly spots above lateral line, soft portion of dorsal fin
L. biguttatus



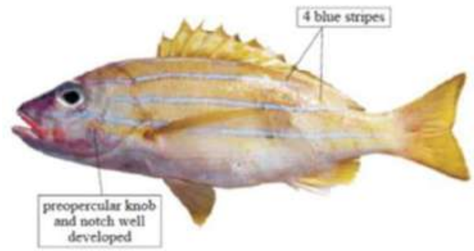
Body depth 2.9 to 3.3 times in standard length; tongue with a patch of fine granular teeth; colour generally silvery-white with a broad yellow stripe along middle of side tocaudal fin base and narrow yellowish lines, corresponding with longitudinal scale rows(eastern Africa to western Pacific) . . . .
Lutjanus lutjanus

3a. Yellow coloured body with a series of 4 or 5 longitudinal blue stripes on sideswhich become brown when preserved.

3b. Colour not as above **6**

4a. Dorsal-fin spines XI or XII ....***Lutjanus bengalensis***

4b. Dorsal-fin spines X **5**



5a**.** Four stripes on side, with white whitish belly sometimes with thin greylines; scale rows on cheek 5 or 6; upper pectoral-fin rays darkish **. .** **. . . .** ***Lutjanus kasmira***

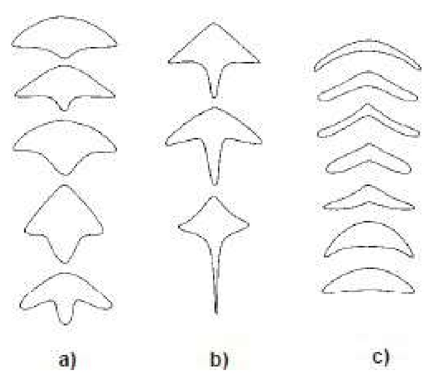
5b. Five stripes on side, belly not whitish, thin lines absent; scale rows on cheek10 or 11; upper pectoral-fin rays pale..... ***Lutjanus quinquelineatus***

6a. Longitudinal scale rows above lateral line obliquely positioned **7**

6b. Longitudinal scale rows above lateral line entirely horizontal or some rows risingobliquely from below middle part of dorsal fin **. . . . . . .**

7a. Vomerine tooth patch triangular or diamond-shaped with a medial posterior extension **8**

7b. Vomerine tooth patch crescentic to triangular without a posterior extension........ **11**

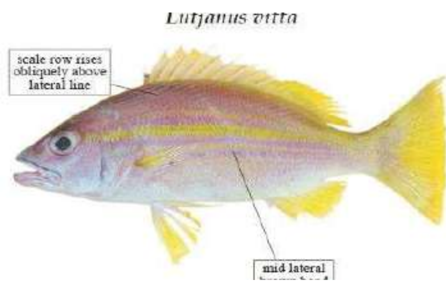


Shapes of the vomerine tooth patch

8a**.** Soft dorsal-fin rays usually 14; a relatively wide gap between temporal scale bands of each side; spot on upper side situated mainly above lateral line; young specimens with series of 4 to 7 broad stripes (blackish to orange or yellow-brown in life) on side, these persisting as thin stripes in adults from the western Indian Ocean...............***Lutjanus russelli***

8b**.** Soft dorsal-fin rays usually 13; little or no gap between temporal scale

bands of each sidespot on upper side situatedmostly below lateral line or bisected by it, spot sometimes very elongated; young specimens without series of 4 to7 broad dark stripes on side **. . . . . . .** ***Lutjanus fulviflamma***

9a**.** 

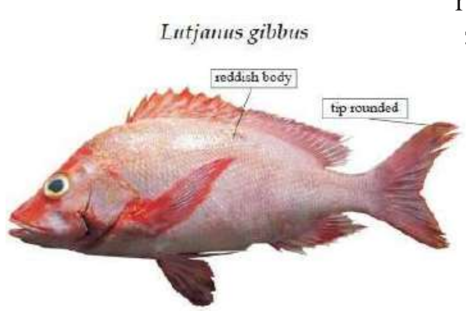
Mid-lateral stripe usually broader and darker than other stripes on side; transverse scale rows on cheek 7 to 10 ***. . . . . . . Lutjanus vitta***

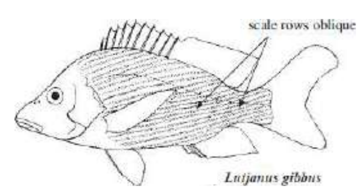
9b**.** Mid-lateral stripe not broader or darker than other stripes on side, yellow in life and faint or absent in preserved specimens; transverse scale rows on cheekusually 6 or 7(occasionally 8)……………***12***

10a**.** Predorsal scales extending to mid-interorbital level; a blunt, flattened spine on upper margin of opercle, above the main centrally located spine; interorbital width 4.4 to 6.5 in head length; total gill rakers on first gill arch (including rudiments) 18 to 21 ....***Lutjanus madras***

10. Total gill rakers (including rudiments) on first gill arch (including rudiments) 25 to30........... ***12***

11. Dorsal fin with X spines and 13 or 14 soft rays; scale rows below lateral lineascending obliquely caudal fin distinctly forked with rounded lobes; colour deep red to grey, fins red or dark brown to blackish.............***Lutjanus gibbus***

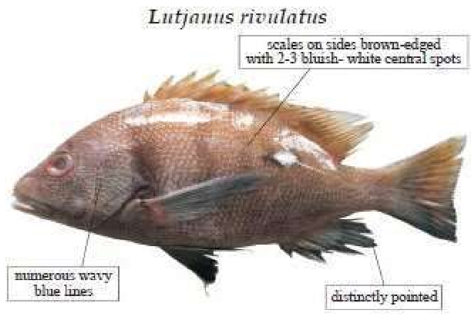




13a**.** Soft anal-fin rays 10; dorsal fin with XI spines and 16 rays; colour pattern consisting of 3 dark brown to red transverse bars (may be indistinct in large adults) ....***Lutjanus sebae***

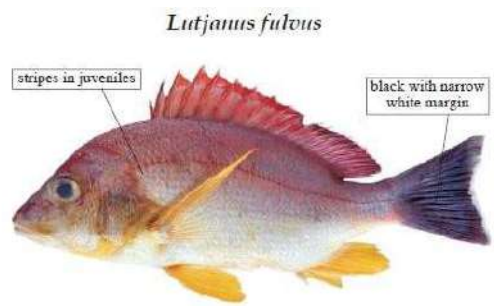
13b**.** Soft anal-fin rays 8 or 9; dorsal-fin elements variable, the fin with X or XI spines and 12 to 16 soft rays; colour not as above............... ***14***

14a. Pre-opercular notch distinctive (moderately to well developed............. **15**
14b. Pre-opercular notch not distinct................ **21**
15a. Soft dorsal-fin rays 15 or 16; body relatively deep, 2.1 to 2.4 times in standard length; head usually with numerous wavy lines (bluish in life); a chalky spot often present below junction of spinous and soft parts of dorsal fin, bordered with black in juveniles, but lost with age; lipsthick in large adults . . . . . . ***.Lutjanus rivulatus***



15b. Soft dorsal-fin rays 13 or 14; body usually more slender, 2.3 to 2.8 times in standard length; colour not as above; lips not thick in adults.............. **16**

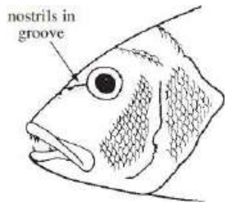
16a. Caudal fin and distal third of dorsal fin blackish or dusky brown with a narrow white border.. ***Lutjanus fulvus***

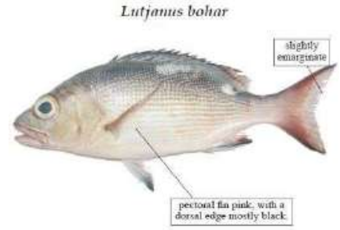


16b**.** Caudal fin yellow or grey basally andyellow distally without narrow white border; distal third of dorsal fin not noticeably darker than remainder of fin **.** ***.17***

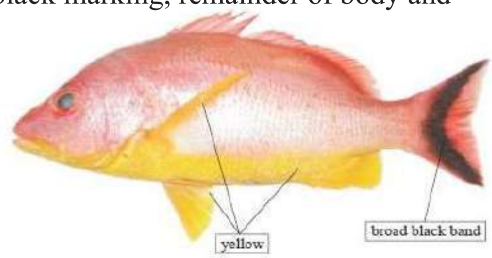
17a**.** Colour pattern consisting of a series of 5 dark stripes on whitish ground colour; 2 or 3 uppermost stripes crossed by dark vertical bars forming a network of light and dark squares; a large dark spot at base of caudal fin ***Lutjanus decussatus***

17b**.** Two whitish spots on upper back, anterior spot below last 4 dorsal-fin spines andposterior one under last 6 dorsal-fin rays and meeting that of other side across top of caudal peduncle; colour brown on upper back grading to tan or light brownish ventrally; dorsal and caudal fins dusky; outer portion of anal and pelvicfins distinctly blackish; upper third of pectoral fins dusky brown; tongue with a patch of fine granular teeth ..... ***Lutjanus bohar***





18a. Caudal fin with a distinctive crescentic black marking, remainder of body and finsuniformly yellowish tan (yellow in life) with a silvery sheen on lowersides..... ***Lutjanus lunulatus***



18b. A black spot on upper side at level of lateral line below soft dorsal fin; rest of body and fins mainly pale; tongue with a patch of find granular teeth, although sometimes absent in juveniles..............***Lutjanus monostigma***

19a

Dorsal-fin spines XII; 5 - 6 yellow stripes; longitudinal rows of scalesbelow lateral line which rise.......
Lutjanus dodecacanthoides

19b Small mouth, length of maxilla less than distanc between bases of last dorsal- and anal-fin rays som longitudinal scale rows below lateral line slantin obliquely in posterior direction toward dorsa profile; convex head profile….***Lutjanu erythropterus***

20a**.** Triangular vomerine tooth patch with medial posterior extension; narrow preorbital space, large prominent black spot, bisected by the lateral line below posterior part of spinous dorsal fin ....***Lutjanus ehrenbergii***

21 A large black spot on upper back groundcolour pale, each scale on side often with a brownish spot forming

longitudinal rows on side . . . .
Lutjanus johnii

22 Body depth 2.5 to 2.9 times in standard length; least depth of caudal peduncle 3 to 3.5 times in head length; longitudinal scale rows on upper back parallel to lateral line anteriorly and some rows usually ascend obliquely below posterior dorsal fin spines . . . .
Lutjanus argentimaculatus

Key to genus *Macolor* species occurring in Indian waters (modified from FAO)

1a**.** First gill arch with 37 - 42 gill rakers on upper limb and 71 - 81 on lower limb (total110 to 122); anal fin with III spines and 10 soft rays; long pointed pelvic fins in juveniles and short rounded pelvic fins in adults.............. ***Macolor macularis***

Key to the species of *Paracaesio*

1a. Body dark purplish brown, with violet lines on body............. ***Paracaesio sordida***

3b. Caudal fin, upper part of caudal peduncle, and upper side of body to anterior end of dorsal fin yellow; rest of body mostly blue; pre-opercle almost always without scales.............. ***Paracaesio xanthura***

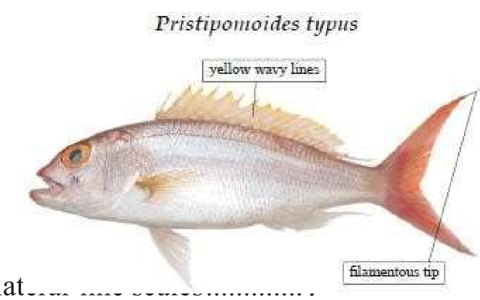
Key to the species of *Pristipomoides* occurring in Indian waters

1a. Lateral-line scales 48 to 50 .... ***2***

1b. Lateral-line scales 57 to 74 ....***3***

2a. Two golden stripes bordered with blue on snout and cheek; transverse vermiculations on top of head.............. ***Pristipomoides multidens***

2b. Golden stripes absent on snout and cheek; longitudinal vermiculations on top of head present . . . . . . ***Pristipomoides typus***

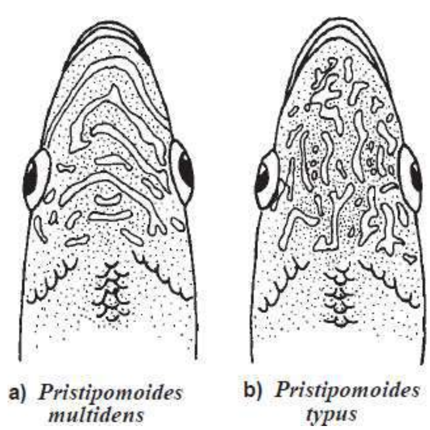


3a. Gill rakers on first gill arch 27 - 33; 67 to 74 lat

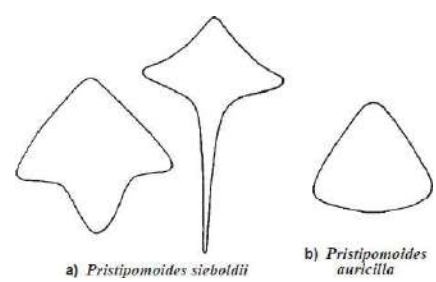
3b. Gill rakers on first gill arch 17 to 27; 57 to 67 lateral-line scales............ ***5***

4a. Backward prolongation in midline for the vomerine tooth patch; tongue with patchof teeth...... ***Pristipomoides sieboldii***

4b. Vomerine tooth patch triangular backward prolongation absent; teeth absent ontongue .... ***Pristipomoides auricilla***



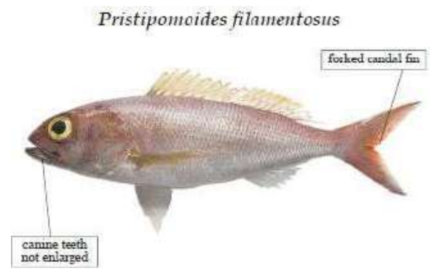
Dorsal view of head



Vermiculations on head

5a. Lateral-line scales 63 to 67; side of body with alternating oblique red and yellowbars....***Pristipomoides zonatus***

5b**.** Total gill rakers on first gill arch 22 to 27; lateral-line scales 57 to 63; side of body without red and yellow bars; caniniform teeth at anterior ends of jaws**. . . . . . .**
Pristipomoides filamentosus



CHAPTER 22

Taxonomy of Eel Fishes (Order: Anguilliformes)

Introduction

The true eels of the order Anguilliformes are one of the most diverse and widely distributed bony fishes all along the world Oceans. The order Angulliformes contains 16 diverse families (Protanguillidae, Synaphobranchidae, Heretenchelyidae, Myrocongridae, Muraenidae, Chlopsidae, Colocongridae, Derichthyidae, Ophichthidae, Muraenesocidae, Nettastomatidae, Congridae, Moringuidae, Nemichthyidae, Serrivomeridae, Anguillidae) with 1009 valid species (Fricke et al., 2021). In the order Anguilliformes the family Ophichthidae contains a highest numbers of valid species (355 species), followed by Muraenidae (223 species) and Congridae (221 species) (Fricke et al., 2021). Work on Ichthyofauna and Anguilliformes in India had a long history from Bloch and Schneider (1801), Russell (1803), Hamilton (1822), Day (1889), Alcock (1889, 1890), Weber and de Beaufort, 1916–1936; de Beaufort, 1940; de Beaufort and Chapman, 1951; Koumans, 1953; de Beaufort and Briggs, 1962), Talwar and Kacker (1984), Fischer and Bianchi (1984) till date. From Indian waters total 11 families were reported so far with 53 genus and 125 valid species till 2015 (Gopi and Mishra, 2015), though subsequently the numbers of species had increased. Maximum species from Indian waters were reported from the family Muraenidae (52 species; Nashad et al., 2020) followed by family Ophichthidae (29 species, Mohapatra et al., 2020; Mohapatra et al. 2021) and family Congridae (17 species from 12 genera) (Gopi and Mishra, 2015) with some subsequent additions. Anguilliformes are one of the poorly studied groups in Indian waters due to their bottom dwelling habit and less economical value. Identification of the fishes of the order largely depends on the vertebral count, teeth pattern, colouration, origin of fins etc. More often fishes of some families looks very alike in external morphology and colouration. Due to the difficulty in collection of the specimens, less economic importance and complexity of identification of the specimens the order Anguilliformes is poorly worked out.

Collection and Preservation

Collection of specimens can be done by operating different types of gears inside the sea in different depth or by landing centre approach. During collection the place, latitude, longitude, depth etc. should be recorded for better understanding of the habitat of the specimens. Specimens can be preserved in either 70% alcohol or 10% formalin (may be added with Glycerine). Tissue samples also can be collected in absolute alcohol for DNA analysis.

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Photography

Photography needs proper care and the specimens should be put in to a contrasting background for better photography (Fig. 1). During photography the fins should be spread properly to have the clear identifying characters. A scale should be added to have the idea regarding the size of the specimen. Markings should be added to the origin of the dorsal fin and anal fin. Proper care should be taken to highlight the mouth cirri, small colouration patterns, spots on body or head etc. If required magnified regions photo should be taken to highlight characters (Fig. 2).

Fig.1 Photograph of a typical congrid specimen

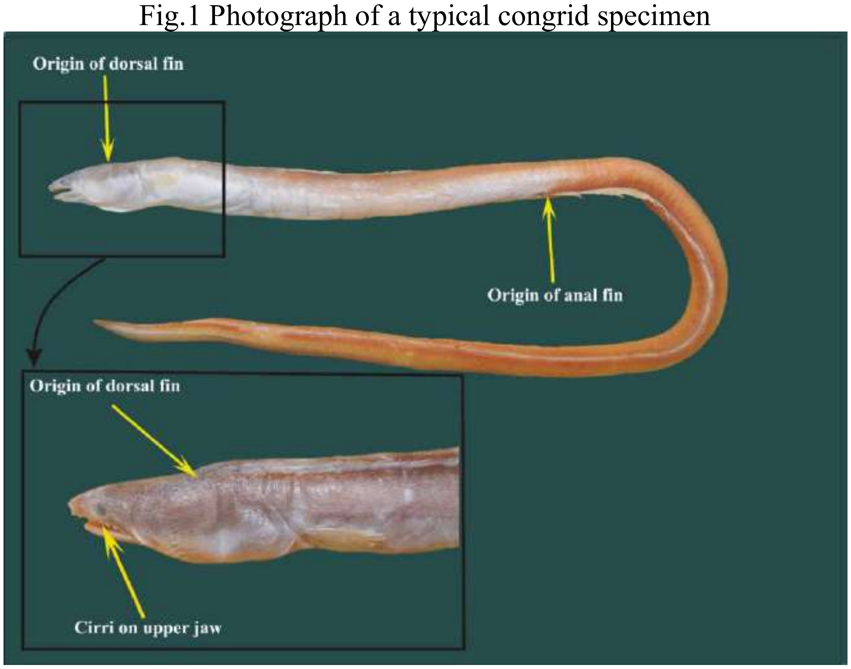

Fig.2 Highlighting characters of a specimen.

Identification

The basic characters for the identifications of the eel specimens are dependent on various characters. The Fig. 3 depicts the details of morphological characters and morpholometric measurements of a typical Anguilliformes. Terminology, counts and measurements for the identification follow Böhlke (1989, 2000).

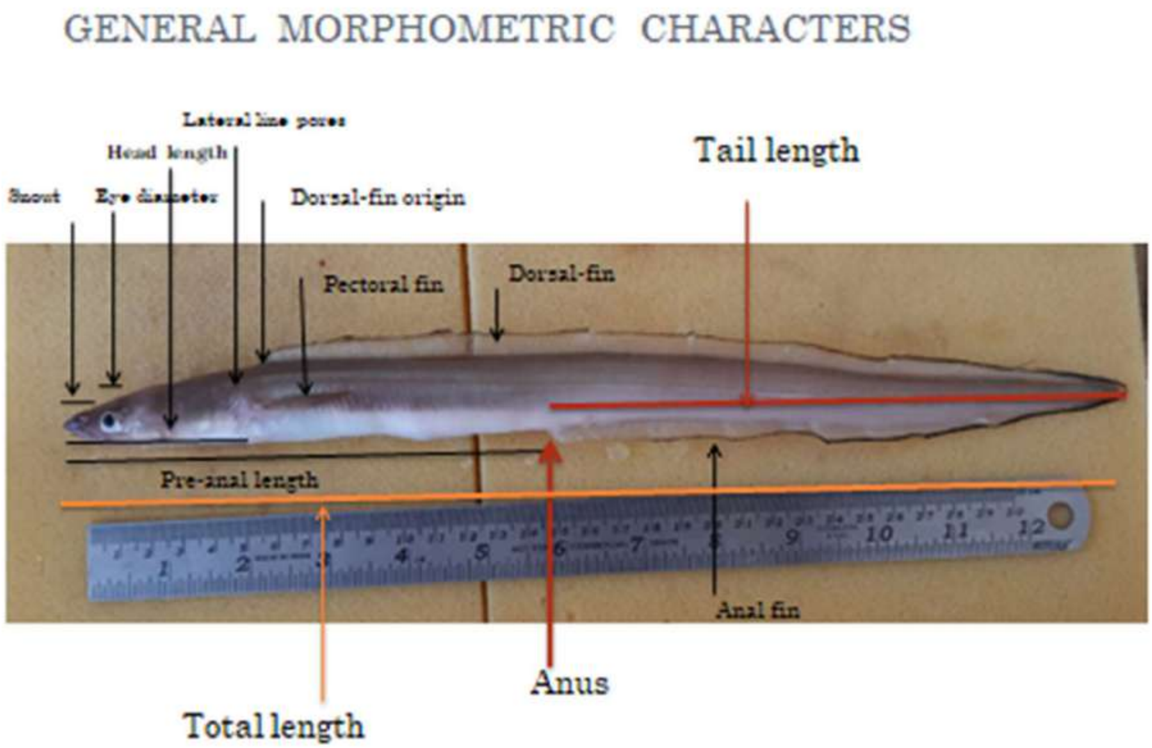

Fig.3 Morphological characters and morphometric measurements of a congrid eel.

For Anguilliformes identifications head pores are one of the very important characters which vary from species to species. The Fig. 4 depicts the typical characters of head pores with the terminology.

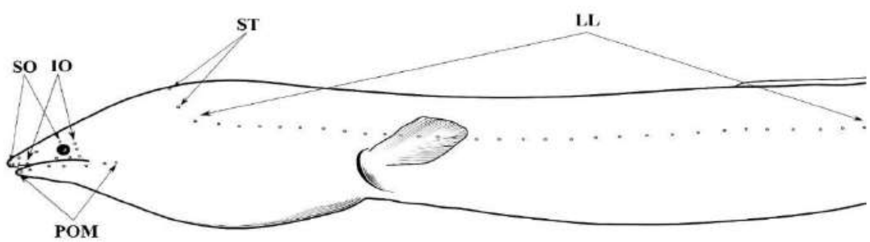

Fig. 4 Head Pores of *Ophichthus johnmccoskeri* Mohapatra, Ray, Mohanty, Mishra, 2018 (SO-supraorbial pores, IO-infraorbital pores, POM-preopercular and mandibular pores, ST-supratemporal pores, LL-lateral line pores).

Teeth are normally modified in the Anguilliformes in accordance with their adaptations and food habit and so are species specific. The teeth characters and arrangements are considered to be one of the major characters for the identification of Anguilliformes specimens. The details of terminology used for Anguilliformes teeth are given in the Fig. 5.

Vertebral characters are also considered as one of the major characters for the identifications of the Anguilliform specimens. Vertebrae were counted by means of digital X-ray and expressed as in Böhlke (1982, 1989) as pre-dorsal vertebrae, pre-anal vertebra and total vertebrae as depicted in Fig. 6.

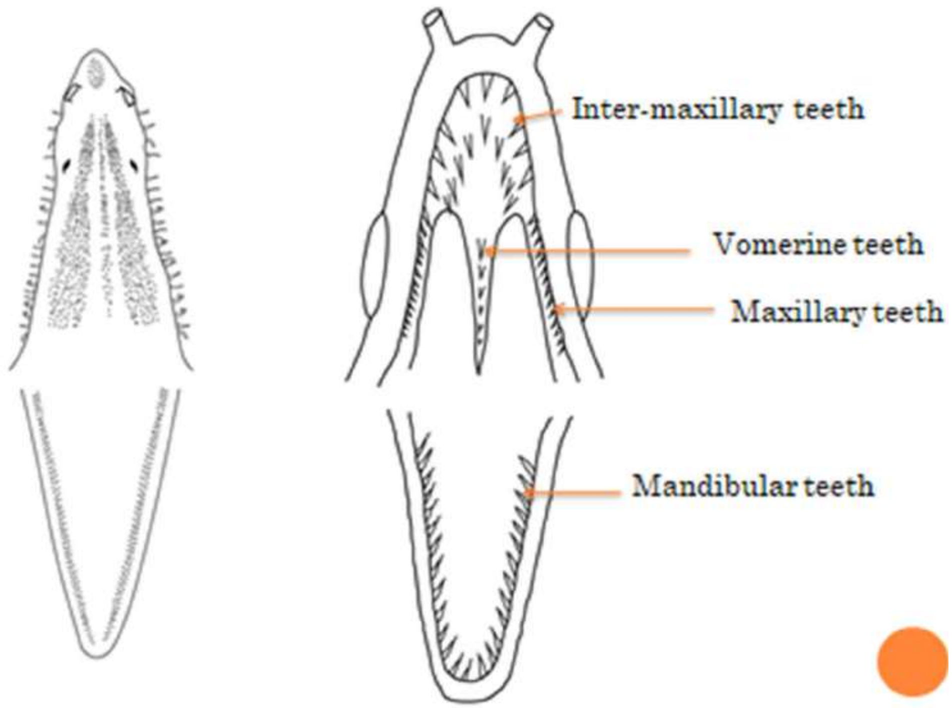

Fig. 5 Typical teeth diagram of Anguilliformes fishes

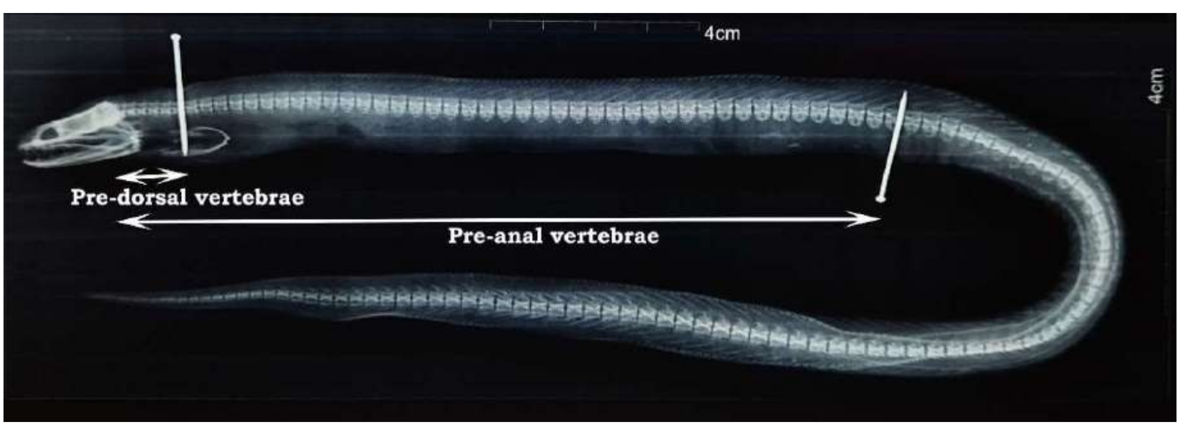

Fig.6. Vertebrae of an anguilliform specimen.

DNA analysis

DNA isolation from tissue samples can be done using any of the standard methods. Targeted genes may be sequenced and compared with the barcodes of the congeners for proper identifications. Based on both morphological and molecular analysis the description of any new species will be of more useful for future research as both the taxonomic skills are essential in future for better understanding on the phylogeny and taxonomy of any species.

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CHAPTER 23

Standardised Protocol for Taxonomic Measurements for Pleuronectiform Fishes

Introduction

Study of fish morphometrics has been the primary source of information for taxonomic and evolutionary studies. Despite the value and availability of genetic, physiological, behavioural, and ecological data for such studies, systematic ichthyologists continue to depend heavily on morphology for taxonomic characters. Morphometric data is important in that it can be used as taxonomic characters to examine evolutionary relationships among species; they have the advantage that size effects can be removed before the data are recoded so that inferred evolutionary relationships are based on body-form rather than body-size differences. Identification of stocks of fish has been the mainstay of morphologists. Large data sets have been collected for a diverse array of commercially important fish (Winans,1985). For over 30 years, most morphometric investigations have based the selection of characters on the set of measurements described by Hubbs and Lagler (1947). Most species of fishes have characteristic shapes, sizes, pigmentation patterns, fin disposition and other external features that aid in recognition, identification, and classification that can be examined by dissection or other means of internal examination. Structural measurements sometimes are used directly as characters if they are sufficiently discrete among taxa or if a tree-building procedure is used that allows the use of continuous characters (Farris 1970; Farris et al. 1970). Standard references for taxonomic study of bony fishes are Hubbs and Lagler (1958), Miller and Lea (1972), Lagler et al., 1977, Bond (1979), Moyle and Cech (1981), and Trautman (1981). The general parameters taken into account are those on the left side for bony fishes unless otherwise mentioned or right side when that side is damaged. In the case of elasmobranchs, a glance through any well-illustrated guide to chondrichthyans (e.g. Compagno 1984; Last and Stevens 1994; Compagno et al., 2005) reveals a huge diversity of body morphology. In odd shaped teleost fishes like box fishes also the basic measurement pattern was based on Hubbs and Lagler (1958) with slight modifications. Compared to the other teleosts, measurements are necessary on both sides for the flatfishes due to the flattened nature of the body like in the ray fishes.

Morphological characters have been commonly used in fishery biology studies to measure discreteness and relationships among various taxonomic categories (Jerry and Cairns, 1998). Morphometric analysis can thus be a first step in investigating the stock structure of species with large population sizes. Study of the morphometric characters are important to understand the interspecific variations among species. Interspecific shape comparisons are best done after an analysis of within species variation has been completed. Intra-species variation has two basic

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components (Barlow 1961) and has been noted for many species (Hubbs, 1922; Taning, 1952; Weisel, 1955; Lindsey, 1958, 1962; Fowler, 1970) and should be taken into account in studies involving meristic characters. Meristic features may also be size-dependent within or among species (Strauss, 1985).

Identification of new species is very important in the present context of the warming oceans and migration and shifting of species to warmer waters. Flatfishes are characterised by their deep bodied unusual flattened shape, larvae with bilaterally symmetrical eyes and presence of both eyes on the same side of the head in juvenile and post-metamorphic individuals, their remarkable ability to match the colour and pattern of their background and to bury deep in the soil with only the eyes protruding out. 678 extant species of flatfishes are recognized worldwide in approximately 134 genera and 14 families. Earlier studies on cynoglossids by Norman (1934), Menon (1977) helped developed a morphometric pattern for data collection; Amoaka (1969) developed a morphometric table for sinistral flounders of Japanese waters which was later modified in the work of Rekha and Gopalakrishnan (2011).

9075 t of flatfishes was landed in Kerala during 2016; landings have shown an increase over the years from 2012; however contribution of *Cynoglossus macrostomus* to the fishery showed a sharp decline since 2012 in Kerala. *Cynoglossus macrostomus* which once formed 98% of the Malabar flatfish fishery has decreased to 78 % of the landings. *Psettodes erumei* the Indian halibut has vanished from the commercial fishery. Studies by Rekha and Gopalakrishnan (2012; 2016) have revealed the presence of 63 species of flatfishes belonging to 8 families and 26 genera in Indian waters. The changing climatic and fishery patterns as well as the natural disasters have been seen to introduce newer fish species into the commercial fishery. For the correct identification of the newer species a standard protocol is very much essential in view of the unusual shape of the fish; hence this paper is attempted.

Procedure

This involves collection of fish from the harbour or lakes and presentation for further analysis. The procedure for handling delicate flounders and soles and strong halibuts are the same. Fish handling and fish preparation for data collection involves a few preliminary steps unlike the other teleosts and elasmobranchs. Care is to be taken to minimize the stress to the animals especially in the case of soles as they exude a lot of slime when obtained live. Flatfishes when collected by trawl loose fins and scales; hence care is to be taken to see that most of the fishes which were collected are in good condition. The fishes are to be packed in ice before being brought to the lab. While packing the fish in ice, they should be placed in horizontal position to prevent the body shape from changing. OHP sheets to be placed horizontally on ice and the flatfishes to be placed on them before the crushed ice is placed on them. Live fishes generally wriggle a lot which causes their body shape to twist leading to *rigor mortis* later. Once the fishes were brought to the lab, they should be thoroughly cleaned to remove dirt and detritus as well as the mucous which laminates the fishes eg. soles when they are stressed. The fishes should be placed on a flat surface preferably on a transparent OHP sheet/plastic sheet with their blind side down. The fins should be spread out using a needle or scalpel so as to preserve them in their natural condition and to facilitate easy counts. They should be injected with 1% formalin in the abdominal region and caudal region; dilute formalin should also be poured onto the body to stiffen the fins in spread out position. Once ready, they are to be stored in wide open mouth bottles, tagged with date of collection, gear and locality and used for further studies. Fishes should be photographed both in fresh condition as well in this preserved stage. Colour in fresh as well as prominent external features/markings is also to be noted immediately.

The side of the body which houses the eye is called the eyed side while the other side is called the blind side. The blind side is also the ventral side of the fish. Measurements are to be made on the eyed side of the psettodid, right side of each soleid specimen and on the left side of the bothid and cynoglossid specimen. In addition, some morphometric measurements like pectoral fin and pelvic fin length, base width, pre-pelvic, pre-pectoral length are to be taken on blind side also. Meristic counts are to be taken on both sides. It is suggested that the measurements presented herewith be taken as the minimal set of measurements for pleuronectiform fishes. Descriptive terms are also provided for description of species. New measurements may be added for morphometrics as well as for descriptions on a case to case basis. Basic flatfish taxonomy follows Amaoka (1969) with the following additions and modifications

Meristic (counts)

1) **Fin count**: All rays whether branched or unbranched were counted as single rays. (D, A, P_1, P_2, V_1, V_2, C where D stands for dorsal fin, A for anal fin, P_1, P_2, stands for the pectoral fin on ocular and blind side, V_1, V_2 for pelvic fin on the ocular and blind side respectively and C for Caudal fin.
2) **Gill raker**: Count was taken for first gill raker on ocular side.
3) **Lateral line count**: The scales of the middle lateral line represented by pores were counted from the first scale above the angle of the gill opening to the scale at the end of the hypural plate on the caudal peduncle. In case of cynoglossids, the scales between the upper and middle lateral lines were also counted in a diagonal line following the natural scale row.
4) **Head scale count**: An oblique row of scales on the head counted posteriorly from the posterior border of the lower eye.

Morphometric measurements (Figs. 1,2)

1) **Total length (TL)**: From tip of snout to the posterior margin of caudal fin.
2) **Standard length (SL)**: From tip of snout to posterior tip of caudal peduncle.
3) **Head length (HL)**: From tip of snout to posterior angle of opercular margin.
4) **Head width (HW)**: Greatest width across head at posterior portion of operculum.
5) **Head depth (HD)**: Distance from anterior origin of operculum to the ventral side of head.
6) **Snout length (SNL)**: Distance between tip of snout and middle outer margin of orbit (taken for both the upper (SNL_1) and lower eye (SNL_2)).
7) **Eye diameter (ED)** (upper and lower): Greatest distance across eye measured parallel to body length (does not include fleshy area) – ED_1 for upper eye and ED_2 for lower eye.
8) **Interorbital distance (ID)**: Narrowest width between two orbits measured vertical to body length.
9) **Chin depth (CD)**: Vertical distance between the end of the maxillary and the most ventral aspects of the head.
10) **Pre orbital (PrOU, PrOL)**: Distance from the tip of snout to the middle point of the orbit; taken for both upper and lower eye respectively.
11) **Post orbital (PBU, PBL)**: Distance from posterior point of orbit to the outer angle of opercular margin
12) **Upper jaw length (UJL)**: Distance from tip of upper jaw to outer free end of maxillary.
13) **Lower jaw length (LJL)**: Distance from inner angle of mouth of outer tip of lower jaw.
14) **Upper head lobe width (UHL)**: Distance from dorsal margin of body to dorsal/upper origin of operculum.
15) **Lower head lobe width (LHL)**: Distance from dorsal origin of operculum to most ventral part of operculum.

16) **Body depth (BD_1)**: The vertical distance across body just in front of anal fin.
17) **Body depth (BD_2)**: Distance across the widest part of the body exclusive of fins measured on ocular side.
18) **Dorsal fin length (DFL)**: The distance from base of the n^{th} dorsal fin to its tip. The n^{th} dorsal fin ray will be the longest dorsal fin ray taken near the middle of the body or near the maximum width of the body. In cases where the first few rays of the dorsal fin are longer, their lengths are taken separately.
19) **Anal fin length (AFL)**: The distance from base of the n^{th} anal fin to its tip. The n^{th} anal fin ray will be the longest anal fin ray taken near the middle of the body or near the maximum width of the body.
20) **Pectoral fin length (P_1FLO, P_2FLB)**: The length of the longest pectoral fin ray; measurements are taken for ocular and blind side separately as size of the fins are found to be different.
21) **Pelvic fin length (V_1FLO, V_2FLB)**: The length of the longest pelvic fin ray; measurements are taken for ocular and blind side separately as size of the fins are found to be different.
22) **Caudal fin length (CFL):** Distance from the hind end of the vertebral column to the maximum length of the caudal fin
23) **Caudal peduncle length (CDL)**: Horizontal distance between last ray of dorsal fin and origin of caudal fin.
24) **Dorsal fin base (DBL)**: Horizontal distance from base of first dorsal fin ray to the last dorsal fin ray. Measurements are taken on blind side when origin of dorsal fin is on blind side.
25) **Anal fin base (ABL)**: Horizontal distance from base of first anal fin ray to the last anal fin ray.
26) **Pectoral fin base (P_1BLO, P_2BLB)**: Vertical distance across the pectoral fin base; measurements are taken for ocular side and blind side.
27) **Pelvic fin base (V_1BLO, V_2BLB)**: Horizontal distance across the pectoral fin base; measurements are taken for ocular side and blind side.
28) **Caudal peduncle depth (CPD)**: Vertical distance from base of last dorsal fin to the base of last anal fin.
29) **Trunk length (TKL)**: Longitudinal distance from posterior angle of operculum to caudal fin base.
30) **Pre dorsal length (PDL)**: Tip of fleshy snout to base of first dorsal ray (measured on ocular/blind side based on position of origin of dorsal fin).
31) **Pre anal length (PAL)**: Tip of fleshy snout to origin of anal fin.
32) **Pre pectoral length (P_1LO, P_2LB)** : Distance from tip of snout to origin of pectoral fin (both ocular and blind)
33) **Pre pelvic length (V_1LO, V_2LB)**: Distance from tip of snout to origin of pelvic fin (both ocular and blind).

Qualitative characters

1) **Eye**: Relative position of upper (migrating) eye and lower (fixed eye) as well as their position on head.
2) **Jaw position**: Relative position of upper jaw with respect to lower eye. The point of the ending of the upper jaw in front of, behind or just below lower eye is also noted. This denotes the length of the upper and lower jaw.
3) **Dentition on upper and lower jaw on ocular and blind side**: Nature and pattern of teeth on both the jaws on both ocular and blind side are noted.
4) **Fin pigmentation**: Presence/absence of characteristic markings on fins or patterns if any.

5) **Body pigmentation**: Presence/absence of pigmentation on body.
6) **Peritoneum pigmentation:** Relative intensity and coverage of pigmentation on the peritoneum; pigmentation varies with different species.
7) **Opercular pigmentation**: Pattern of pigmentation varies on the surface of the operculum.
8) **Membrane ostia:** Presence /absence of membrane ostia (small pores) in the basal part of the membranes of the dorsal and anal fins.
9) **Ocular/ rostral spines:** Presence/absence of spines near/ around eye and snout.
10) **Dorsal fin origin:** Relative position of the dorsal fin on the body with respect to the migrating eye (upper) varies between genera. Point of insertion also varies between ocular and blind side.
11) **Scale:** Nature and type of scales on body varies between ocular and blind side in species; in the same species it sometimes varies at different regions of the body.
12) **Squamation on dorsal and finrays:** Scales may be present/ absent on finrays on ocular and blind side.

Conclusion: Fish length measurements are important for resource assessment and management (Petrell et al., 1997; Harvey et al., 2001a, 2002b; Cadiou et al., 2004), including evaluation of population age structure and biomass for harvest regulations and habitat protection and particularly useful when methods to obtain age or weight are impractical as part of a sampling program (Karpov et al.,1995). Though details of cynoglossid taxonomy is available in plenty, detailed literature on the psettodid morphomeristic taxonomy is lacking. Morpho-meristics of soles is similar to cynoglossids with modification in dorsal fin ray origin position and structural differences on the blind side below the eye. Counts of pectoral and pelvic fin rays which are generally taken only on dorsal side or eyed side of body in case of bilaterally fishes are taken on both sides in the cases of these flatfishes. Since studies on Indian sole fishes is lacking, morphomeristic detailing is also less. A comparative statement of the morphomeristic characters across species along with a compilation of meristic data of previous studies along with the present study can give a bird's eye view of all information as well as the range in different localities studied. This will help easier identification of species. Studies
of morphological variation among populations continue to have an important role to play in stock identification, despite the advent of biochemical and molecular genetic techniques which accumulate neutral genetic differences between groups. (Swain and Foote, 1999). Hence methods in classical taxonomy are to be given more importance and stress in such taxonomic studies. A document on the morphometrics is very important in identification of resources and hence in the documentation of biodiversity. Hence it is important that a consolidated list of the morphomeristic characters of the psettodids, cynoglossids and soles is prepared for future researchers in this area.

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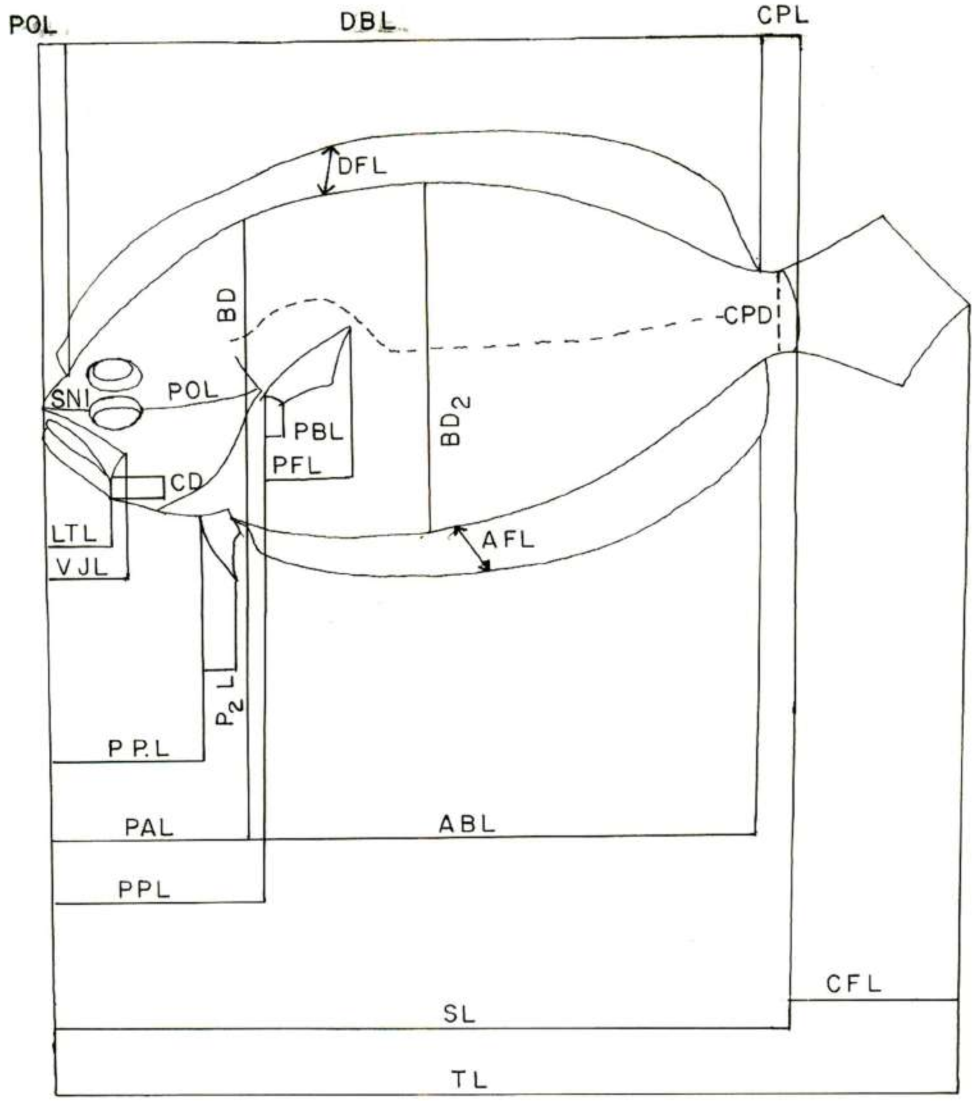

Fig.1 Morphometric measurements on ocular side of Flounder and Halibuts

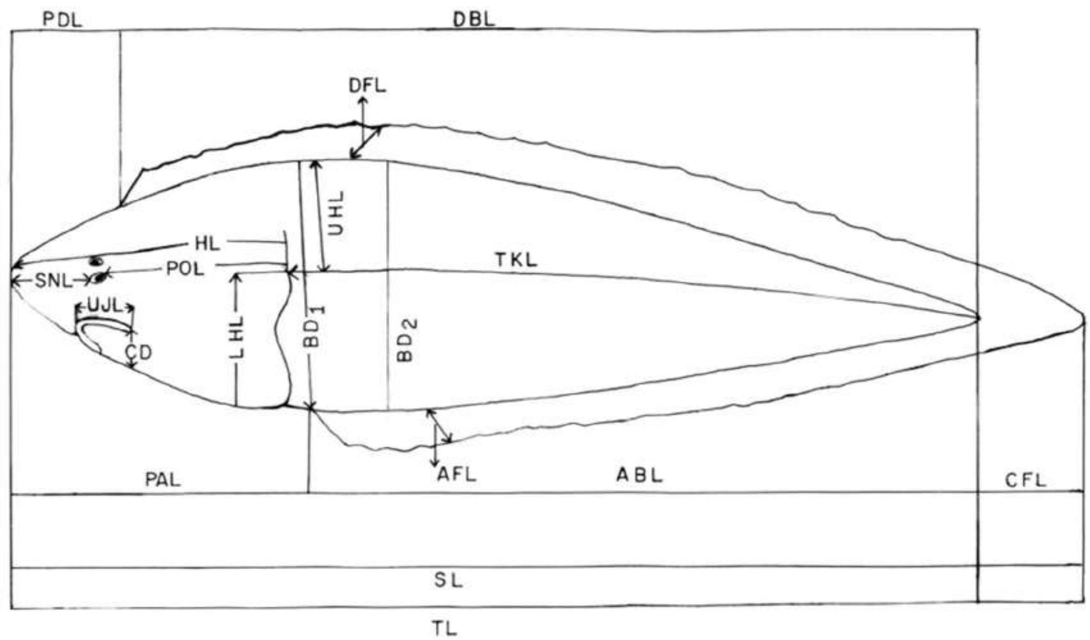

Fig.2 Morphometric measurements on ocular side of Cynoglossids

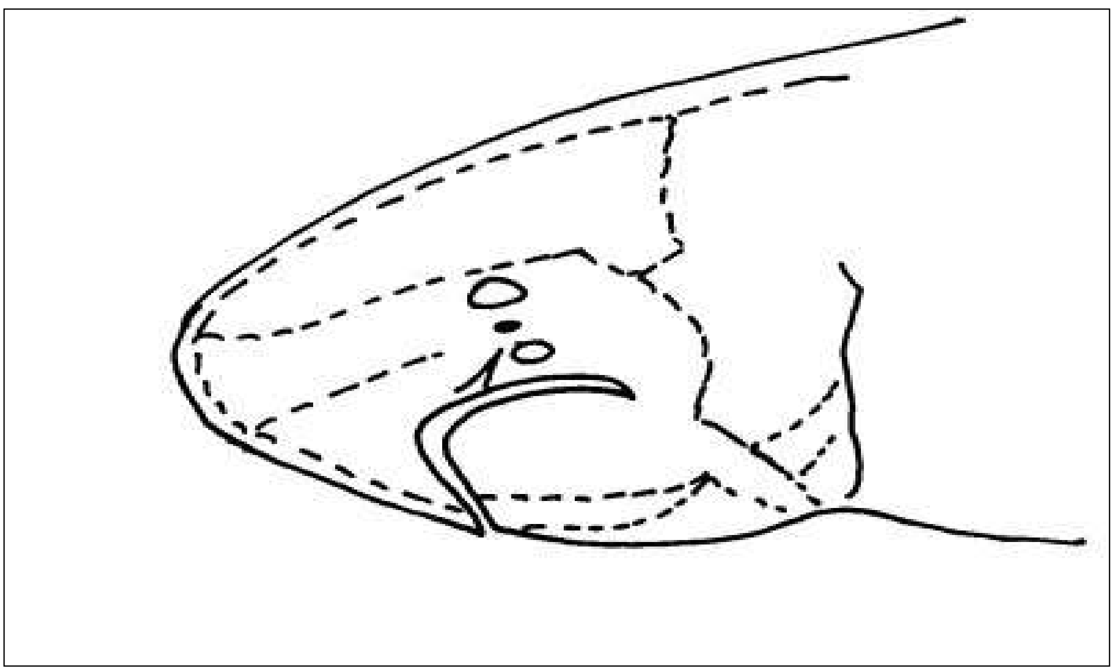

Fig.3 Lateral line pattern on head of Cynoglossid fishes

CHAPTER 24

Taxonomy and Fishery of Flatfishes

STATUS OF THE FLATFISHES OF THE WORLD

According to Nelson (2016), 772 extant species of flatfishes are recognized worldwide in 14 families with 129 genera; about 10 species (six achirids, one soleid, and three cynoglossids) are said to be fresh water. The first mention of flatfishes in Ichthyology was in 1686 by Willughby in L'Historia piscium where flatfishes were placed as Ossei Plani (Flat bony). Broussonet (1782) described a single flatfish Pleuronectes mancus in his work "Ichthyologia." Artedi (1792) placed all flatfishes in the one genus Pleuronectes in the group Malacopterygii based on "laterally compressed body, single continuous dorsal fin, and pelvic fin thoracic in position." The name "Pleuronectes" was introduced in zoology for the first time by Artedi and Linnaeus followed his example. in Genera Piscium described genus *Pleuronectes* as "fish with dextral eyes, oblong body," and included 29 species. Lacepede (1801) in his "Histoire Naurelle des Poissons" placed flatfishes in genus Pleuronectus with 4 subgenera without assigning them any names and described 29 species in them. Later, Russell (1803) recorded eight species of flatfish from the Coramendal coast – *Hippoglossus erumei, Rhombus marginatus, R. triocellatus, Synaptura Russellii, Synaptura lata* Blkr (*Solea lata*, Hass), *Synaptura cornuta* Blkr (*Solea cornuta* Cuv), *Plagusia potous* Cuv, and Plagusia Blochii Blkr. This was followed by Dumeril (1804) who raised flatfishes to family status and gave the name Heterosomes. Quensel (1806) further divided the genus Pleuronectes into two – Pleuronectes and Solea. Hamilton (1822) in his account of the fishes in the River Ganges described two genera *Pleuronectes* and *Achirus* with 4 species Pleuronectes nauphala, *Pleuronecetes arsius, Pleuronectes pan, and Achirus cynoglossus*. Richardson (1843), in contributions to the Ichthyology of Australia, Vol. XI of "The Annals and Magazine of Natural History" described a new species of flatfish Rhombus lentiginosus. In 1843, Temminck and Schlegel published "Fauna Japonica" wherein four species were described. Later, Muller in 1846 erected a new order Anacanthinii to include Pleuronectoids, Gadoids, and Ophidiods. Cantor (1849) in his Catalogue of Malayan Fishes described Family Pleuronectidae in Order Anacanthini with 14 species in 7 genera; fishes were grouped based on presence of eye and color patterns on right or left side. Bleeker in "*Sur quelque genre de la Famille des Pleuronectoides*" placed flatfishes in genera in the family Pleuronectoides. The main character of differentiation between genus Psettodes and the remaining were "presence/absence of teeth on palatine, presence/absence of anal spine, lateral line with a curve anteriorly and sinistral eyes." Bleeker (1852) reported 19 species of flatfishes from Java and Amboina, 2 from Madura, 1 from Bali, 6 from Sumatra, 1from Banka, 6 from Borneo, 2 from Celebes, 1 from Moluccan

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Islands, and 9 from Indo-Archipelago; three families were collected from Amboina – Pleuronectoidei, Soleidae and Plagusioidei – Psettodes was placed along with Pseudorhombus and Platophrys in Family Pleuronectoidei. Later in 1853, Bleeker recorded 5 genera and 17 species of Pleuronecteoidei from1339 nominal species of flatfishes were described, named or recognised, 716 species are considered valid (e.g. recognised by taxonomic authorities), while another 670 names are regarded as synonyms for pleuronectiform fishes.

However, according to Munroe's (2005), compilation of all published and personal queries, of the 1,339 nominal species of flatfishes described, named, or recognized, 716 species are considered valid, while another 670 names are regarded as synonyms for pleuronectiform fishes. A review of Eschmeyer (2012 online) shows that species are also not uniformly distributed among families. Families with low species diversity include the monotypic Paralichthodidae, Psettodidae (2 species each), Achiropsettidae (6 species), Citharidae (7 species), Scophthalmidae (9 species), with moderate diversity Rhombosoleidae (19 species), Samaridae (28 species), Poecilopsettidae (30), Achiridae (31), Pleuronectidae (60) and with high diversity Paralichthyidae (95), Soleidae (139), and finally Cynoglossidae and Bothidae (145 species each).

Table 1. Present status of Flatfishes of the world

Taxon	Nominal species	Valid species	Names in synonymy
Psettodidae	8	2	6
Citharidae	12	7	5
Scophthalmidae	39	9	30
Paralichthyidae	190	95	95
Bothidae	267	145	124
Pleuronectidae	177	60	117
Tephrinectes	4	1	3
Rhombosoleidae	48	19	29
Achiropsettidae	9	4	5
Poecilopsettidae	34	30	11
Samaridae	30	28	9
Paralichthodidae	2	1	1
Achiridae	56	31	30
Soleidae	227	139	95
Cynoglossidae	236	145	110
Totals	1339	716	670

(Source: Rekha & Gopalakrishnan, 2014)

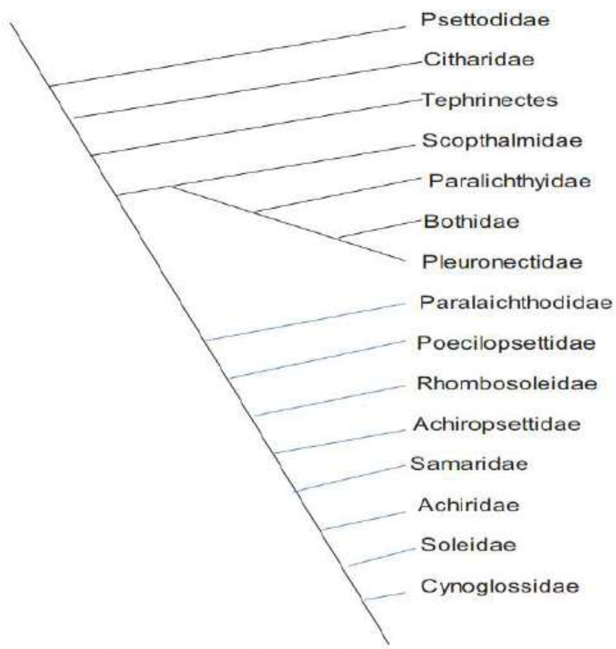


Figure 3 Phylogeny tree of the flatfish families of the world. (Source: Munroe, 2005, p. 391).

Table 2 Family wise list of valid species in Order Pleuronectiformes

Family	Subfamily	Valid species	New species in the last 10 years (2004–2013)
Psettodidae		3	0
Citharidae		6	0
Scophthalmidae		9	0
Paralichthyidae		110	2
Bothidae		166	3
Achiropsettidae		4	0
Pleuronectidae		106	4
	Poecilopsettinae	21	3
	Rhombosoleinae	20	0
	Pleuronectinae	64	1
	Paralichthodinae	1	0
Samaridae		27	7
Achiridae		36	2
Soleidae		179	39
Cynoglossidae		145	7
	Symphurinae	78	6
	Cynoglossinae	67	1

Source: Data taken from Catalog of Fishes (2013 version).

Suborder Psettodoidei. Body elliptical, dorsal fin arising above the maxillary, not extending onto front region of head, anterior rays spinous; first two rays of anal fin spinous; eyes either sinistral or dextral; nostrils placed in front of interorbital space. Mouth large, teeth on jaws barbed, palatine toothed with a single row; anus on mid-ventral line of body.

The suborder has only **one Family with one genus** – Family **Psettodidae** and Genus ***Psettodes***.

Genus *Psettodes*

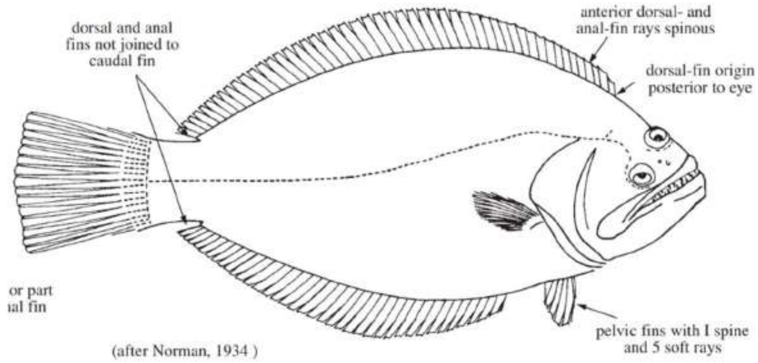
Characters

These large flatfishes with both sinistral and dextral individuals
Externally, these fishes are easily recognized by such pleisomorphic characters as the posterior location of the dorsal fin, which does not advance onto the cranium anterior to the eyes,

- occurrence of spines in dorsal and anal fins,
- large mouth with specialized teeth,
- Oval to round bodies without the obvious bilateral symmetry in lateral musculature development evident in other flatfishes
- palatine with teeth;
- basisphenoid present;
- supramaxilla large; 24 or 25 vertebrae.
- Body oval-shaped, flat but fairly thick; caudal peduncle deeper than long.
- Head length 3.2 to 3.6 times in standard length.
- Both eyes on right or left side of head; upper eye on dorsal surface of head.
- Supramaxillary bone well developed. Mouth large, extending well beyond posteriormargin of lower eye; lower jaw projecting. Teeth large canines, many with barbed tips. Vomer and palatines with teeth.
- Preopercular margin easily seen, not hidden by skin or scales. Gill rakers tooth-like.
- Dorsal fin not extending onto head (to or past eye); anterior dorsal and anal rays spinous; Dorsal-fin origin well posterior to upper eye; dorsal-fin rays 48 to 56; anal-fin rays 34 to 44;
- Urinary papilla and anus on midventral line anterior to origin of anal fin;
- Caudal fin free from dorsal and anal fins, with truncate or double truncate posterior margin with 24 or 25 rays; pectoral fins on eyed and blind sides nearly equal in length, both with 13 to 16 rays; pelvic fins with spine and 5 soft rays, and nearly symmetrically placed on each side of midventral line.
- Scales small, weakly ctenoid on both sides of body; lateral line present on both sides of body, only slightly curved above pectoral fin, with 61 to 77 scales, with no supratemporal branch, branch present below lower eye; scales around caudal peduncle 32 to 38. Epipleural and pleural ribs present

***Psettodes erumei* (Bloch and Schneider, 1801)**

Pelvic fins nearly symmetrical, with one spine and five soft rays; mouth large; jaw teeth barbed; gill arches with groups of teeth; eyes sinistral or dextral; pre-opercular margin distinct, not covered with skin; 15 branched caudal-fin rays.
Maximum length about 60 cm.



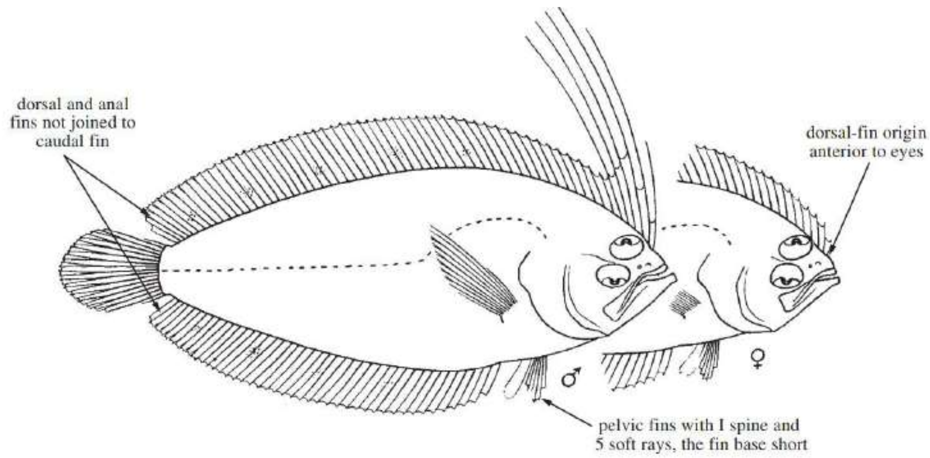
IUCN Status: Data Deficient ver 3.1
Source: FAO, WCP

Body oval-shaped, flat but fairly thick; caudal peduncle deeper than long. Head length 3.2 to 3.6 times in standard length. Both eyes on right or left side of head; upper eye on dorsal surface of head. Supra maxillary bone well developed. Mouth large, extending well beyond posterior margin of lower eye; lower jaw projecting. Teeth large canines, many with barbed tips. Vomer and palatines with teeth. Preopercular margin easily seen, not hidden by skin or scales.

Suborder Pleuronectoidei
Body elliptical, dorsal and anal fins not confluent with caudal. Dorsal origin above eyes, anal fins without spines, palatine without teeth.
The suborder is further divided into three superfamilies; fourteen families are recognized in these superfamilies. Hensley and Ahlstrom (1988) considered this suborder to comprise all fishes except the Psettodidae and soleoid taxa (Cynoglossidae, Achiridae and Soleidae).

Chapleau and Keast (1988) suggested the suborder described by Hensley and Ahlstrom (1988) as paraphyletic and also recommended that the Pleuronectinae, Poecilopsettinae, Rhombosoleinae and Samarinae be raised to family rank.

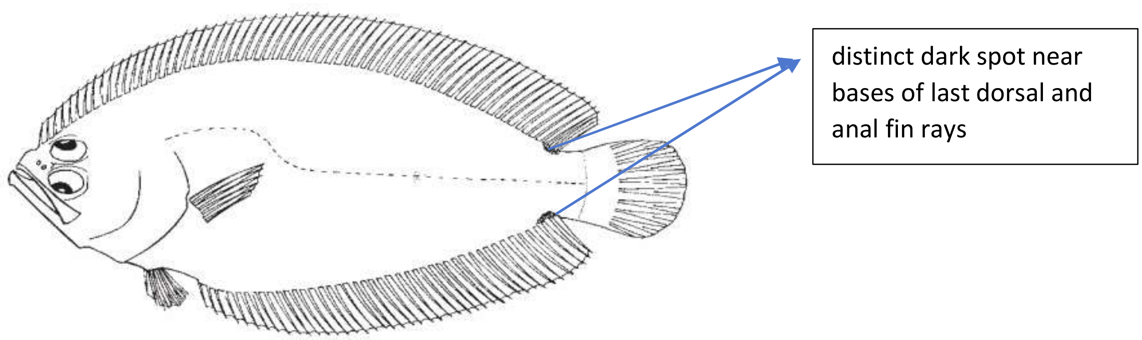
Family : Citharidae - large-scale flounders
Erected by Hubbs (1945) by regrouping two genera (sinistral) Bothidae (taxa) and (dextral taxa) from Pleuronectidae. Four genera and seven small to medium-sized species collectively referred to as ‘large scale flounders”



Source: FAO, WCP

Four genera: ***Brachypleura*** ***(1),*** ***Citharoides,*** ***Citharus,*** ***Lepidoblepharon***, with about six species
Populations feature both sinistral and dextral individuals

Genus *Citharoides*: Sinistral with eyes normally on left side of head; fins rays of dorsal, anal, and pelvic fin branched; distinct dark spot near bases of last dorsal and anal fin rays



Citharoides macrolepidotes

Eyes on right side of head; only posterior dorsal- and anal-fin rays branched,at least anterior pelvic-fin rays unbranched; no distinct dark spot near bases of last dorsal and anal fin rays
Brachypleura **and** ***Lepidoblepharon***

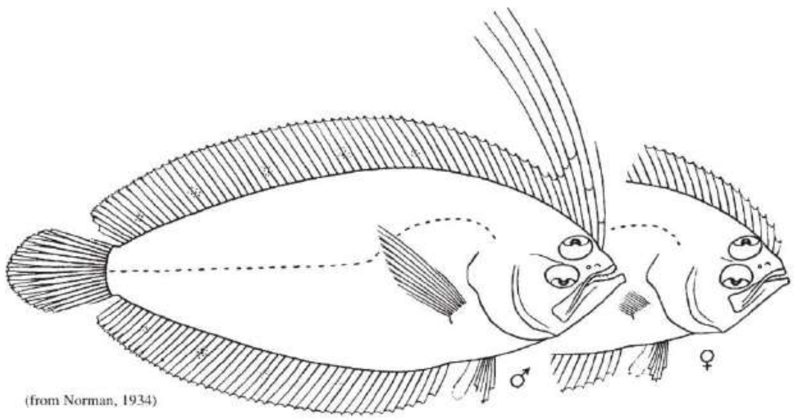
Lepidoblepharon **:** Known from depths of 310 to 435 m on mud bottoms.

- Anterior margins of both eyes at about same level;
- more than 50 scales in lateral line;
- eyes, interorbital area, snout, and jaws scaly;
- caudal fin with 15 branched rays

Brachypleura:

- Both eyes on right side of head,

- front margin of upper eye anterior to front margin of lower eye.
- Sexual dimorphism noticed -males with anterior rays of dorsal fin prolonged, females short
- Dorsal-fin rays 65 to 77, all rays except a few at posterior end of fin unbranched
- Anal-fin rays 41 to 50, all rays except a few at posterior end of fin unbranched;
- caudal fin with 13 or 14 branched rays
- pelvic fins with I spine, 1 unbranched ray, and 4 branched rays



(from Norman, 1934)

Brachypleura novaezeelandiae

Family Scophthalmidae: Commonly called **Turbots**.
A small family consisting of four genera with about nine species of small to large-sized sinistral flatfishes

- Relatively large mouth and large eyes
- Two elongated pelvic fin bases (slightly asymmetrical) extending anteriorly to the urohyal,
- An elongated supra-occipital process forming a bridge with the dorsal margin of the blind-side frontal bone,
- Caudal vertebrae with asymmetrical transverse apophyses
- Larger species have commercial importance and some are used in aquaculture

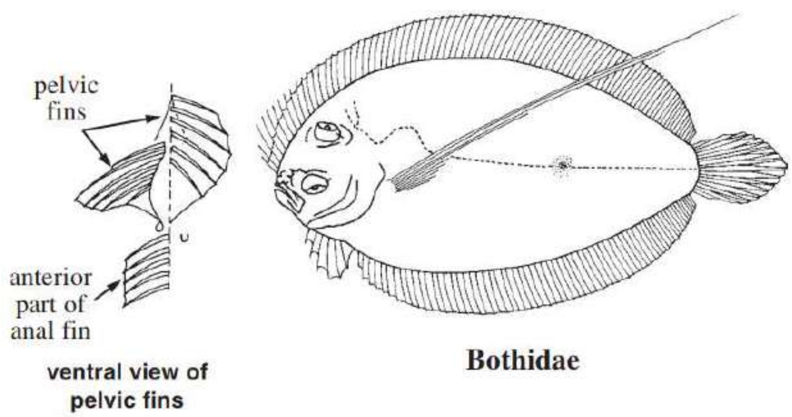
Four genera, *Lepidorhombus* (2), *Phrynorhombus* (1), *Scophthalmus* (4, synonym *Psetta*; see Bailly and Chanet, 2010), and *Zeugopterus* (2), with about nine species
Lepidorhombus
native to the northeastern Atlantic Ocean.

Family Bothidae : Large, diverse monophyletic family of sinistral flatfishes
23 genera, *Arnoglossus, Asterorhombus, Bothus, Chascanopsetta* (synonym *Pelecanichthys), Crossorhombus, Engyprosopon, Engyophrys, Grammatobothus, Japonolaeops, Kamoharaia, Laeops, Lophonectes, Monolene, Neolaeops, Parabothus, Perissias, Psettina, Taeniopsetta, Tosarhombus, and Trichopsetta*, with about 163 species

- No fin spines.
- Eyes on left side of head.
- Left pelvic fin with long base on midventral line with origin anterior to origin of pelvic fin of right side;
- Right pelvic fin with short base above midventral line

Genus *Arnoglossus* Bleeker, 1862

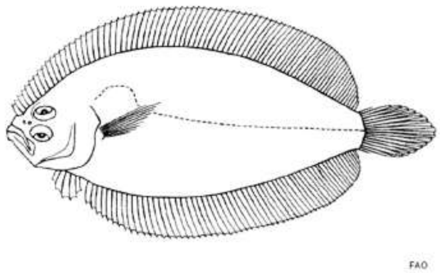
Mouth of moderate size. Interorbital region narrow, bony ridge forms the interorbital area. Males without rostral spines. Scales on eyed side with short ctenii or scales cycloid.



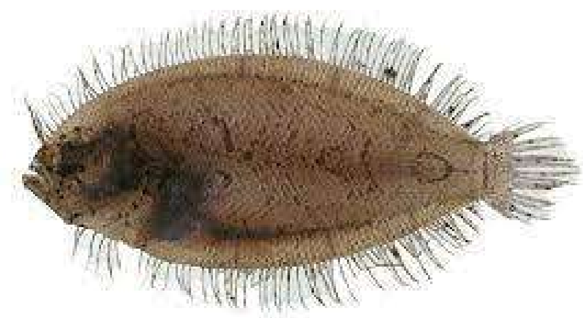
(Source: FAO, WCP)

***Arnoglossus aspilos* (Bleeker, 1851)**

- Dorsal-fin rays 80–95, anterior rays not prolonged.
- Small sized teeth in both jaws, closely spaced.
- Gill rakers not serrate.
- Lateral-line scales 46–53.
- Body depth 1.9 to 2.9 times in SL.
- No dark spot on distal portion of pectoral fin.



Genus *Asterorhombus* Tanaka, 1915



- Mouth small.
- Interorbital region concave, narrow in both sexes,
- no rostral or orbital spines.
- Gill rakers palmate with small tooth-like structures on margins.
- First dorsal-fin ray elongate 1.4 to 3.1 times in head length, longer than second ray. Both eyes usually with one unbranched tentacle, rarely missing or branched.

Genus *Bothus* Rafinesque, 1810

- Mouth small.
- Interorbital region broad and concave, broader in males than females.

Bothus myriaster **(Temminck and Schlegel, 1846). -Indo Pacific oval flounder**

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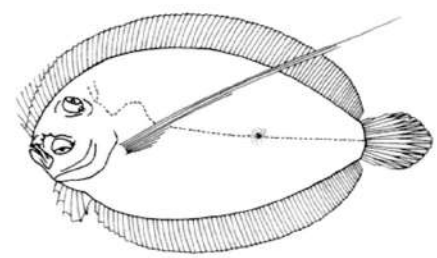
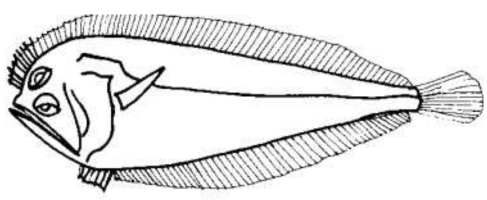


- Clear sexual dimorphism seen in adult fishes;
- Males are generally bigger in size compared to females.
- Rostral spine prominent in males and interorbital area is more concave.
- Pectoral fin is longer in males with the first fin highly elongated
- Males have a prominent spine on the snout, another at the junction of lower and upper jaw, several small spines around orbit
- Colour pattern on the ventral side which progresses with maturity

***Bothus pantherinus* (Ruppell, 1821)**
Both eyes with 2 or 3 ocular tentacles in males, females usually with 2 ocular tentacles on each eye, less frequently with 0 or 1.
Dorsal-fin rays 81–97, anal-fin rays 61–73,
pectoral fin on eyed side with 9–12 rays, greatly elongate in males larger.
Scales ctenoid on eyed side, cycloid on blind side.
Eyed side with numerous dark spots, blotches, and rings on body and median fins, one distinct dark blotch on middle of straight section of lateral line, pectoral fin on eyed side usually with narrow dark cross bars.
Blind side tan or whitish, without distinctive markings

Genus *Chascanopsetta*
Chascanopsetta lugubris Alcock, 1894 -Pelican flounder

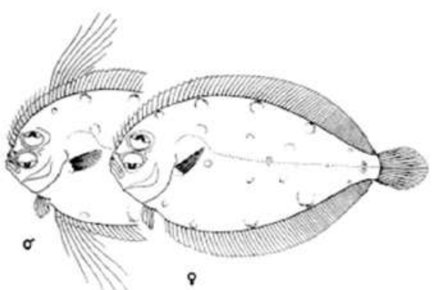


Keys:
1. Lower jaw projecting slightly in front of upper jaw, its length 0.9-1.4 in head length; upper-jaw length 1.1-1.7 in head ....*Chascanopsetta lugubris*
(Indo-West Pacific and eastern and western Atlantic)
Lower jaw projecting well beyond upper jaw, its length 0.6-0.8 in head;
upper-jaw length 0.9-1.0 in head
Dorsal-fin rays 111-118; anal-fin rays 71-81; caudal vertebrae 36-39
....*Chascanopsetta megagnatha*
(seamounts of Sala-y-Gomez Ridge, eastern Pacific)
Dorsal-fin rays 119-133; anal-fin rays 84-93; caudal vertebrae 39-44
Lateral-line scales 185-196; lower-jaw length ca. 0.8 in head length,
less than 18% of lower-jaw length projecting anterior to symphysis of
upper jaw; caudal vertebrae 42-44................................. *Chascanopsetta prognatha*
(Sagami Bay, Japan, Okinawa Trough, Maldive Islands area)

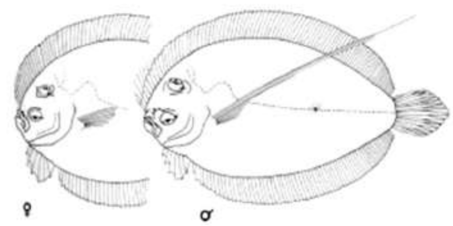
Lateral-line scales 171-181; body depth 3.6-4.7 in SL;
upper-jaw length 1.4-1.6 in head; maxilla extending a short distance posterior to lower eye; no conspicuous dark blotches on lateral line,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,, *Chascanopsetta kenyaensis*
(coasts of Kenya and southern Somalia)
Lateral-line scales 190-241; lower-jaw length 0.6-0.8 in head length,
ca. 28% of lower-jaw length projecting anterior to symphysis of upper jaw;
caudal vertebrae 39-41,, *Chascanopsetta crumenalis*
(Hawaiian Archipelago)

***Crossorhombus* -Left eye flounders**

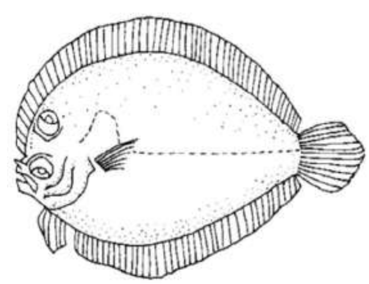
Five species of the bothid genus *Crossorhombus,*
Crossorhombus azureus,
C. valderostratus,
C. kobensis,
C. kanekonis
C. howensis are currently recognised worldwide.



examples of deep-bodied lefteye flounder species showing various combinations of sexually dimorphic characters



***Crossorhombus azureus* (Alcock, 1889) - Blue spotted Flounder)**



Male

Female

- ✓ Males present with ocular flaps.
- ✓ Snout projects out and bears a short orbital spine in males;
  Shorter than eye diameter.

✓ Bony ridge present in front of orbit, inner margins of orbit very sharp; inter orbital area very concave and wider in males.

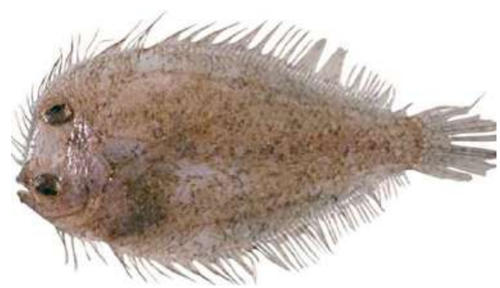
Genus *Engyprosopon* Günther, 1862

- Mouth small.
- Interorbital region clearly concave, increasing in relative width with size
- Sexual dimorphism- wider in males than females.
- First ray of pelvic fin of eyed side below posterior margin of lower eye.
- Lateral-line scales 36–63.
- The caudal bones with deep clefts.

Engyprosopon grandisquama

2 prominent spots at the widest parts of the caudal fin

E. maldivensis



- A strong rostral spine in males, absent in females.
- Gill rakers not serrate, less than 10 on lower limb.
- Teeth biserial in upper jaw
- Pectoral fin on eyed side longer than head length.
- Caudal fin with no blotches
- Blind side of males dark brown except pale yellowish-white head

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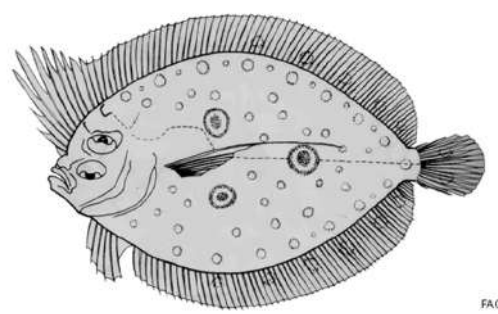
Genus *Grammatobothus*

Grammatobothus polyophthalmus



✓ sexually dimorphic features in the ocular-side pectoral-fin length,

✓ anterior dorsal-fin ray length, and cephalic blotches (Amaoka et al., 1992)

Genus *Laeops* Günther, 1880

small lefteye flounders from the Indo-Pacific.

- Mouth small, teeth present mostly on blind side (teeth present on both sides of jaws in all other bothid genera).
- First pelvic-fin ray on eyed side on or near isthmus,
- first pelvic-fin ray on blind side opposite third or fourth ray of pelvic fin on eyed side.
- Lateral line absent on blind side.

Genus *Neolaeops*
Genus *Parabothus*

Family PARALICHTHYIDAE (347)—sand flounders/ largetooth flounders.
Marine, rarely freshwater;
Atlantic, Indian, and Pacific.
14 genera, *Ancylopsetta, Cephalopsetta, Citharichthys, Cyclopsetta, Etropus, Gastropsetta, Hippoglossina, Paralichthys, Pseudorhombus, Syacium, Tarphops, Tephrinectes, Thysanopsetta, and Xystreurys*, and about 111 species

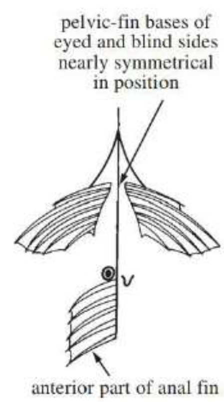
No fin spines. Eyes on left side of head. Pelvic fins short-based, subequal and subsymmetrical in position.

Genus *Cephalopsetta*

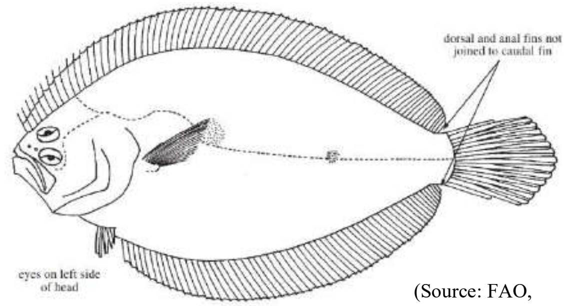
Cephalopsetta ventrocellatus Dutt &Hanumanta Rao

Genus *Pseudorhombus*

- Body oval, large in size upto 40 cm,
- Two nostrils on each side of head, the anterior nostril with a flap covering the aperture posteriorly.
- Mouth large, teeth villiform in a single row in both jaws.
- Gill rakers palmate, with posterior serrations.
- Dorsal and anal fins not joined to anal fins
- Caudal fin double truncate; pectoral fins not elongated, middle 6 to 9 rays branched on eyed side, but all rays unbranched on blind side;
- pelvic fins short-based, posterior 3 - 4 rays branched.
- Scales cycloid or ctenoid on both sides;
- lateral line equally developed on both sides, with a distinct curve above pectoral fins and a supratemporal branch, running upward to anterior part of dorsal fin. Four plates of caudal skeleton with deep clefts along distal margins.
- Commercially important



Species available in India:



(Source: FAO, WIO)

- ✓ *Pseudorhombus argus* Weber, 1913
- ✓ *Pseudorhombus arsius* (Hamilton, 1822)
- ✓ *Pseudorhombus cinnamoneus* (Temminck and Schlegel, 1846)
- ✓ *Pseudorhombus diplospilus* Norman, 1926
- ✓ *Pseudorhombus dupliciocellatus Regan, 1905*
- ✓ *Pseudorhombus elevatus Ogilby, 1912*
- ✓ *Pseudorhombus javanicus* (Bleeker, 1853)
- ✓ *Pseudorhombus jenynsii (Bleeker, 1855)*
- ✓ *Pseudorhombus malayanus Bleeker, 1866*
- ✓ *Pseudorhombus megalops Fowler, 1934*
- ✓ *Pseudorhombus neglectus Bleeker, 1866*
- ✓ *Pseudorhombus oligodon (Bleeker, 1854)*
- ✓ *Pseudorhombus pentophthalmus Günther, 1862*
- ✓ *Pseudorhombus quinquocellatus Weber and Beaufort, 1929*
- ✓ *Pseudorhombus spinosus McCulloch, 1914*
- ✓ *Pseudorhombus tenuirastrum (Waite, 1899)*
- ✓ *Pseudorhombus triocellatus* (Schneider, 1801)

Genus ***Tephrinectes*** (Lacepède, 1802)

- Monotypic genus of uncertain taxonomic status. This genus contains only one species, the flower flounder, *Tephrinectes sinensis*, which occurs in coastal seas off China
- Eyes on left or right side of head.
- Dorsal-fin origin above middle of upper eye, its anterior rays much more widely separated than those which follow, all the rays branched, not scaled

Family PLEURONECTIDAE - Righteye flounders.

- Marine mostly distributed in the Arctic, Atlantic, Indian, and Pacific Oceans
- Margin of preopercle distinct, not covered by skin and scales.
- Eyes on right side of head; reversals rare.
- Mouth and teeth small
- Dorsal fin origin anterior to posterior margin of upper eye; no fin spines; urinary papilla on eyed side; caudal fin not attached to dorsal and anal fins; pectoral fin on blind side smaller than fin on eyed side or missing; pelvic-fin bases short or somewhat elongate, fin on eyed side slightly anterior to that of blind side and closer to or on midventral line. Scales small; lateral line weakly developed or missing on blind side of body.
- Dextral eyes
- Dorsal fin origin above eyes
- Well developed lateral line on both sides
- Symmetrical pelvic fins.

23 genera with about 56 species.

Following Nelson (2016)
SUBFAMILY HIPPOGLOSSINAE. Five genera, *Atheresthes (2), Clidoderma (1), Hippoglossus (2), Reinhardtius (1), and Verasper (2)*, with eight species

SUBFAMILY EOPSETTINAE. One genus, *Eopsetta*, with two species (Cooper and Chapleau, 1998).

SUBFAMILY LYOPSETTINAE. One monotypic genus, *Lyopsetta* (Cooper and Chapleau, 1998).

SUBFAMILY HIPPOGLOSSOIDINAE. Three genera, *Acanthopsetta* (1), *Cleisthenes* (2), and *Hippoglossoides* (4), with seven species (Cooper and Chapleau, 1998b).

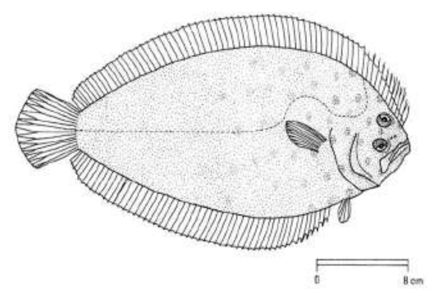
SUBFAMILY PLEURONECTINAE. Thirteen genera and 38 species.

TRIBE PSETTICHTHYINI. One monotypic genus, *Psettichthys*.
TRIBE ISOPSETTINI. One monotypic genus, *Isopsetta*. Garrett (2005) reported hybrids between *Isopsetta* and *Parophrys* (in tribe Pleuronectini, below).

TRIBE MICROSTOMINI. Six genera, *Dexistes*, *Embassichthys*, Glyptocephalus, *Lepidopsetta*, *Microstomus* and *Pleuronichthys* with 19 species

Superfamily Soleoidea. Eight families.

Family PARALICHTHODIDAE—Measles or peppered flounders.
- ✓ Reportedly Marine from southern Africa.
- ✓ One species reported from *Paralichthodes algoensis* of southern Africa (Heemstra in Smith
- ✓ and Heemstra, 1986:864; Evseenko, 2004
- ✓ Dorsal fin origin before the eyes; mouth asymmetrical, prominent curve of lateral line over pectoral fin; vertebrae 30–31;
- ✓ eyed side brownish grey with small dark spots. peppered
- ✓ Considered a subfamily of Pleuronectidae in Nelson (1994) and Evseenko (2004).



(Source: FAO, WIO)

Family POECILOPSETTIDAE

- ✓ Commonly called bigeye flounders.
- ✓ Distributed primarily in deep water waters in the Marine habitat of the Atlantic, Indian, and Pacific Oceans;
- ✓ Dorsal fin origin above the eyes;
- ✓ Lateral line rudimentary on eyeless side;
- ✓ Pelvic fins symmetrical; vertebrae 36–43.
- ✓ Three genera, *Marleyella*, *Nematops*, and *Poecilopsetta*, with 20 species

***Genus Poecilopsetta*:**

The counts of dorsal and anal fin rays and lateral line scales are considered as key features for diagnosing species of *Poecilopsetta*

Bigeye flounders of the genus *Poecilopsetta* Günther, 1880 include 15 currently recognized Seven species of *Poecliopsetta* occur in the Indian Ocean -

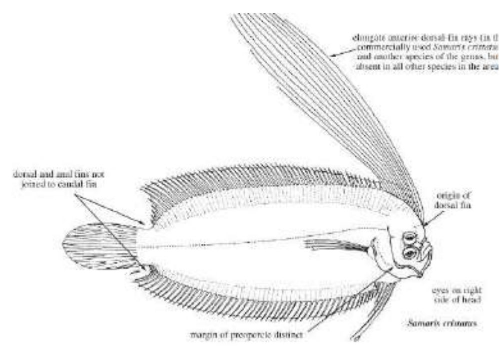
P. albomaculata Norman, 1939,
P. colorata Günther, 1880,
P. natalensis Norman, 1931,
P. macrocophala Hoshino, Amaoka and Last, 2001,
P. normani Foroshchuk & Fedorov, 1992,
P. praelonga Alcock, 1894,
P. vaynei Quéro et al., 1988, and
P. zanzibarensis Norman, 1939)

Family **RHOMBOSOLEIDAE**

- ✓ Predominantly marine; primarily a South Pacific group, occurring mostly around Australia and New Zealand, with one species in the southwestern Atlantic.
- ✓ Pelvic fins asymmetrical (one on the eyed side may be joined to anal fin);
- ✓ Lateral line equally developed on both sides; pectoral radials absent;
- ✓ vertebrae 30–46.
- ✓ Only *Oncopterus darwini* occurs in the southwestern Atlantic.
- ✓ Two species of *Rhombosolea* enter fresh water in New Zealand (McDowall, 1990).
- ✓ Some of the species resemble the Soleidae.

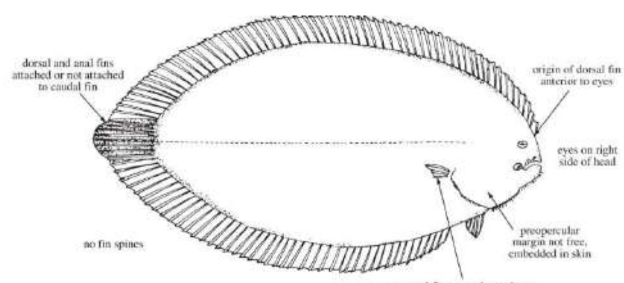
Family SAMARIDAE

- ✓ They are also called **crested flounders**.
- ✓ Reported from marine tropical and subtropical waters of the Indo – Pacific mainly from deep waters.
- ✓ Dorsal fin origin is in front of the eyes; lateral line well developed, pelvic fins symmetrical



Family SOLEIDAE

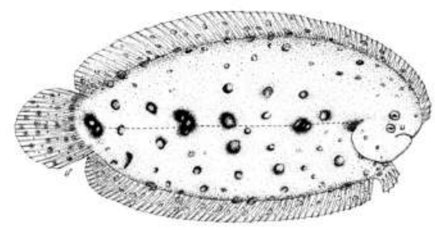
- ✓ Soles have eyes dextral in position, margin of the preoperculum concealed completely,
- ✓ Dorsal and anal fins not contiguous with caudal in some, in some contiguous.
- ✓ Pelvic fins free and not attached to anal fin.
- ✓ Preopercle without free margin, embedded in skin. Eyed-side lips not fringed with labial papillae.



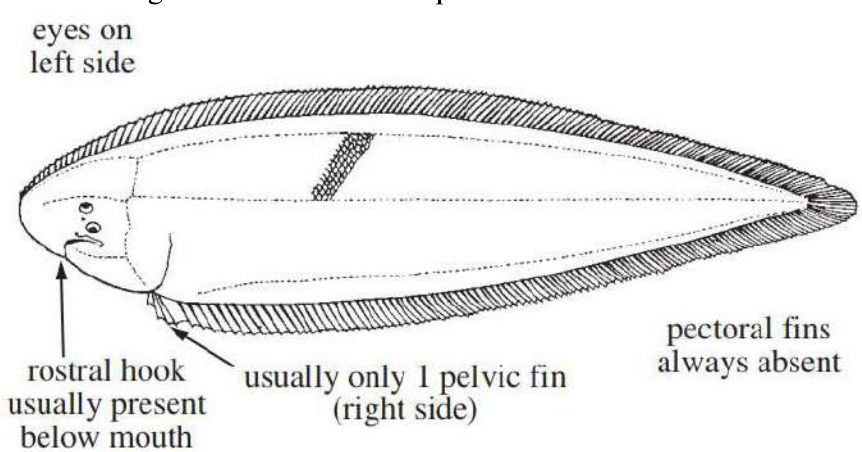
Key to the genera of Soleidae occurring in the area

Genus *Heteromycteris*
Snout with a distinct hook inferior mouth;markedly contorted; caudal fin completely free separate from dorsal and anal fins; branchial septum perforated; ocular lips not fringed with labial papillae; branchial septum perforated by a foramen in its dorsal region; posterior nostril of ocular placed close to anterior edge of lower eye

Genus *Pardachirus*
- ✓ Snout not forming a distinct hook;
- ✓ mouth only slightly contorted;
- ✓ caudal fin separate or joined to dorsal and anal fins;
- ✓ branchial septum entire
- ✓ every fin ray of dorsal and anal fins with a pore at base of each fin ray (eyed and blind side)



Family CYNOGLOSSIDAE
- ✓ Commonly called tonguefishes; they have eyes sinistral.
- ✓ Preopercular margin concealed by skin and scales;
- ✓ dorsal and anal fins contiguous with caudal, caudal pointed in most cases.
- ✓ Pelvic fin may/may not be attached to anal fin.
- ✓ Pectoral fin absent; eyes very small, placed close together,
- ✓ Mouth assymetrical.
- ✓ Three genera with about 143 species



Source: FAO, WCP

The family is divided into two subfamilies – Symphurinae and Cynoglossinae. Three genera with 127 species reported; in the present study, 2 genera with 12 species were collected in subfamily Cynoglossinae.

SUBFAMILY CYNOGLOSSINAE
- ✓ Snout hooked,
- ✓ inferior mouth assymetrical,.
- ✓ Lateral lines well developed on the ocular side.

- ✓ Lips fringed in *Paraplagusia*, plain in *Cynoglossus*.
- ✓ Most of the species occur in sandy beds and are burrowing forms, some are collected from brackish and freshwaters.

SUBFAMILY SYMPHURINAE.

- ✓ Snout not hooked;
- ✓ mouth terminal mostly straight;
- ✓ lateral line absent on both sides;
- ✓ pelvic fin free from anal fin.
- ✓ Deepwater species

PRESENT STATUS OF FLATFISH PHYLOGENY

Eschmeyer (2013) mentions of 75 new species of flatfish records during the period 2004–2013. The Order is now classified into two suborders – Psettodoidei and Pleuronectoidei; theformer with one family Psettodidae and the latter with 13 families in three superfamilies Citharoidea, Pleuronectoidea, and Soleoidea. Around 1042 valid species have been recorded in the Order at present. Taxonomic relations especially within the subfamily Pleuronectinae remain uncertain in spite of numerous investigations into the biology and systematic of the flatfish.

Proper identification of organisms is necessary to monitor biodiversity at any level (Vecchione and Collette 1996). Furthermore, if decisions are to be made about preserving species, then relationships among species must be known to determine the evolutionary uniqueness of the species. Flatfish resources require more attention as these are a mixture of highly valuable table fish as well as export items; besides many species are dwindling in the landings. A study on the taxonomy and diversity of the flatfishes available in the Indian waters is a requisite for successful management of the fishery as well as accurate documentation and maintenance of biodiversity.

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CHAPTER 25

Taxonomy of Fishes of the Family Balistidae in India

Abstract

The fishes of the family Balistidae are popularly known as trigger fishes and distributed along the Indian and the Pacific Oceans, though certain species are restricted to particular regions. In India, these fishes are abundant in the Gulf of Mannar, Palk Bay, off Maharashtra and Gujarat coast, off Kerala, Andaman and Lakshadweep Islands. The recent trend in exploitation for human consumption and export and the fast increasing demand for these fishes in live condition for aquarium purpose warrant knowledge on taxonomy and distribution in space and time of the individual species for formulating strategies for sustaining yields and addressing the issues of biodiversity conservation. They feed mainly on zooplankton, molluscs, sponges and other associated fauna and the schooling behaviour is directly correlated to its grazing and grabbing nature. Added to this balistids have preference to coral reef habitat for feeding during their younger stages. The coral reefs and sand beds along the coast serve as the feeding ground for them and juveniles migrate to these grounds for feeding. It is also to be noted that trawl catch was constituted exclusively by 8-32 cm fishes, with total absence of small juveniles and mature fishes. Descriptions of the species of the genera viz. *Abalistes*, *Balistapus, Zenodon, Canthidermis, Melichthys, Pseudobalistes, Parabalistes, Rhinecanthus* and *Sufflamen* were done.

Introduction

Exploitation of marine living resources for food is an age-old practice but this exploitation was largely restricted to near shore regions in the sea. The improvements in the capabilities of exploitation during the past half a century have helped in increasing harvests of living resources from the coastal waters as well as deeper regions of the sea. The rapid increase in the human population and the consequent increased demand for protein-rich seafood, have led to the exploitation of marine fisheries resources to their optimum levels in most cases. Fisheries resources being renewable, managing them on a sound scientific basis is essential to harvest maximum sustainable economic yields on a continual basis, year after year. The basis for such a management is knowledge of the dynamics of every species that contribute to the fishery. The tropical seas, however, unlike their counterparts in the temperate regions, are inhabited by a large number of species. In many cases the species live together sharing the same habitat and food. Several families are represented by several genera and several closely resembling species and any non-selective (or the least selective) gear exploits a large number of species in one haul. If these species are not correctly differentiated, there is a likelihood of treating two or

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more closely resembling species as one species, in detailed biological studies like growth, spawning, fecundity etc., leading to erroneous conclusions. A sound knowledge of the taxonomy of the fishes contributing to the fishery and the capability to identify them to species level correctly therefore plays a vital role. As the biological characteristics are known to be different between species and as they form the basis for studies on stock assessment of exploited resources, the capability to distinguish species effectively is of immense value, without this all species-oriented studies do not lead to any meaningful results. Moreover, in recent years there is increasing concern on the protection of the environment and conservation of biodiversity and the issues of marine biodiversity cannot be addressed effectively without a proper understanding of the species constituting to the biodiversity. This is particularly serious in the tropical ecosystems where a multiplicity of species from lower invertebrates to higher vertebrates inhabits the same ecosystem in certain assemblages. Hence, the value of taxonomic studies in fisheries research is invaluable; it is a prerequisite for any detailed study on species and ecosystem.

Growth of fish taxonomy in India can be traced back to the late 18th century, when European scientists and British Officers of the East India Company, particularly medical doctors, began to collect and describe Indian fishes. Bloch (1795) is one of the pioneers in the field of taxonomy of Indian fishes.

The nineteenth century saw several publications on Indian fishes. Among them are the publications of Schneider in Bloch and Schneider (1801), Lacepede (1798 - 1803), Hamilton (1822), Cuvier and Valenciennes (1828 – 1849), Sykes (1839), Gunther (1860, 1872, 1880) and several publications of Dr. Day (1865-1877) culminating in the “Fishes of India." (Day 1875, 1878) and the “Fauna of British India” (1889).

During the twentieth century, subsequent to Chaudhuri (1912, 1916) and Raj (1916, 1941), the significant taxonomic contributions of Hora and his coworkers (1920-1951) based on collections made during extensive surveys in India and the neighbouring countries provide the basis for more intensive studies on different groups/families. Most of these works pertain to freshwater fishes. The reports of the new species of fishes discovered in India were also published in the various journals and the information is scattered. Misra (1962) consolidated the available information on important species and published “An aid to identification of the common commercial fishes of India and Pakistan”. Later he continued his work and published in 1976 “The fauna of India and Adjacent countries (Pisces)” in three volumes. Jones and Kumaran (1980) published descriptions of over 600 species of fishes from Lakshadweep. Recently, Talwar and Jhingran (1991a, 1991b) published descriptions of a total of 930 species of inland (fresh and brackishwater) fishes of India, including all species known till date.

As on date, a total of about 2500 species of fish are known from India (Talwar and Jhingran 1991a) of which about 1570 are truly marine. While the work of Talwar and Jhingran (1991a, 1991b) largely fulfils the long felt need of the workers on inland fishes, a similar treatment on the Indian marine fishes is yet to be made. Consequently the workers, perforce, refer to either the publication of Day (1878), which needs to be updated, or some regional publications (as those of Munro, 1955; Smith and Heemstra, 1986 etc), which do not contain all species known from the country till date, resulting in most cases, in inaccurate identifications. While there is an urgent need for a comprehensive publication on Indian marine fishes also, the taxonomic studies carried out in recent years on certain groups have shown that there is considerable scope for work in this area because the earlier species descriptions were made on single or a few specimens and did not take intraspecific variation into account thus leading in certain instances to `recognition' of different stages in the life history of a particular species as belonging to different species (as in the case of *Caranx melampygus* Cuvier and *Caranx stellatus* Smith, see Berry, 1968) or creation of new species on the basis of certain abnormal specimens of a species (*Cirrhinus chaudhryi* Srivastava, 1968) and to a lot of confusion on the identity of the species in many instances. In this connection it is worthwhile to quote the following:

1. Leaders in many fields of biology have acknowledged their total dependence on taxonomy (Mayr, 1969:6)

2. The extent to which progress in ecology depends upon accurate identification, and upon the existence of a sound systematic groundwork for all groups of animals, cannot be too much impressed upon the beginner in ecology. This is the essential basis of the whole thing; without it the ecologist is helpless, and the whole of his work may be rendered useless (Elton, 1947, as cited by Mayr, 1969:6)

There have been very few taxonomic revisions of families or genera of marine fishes of India (flatfishes of different families by Norman, 1927, 1928, 1934 and Menon, 1977; Scombridae by Jones and Silas, 1962a, 1962b, 1962c; Mugilidae by Sarojini, 1962a, 1962b; Clupeioids by Whitehead, 1965, 1973, 1985; Trichiuridae by James, 1967; Leiognathidae by James, 1978; Chirocentridae by Luther, 1968; Mullidae by Thomas, 1969; Sphyraenidae by De Sylva, 1975; Syngnathidae (genus *Hippichthys*) by Dawson, 1976; Scorpaenidae (Choridactylinae) by Eschmeyer 1969; Platycephalidae by Murty, 1982; Callionymidae by Ronald, 1983; Sciaenidae by Lal Mohan, 1972, 1982 and Trewavas, 1977; genus *Nemipterus* (Nemipteridae) by Russell, 1986. etc.,) resulting in the nonavailability of comprehensive work (of a family or genus) incorporating all species described by and discovered subsequent to Day (1878) which could help workers to carry out their work satisfactorily and without difficulty and to address the research needs in the biodiversity conservation efficiently. Though this problem, to some extent, has been solved by the work of Weber and De Beaufort (1911-1962) and the `Fish identification sheets' issued by FAO (Fischer and Whitehead, 1974; Fischer and Bianchi, 1984), there is still need to provide adequate descriptions of genera and species of a large number of families such as Balistidae and to sort out nomenclatural issues in many cases.

The fishes of the family Balistidae unlike a large number of other teleosts do not form a major fishery any where along their distribution range. Further, these fishes until very recently were not used for human consumption even at places where they occur in catches regularly. As the major interest in research has been on the commercially important fishes, no significant research effort has been paid to any aspect of these fishes. A large number of research workers starting from Linnaeus (1758) (Linnaeus, 1758; Bloch, 1786; Bonnaterre, 1788; Mungo Park, 1797; Lacepede, 1798; Bloch and Schneider, 1801; Latreille, 1804; Shaw, 1804; Tilesius, 1820; Quoy and Gaimard, 1824; Ruppell, 1828, 1835,1852; Lay and Bennett, 1830; Swainson, 1839: Berry and Bladwin, 1966; David, 1966; Moore, 1967; Randall and Klausewitz, 1973; Randall *et.*

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1. The species were described on the basis of one or few specimens, hence did not take into account the possible intraspecific variation with growth,

2. A large number of inconsistencies occur in the nomenclature,

3. A comprehensive taxonomic revision of the family is not available from the Indian ocean region,

4. There has not been any taxonomic research in India after Day (1878),

5. The absence of regional works on these fishes resulted in misidentification of different species by different workers,

A critical study of the available species in the range of their distribution shows that the descriptions were rather cursory depending mainly on colour, shape and such others but did not take into account certain morphological characters (scales, nostrils, ventral flap, pelvic spine etc.) or anatomy, resulting in inadequate definition of species.

So far as the Balistids are concerned, the total lack of taxonomic work has been the stumbling block to the fisheries scientists and fishery managers. However in the recent years there has been some demand for these fishes for human consumption and these fishes have been contributing to seasonal fishery in certain pockets along Indian coasts.

Another issue that has emerged in recent years is the one pertaining to marine biodiversity conservation and management and in this respect top priority attention is given to the coral reef ecosystems which are under the severe threat of degradation and, Balistids are an integral part of the coral reef ecosystems. Without strong taxonomic database on the various organisms inhabiting the ecosystem, issues pertaining to sustainable utilization of the living resources and biodiversity conservation cannot be effectively addressed.

The present study on the taxonomy of the Balistids of India is not only an attempt to provide adequate descriptions of all known species from the country, but also to sort out various issues relating to genera, nomenclature and synonymies.

Material and methods

In addition to the collections from Mumbai, Veraval, Chennai, Mandapam, Kilakarai, Tuticorin, Vizhinjam, Colachel, Kanyakumari and Minicoy (Fig.1), specimens in the collections of Zoological Survey of India (ZSI), Kolkatta and those in the reference collection Museum of the

Central Marine Fisheries Research Institute (CMFRI) at Cochin and Mandapam were also examined.

Soon after collection, the fresh colour and pigmentation of the specimens were recorded at the landing centre and photographs taken. The specimens were then injected with 5% formalin and brought to the laboratory in containers filled with 5% formalin for detailed studies. In the laboratory, the specimens from different localities were preserved separately and all relevant biometric data taken. After taking the biometric data, the belly was cut open to note the sex.

In taking the meristic and morphometric data, the methodology of Hubbs and Lagler (1958) was followed; all the linear measurements were made in the median longitudinal axis (Fig.2). Examination of the nasal apertures and the counts of lateral line scales, arrangement and morphology of the scales on the cheek, body, abdomen, caudal peduncle and fin rays counts were made under a binocular stereo zoom microscope.

For uniformity, pectoral fin rays, gill rakers and, morphology and arrangement of scales on cheek, body, abdomen and caudal peduncle, were recorded from the left side only. The abbreviations of Hubbs and Lagler (1958) were followed for various meristic characters. In the case of Dorsal, it is cited as 'D'. The number of spines are shown in upper case Roman numerals, unbranched rays in lower case Roman numerals and branched rays by Arabic numerals (for example D. III, i, 31-36 means the first dorsal fin has three spines and the second dorsal fin has one unbranched ray and thirty one to thirty six branched rays). The number of Pectoral rays shown as P.i, 11-12, meaning the presence of one unbranched ray on the upper side of the pectoral fin and eleven to twelve branched rays. The count of caudal fin rays includes all the branched rays plus two unbranched rays, one above and the other below. The method of counting scales from origin of the second dorsal to base of anal is shown in Fig.3. A. The anterior and posterior margin of first dorsal spine is described in same figure. The lateral line is interrupted in some species, consisting of anterior curved portion and the posterior straight portion, in such cases the range of lateral line scales in the anterior portion is given first followed by posterior portion. In most of the species the lateral line is continuous. The teeth and spines in the ventral flap, are described with suitable figures. The scales on cheek, body, abdomen and caudal peduncle were studied using stereo zoom microscope under different magnification, which ranged from 5x – 20x, (Fig. 3.B); the marked area indicates the position of the scales which were studied. To study the arrangement, shape and morphology of the scale. Photographs taken during the study were arranged in the figures given at the end of the species description of each species. After this initial study, scales with skin were dissected out and boiled in 5% KOH solution for 5 minutes to separate the scales from tissue and study its shape and arrangement of protuberances. For this the scales were first examined under the stereo zoom microscope and later the scales were treated in 1% osmium tetra oxide and coated with gold in the gold spatter for observing under scanning electron microscope. The observations were made in the Hitachi H600 electron microscope having an H6010-A scanning electron microscope attachment, in magnification of 100x and 200x.

The nasal apertures were also studied under similar magnifications; the figures of these are presented in the species description of each species. The number of gill rakers present on the

C- shaped gill arches is given in Arabic numerals. In trigger fishes, the upper and lower limbs of gill arches cannot be distinguished.

Attempts were made to collect adequate number of specimens of each species. However as already stated, the landings of Balistids are poor and only two species (*Sufflamen fraenatus* and *Zenodon niger*) are common. For the rest of the species only a few specimens could be collected. Hence in the case of seven species, the descriptions were made on the basis of less than thirty specimens.

The descriptions of species were made on the basis of specimens collected from one locality and such specimens were indicated in "Material examined". The specimens collected from other localities were used for comparison and supplementing the description and such material was indicated in the "Additional material examined". The frequency distribution of meristic characters together with estimated values of mean, standard deviation and standard error are given for all species.

Colour description was always based on fresh specimens. Specimens of certain species were not available in fresh condition; in such cases colour descriptions were made from formalin-preserved specimens.

Results and discussion

Certain terms used for the description of shape of body, teeth and fins are as follows: rhomboid, oval, rectangular, concave, convex and diamond shaped. For describing scales the following terminologies were used.

1. Anterior margin: - embedded part, anterior margin of the scale (Fig. 4.A)
2. Posterior margin: - exposed part, posterior margin of scale when scale is on fish. (Fig.4.A)
3. Protuberances: - a projection on the scale surface which is ridge-like (Fig.4.B), round (Fig.4.C), spiny antrose or retrose (Fig.4.D & E).

Body shape

The fishes of the family Balistidae have a laterally compressed body. Most of the species have rhomboid or an oval shaped body, where as some have an oval-elongate body.

Second dorsal and anal fin

The unpaired fins, second dorsal and the anal fins display symmetry in these fishes. The shapes are species specific. These fins can be divided into two types based on the height, 1) fins with height less than half the depth of the body; 2) fins with height more than half the depth of the body. The fins belonging to the first category are mostly rectangular, transparent, thick at base thin at the top with different types of outer borders, which range from straight (Fig.5.A), convex (Fig.5.B), elevated at the anterior (Fig.5.C) and wavy edged (Fig.5.D). The rays in these fins are almost of the same length except in some cases the anterior rays are the longest compared to the other rays "elevated at the anterior". In case of "convex" the middle rays are the longest.

The fins belonging to the second type have a concave upper border (Fig.5.E) with the base being thick and upper margin thin, in some case wavy, the anterior longest ray gives a appearance of a separate lobe, posterior most rays being less than half the length of the first ray.

Teeth

Balistids have two types of teeth, arranged in two separate rows on the upper jaw. The inner row consisting of three teeth, which is pear shaped to rectangular shaped having thin and sharp edge, placed in the interdental gap of the outer teeth. The outer row has four teeth, the first teeth are flat and projects outside. The lower jaw has a single row of four teeth.

Based on the shape of the first and second teeth of the upper and lower jaws, five types have been identified. They are as follows: 1) The first and the second teeth conical (Dagger shaped), with tips pointed and directed inward (Fig.6.A). 2) The first and the second teeth rectangular with the tip convex towards the inside (Fig.6.B). 3) The first teeth of the upper jaw rectangular but teeth of lower jaw rectangular with a concave tip, the second teeth caniniform and orange coloured (Fig.6.C). 4) The first teeth of upper jaw conical with pointed tip diverging outside, the first teeth of the lower jaw also conical with the tip diverging towards the inside, rest of the teeth of both jaws with a rectangular base, with a conical projection, towards the anterior. (Fig.6.D). 5) All the teeth of upper jaw rectangular with serrated edge (Fig.6.E). The teeth of the lower jaw symmetrical to upper jaw, but directed inwards.

Nasal aperture

The nasal apertures – anterior and posterior, are situated in small depression along the anterior border of the eye. The anterior nasal aperture has different shapes, which is species specific but the posterior aperture is similar in all species. Based on the shape of the anterior nasal aperture five types have been identified. 1) Funnel shaped with edges decurved and a lobe towards the posterior (Fig.7.A). 2) Dome shaped with a pore at the tip (Fig.7.B). 3) Tube like with an irregular edge, in some it is a short tube, which is directed forward (Fig.7.C). 4) The anterior nasal aperture has a circular flap bend over the circular opening (Fig.7.D). 5) Dome shaped with a circular opening, guarded by a fleshy cone from inside (Fig.7.E).

Gills

Trigger fishes have 4 pairs of gills, supported on C- shaped branchial arch. The outer most branchial arch possesses gill rakers. Based on the shape they are divided into five types. 1) Slender, hyaline, pointed and elongated (Fig.8.A). 2) Short and conical with pointed tip (Fig.8.B). 3) Blunt with globular protuberances towards inside (Fig.8.C). 4) Pointed with bristles towards the inside (Fig.8.D). 5) Blunt tipped, hyaline, serrated towards the inside (Fig.8.E).

Scales

a) Morphology

In trigger fishes scales on body and caudal peduncle are diamond-shaped where as scales on cheek and abdomen are rhomboid, rectangular, square or round shaped with the round edges. These scales have a dorsal exposed part called posterior margin and a ventral basal plate called anterior margin (Fig.4.A). The anterior margin forms anterior part of the basal plate, which is embedded in the dermis. Based on the position of the scale on the body, the width of the anterior margin varies. It is widest in the scales found on the body and narrowest on the scales on cheek. The posterior margin consists of horizontal or vertical rows of ridges, round protuberances, antrose spines or retrose spines. Arrangement and type are species specific. At the centre of the posterior margin is present the central canal (minute pore). The morphology and arrangement of scales on cheek, body, abdomen and caudal peduncle are described below.

i) Cheek

These scales have “<” shaped anterior margin. The posterior margin is elevated from the anterior margin. The width of the anterior margin is equal to the posterior margin in most of the cases, wherever there is a change, it is mentioned. Cheek scales are of seven types:

Type I

The scales are rhomboid, diamond or rectangular shaped. The anterior margins are “**<**” or “**L**” shaped, thin and smooth. The width of the anterior margin is half of the posterior margin. The posterior margin is rhomboid and consists of 3-8 vertical rows of round protuberances (Fig.9.A).

Type II

The scales are diamond shaped. The anterior margin is “**<**“ shaped, thin and have horizontal ridges. The posterior margin diamond shaped and consists of 3-5 vertical rows of horizontal ridges (Fig.9.B).

Type III

The scales are round, square, diamond or rectangular shaped. The anterior margin is “<”, “**[**” or “**C**” shaped, thin at the anterior most edges and thick posteriorly. Width of the anterior margin is twice that of posterior margin. The posterior margin is square, rhomboid or round having round protuberances and transverse ridges, which are arranged in 3 -5 vertical rows. In round scales the posterior margin is not very clearly demarcated (Fig.9.C).

Type IV

The scales are pentagonal, hexagonal or round in shape. The anterior margin is thin “<” or “**(**” shaped. The posterior margin is rhomboid with “**<**” or “**l**” shaped 5-8 vertical rows having horizontal ridges at the anterior first row and round protuberances as well as ridges in subsequent posterior rows (Fig.9.D).

Type V

The scales are diamond or rhomboid shaped, anterior-posteriorly compressed and dorso-ventrally elongated. The anterior margin is thin having horizontal ridges. The width of the anterior margin is half that of the posterior margin. The posterior margin is rhomboid having 3-5 vertical rows of small to large round protuberances (Fig.9.E).

Type VI

Some of the scales are rectangular or rhomboid; few are anterior-posteriorly compressed and dorso-ventrally elongated, have a smooth surface and covered with a thin skin when found on the fishes, especially occupying fleshy groove. The anterior margin is thin. The width of the anterior margin is one-fourth that of the posterior margin. The posterior margin is rhomboid having 1- 4 vertical rows of small round protuberances and ridges; some the scales have a smooth surface with shallow depressions and ridges (Fig.9.F).

Type VII
The scales are diamond, rhomboid, round or triangular. The anterior margin is thin with few ridges. The width of the anterior margin is half that of the posterior margin in some and in others it is one-fourth that of the posterior margin. The posterior margin is rectangular, square or rhomboid having 3 - 8 vertical rows of round protuberances arranged in “<” or “**l**” shaped vertical rows. (Fig.9.G).

ii) Body
In body scales, the width of the anterior margin is equal to that of the posterior margin. The anterior margin is “<” shaped. The posterior margin is diamond shaped. Body scales are of five types:

Type I
The anterior margin is thin and smooth. The posterior margin is slightly elevated from the anterior margin and has ridges on the first row with a large round protuberance at the middle of the scale. Round protuberance is arranged in 2-7 vertical rows (Fig.9.H).

Type II
The anterior margin is thick. The posterior margin has 5 - 10 vertical rows of round protuberances; the anterior most rows of round protuberances are small followed by larger protuberances (Fig.9.I).

Type III
The scales are diamond or rectangular shaped with round edges. The anterior margin thick. The posterior margin has 5 - 10 vertical rows of ridges tapering towards the posterior; the anterior most rows of ridges are large (Fig.9.J).

Type IV
The anterior margin is thick. The posterior margin has 3-5 vertical rows of retrose spines (Fig.9.K).

Type V
The anterior margin is thin. The posterior margin is having 3-5 vertical rows of ridges (horizontally placed) (Fig.9.L).

iii) Abdominal
The scales on the abdomen are diamond or rhomboid shaped, with round edges. The anterior margins are “<” shaped, thin anteriorly with smooth surface. The width of anterior margin is

equal to that of the posterior margin. The posterior margin is diamond shaped. They are of three types:

Type I
The posterior margin is rhomboid having 3-4 oblique rows of protuberances. The protuberances are either horizontal ridges or ridges which tapers towards the posterior or ridges which tapers towards the anterior or round protuberances. In some the posterior margin has horizontal ridges on the first row, followed by 3-5 rows of round protuberances (Fig.9.M).

Type II
The posterior margin is rhomboid having a round posterior edge. These scales have horizontal ridges on the first row followed by 3-5 oblique rows of round protuberances (Fig.9.N & O).

Type III
The posterior margin is rectangular or square shaped, having 3-5 oblique rows of round protuberances. At the anterio-ventral corner is present a round protuberance slightly larger than the other protuberances (Fig.9. P-R).

iv) Caudal peduncle
Posterior margin slightly elevated from the anterior margin in case of scales on the caudal peduncle. Diamond shaped, with round edges. The anterior margin is smooth, “<” shaped, thin anteriorly and thick posteriorly. The width of anterior margin equal to the width of the posterior margin. The posterior margin is diamond shaped. These scales are of five types:

Type I
The posterior margin has 3-4 rows of horizontal ridges at the middle and 3 -5 horizontal rows of round protuberance on both sides of the ridges (Fig.9.S).

Type II
The posterior margin has 5 - 10 vertical rows of round protuberances; the anterior most row has a large round protuberance at the middle (Fig.9.T).

Type III
The posterior margin has 10 - 20 horizontal rows of ridges with 3- 4 ridges at the centre slightly elevated and at the anterior of these ridges is present a pointed round protuberance (Fig.9.U).

Type IV
The posterior margin has 3-5 vertical rows of round protuberances with the anterior most rows having a ridge at the centre, which tapers towards the anterior (Fig.9.V).

Type V
The posterior margin has 3-5 vertical rows of horizontal ridges tapering towards the posterior and an antrose spine at the middle. Where as in others there are 5-8 horizontal rows of ridges tapering towards the posterior (Fig.9.W).

f) Type VI
The posterior margin is having 3-5 vertical rows of round protuberances. (Fig.9.X).

b) Arrangement
Examination of the scales on cheek, body, abdomen and caudal peduncle revealed that the general pattern of arrangement were similar between species in case of scales on the body, abdomen and caudal peduncle. Arrangement of scales on cheek varies among species.

i) Cheek scale
There are three types of arrangement of scales on cheek:

Type I
The rhomboid scales arranged in vertical rows, anteriorly and obliquely at the posterior (Fig.10.A).

Type II
The rhomboid to square scales is arranged in horizontal rows. The type of scales in horizontal row varies. a) The scales are square at the anterior and rhomboid to rectangular posteriorly. b) The scales are square at the anterior, with some triangular scale in between and rhomboid scale posteriorly. c) The scales are completely rectangular (Fig. 10.B).

Type III
The square and rhomboid scales are arranged in horizontal rows with wide transverse fleshy horizontal grooves (the horizontal grooves also possess rectangular, rhomboid and elongated scales which is completely covered by a thick skin). In this type of arrangement there are three types. a) Scales at the anterior irregular shaped, posteriorly rhomboid with horizontal grooves. b) Scales at the anterior covered by skin, posteriorly 3-5 horizontal rows of square and rectangular scales; in between the posterior rows are present horizontal grooves. c) Scales covered by skin anteriorly, posteriorly horizontal rows of square scales are present with wide horizontal fleshy grooves (Fig.10.C).

i) Body
The diamond scales are arranged in vertical rows (Fig.10.D).

ii) Abdomen
The scales are arranged in oblique rows. There are two types of scales on the abdomen, rhomboid and rectangular (Fig.10.E).

iii) Caudal peduncle
The diamonds shaped scales are arranged in transverse rows (Fig.10.F).

c) Ultra structure
The analysis of the transverse sections of the body scales under the scanning electron microscope revealed that the scale consists of 4 layers, the upper most layer is glassy, just below is a perforated layer, followed by a vascular area consisting of transverse and longitudinal

canals; the fourth layer is the thickest and opaque. These four layers are well demarcated at the anterior and middle portions of the posterior margin, but the posterior portion of the posterior margin is highly compressed and the layers not well demarcated (Fig.11.A-F). The gross morphology is very similar to that of the ganoin scale (Sire, 1989). Since peg like extensions are not found in these scales, (which is the character of the ganoin scales) these scales cannot be classified as ganoin. Hence they are classified as palaeoniscoid scales, which are also found in fishes of the family Polypteridae (Bond, 1979). The anterior margins and posterior margins are different characteristically between species.

i) Anterior margin

The anterior margin of the scales are of 5 types, based on the type of protuberances it possess, (ridges, pits, and network of fibres).

Type I (Ridges)
The anterior margin has horizontal ridges, which are arranged in many semicircular rows (Fig.12.A).

Type II (Pits)
The anterior margin has many pits arranged in transverse rows. All the pits have many pores (Fig.12.B).

Type III (Ridges and circular protuberances)
The anterior portion has many round protuberances, with ridges in between. The arrangement varies in some species with horizontal ridges at the anterior part arranged in different layers (placed one above the other) and round protuberances and pits posteriorly (Fig.12.C).

Type IV (Fibre and pits)
The anterior margin has a network of thin fibres. Between these fibres are present many minute pits (Fig.12.D). In some the fibrous network is made up of broad fibres with very few pits, circular and shallow. In few others the fibrous network is marginal but the pits are large and almost circular.

Type V (Round, triangular, ridge like protuberances, grooves and pits)
The anterior margin consists of horizontal ridges and round, triangular protuberances (Fig.12.E). In some the ridges are arranged in semicircular rows and between rows are present shallow grooves.

ii) Posterior margin

The posterior margin is also of four different types. The protuberances of the posterior margin include, horizontal ridges, ridges tapering towards the posterior, retrose spine, round and cones. These protuberances are arranged on the perforated layer.

Type I (Horizontal ridges and pointed conical protuberance)
The posterior margin has horizontal ridges and conical pointed protuberances. The horizontal ridges occupy the anterior row (Fig.12.F).

Type II (Horizontal ridges and retrose spines protuberance)
The posterior margin has horizontal ridges and retrose spines; the former occupies the first row (Fig.12.G).

Type III (Horizontal ridges like protuberance)
Ridge like protuberances are arranged on few vertical rows (Fig.12.H)

Type IV (Round protuberance)
Round protuberances are arranged in 3-5 vertical rows (Fig.12.I)

Nine genera of the family Balistidae were studied not only to provide adequate descriptions of twelve known species from the country but also to sort out various issues relating to genera, nomenclature and synonymies.

1. *Balistapus Tilesius, 1820*
2. *Zenodon (Ruppell, 1835) Swainson, 1839*
3. *Rhinecanthus Swainson, 1839*
4. *Melichthys Swainson, 1839*
5. *Canthidermis Swainson, 1839*
6. *Parabalistes Bleeker, 1866*
7. *Pseudobalistes Bleeker, 1866*
8. *Sufflamen Jordan, 1916*
9. *Abalistes Jordan and Seale, 1906*

Genus *Balistapus* Tilesius, 1820

(Type species *Balistapus capistratus* Tilesius, 1820)

Diagnosis

Anterior nostril conical with pore at the tip. Groove before eye absent. Scales on cheek rhomboid, arranged in vertical rows. Body scales have retrose spines. Caudal peduncle short and deep, with two rows of antrose spines. Ventral flap absent. Caudal fin truncate.

2.5.1.1 *Balistapus undulatus* (Mungo Park, 1797)

Balistes undulates Mungo Park, 1797, p.37.
Balistes undulatus Day, 1878, p.691.
Balistapus undulatus Jones and Kumaran, 1980, p. 672, fig.572.

Material examined: 12 specimens from Lakshadweep, (8 females, 3 males, 1 indeterminate,) ranging from 41 to 277 mm TL, 11 specimens from Lakshadweep, CMFRI-LA-F. Reg. No. 154/478, ranging from 98 to 254 mm TL, one specimen from Lakshadweep, Reg. No. 565, of length of 191 mm TL.

Additional material examined: Three specimens from Tuticorin, (2 females, 1 male) of lengths 204, 240, 274 mm TL (Fig. 13.A.), one specimen from Nicobar, ZSI. Reg. No. F 6028/2, of length of 212 mm TL, Three specimens no locality mentioned, ZSI Reg. No. 8899

(Fig.13.F.), No.2737 (Fig. 13.E.), of lengths 127, 170,177 mm TL, one specimen from Andaman, ZSI Reg. No. 2256, of length of 167 mm TL, collected by Dr. F. Day (Fig. 13.D.).

Description

D. III, i, 24–26; P. i, 11–13; ventral spines 11–24; A. i, 22-23; C. ii, 10; gill rakers 30-33; number of scales from origin of second dorsal to base of anal 16–20; lateral line scales 32–36; scales round the caudal peduncle 7–11.

Body deep, rhomboid. Head profile, straight. Lips broad thick, continuous at the corner. Interorbital straight. First spine, stout, laterally elliptical, third spine ¼ the length of first spine. Nasal apertures placed in two separate shallow depressions (Fig.14. A). The first teeth of upper and lower jaw conical with pointed tips diverging outside, other three teeth rectangular with the upper side conical on one side (Fig.14. B).

There are four to five large scales, rectangular with edges round, above pectoral base, arranged in an rectangular region, smaller scales, few, arranged at its periphery. The gill rakers hyaline with blunt edges and hairy bristle like projection (Fig.14.C). The second dorsal and anal fin profile convex, transparent. Pectoral round.

Scales on cheek are rhomboid, having 3-8 vertical rows of round protuberances (Fig. 14. D & Fig. 15.A). Body scale, with 2 - 4 vertical rows of retrose spines (Fig. 14.E & Fig.15.B). The ultra structure of the anterior portion of the body scale has pits and ridges (Fig.15. E –G) and the posterior portion has retrose spines (Fig.15. H - J). Scales on abdomen are rhomboidal and rectangular, with 3-4 oblique rows of ridges (Fig.14.F & Fig.15.C). Caudal peduncle has two types of scales 1) Diamond shaped scales with antrose spine at the anterior middle and 5-8 horizontal rows of ridges. 2) Diamond shaped scales with ridges and retrose spines arranged in 2 –4 vertical rows (Fig.14.G & Fig. 15.D).
Ventral spine 11 – 24 pointed. Pelvic spine, short, blunt and spinules blunt.

Colour

Fish green, with 13–14 orange, curved oblique bands, originating just anterior to eye, below first dorsal, space between first dorsal and second dorsal. The bands end at anus, base of anal and at base of caudal. Inter orbital has 7–8 orange transverse bands. The anterior part of cheek has orange dots (male) or bands (female). Lower lip is orange upper lip black. Just above upper lip is an orange band followed by blue and orange band. Just below lower lip is blue band followed by a orange and blue band, which merge at the corner of the mouth forming orange, blue, orange and blue band which extend ventrally towards anus. The first dorsal dull yellow, with triangular black blotch at the tip. Second dorsal, anal and pectoral fins have orange ray, base of rays blue and membrane transparent. Caudal orange.

Colour of the preserved specimens: The formalin-preserved specimens dark brown. Just above upper lip are present two yellow bands and just below lower lip is a yellow band, which merges at corner of the mouth and form two yellow bands, which extend ventrally towards anus. A triangular black blotch at the tip of first dorsal, membrane transparent. The second dorsal, anal, and pectoral fin have yellow rays, membrane transparent. Caudal yellow. The alcohol preserved specimens also have a similar colour.

Remarks

1) This species is rare in catches along the east coast of India and only three specimens could be collected.
2) The specimens of 20 mm length are metallic brown dorsally and silvery ventrally (Fig.13.B). In those of 40 mm length, the body is green with orange undulating lines laterally (Fig.13.C).

2. Genus Zenodon (Ruppell, 1835) Swainson, 1839

(Type species *Xenodon niger*, Ruppell, 1835)

Diagnosis

Nostrils short tubes. Groove before eye present. Scales on cheek rhomboid with round protuberances and ridges. Body scales and caudal peduncle scales have round protuberances and ridges and a large spherical protuberance at the anterior middle of these scales. Caudal peduncle longer than deep, laterally elliptical. Ventral flap present. Caudal lunate with lobes produced.

The genus *Xenodon* was erected by Ruppell (1835) with *Xenodon niger* Ruppell (1835) as the type species. Swainson (1839) gave the name *Zenodon* to this genus and ascribed it to Ruppell (1835); he (Swainson, 1839) apparently treated this as the subgenus of *Capriscus*. In 1848 Gistel erected another genus: *Odonus* for *Xenodon niger* Ruppell, 1835. Ruppell 1852 gave the genus name *Erythrodon* to his *Xenodon* (1835) with the remark that the genus name *Xenodon* was already available in Amphibia and therefore preoccupied. Kaup (1855) described the genus *Pyrodon* for *Xenodon niger* Ruppell, 1835 and ascribed the authorship to Ruppell. He also treated *Zenodon niger* Swainson, 1839 as synonym of this species.

***Zenodon niger* (Ruppell, 1835)**

Xenodon niger Ruppell, 1835, p.53, *pl*. 14, fig. 3.
Balistes erythrodon Day, 1878, Part IV, p.692.
Odonus niger Jones and Kumaran, 1980, p. 664, fig.565.

Material examined: 54 specimens from Colachel, (31 females, 23 males) ranging from 147 to 346 mm TL (Fig. 16A), 7 specimens from Vizhinjam, (3 females, 4 males) ranging from 209 to 300 mm TL, 32 specimens from Vizhinjam, (indeterminate) ranging from 100 to 128 mm TL.

Additional material examined: Four specimens from Tuticorin, (2 females, 2 males) of lengths 217,275,299,304 mm TL, 23 specimens from Minicoy, (3 females, 20 males) ranging from 190 to 273 mm TL, 9 specimens from Chennai, (indeterminates) ranging from 102 to 118 mm TL, one specimen from Mumbai, (female) of length of 158 mm TL, three specimens from Vizhinjam, CMFRI - F. Reg. No. 154/440, of lengths 114,159,162 mm TL (Fig. 16.C), one specimen from Trivandrum, ZSI. Reg. No. F 2611/2, 130 mm TL (Fig.16. D), one specimen from Madras, ZSI. Reg. No. 8063, of length of 366 mm TL, collected by Dr. F. Day, (Fig.16. E), one specimen from Andaman, ZSI. Reg. No. 7250, TL 164 mm (Fig.16. F).

Description

D. III, i, 31–36; P. i, 10–14; ventral spines 9–23; A. i, 26-30; C ii, 10; gill rakers 30-33, number of scales from origin of second dorsal to base of anal 10–14; lateral line scales 21-32 + 13-18; scales round the caudal peduncle 9–12.

Body rhomboid. Head profile straight, with a jetting chin. Mouth superior, lips thin and narrow. Interorbital convex. Groove longer than orbit, deep at the centre, shallow at anterior, broad towards posterior, directed downwards. First dorsal spine, short, stout, blunt, anterior margin broad, with small protuberance and large blunt protuberances at the tip. Third spine ¼ the length of first spine. Nostrils placed in two separate depressions (Fig.17. A). The first tooth on the upper jaw rectangular and the second one caniniform and rest rectangular. The first tooth of the lower jaw is nearly concave on the upper side, with one side longer than the other (Fig. 17.B).

There are 3-5 scales in a triangular region above pectoral. Gill opening vertical. Gill rakers, thin, with pointed tip (Fig. 17.C). The anterior most rays in the second dorsal and anal are longer giving the appearance of a lobe, at the anterior side. The fins are thick, having serrated edge.

Scales on cheek have first row of ridges and followed by 4-8 rows of round protuberances (Fig. 17.D & Fig. 18.A). Body scales and scales on caudal peduncle have a large spherical protuberance and first row of ridges, followed by 5-9 vertical rows of round protuberances (Fig. 17. E & G & Fig. 18. B & D). The ultra structure of the anterior margin of the body scale has round pits (Fig. 18.E-G) and the posterior margin has round protuberances with pointed tip (Fig. 18.H-J). scales on abdomen rhomboid arranged in oblique rows with first row of ridges and followed by round protuberances arranged in 4-6 oblique rows (Fig. 17.F & Fig. 18.C).

Ventral spines arranged in two rows between the rudimentary pelvic spine and anus. The spines are pointed, in adult and bifid in juveniles (Fig. 17.H). Pelvic spine is movable, with many spinules.

Colour

Fishes above 100 mm length**:** The body and fins violet. Cheek with two bands one of which dark blue and other light blue, starting from the edge of the mouth and extending till the gill opening. The second dorsal, anal and caudal fins are dark blue.

Fishes below 100 mm length**:** Body blue, cheek with three bands which extend between mouth and gill opening; the upper and lower bands is light blue and middle band black. One band connecting the tip of snout to eye. The caudal, second dorsal and anal edged white.

Colour in the preserved specimens: The formalin preserved specimens are dark brown with a black band on cheek starting from the edge of the mouth and ending at branchial opening. Similar colour pattern are observed in alcohol preserved specimens.

Remarks: Fishes above 190 mm exhibit sexual dimorphism. In males the lobes of lunate caudal fin are long and blunt. In females the lobes are short and pointed (Fig. 16. B).

Genus *Rhinecanthus* Swainson, 1839

(Type species *Rhinecanthus ornatissimus* Lesson, 1831, Zoologie, v. 2 p.114.)

Diagnosis

Anterior nostril tube like, directed forward. Groove before eye absent. Scales on cheek anteriorly square, posteriorly rectangular and rhomboid, with triangular scale in-between, arranged horizontally, having round protuberance. Body scales with ridges and retrose spines. Caudal peduncle equally long and deep, laterally elliptical, consists of 3-5 rows of antrose spines. Caudal rounded with lobes produced dorsally and ventrally.

Swainson (1839) erected the subgenus *Rhinecanthus* under the genus *Balistes,* with the following characters "First dorsal spine thick, obtuse, serrated or tuberculated; caudal fin rounded; pelvis with spine but no rays".

Swain (1888) designated *Rhinecanthus ornatissimus* (Lesson, 1831) as the type species. Bleeker (1866) treated *Rhinecanthus* as a synonym of subgenus *Balistapus* Tilesius (1820). Whitely (1930) also considered *Rhinecanthus* as a subgenus of *Balistapus* Tilesius (1820). Fraser-Brunner (1935) elevated this subgenus to genus since he observed that:

"With the exclusion of *Balistapus undulatus* these fishes form a very well-marked and sharply defined genus a salient feature being the pronounced rectangular form and rather long straight snout".

Further he added:

"Third spine minute, caudal peduncle much constricted with numerous small spines in 2-4 rows".

Smith (1986) summarised the genus character as:

"No groove before eye, enlarged plates behind gill opening, soft dorsal and anal low, 3rd dorsal spine very small, spines on caudal peduncle, cheek fully scaled, teeth unequal, notched, caudal peduncle with 3-5 rows of small spines".

1. The distinctive characters put forward by Fraser-Brunner (1935) are valid to distinguish the two genera *Balistapus* and *Rhinecanthus* and they cannot be considered as synonyms.

2. Characters like nasal apertures, arrangement and morphology of scales on cheek, abdomen, caudal peduncle and body were not previously used for bringing out the variation between these two genera.
3. The genus *Rhinecanthus* can be redefined as

   "Scales on cheek square anteriorly, rhomboid posteriorly and triangular in between having round protuberance. Nasal aperture is a narrow tube directed forward, posterior nasal aperture circular. Body scales with 3 - 4 vertical rows of ridges or retrose spines. Caudal peduncle cylindrical with 2-5 rows of black antrose spines."

***Rhinecanthus aculeatus* (Linnaeus, 1758)**

Balistes aculeatus Linnaeus, 1758, p.328.
Balistes aculeatus Day, 1878, p.690.
Rhinecanthus aculeatus Jones and Kumaran, 1980, p. 674, fig.573.

Diagnosis
The anterior nostril is a tube directed forward with a "V" shaped flap at the opening. Scales on cheek square anteriorly, rhomboid posteriorly, arranged horizontally. Body scale with ridges and retrose spine. Caudal peduncle equally long and deep, laterally elliptical, with 3 rows of antrose spines. Ventral flap present. Caudal round with dorsal and ventral lobes produced.

Material examined: 22 specimens from Minicoy, (14 females, 5 males, 3 indeterminate) ranging from 38 to 181 mm TL, 12 specimens from Kiltan, (10 Females, 2 Males) ranging from 94 to 162 mm TL, 9 specimens from Agatti, (9 Females) ranging from 105 to 215mm TL, (Fig.19.D), one specimen from Lakshadweep Islands, (Female) of length of 118 mm TL, one specimen from Kavaratti, (Female) of length of 203 mm TL, five specimens from Kavaratti, CMFRI Reg. No. LA-F-154/480, of lengths 121, 143, 147, 160, 162 mm TL, (Fig. 19.B), four specimens from Minicoy, CMFRI Reg. No. LA – F- 154/480, of lengths 93, 128, 137, 195 mm TL, one specimen from Kalpitti, CMFRI Reg. No LA-F-154/480, of length of 175 mm TL, one specimen from Suheli, CMFRI Reg. No LA-F-154/480, of length of 108 mm TL, two specimens from Agatti, ranging CMFRI Reg. No.LA-F-154/480, of lengths 105,133 mm TL.

Additional material examined: 1 specimen from Andaman, ZSI Reg. No. 2253, of length of 191 mm TL, collected by Dr. F. Day (Fig. 19.C).
Description

D. III, i, 22-26; P. i, 10-13; ventral spines 8-14; A. i, 19-23; C. ii, 10; gill rakers 16-19; number of scales from origin of second dorsal to base of anal 14-17; lateral line scales 20-47; scales round the caudal peduncle 9-12.

Body rhomboid. Head profile, straight, prominent chin. Eye placed high. Upper lip fleshy, soft, broad and covers the lower lip. Lower lip is broad and thin. inter orbital flat. First dorsal spine compressed laterally, anterior broad with small spinules at base and blunt large spinules at tip.

Third spine minute. The anterior and posterior nostrils placed in separate depressions (Fig.20.A). All the teeth rectangular with the upper side straight but one side slightly longer than other (Fig.20.B).

There are 3-5 scales in a rectangular region above pectoral, each of these scales are engraved with longitudinal ridges. Gill opening oblique. Gill rakers have broad base, short, hyaline, blunt tipped and having globular protuberance towards the inside (Fig. 20.C). Second dorsal and anal short, thin, rectangular with edges round. Caudal round with lobes produced dorsally and ventrally in fishes having TL of 150- 200 mm and round in fishes having TL of 40 – 100 mm. Pectoral fin rounded.

The scales on check have round protuberances arranged in 3-8 rows vertically (Fig. 20.D & Fig.21.A). The body scales have 3 - 4 vertical rows of ridges and blunt retrose spines (Fig. 20.E & Fig. 21.B). The ultra structure of the anterior margin of the body scale shows round and triangular projections arranged in semicircular rows (Fig. 21.E-G) and the posterior margin has blunt retrose spines (Fig. 20.H-J). The scales on abdomen are rhomboidal arranged obliquely, with round protuberances arranged in 3-5 oblique rows (Fig. 20.F & Fig.21.C). The caudal peduncle has two type of scales 1) scales having 3-5 rows of antrose spines and also an antrose spine at the anterior middle. 2) Scales having 3-5 vertical rows of blunt retrose spines (Fig.20.G & Fig. 21.D).

Ventral flap is narrow, translucent, supported by ventral spines (Fig. 20.H) Pelvic spine, stout broad with 3 to 4 rows of sharp ridges at the centre and small spinules dispersed all over the spine with stellate spines at the posterior edges.

Colour

Body dorsally brown and ventrally white. Inter orbital with 4 bands of blue and three black bands. At the center of the body is a dark brown to black blotch, from which two black bands, meets the base of the second dorsal and anal. From base of anal arises 4 white bands, which meet the central black blotch. Three blue lines extend from interorbital bands and ends till the base of pectoral, between these lines are two bands anterior one light brown and posterior one black. Lips yellow, just above upper lip a blue and yellow band is present which reach the base of the pectoral crossing the cheek. On the caudal peduncle are arranged 3 rows of black antrose spines, which are placed on a white patch. Caudal fin, second dorsal, anal and pectoral fins transparent with light pink color. Pelvic spine pink. Anus surrounded by dark blue ring (Fig. 19.A).

Colour in the preserved specimens: Formalin preserved specimens have light brown, the interorbital with a dark brown band with 3 slightly darker bands at the anterior. Brown band starting from the eye reach the branchial aperture. A dark brown blotch occupies the centre of the body from which originates 2 bands towards dorsal base and two bands towards anal base. Four white bands originating from anal base reaches the central blotch. Except for the first dorsal which is dark brown rest of fins are light brown. The antrose spines at caudal peduncle black (Fig. 19.D).

Alcohol preserved Specimen has light brown color with four white bands arising from base of anal reaches the center of the body. Inter orbital has 4 white bands which are placed between 3 dark brown band. Two white bands originating from the interorbital area reaches the base of the pectoral. Another white band is found at the center of the caudal peduncle, on which 3 rows of spine (dark brown) is placed. The lips surrounded by white band (Fig. 19.C).
Remarks: In Minicoy these fishes are found in the sandy, coral area of the lagoon, hiding in the corals.

***Rhinecanthus echarpe* (Lacepede, 1798)**

Balistes echarpe Lacepede, 1798, p.333, 352.
Balistes rectangulus Day, 1878, p.691.
Rhinecanthus rectangulus Jones and Kumaran, 1980, p. 674, fig.573.

Diagnosis
Nostrils anterior tube directed forward. Groove before eye absent. Scales on cheek square at the anterior and rectangular at the posterior with triangular scale in between, arranged horizontally, with round protuberance. Body scales with blunt retrose spines. Caudal peduncle equally long and deep with 4-5 rows of antrose spines arranged horizontally. Ventral flap present. Caudal round with lobes produced dorsally and ventrally.

Material Examined: 2 specimens from Minicoy, (1 male) of lengths 152, 165 mm, TL (Fig. 22.A).

Additional material examined: 1 specimen from Malay Archipelago, ZSI Reg. No. 2252, of length of 179 mm TL, collected by Dr. F. Day (Fig. 22.B).

Description

D. III, i, 22-24; P. i, 12-13; ventral spines 11-12; A. i, 19-20; C. ii, 10; gill rakers 17-20; number of scales from origin of second dorsal to base of anal 16-19; lateral line scales 35-49.

Body rhomboid, head profile straight with a prominent chin. Eye placed high. Interorbital straight. Lips thick, fleshy, continuous at the corner, the upper lip covers the lower lip, which is thin and flat. First dorsal spine long, stout, laterally compressed, anteriorly broad with short ridges at the base and long ridges at tips, small spinules present on the lateral side. Third spine minute and less than ¼ the first spine. Nostrils slightly elevated (Fig. 23.A). The teeth are rectangular with the upper side straight with one side slightly elevated (Fig. 23.B).

Two rectangular and a triangular scale placed above the base of the pectoral. Gill opening oblique. Gill rakers are short, blunt, hyaline and having hairy projection towards the inside (Fig. 23.C). The second dorsal and anal fin rectangular and anteriorly elevated, edges round and transparent. Pectoral rounded.

Scales on cheek have 3-8 vertical rows of small round protuberance (Fig. 23.D & Fig.24.A). Body scale has 5-6 horizontal rows of blunt retrose spines (Fig. 23.E & Fig. 24.B). The ultra structure of the anterior margin of the body scale shows a network of fibers and circular depressions (Fig. 24.E-G) and the posterior margin has blunt retrose spines and ridges (Fig.24.H-J). Scales on abdomen are rhomboid with round protuberances arranged in 3-5 oblique rows (Fig.23.F & Fig.24.C). Scales on caudal peduncle are of two types 1) wedge shaped scales with an antrose spine at the anterior middle and 1-2 vertical rows of ridges, 2) diamond shaped scales having 4-5 vertical rows of ridges (Fig. 23. G & Fig. 24D).

The ventral spines are laterally compressed, arranged in a single row with spines from both sides alternating (Fig.23.H). Pelvic spine rectangular with many antrose spinules at the anterior and retrose spinules at the posterior. This pelvic spine has two portions the anterior fixed portion and posterior movable portion.

Colour

The fish is uniformly brown. A black band at the interorbital, which has three white bands, one at the anterior middle and the posterior. A wide black band extending from eye to the base of anal passes through the base of pectoral base. A black band occupies the caudal peduncle, which is triangular, bordered with white. The first dorsal black. Pectoral and caudal transparent with a brown ting. Second dorsal and anal transparent.

Colour of preserved specimen: Body uniformly light brown, brown band at the interorbital. A brown band originates from eye and reaches to anal base, passing through the pectoral base. Caudal peduncle has triangular brown band. First dorsal fin black. Second dorsal and anal fin transparent pectoral and caudal brown (Fig. 22.A).

Genus *Melichthys* Swainson, 1839

(Type species *Balistes ringens* Osbeck, 1765.)

Diagnosis

The anterior nostril conical with a circular opening at the tip. Groove before eye. Scales on cheek rectangular to diamond shaped, arranged in vertical rows and having horizontal ridge. Body scales with horizontal ridges. Caudal peduncle deeper than long, laterally elliptical having 6 - 8 rows, of horizontal ridges. Ventral flap absent. Caudal truncate.

***Melichthys indicus* Randall and Klausewitz, 1973**

Melichthys indicus Randall and Klausewitz, 1973, p.57-69, fig.5.
Balistes ringens Bleeker, 1860, p. 69.
Melichthys niger Jones and Kumaran, 1980, p. 666, fig.567.

Material examined: 23 specimens from Minicoy, (15 females, 7 male) ranging from 155 to 210 mm TL.

Additional material examined: 1 Specimen from Lakshadweep, CMFRI Reg. No. 554, 200 mm TL (Fig. 25.B) collected by Jones and Kumaran.

Description

D. III, i, 30-34; P. i, 13-14; ventral spines 0–26; A. i, 26-29; C ii, 10; gill rakers 26-28; number of scales from origin of second dorsal to base of anal 19–24; lateral line scales 30–77; scales round the caudal peduncle 12–18.

Body oval, deep. Head profile, convex with a prominent chin. Lips flat, thin. Inter orbital straight. Groove equal to orbit, deep at the centre, shallow at anterior, broad towards posterior, directed downwards. First dorsal spine short, stout, blunt, laterally compressed. Anterior base has long ridges, and at the middle are present small round protuberances, which spread laterally, tip has large round protuberances. Third dorsal spine, less than ¼ the length of first spine. Nostrils placed in a shallow depression, anterior nostril has a semicircular flap on the opening (Fig.26.A). The teeth are rectangular with a convex upper side (Fig. 26.B).

Four to five large scales, thin, engraved and arranged in a rectangular region above pectoral base. Gill opening vertical. The gill rakers are thin, hyaline with pointed tips (Fig. 26.C). The second dorsal, and anal fins are thick at base and thin towards the tip, anteriorly elevated and posteriorly short with edges round, with a rectangular shape and convex profile. Pectoral fin rounded, black.

Scales on cheek have 3–4 vertical rows of horizontal ridges (Fig.26.D & Fig. 27.A). Body scales have 3-5 vertical rows of transverse ridges (Fig.26.E & Fig. 27.B). The ultra structure of the anterior margin of the body scale shows broad fibres and circular depressions (Fig. 27.E-G) and the posterior margin has ridges (Fig. 26.H-J). Scales on abdomen are rectangular and rhomboid with short ridges arranged in 3-5 vertical rows (Fig. 26.F & Fig. 27.C). Scales on caudal peduncle have 10-20 horizontal ridge and 3-4 short pointed and blunt ridges at the centre (Fig. 26.G & Fig. 27.D).

The ventral spines are very short and pointed in few specimens, in others the spines are absent and the region is thickened (Fig. 26.H). Pelvic spine short blunt.

Colour

Body black. Second dorsal and anal fin base has a white band. A blue band is seen just at the centre of cheek passing obliquely downward up to the ventral portion of cheek. Six blue lines radiate from the eye in six different directions dorsally (Fig. 25.A).

Colour of the preserved specimens: Formalin preserved specimens are brown. First dorsal, second dorsal, anal fins are white. Caudal and pectoral fin are brown with edges brownish white. An oblique streak on cheek is reddish brown (Fig. 25.B).

Taxonomic Note: According to Randall and Klausewitz (1973)

"This species resembles *M. niger* in colouration-particularly in preservative- and has been confused with it by a number authors. In its caudal shape, counts, and weakly developed ridges along posterior scale rows, however it is closer to *vidua*".

"All of our specimens have come from the Indian Ocean, SANZO's specimens from the southern Red Sea. In the belief that the species may be confined to this ocean (including the western Indo-Australian Archipelago and the southern Red Sea), we have named it *indicus*".

Jones and Kumaran described *Melichthys niger* from the Lakshadweep archipelago (CMFRI specimen Reg. No.554). On examination it was found that, this specimen was *Melichthys indicus* Randall and Klausewitz, 1973. Thus *Melichthys niger* of Jones and Kumaran becomes the synonym of *Melichthys indicus* of Randall and Klausewitz, 1973.

Genus *Canthidermis* Swainson, 1839

(Type species: - *Canthidermis oculatus* Gray, 1830.)

Diagnosis

Anterior nasal funnel shaped. Groove present. Scales on cheek square at the anterior, posteriorly rhomboid with some triangular scale in between arranged horizontally with fleshy row in between. Body scales with ridges and a large ridge at the anterior middle. Caudal peduncle, longer than deep, laterally elliptical, 8-10 rows of scales with blunt ridges at the centre, arranged horizontally. Ventral flap absent. Caudal double lunate.

2.5.5.1. *Canthidermis maculatus* (Bloch, 1786)

Balistes maculatus Bloch, 1786, p.25,pl. 151.
Balistes maculatus Day, 1878, p.687.
Canthidermis rotundatus Jones and Kumaran, 1980, p. 665, fig.566.

Material examined: 23 specimens from Vizhinjam, (12 females, 11 males) ranging from 220 to 369 mm TL(Fig.28.A & B).

Additional material examined: 1 specimen, from Bay of Bengal, ZSI. Reg. No. 11882, of length of 162 mm TL, (Fig.28.F), 2 specimens, from Madras coast, ZSI Reg. No. 13748, 13750, of lengths 113, 98 mm TL, (Fig.28.D & E) , 2 specimens, from Sand Head, ZSI Reg. No. 8164, 8165, of lengths 70 - 86 mm TL, (Fig. 28.C).

Description

D. III, ii, 21–26; P. i, 13 –14; ventral spines 0 –12; A. i, 18 –22; C. ii, 10; gill rakers 19-23; number of scales from origin of second dorsal to base of anal 16–20; lateral line scales 48 –70; scales round the caudal peduncle 11–15.

Body elongated. Head profile, convex, with a prominent chin. Lips broad at centre and narrows at edges. Interorbital convex. Groove equal to eye diameter, narrow and deep anteriorly and broad posteriorly, connected to nasal depression by narrow groove. First dorsal spine pointed, anteriorly with large spinules on tip, compressed and smooth laterally. Third spine ¼ the length of first spine. Nostrils placed in a shallow depression with blunt round protuberances bordering the depression (Fig. 29.A). The teeth of the upper jaw is rectangular with conical edge, the teeth of the lower jaw is rectangular with a conical upper side (Fig. 29.B).

Scales above the base of pectoral absent. The Gill rakers are short and do not project above the edge of the branchial arch, the tip is pointed (Fig. 29.C). Second dorsal and anal fins highly elevated anteriorly and short posteriorly. Pectoral fin rounded.

Scales on cheek have round protuberances and ridges arranged in vertical rows (Fig. 29.D & Fig. 30.A). Body scale with large ridge at the anterior middle (narrow posteriorly) and with many ridges and round protuberances. (Fig. 29.E & Fig. 30.B). The ultra structure of the anterior margin of the body scale shows round depressions and a network of fibres (Fig. 30.E-G) and the posterior margin has blunt round protuberances (Fig. 30.H-J). Scales on abdomen rectangular to rhomboid shaped with many ridges and round protuberances arranged in 3-6 oblique rows (Fig. 29.F & Fig. 30.C). scales on caudal peduncle have ridge (tapering towards posterior and pointed) at the anterior middle and ridges and round protuberances arranged in horizontal rows (Fig. 29.G & Fig. 30.D).

Ventral flap is reduced. The ventral spines are modified into a single row of modified scales, present at the ventral side and each scale has many spines directed back wards giving a comb like appearance (Fig. 29.H). Pelvic spine is movable, short, flat, thick and blunt, with small, blunt minute protuberance.

Colour

The whole fish is dark brownish black. Three types of colour pattern was recorded in the specimens collected from Vizhinjam area,

1. Body brownish black with dash like white spots, which becomes round on the head and caudal area.
2. Body brownish black with white round spots, spread all over the body.
3. Body brownish black light brown ventrally.

Colour of the preserved specimens: Formalin preserved specimens have dark brown with white spots, in some cases it is without spots. Alcohol preserved specimens have light brown colour.

Taxonomic note

According to Fedoryako (1981) in Pacific and Indian oceans there are 5 species of *Canthidermis, viz., C. willughbeii* (Lay and Bennet, 1839), *C. maculatus* (Bloch, 1786), *C. rotundatus* (Proce, 1822), *C. sufflamen* (Mitchill, 1815), and a fifth species *C. villosus (new)* collected from Gulf of Aden.

Fedoryako (1981) observed that *C. villosus* and *C. rotundatus* have same number of fin rays, number of gill rakers and armature of trunk scales. He indicated the differences as, presence of branched dermal protuberances on scales, relatively smaller number of transverse rows of trunk scales, different length/depth ratio of the caudal peduncle and colouration of body and fins.

In case of *C. maculatus*, the author has mentioned that the number of rays of second dorsal and anal fins differs slightly in the limits of variability and these fins are shorter compared to Moore (1967) description. It differs from *C. rotundatus* and *C. villosus* due to smaller number of fin rays and gill rakers, a greater number of small spinules on the trunk scales mottled body colouration.

C. rotundatus is different from *C. maculatus* because of difference in scale armature on the trunk, number of fin rays and gill rakers while longer specimens of *C. rotundatus* and *C. maculatus*, has a longer second dorsal fin, a taller anal, pre-anal distance was less in former. But *C. rotundatus* was similar to *C. villosus* and *C. sufflamen* except that the latter has a greater number of transverse rows of scales, body depth and height of second dorsal and anal fins in comparison to *C. maculatus*. The fin ray counts of all the species are given in the table 1.

Table 1. The fin ray counts of different species of *Canthidermis*

	Second dorsal	Anal	Pectoral	Standard length (mm)
C. maculatus	23-26	21-23	13-15	50-100
C. willughbeii	23-24	21-22	13-14	90-131
C. rotundatus	25-27	22-23	14-16	39-111
C. villosus	24-26	22-23	14-15	71.7-177.7
C. sufflamen	23-25	20-22	13-15	20-300(Moore, 1967)

Berry and Baldwin (1966) observed that,

> "The synonym of this species has been confused because identifications and names based on small specimens (as "*rotundatus"* Proce and "*oculatus*" Gray) have not been recognized as co specific with larger, more elongate specimens (as "*maculatus*" Bloch, w*illughbei*i, Lay and Bennet and "*longirostris*" Tortonese). As the body length increases there is a proportional decrease in head length, eye diameter, body depth and first dorsal spine length and a proportional increase in length of the lobes of the anal and caudal fins".

1. From the above table it can be observed that the fin counts of *C. maculatus*, *C. willughbeii*, *C. rotundatus* and *C. villosus* falls within a narrow range and cannot be used for differentiating between species.
2. Fedoryako collection consists of narrow length range, having length ranges of 50-177.7 mm, except for *C. maculatus*, represented by a large sample, but smaller length groups.
3. Berry and Baldwin (1966) and Matsuura (1981) observed that, the three species of Swainson (1839) i.e. *Canthidermis angulosus* (Quoy and Gaimard, 1824), *Canthidermis gaimardii*

(Swainson, 1839) and *Canthidermis oculatus* (Gray, 1831) are synonyms to *Canthidermis maculatus* (Bloch, 1786). They also established that *Balistes maculatus* (Gmelin, 1879) and *Balistes aureolus* (Richardson, 1845) of Gunther (1870) is also a synonym of *Balistes maculatus* (Bloch, 1786).

4. Some observations made on *Canthidermis maculatus* collected from west coast of India and Minicoy islands showed that 3 different colour patterns exist, i) uniform brownish black dorsally and light brown ventrally, ii) uniform brownish black with round white spots well distributed on the body, iii) brownish black body with white longitudinal dashes distributed on the body. The regression graphs drawn using data of various morphometric measurements on standard lengths revealed low relationship, suggesting that *Canthidermis maculatus* has high degree of variability in case of body colour and certain morphological characters.
5. Thus it is concluded that, *C. willughbeii* (Lay and Bennet, 1839), *C. rotundatus* (Proce, 1822), *C. villosus* Fedoryako, 1981 are junior synonym of *C. maculatus* (Bloch, 1786).

Genus *Parabalistes* Bleeker, 1866

(Type species *Parabalistes chrysospilus* Bleeker, 1866 = *Balistes chrysospilus* Bleeker,1853.)

Diagnosis

The anterior nostril ridge-like, with a circular opening at the top. Groove before eye. Scales on cheek absent anteriorly, posteriorly transverse rows of square scales are present with wide fleshy rows in between. Body scales have spherical protuberances. Caudal peduncle is short and deep, with round protuberances, arranged horizontally. Caudal truncate with filamentous rays on the upper and lower lobes.

The subgenus *Parabalistes* was erected by Bleeker (1866) with the following characters, 1) head profile obtuse, convex. 2) Rostrum naked, scales arranged in rows with some longitudinal gaps in between on the cheek. 3) Longitudinally 45 scales. 4) Caudal peduncle without spines. 5) Second dorsal and anal elevated anteriorly and angulated, caudal rounded with marginal lobes produced.

Herre (1924) mentioned that this genus is not distinctive enough to be considered as a separate genus in the family Balistidae and included *fuscus* in the genus *Balistes*.

Fraser – Brunner (1935) and Matsuura (1980) treated this subgenus as a synonym of genus *Pseudobalistes*.

Characters like i) scales on cheek are horizontally arranged, with shallow fleshy groove in between, ii) the soft dorsal and anal are elevated anteriorly and angulated, iii) caudal peduncle without spines, iv) caudal truncate with filamentous rays in the upper and lower lobes, make this genus very distinct from the other genera of family Balistidae.

Balistes fuscus of Bloch and Schneider (1801) and *Parabalistes chrysospilus* of Bleeker (1866) are synonym (Herre, 1924).

The specimen recorded from the Lakshadweep archipelago and another specimen at the CMFRI museum, collected from south west coast of India conforms to the species description *Balistes* *fuscus* of Bloch and Schneider (1801) and *Parabalistes chrysospilus* of Bleeker (1866). Some of the distinctive characters of these specimens are used for redefining the genus as:

> " Anterior nostril ridge-like, with a circular opening at the top. Groove before eye. Scales on cheek absent anteriorly, posteriorly transverse rows of square scales are present with wide fleshy rows. Body scales diamond shaped, having spherical protuberances. Caudal peduncle is short and deep with diamond shaped scales arranged in horizontal rows, with round protuberances. Caudal truncate with filamentous rays on upper and lower lobes."

Thus *Parabalistes* is a valid genus and monotypic.

***Parabalistes fuscus* (Bloch and Schneider, 1801)**

Balistes fuscus Bloch and Schneider, 1801, p.471.
Balistes fuscus Day, 1878,p.690.

Material examined: One specimen from Agatti, (male) 145mm TL (Fig.31.A).

Additional material examined: One specimen from south west coast of India, CMFRI Reg. No. 1025, 362mm TL (Fig.31.B).

Description
D. III, i, 25; P. i, 12; Ventral spines 11; A. i, 22; C. ii, 10; number of scales from origin of second dorsal to base of anal 22; Lateral line scales 51; round the caudal peduncle 15.

Body oval, deep. Head profile convex, chin prominent. Lips, thick, fleshy, broad, and continuous at corner. Interorbital straight. Groove, shallow, equal to orbit, directed downwards. First dorsal spine, long, stout, tip pointed. Laterally compressed smooth. Third spine ¼ the length of first spine. Nostrils placed in depression, with a thin translucent "C" shaped flap on the anterior opening (Fig.32.A). The first teeth of the upper jaw conical with the tip pointed and diverging outside. The first teeth of the lower jaw conical with pointed tip. The other teeth are rectangular with conical upper edge (Fig. 32.B).

Few large and small-scale form a cluster, arranged on a depressed rectangular area above the base of pectoral. Gill opening vertical. The anterior rays of the second dorsal fin and anal fin are long and the posterior rays shortest thus making the fin elevated anteriorly and short posteriorly, fin profile concave. Pectoral fin rounded.

Scales on cheek are of two type i) scales with round protuberances and ridges arranged in 1- 4 vertical rows ii) scales of the fleshy rows (covered by skin) have shallow depressions and ridges and smooth surface (Fig.32.C). Body scales with vertical rows of spherical protuberances arranged in 5 - 10 vertical rows, with the anterior most row having the larger protuberances (Fig.32.D). Scales on abdomen rhomboid which are arranged in oblique rows, each scale has ridges on the first row and round protuberances in 3-5 oblique rows (Fig. 32.E). Scales on caudal peduncle have short round blunt protuberances arranged in 3-5 vertical rows (Fig.32.F).

Ventral flap, narrow, supported by hyaline spines (Fig.31.G). Rudimentary pelvic spine movable with many pointed and blunt glassy protuberances.

Colour

Formalin preserved fish whitish-brown, with horizontal wavy or undulating brown bands. First dorsal fin brown. Second dorsal anal fin whitish-brown with undulating brown bands. Caudal fin whitish-brown with brown vertical bands, pectoral translucent. Lips white.

Remarks: This species was recorded from Agatti Island for the first time (Lakshadweep archipelago).

2.5.7. *Pseudobalistes* Bleeker, 1866

(Type species Pseudobalistes viridescens Bleeker, 1866 = Baliste verdatre Lacepede, 1798)

Balistoides Fraser-Brunner, 1935, p.662.
Type species *Balistes viridescens* Bloch and Schneider, 1801

Diagnosis

Nasal apertures in a depression, anterior nasal conical with an opening at the tip. Groove before eye. Scales on cheek, absent at the anterior, posteriorly 5-6 horizontal rows of small rectangular to square scales with fleshy grooves between these scale rows. Body scales have spherical protuberances. Caudal peduncle with 5-6 horizontal rows of antrose protuberance. Caudal round with lobes produced.

Bleeker (1865) published the drawings together with their names *Balistes* (*Pseudobalistes*) *flavimarginatus* as plate CCXVIII Fig.3 and *Balistes* (*Pseudobalistes*) *viridescens* plate CCXXIV Fig.3 in *Atlas Ichthyologique.*

In 1866 he (Bleeker) published the description of subgenus *Pseudobalistes* and designated *Pseudobalistes viridescens* Bleeker, as the type species. The description of *Balistes viridescens* was first published by Bloch and Schneider (1801) and Bleeker's *Pseudobalistes viridescens* is co specific with this.

Fraser-Brunner (1935) erected the genus *Balistoides* with the same type species as that of *Pseudobalistes*, hence *Balistoides* Fraser-Brunner, 1935 is a junior synonym of *Pseudobalistes*, Bleeker, 1866, though none of the authors including Fraser-Brunner, 1935 mentioned it. Jordan (1917) believed that *Balistes* (*Pseudobalistes*) *flavimarginatus* Ruppell (1829) as the type species of *Pseudobalistes* apparently because this name together with its figure appeared first in *Atlas Ichthyologique* of Bleeker (1865). However in about one year of publication of *Atlas Ichthyologique* a revision of Family Balistidae was published by Bleeker (1866) where in he has described the genus and designated the type species. Hence the impression of Jordan (1917) that *Balistes* (*Pseudobalistes*) *flavimarginatus* is type of *Pseudobalistes* is invalid.

Thus it is concluded that the type species of *Pseudobalistes* of Bleeker (1866) is *Pseudobalistes viridescens* (Bleeker, 1866) = *Balistes viridescens* (Bloch and Schneider, 1801) and since the type of *Balistoides* of Fraser-Brunner (1935) also *Balistes viridescens* (Bloch and Schneider, 1801), it becomes the junior synonym of *Pseudobalistes.*

***Pseudobalistes viridescens* (Bloch and Schneider, 1801)**

Balistes viridescens Bloch and Schneider, 1801, p. 477.
Balistes viridescens Day, 1878, p.689.
Balistoides viridescens Jones and Kumaran, 1980, p.668, fig.569.

Diagnosis
Nostrils placed in depression surrounded by spinules, anterior nostril dome shaped with a circular opening at the top. Groove before eye. Scales on cheek square at the anterior and rectangular towards the posterior, arranged in 5-6 horizontal rows with fleshy rows in between. Caudal peduncle equally long and deep, laterally elliptical, having spherical protuberances or antrose spines arranged in 4-5 rows. Ventral flap absent. Caudal fin round.

Material examined: One specimen from Kalpeni, of length of 139 mm TL, 9 specimens from Minicoy, (1 female, 5 males and 3 indeterminates) ranging from 43 to 474 mm TL, (Fig.33.D), Five specimens from Lakshadweep Islands, CMFRI-LA-F. Reg. No. 154/475, of lengths 56, 82, 107, 235, 308 mm TL.

Additional material examined: Six specimens from Tuticorin, (4 females, 2 males) of lengths 287, 370, 370, 422, 450, 527 mm TL, (Fig.33.C), three specimens from Kelakarai, (3 females) of lengths 83, 141, 326 mm TL, (Fig.33.B), one specimen from Mandapam, (female) of length of 316 mm TL, (Fig.33.A), Two specimens from Gulf of Mannar, CMFRI – F. Reg. No. 154/ 699, of lengths 105,155 mm TL.

Description
D. III, i, 21–26; P. i, 13–14; ventral spines 6–14; A. i, 22-23; C. ii, 10; Gill rakers 30-35; number of scale from origin of second dorsal to base of anal 11–15; lateral line scale 38–49; round the caudal peduncle 10–12.

Body oval, deep. Head profile, convex. Inter-orbital straight. Lips thick cylindrical, broad. Groove, longer than orbit, narrow at the anterior, broad and shallow towards posterior, with some minute sharp protuberances. First dorsal spine with small protuberances, third spine less than ¼ length of first spine. A thick "C" shaped flap covers the circular opening of anterior nostrils (Fig.34. A). The first teeth of the upper jaw conical with pointed tip diverging outside. The first teeth of the lower jaw conical with pointed tip. Other teeth are conical with a broad base (Fig.34. B).

Few scales arranged just above the base of pectoral are small, round and engraved. Gill opening oblique. The gill rakers are elongated, hyaline, pointed and laterally compressed (Fig.34. C).

The second dorsal and anal fins are anteriorly elevated and posteriorly round having serrated edge. Pectoral fin round.

Square and rectangular scales on cheek have spherical protuberances arranged in 4-6 vertical rows (Fig.34.D & Fig.35.A). Body scales have vertical rows of spherical protuberances arranged in 4-9 rows. Fresh specimens have a dark central blotch (Fig. 34.E & Fig.35.B). The ultra structure of the anterior margin of the body scale has irregular shaped projections and long ridges (Fig.35. E –G) and the posterior margin has round protuberances (Fig.35. H - J). Rectangular and rhomboid scales on abdomen have spherical protuberances arranged in oblique rows (Fig.34.F & Fig.35.C). There are two types of scales on caudal peduncle i) scales with 4-6 rows of spherical protuberances, ii) scales with a large spherical protuberance or antrose spine at the anterior middle of the scales with 3-5 vertical rows of spherical protuberance (Fig.34. G & Fig.35.D).

The ventral flap is absent. Ventral spines are transparent, elongate, thick and blunt in adults, the spines are thick, short and hyaline having pointed tips in juveniles (Fig. 34. H). Pelvic spine is movable, club shaped fully decorated with hyaline spinules, edges are stellate.

Colour

Variation in colour pattern (fresh specimens) was observed in specimens collected from south east coast (Kelakarai, Mandapam and Tuticorin) and Minicoy.

(1) **Kelakarai**

Body Olive green. **Body scales** dark green patch at the center. **Cheek** orange, with black and white band above upper lips. A dark longitudinal blotch originates at the inter-orbital to base of pectoral. **First dorsal fin** orange with few darker patches. **Second dorsal and anal fins** orange, bordered with black band. **Caudal** orange, bordered with black band. Pectoral orange (Fig. 33.B).

(2) **Mandapam**

Body Yellow. **Body scales** with a dark brown patch at the center. **Cheek** bright yellow, just above upper lip reddish brown, pink and black band. Breast pink. A dark longitudinal blotch originates at the inter-orbital to base of pectoral. **First dorsal** brown, with a pink patch at the base. **Second dorsal and anal fin** yellow, bordered with a black band. **Caudal fin** yellow, bordered with a broad black band (Fig. 33.A).

(3) **Tuticorin**

Body bright yellow. **Body scales** brown-green colour at the center. **Cheek** orange, just at the edge of the mouth greenish yellow band, upper lip brown, lower lip pink. Just above upper lip dark brown and white band. Longitudinal blotch from inter-orbital to base of pectoral, breast pink. **First dorsal fin** brown. **Second dorsal and anal fin** brown, dark brown band at edges and base. **Caudal** yellow, with dark brown band at edges. **Pectoral fin** yellow, with orange brown edges (Fig. 33.C).

(4) **Minicoy**

Body yellow. **Body scales** brown-green at the center. **Cheek** yellow, upper lip black, lower lip pink just above upper lip a white, black and a narrow white band. Longitudinal blotch from inter-orbital to base of pectoral, breast white. **First dorsal fin** yellow. **Second dorsal and anal fin** Yellow, black band at edges and base. **Caudal** yellow, with black band at edges. **Pectoral fin** yellow, with black edges. A white-yellow blotch at caudal peduncle (Fig. 33.D).

Colour of the preserved specimens: Body Brown, body scale with a black blotch at the enter. Longitudinal blotch from inter-orbital to base of pectoral.

Remarks: The fishes collected from Kelakarai, Mandapam, Tuticorin and Minicoy Islands**,** showed some variations in the colour pattern. These fishes were very rare in the catches and only 27 specimens could be collected during the study period.

2. *Pseudobalistes flavimarginatus* (Ruppell, 1828)

Balistes flavimarginatus Ruppell, 1828, p. 33.
Balistes flavimarginatus Day, 1878, p.690.
Pseudobalistes flavimarginatus Jones and Kumaran, 1980, p. 671, fig.571.

Diagnosis

Anterior nostril, in a depression, dome shaped with a circular opening at the top, Groove before eye. Scales on cheek absent anteriorly, posteriorly square arranged horizontally in 5-6 narrows rows with fleshy rows in between. Body scales with spherical protuberances. Caudal peduncle longer than deep with 4-5 rows of sharp ridge or blunt spherical protuberances. Caudal truncate with lobes produced.

Material examined: One specimen from Minicoy, (female) of length of 233 mm TL, two specimens from Minicoy, of lengths 273, 233 mm TL, four specimens from Minicoy, (3 females, 1 male) of lengths 271, 324, 429, 435 mm TL, (Fig. 36.A), four specimens from Minicoy, CMFRI-F. Reg. No. 154/447, of lengths 123, 160, 160, 287 mm TL, one specimen from Agatti, CMFRI-LA-F. Reg. No. 154/443, of length of 317 mm TL, (Fig.36.D), one specimen from Minicoy, CMFRI Reg. No. 2251, of length of 183 mm TL,

Additional material examined: Two specimens from Tuticorin, of lengths 484, 490mm, TL, (Fig.36.B), one specimen from Mandapam, (female) of length of 345 mm TL, (Fig. 36.C) one specimen from Andaman, ZSI Reg. No. 2251, of length of 183 mm, TL, collected by Dr. F. Day (Fig.36.E).

Description

D. III, i, 24-25; P. i, 13-14; ventral spines 8-13; A. i, 23-24; C. ii, 10; Gill rakers 29-31; number of scales from origin of second dorsal to base of anal 12-14; lateral line scales 44-51; round the caudal peduncle 10-11.

Body oval. Head profile convex. Lips broad, thin and narrow at the center. Interorbital convex. Groove, straight, equal to orbit, narrow and shallow towards anterior, deep and broad posteriorly. First dorsal spines strong, stout, laterally compressed, broad. Numerous spinules, at the anterior portion with larger spinules at tip. Anterior nostril covered by a "C" shaped flap. Posterior nostril circular and placed slightly elevated from the anterior nostril, (Fig. 37.A). The first teeth of the upper and lower jaw conical with pointed tip, tips diverge in case of upper jaw. The other teeth are rectangular elongated with the upper end conical towards one side (Fig.37.B).

Scales above the pectoral base is arranged in an irregular fashion having round, rectangular and hexagonal shapes. Gill opening vertical. The gill rakers are elongated, blunt tipped, laterally flat, with rough inner edge (Fig.37.C). The second dorsal and anal is elevated anteriorly and short and rounded posteriorly with a wavy edge. Pectoral fin rounded.

Scales on the cheek are of two types i) scales on cheek with 1- 4 vertical rows of spherical protuberances with few ridges. ii) scales covered by skin with smooth surface and shallow depressions and ridges (Fig.37.D & Fig.38.A). Body scales, with a dark blotch at the center and have 5 – 6 vertical columns of spherical blunt protuberances (Fig. 37.E & Fig.38.B). The ultra structure of the anterior margin of the body scale has network of fibers (Fig.38. E –G) and the posterior margin has round protuberances (Fig. 38. H - J). Scales on abdomen have ridges on the first row followed by 3-5 oblique rows of round protuberances (Fig.37.F & Fig.38.C). There are two types of scales on caudal peduncle i) scales with spherical or sharp ridges at the anterior middle of the scale. ii) Scale with spherical protuberance arranged in 3-4 vertical rows (Fig.37.G & Fig. 38.D).

The anterior ventral spines are transparent, elongated; posterior spines are broad and pointed (Fig.37.H). The ventral pelvic spine is rectangular and laterally elliptical with large number of blunt protuberances.

Colour

Variation in colour pattern (fresh specimens) was observed in specimens collected from south east coast (Mandapam and Tuticorin) and Minicoy.

(1) **Minicoy**

Body grey, upper and lower lips orange. **Cheek**, orange, with dorsally lighter and ventrally darker. **First dorsal** brown. **Second dorsal, Anal and caudal fins** have red, grey and a narrow orange band at the edge. **Pectoral** yellow bordered with orange (Fig. 36.A).

(2) **Tuticorin**

Body dark brown. Upper and lower lips pink. **Cheek** dorsally dark brown ventrally orange. **First dorsal** black. **Second dorsal, anal and caudal fins** have orange and grey band at the edge. First and last ray of second dorsal, anal and caudal fin bright red (Fig. 36.B).

(3) **Mandapam**

Body yellow. Upper and lower lips are orange. **Cheek** is orange, dorsally lighter and ventrally darker. **First dorsal** brown. **Second dorsal, anal and caudal fins** have red, grey and narrow orange band at the edge. **Pectoral** yellow bordered with orange (Fig. 36.C).

Colour of the preserved specimens: The whole fish is brown (Fig.36.D).

Remarks: The fishes collected from Mandapam, Tuticorin and Minicoy Islands, showed some variations in the colour pattern. These fishes were very rare in the catches and only 14 specimens could be collected during the study period.

2.5.7. 3. *Pseudobalistes conspicillum* (Bloch and Schneider, 1801)

Balistes conspicillum Bloch and Schneider, 1801, p.474.
Balistes conspicillum Day, 1878, p.689.
Balistoides conspicillum Jones and Kumaran, 1980, p.670, fig.570.

Diagnosis

Nostrils in a shallow depression, anterior nostril conical with a circular opening at the top. Groove before eye. Scales on cheek diamond shaped, obliquely arranged at the anterior and vertical posteriorly. Body scales with spherical protuberances. Caudal peduncle equally deep and long cylindrical, having two rows of spherical protuberances. Ventral flap absent. Caudal round.

Material examined: One specimen from Lakshadweep, CMFRI. Reg. No. CMFRI-LA-F-154/476, of length of 282 mm TL (Fig. 39).

Description

D. III, i, 25; P. i, 13; ventral spines 20; A. i, 21; C. ii, 10; number of scales from origin of second dorsal to base of anal 21; lateral line scales 57; round the caudal peduncle 11.

Body oval. Head profile, dorsally concave, ventrally convex. Lips, thick, cylindrical. Eye placed high. Inter-orbital straight. Groove equal to orbit, narrow towards the anterior, broader and deep towards the posterior, parallel to head profile. First dorsal spine broad, blunt, with small protuberances at the anterior portion. Third spine, less than ¼ the length of first spine. Opening of the anterior nostril covered by a “C” shaped thick flap.

Rectangular scales placed in a rectangular area just above pectoral base. Gill opening vertical. Second dorsal and anal fins, have a convex profile. The length of anal fin base is half to that of second dorsal fin base; both the fins are translucent Pectoral fin round.
Scales on cheek have 3–4 vertical rows of round protuberances (Fig.40.A). Body scales with a spherical pointed protuberance at the anterior middle and 4-6 vertical rows of round protuberances (Fig.40.B). Scales on abdomen rectangular or rhomboid arranged in oblique rows with round protuberances also arranged in oblique rows (Fig.40.C). Scales on caudal peduncle are of two types i) scales with a large spherical protuberance at the anterior middle of the scale and round protuberances, ii) scales with round protuberances arranged in vertical rows (Fig.40.D).

Ventral spines 20 in number arranged in a single row with the spines from either side alternating. Each spine is a triangular projection arising from the lateral side of an elongated rectangular scale (Fig. 40.E). Rudimentary pelvic spine short stout has minute spinules.

Colour

Formalin preserved fish, dark brown. Lips pink, behind lips pink followed by a circular whitish-brown ring. Whitish-brown band below eye. First dorsal fin black. Second dorsal and anal fin pink and translucent. Caudal brown edge blackish - brown. Ventrally 6–7 circular to hexagonal whitish-brown patches arranged in three rows. Caudal peduncle has broad whitish-brown streak (Fig.39).

.

***Sufflamen* Jordan, 1916**

(Type species *Balistes capistratus* Shaw, 1804 = *Balistes fraenatus* Latreille,1804)

Diagnosis

Anterior nasal aperture dome shaped with a circular opening or tube directed forward. Scales on cheek rectangular or square or rhomboid with round protuberances. Groove before eye. Body scale with blunt retrose spine. Caudal peduncle equally long and deep. Caudal peduncle with five to eight rows spherical protuberances or antrose spines. Caudal emarginate or lunate.

2.5.8. 1. *Sufflamen fraenatus* (Latreille, 1804)

Balistes fraenatus Latreille, 1804, p.74.

Balistes mitis Day, 1878, p.689.

Balistes verres Gilbert and Stark, 1904, p.153, fig. 49.

Diagnosis

The nostrils placed in a circular depression, anterior nostril dome shaped with an opening at the tip. Scales on cheek rectangular arranged in horizontal rows with round protuberances. Groove before eye. Body scales have round protuberances. Caudal peduncle equally deep and long, have 5-10 rows of spherical protuberance. Caudal lunate with lobes produced.

Material examined: 30 specimens from Colachel, (17 females, 13 males) ranging from 156 to 291 mm TL, 30 specimens from Vizhinjam, (18 females, 12 males) ranging from 184 to 334 mm TL (Fig. 41.A), 29 specimens from Vizhinjam, (indeterminate) ranging from 85 to 118 mm TL, two specimens from Vizhinjam, CMFRI Reg. No. 154/441 and 442, (male and indeterminate) of lengths 120,166 mm TL (Fig. 41. D).

Additional material examined: Eight specimens from Tuticorin, (3 females, 5 males) ranging from 203 to 292 mm TL, three specimens from Chennai, (indeterminate) of lengths 94, 96, 102 mm TL, one specimen from Akyab bazaar, ZSI Reg. No. 10622, 182 mm TL (Fig.41.C) one specimen from Travancore, coast ZSI Reg. No. F 4160/1, 205 mm TL.

Description

D. III, i, 28–32; P. i, 13–15; ventral spines 9–21; A. i, 25-29; C. ii, 10; gill rakers 25-30: number of shield from origin of second dorsal to base of anal 21–28; lateral line shields 41-50 + 22–27; round the caudal peduncle 13–17.

Body rhomboid. Head profile straight with a prominent chin. Eye placed high. Inter orbital convex. Groove longer than orbit, deep, narrow at anterior, broader at posterior. First spine stout laterally compressed smooth, anteriorly flat with minute spinules, which are broad and blunt towards tip. Anterior nostril has a fleshy cone like projection from the inside at the opening (Fig.42.A). The first teeth of the upper and lower jaw conical with pointed tip, other teeth rectangular with upper side uneven (Fig. 42.B).

Enlarged scales arranged on a loose membrane above the base of pectoral. Gill opening oblique. Gill rakers narrow, elongated, with pointed and fragile tip (Fig.42.C). The second dorsal and anal is anteriorly elevated and posteriorly rounded. Fins are thick at base thin at tips. Pectoral round.

Scales on cheek have round protuberances arranged in 6-9 vertical rows (Fig.42. D & Fig.43.A). The body scales have ridges on the first row and 3-6 vertical rows of blunt retrose spines (Fig.42. E & Fig.43.B). The ultra structure of the anterior margin of the body scale has irregular shaped projections (Fig.43. E–G) and the posterior margin has first row of ridges and retrose spines (Fig.43. H-J). The scales on Abdomen are rectangular with the first row of ridges and 3-6 oblique rows of round protuberances (Fig. 42.F & Fig.43.C). Scales on caudal peduncle have a spherical protuberance at the anterior middle of the scale and 4-6 rows of ridges and blunt retrose spines (Fig.42. G & Fig. 43.D).

Ventral flap present with hyaline pointed spines (Fig.42.H). Pelvic spine movable.

Colour

Body brown, abdomen yellow. Iris golden when fresh. Lips pink to red in colour. Yellow or grey band above upper lip, white band below the lower lip together form a complete circle around mouth. In some specimens a lateral pink or red or white band originates at the edge of the mouth up to base of pectoral across the cheek. The first dorsal black. Second dorsal and anal are black at the base and yellowish or transparent at outer margin. Pectoral yellow. Caudal dark brown to black (Fig.41.A).

Colour of the preserved specimens: Body brown. White band below lower lip. Another white band across cheek originating from edge of mouth up to base of pectoral, in case of male (Fig.41.C & D).

Remarks: A yellow band above upper lips, in case of male and grey in case of female. A horse bridle like band around mouth and cheek, which extends till base of pectoral, which is present in male. It is white in immature males but pink to red in mature male.

Taxonomic Note

Gilbert and Stark (1904) described *Balistes verres* and observed

> " We describe as new the species that has commonly been referred to as *B. capistratus* on the Pacific coast of Central America. *B. capistratus* was probably based on east Indian material but we have had for comparison specimens from the Hawaii Islands only. From this *B. verres* differs in having smaller scales and a greater number of dorsal and anal rays. Specimens from Panama and Mazatlan have the scales 58 - 65; the dorsal has 30-32 rays and anal 28 or 29. Five specimens of *B. capistratus* from Hawaii have 50 or 51 oblique series of scales (counted from the upper end of gill opening); the dorsal has 29 or 30 rays; the anal has 25-27 rays. Caudal fins of the Hawaiian specimen are truncate, with outer rays not produced. The caudal is noticeably lunate in the Panama and Mazatlan specimens."

According to Berry and Baldwin (1966)

> " *Sufflamen verres* is closely related to *S. fraenatus* (Latreille) [= *S. capistratus* (Shaw) = *S. mitis* (Bennett)] which ranges from Hawaii westward to South Africa. The two species are very closely similar in Morphology and in adult pigmentation. Specimens of *S. fraenatus* from the central Pacific have lower number of soft rays (about D. 28-30, A. 24-26) than *S. verres*; but a specimen of *S. fraenatus* (ANSP 101164) from South Africa, at western extreme of the range, has D. 31 and A. 27, very similar to *S. verres*".

The meristic characters of *Sufflamen fraenatus* of west coast of India and *Sufflamen verres* Pacific coast of Central America are given in the following table.

The meristic characters of *Sufflamen fraenatus* and *Sufflamen verres*	*Sufflamen fraenatus* n.90 (south west coast of India)	*Sufflamen verres* n 60 (Pacific coast of central America) Berry and Baldwin (1966)	*Sufflamen verres* n 6 (Pacific cost of central America) Gilbert and Stark (1904)
Dorsal	III, 30-33	III. 30-33	III. 30-32
Anal	27- 30	27-30	28-29
Pectoral	14-15	14-15	
Caudal	12	12	

The species cannot be distinguished with the help of meristic characters.

The caudal fin shape cannot be considered as marked variation as believed by Gilbert and Stark (1904), because the specimens in different length groups show different caudal fin shapes. The smaller (80-200 mm) length groups have truncate caudal fin and the larger length groups (250-300 mm) have lunate caudal fin, specimens above 300 mm have double lunate caudal fin.

The sexual dimorphism in *Sufflamen verres* was observed by Berry and Baldwin (1966) from the eastern Pacific. A similar observation was made from east coast of India. A detailed study on the sexual dimorphism revealed that the immature males have white bridle like band and maturing and mature males have pink and bright red band.

Thus it is clear that both the species *S. fraenatus* and *S. verres* are similar and *S. verres* should be considered as a junior synonym of *S. fraenatus*.

2.5.8. 2. *Sufflamen chrysopterus* (Bloch and Schneider, 1801)

Balistes chrysopterus Bloch and Schneider, 1801, p.466.
Balistes chrysopterus Day, 1878, p.688.
Sufflamen chrysoptera Jones and Kumaran, 1980, p.667. Fig. 568.

Diagnosis

The anterior nasal aperture is dome shaped with a tube at the tip. Scales on cheek rectangular at the anterior, arranged obliquely, diamond at the posterior, arranged vertically. Groove before eye. Body scales have retrose spines. Caudal peduncle equally long and deep with 8–9 rows of antrose spines. Caudal truncate.

Material examined: Two specimens from Kavaratti, (1 male, 1 indeterminate) of lengths 155, 154 mm TL, three specimens from Minicoy, (2 females, 1 indeterminate) of lengths 52, 82, 110 mm TL, (Fig.44.A), two specimens from Lakshadweep, CMFRI Reg. No. F4124/1, of lengths 112,154 mm TL.

Additional material examined: One specimen from Minicoy ZSI Reg. No. F 4124/1. 154 mm TL, (Fig.44.B).

Description

D. III, i, 26–27; P. i, 12; ventral spines. 11–17; A. i, 23-25; C. ii, 10; gill rakers 20- 24; number of scales from origin of second dorsal to base of anal 15–18; lateral line scales 25-60; round the caudal peduncle 11–13.

Body rhomboid. Head profile straight with a prominent chin. Lips thick fleshy and broad, continuous at the corner. Interorbital straight. Groove longer than orbit, narrow at anterior, broader deep towards posterior spiny protuberances present in the groove. First dorsal spine stout, short, blunt, laterally flat and smooth. Minute protuberances at the anterior flat surface, which are round at the bottom, ridges at the mid portion and large ridges at the tip. Nostrils placed in a shallow depression (Fig. 45.A). All the teeth rectangular with the upper side serrated (Fig. 45.B).

Two enlarged rectangular scales arranged opposite to each other and numerous smaller scales arranged in a mosaic fashion in a rectangular area just above the base of pectoral. Gill opening oblique. Gill rakers narrow, hyaline, elongated; with pointed tips and minute blunt protuberances towards the inside (Fig. 45.C). Second dorsal and anal fin are short and have a convex profile. Pectoral round.

The scales on cheek have ridges and round protuberances arranged in 4–5 vertical rows (Fig.45. D & Fig.46.A). Body scales have blunt retrose spines arranged in 3-6 vertical rows (Fig.45. E & Fig.46.B). The ultra structure of the anterior portion of the body scale has irregular shaped projections (Fig. 46. E –G) and the posterior portion has blunt retrose spines (Fig. 46. H - J). The scales on abdomen are rectangular with ridges and blunt retrose spines arranged in 3-5 oblique rows (Fig.45.F & Fig.46.C). Caudal peduncle laterally elliptical. Scales on caudal peduncle are of two types i) scales with an antrose spine at the anterior middle and 3-5 vertical rows of blunt retrose spines and ridges ii) scales have blunt retrose spines and ridges arranged in 3-6 vertical rows (Fig. 45.G & Fig.46.D).

Ventral flap broad at the anterior and narrow posteriorly. Ventral spines 11–17 are short, pointed, and transparent (Fig.45.H).

Colour
Fish dark reddish blue, with yellow lips. First dorsal dark brown. Second dorsal and anal light yellow to brown, translucent. Caudal brown with the edges white a white crescent at the posterior. Just above the lips a blue band which extends from corner of mouth to the pectoral base across cheek. A narrow bright blue band originates behind the eye and meets the pectoral base (Fig.44.A).

Colour of the preserved specimen: The whole fish is brown caudal has a white crescent at the posterior edge (Fig.44.B).

***Abalistes* Jordan and Seale, 1906**
(Type species *Balistes stellaris* Bloch and Schneider, 1801 = *Balistes stellatus* Lacepede, 1798)

Diagnosis

Anterior nostril funnel shaped. Scales on cheek rhomboid, arranged in vertical rows, have round protuberances. Grove before eye. Body scales with spherical and round protuberances and ridges. Caudal peduncle depressed dorso-ventrally, longer than deep. Caudal peduncle has 3-4 rows of ridges. Caudal double lunate.

1. *Abalistes stellatus* (Lacepede, 1798)
Balistes stellatus Lacepede, 1798, p. 350.
Balistes stellatus Day, 1878, p.687.

Material examined: Ten specimens from Colachel, (2 males, 8 females) ranging from 158 to 411 mm TL, (Fig.47.A), seven specimens from Vizhinjam, (2 males, 5 females) ranging from 201 to 287 mm TL, (Fig.47.C).

Additional material examined Eleven specimens from Tuticorin, (7 males, 4 females) ranging from 260 to 425 mm TL (Fig.47.B), 2 specimens from Madras, ZSI. Reg. No. 2254 and 2717, of lengths 135, 166 mm TL (Fig.47.D & F) collected by Dr. Day, one specimen from Bay of Bengal, ZSI. Reg. No. F603/2, of length of 246 mm TL, (Fig. 47.E).

Description

D. III, i, 25-26; P. i, 13-14; ventral spines 5-13; A. i, 23-25; C. ii, 10; gill rakers 29-33; number of scales from origin of second dorsal to base of anal 14-18; lateral line scales 29-68; scales round the caudal peduncle 9-12.

Body oval, head profile, convex dorsally, straight ventrally, chin prominent. Lips thick, cylindrical. Inter-orbital straight and broad. Groove before eye, deep longer than orbit, directed downwards. Nostrils, placed in a shallow depression with the anterior nostril (funnel shaped) having curved edges and a small lobe towards the posterior (Fig. 47.A). First dorsal spine, cylindrical, slender, pointed. Third spine ¼ the length of first spine. All the teeth are conical with pointed tip (Fig.48.B).

Enlarged scales (rectangular with edges round), five to six, arranged in an oval area at the base of pectoral. In 200-300 mm length groups enlarged scales are fused together, in 80–150 mm length groups the enlarged scales are attached on a flexible membrane. The gill rakers are hyaline, elongated with pointed tips (Fig.48.C). Second dorsal and anal, rectangular, with serrated edge. Pectoral round.

Scales on cheek have 3-8 vertical rows of round protuberances (Fig.48. D & Fig. 49.A). Body scales have a large spherical protuberance at the anterior middle. Ridges from the anterior most row followed by round protuberance arranged in 2-7 vertical rows (Fig.48. E & Fig.49.B). The ultra structure of the anterior margin of the body scale has ridges arranged in rows (Fig.49. E–G) and the posterior margin has first row of ridges and round protuberances (Fig.49. H-J). Scales on abdomen rectangular or rhomboid, arranged obliquely and have ridges (Fig.48. F & Fig.49.C). Scales on caudal peduncle have a transverse ridges at the centre and 3 -5 horizontal rows of round protuberance (Fig.48. G & Fig. 49.D).

Ventral flap wide supported by many pointed, elongated, hyaline, slender ventral spines. Two rows of retrose spines arranged on the flap (Fig. 48. G). Pelvic spine short, moveable, broad, cylindrical decorated with spinules. Few larger spinules are arranged at the anterior portion directed backwards and some are also arranged laterally and posteriorly.

Colour

Dorsally olive green with bluish-white spots, ventrally white, with few narrow green bands obliquely. Iris gold. Upper lip grey and lower lip white. A white streak present on the middle of the body. First dorsal fin with 5-7 parallel yellow bands and a black blotch at the tip. Second dorsal and anal fins have yellow bands which are arranged parallel to body, pectoral fin yellow. Four white blotch, first blotch anterior to first dorsal fin, second blotch between first and second dorsal fin, third blotch exactly at the middle of second dorsal fin, fourth blotch on caudal peduncle. Caudal fin brown.

Colour of the preserved specimens: The whole body golden brown, with prominent white spots dorsally. Four white blotches, one at the origin of the first dorsal, second blotch between first dorsal and second dorsal, third blotch at the middle of the second dorsal, fourth blotch on the caudal peduncle. White streak at the lateral middle. Fins brown.

Remarks

The Body shape of the figure in Histoire Naturelle of Lacepede (1798) (plate 15, figure1) does not exactly represent the species but gives a rough shape of the fish. Few white dots are seen scattered dorsally but lacks the prominent four white blotches and a white streak at the middle of the body. The caudal is shown as forked but this fishes from Indian seas have double lunate caudal.

Bleeker in his Atlas Ichthyology (1865) has brought out colour patterns of this fish in minute details. But few of the bands, which originate below eye and at the corner of the mouth was not present in the specimens caught from our region.

Taxonomic note: The genus is monotypic and the description of genus given by Jordan and Seale (1906) and species description of Bloch and Schneider (1801) conform to the specimens of this species (this species is rare) collected from the southeast and west coast of India.

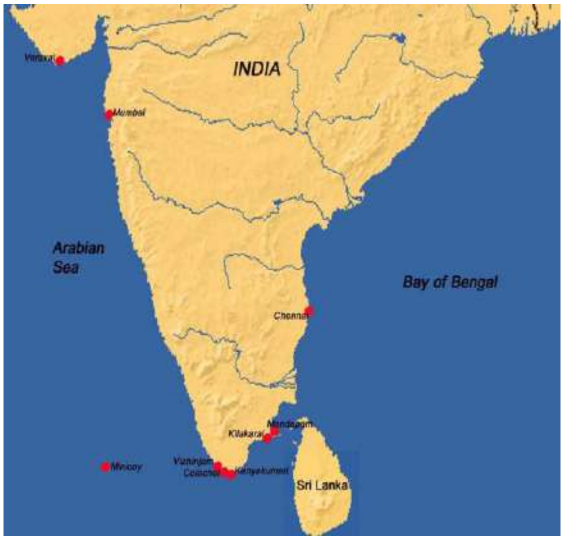


Fig 1

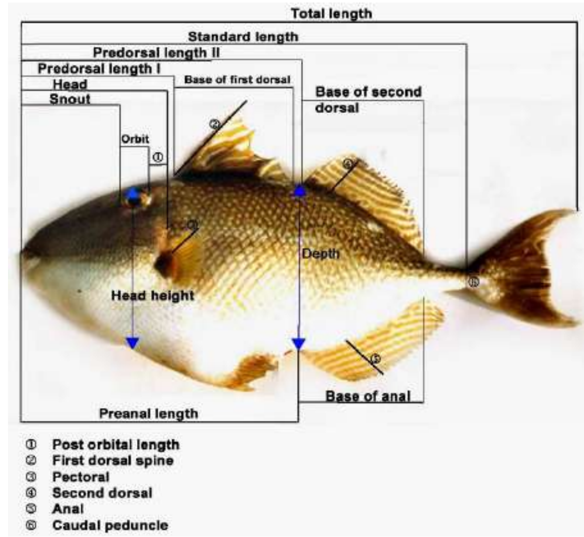


Fig 2

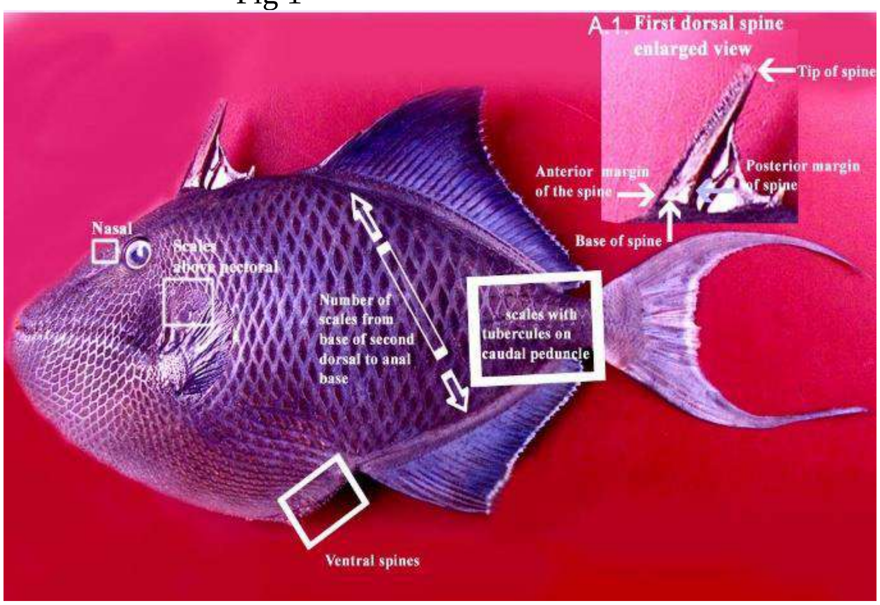


Fig 3A

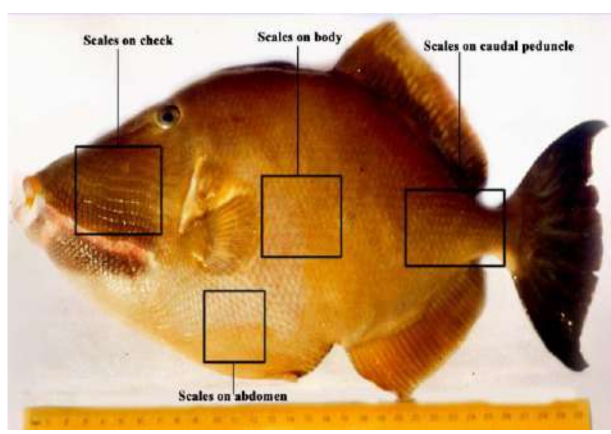


Fig 3B

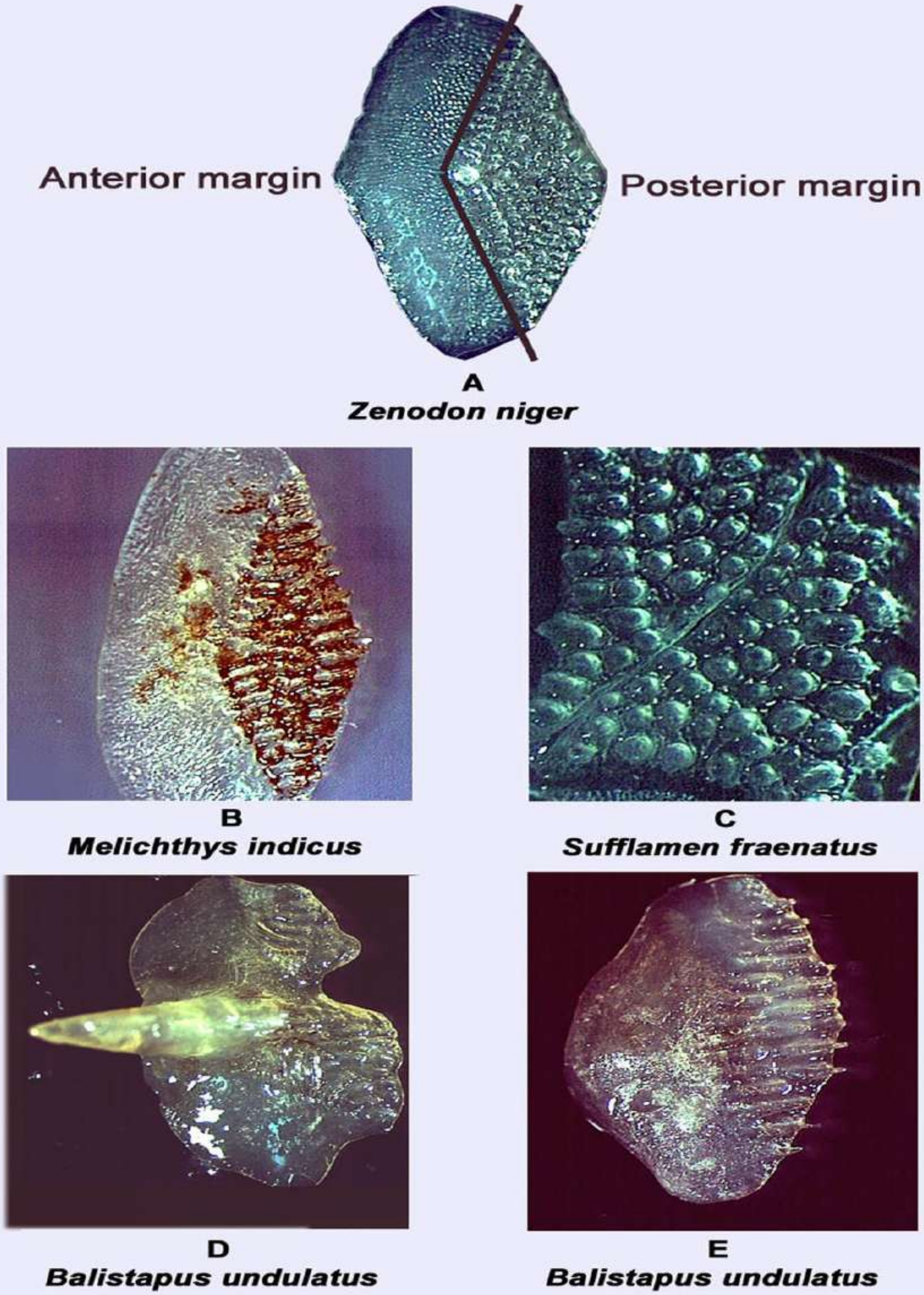
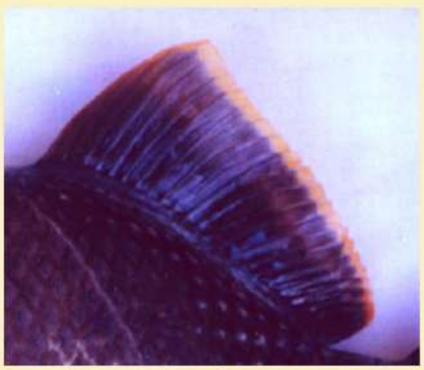


Figure 4. A. The anterior margin and posterior margin of the scale, B. Ridge-like protuberances, C. Round protuberances, D. Antrose spines, E. Retrose spines.

A
Rhinecanthus aculeatus

B
Balistapus undulatus



C
Pseudobalistes flavimarginatus

D
Abalistes stellatus

E
Canthidermis macualtus

Figure 5. The second dorsal fin of the fishes of the family Balistidae

A
Abalistes stellatus

B
Melichthys indicus

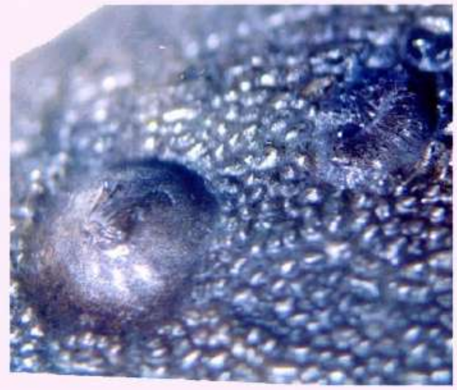
C
Zenodon niger

D
Pseudobalistes flavimarginatus

E
Rhinecanthus aculeatus

Figure 6. Teeth pattern in the fishes of the family Balistidae

A
Abalistes stellatus



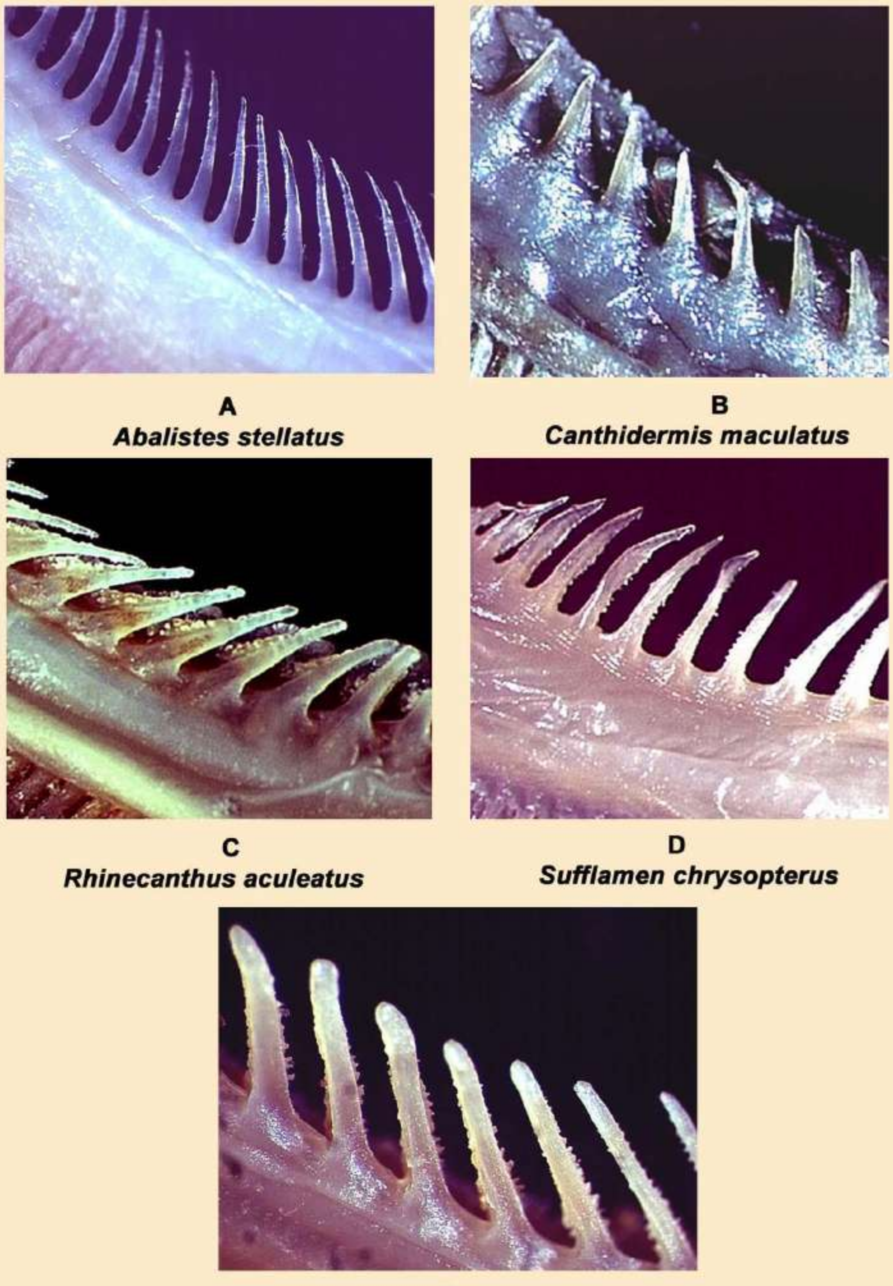
B
Balistapus undulatus

C
Sufflamen chrysopterus

D
Pseudobalistes viridescens

E
Sufflamen fraenatus

Figure 7. The nasal apertures of the fishes of the family Balistidae



A
Abalistes stellatus

B
Canthidermis maculatus

C
Rhinecanthus aculeatus

D
Sufflamen chrysopterus

E
Rhinecanthus echarpe

Figure 8. Gill rakers of the fishes of the family Balistidae

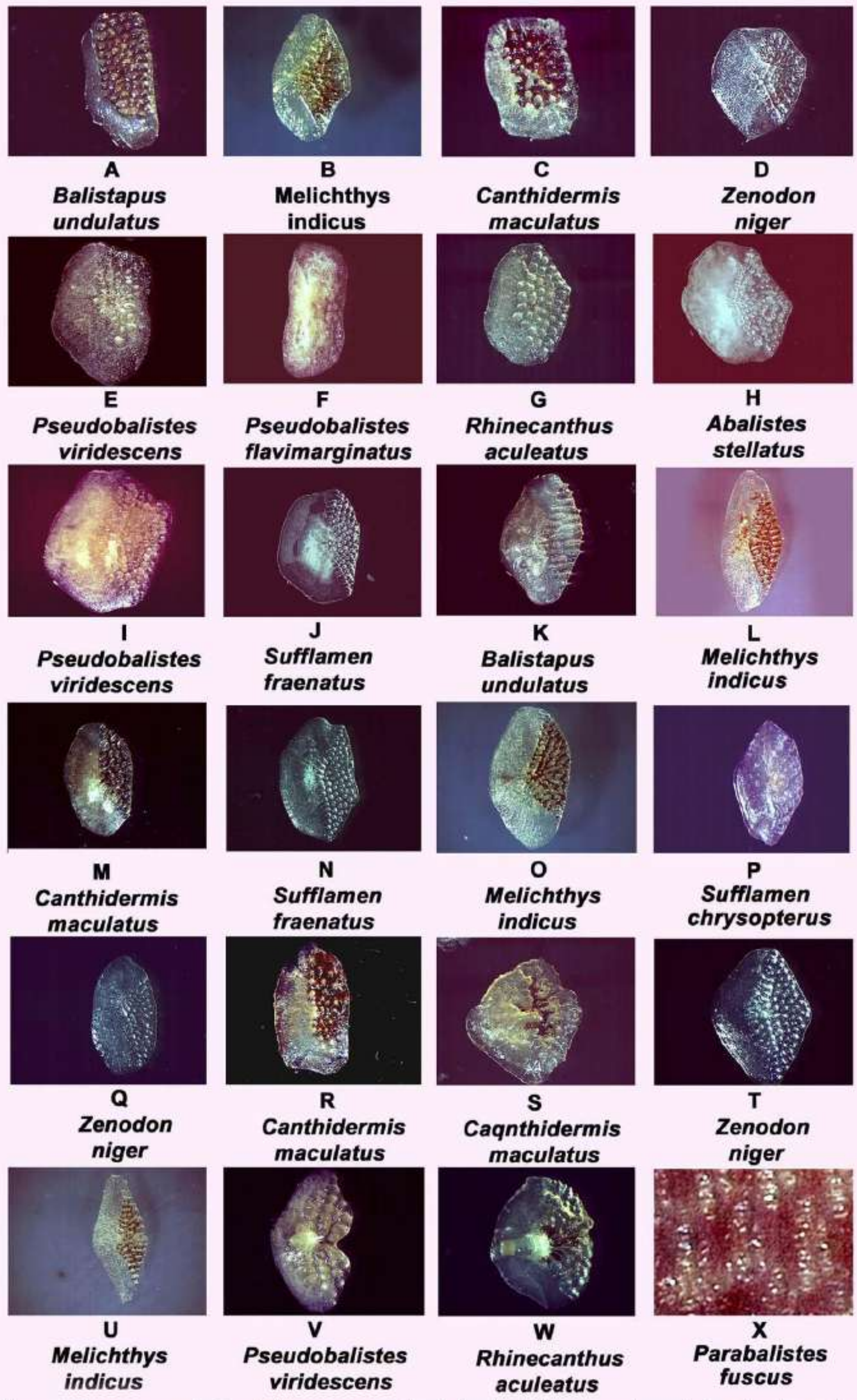
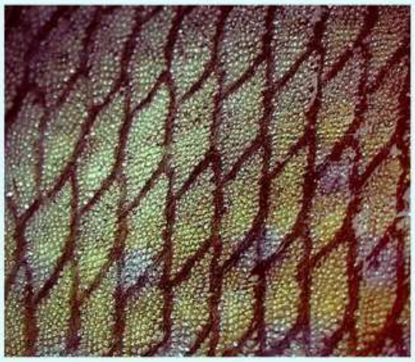
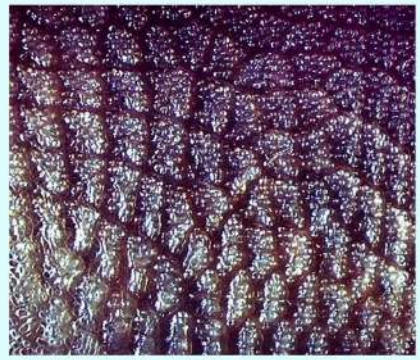


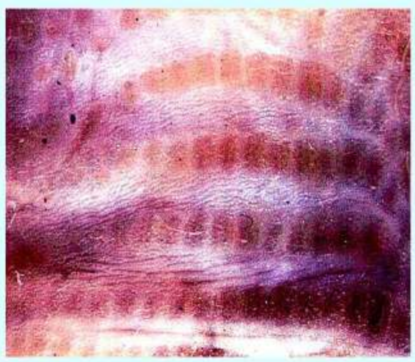
Figure 9. Arrangement of protuberances on cheek, body, abdomen and caudal peduncle scales in the fishes of the family Balistidae



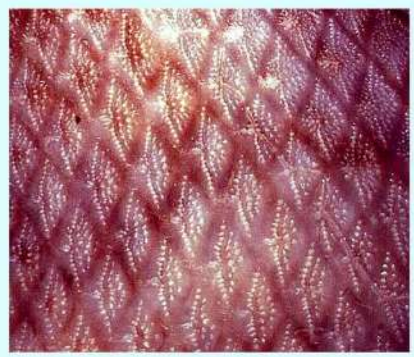
A. ***Abalistes stellatus***



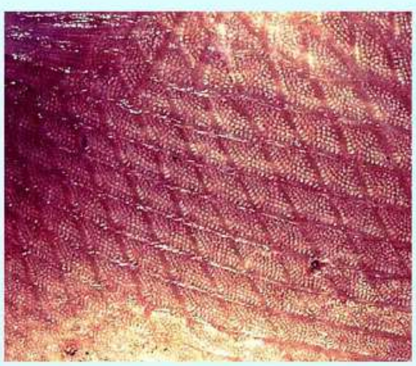
B. ***Rhinecanthus echarpe***



C. ***Parabalistes fuscus***



D. ***Abalistes stellatus***



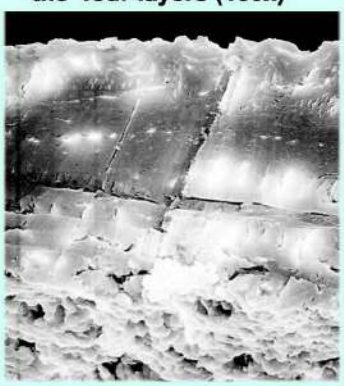
E. ***Sufflamen fraenatus***

F. ***Sufflamen fraenatus***

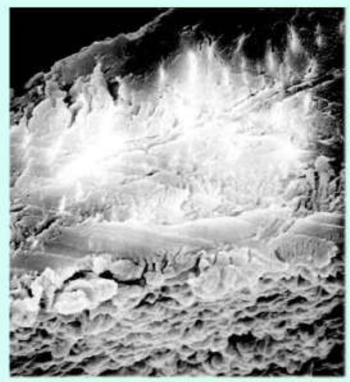
Figure10. Arrangement of scales on cheek, body, abdomen and caudal peduncle of the fishes of the family Balistidae

A. Transverse section showing the four layers (100x)

B. Glassy layer (100x)



C. The network of canals (200x)

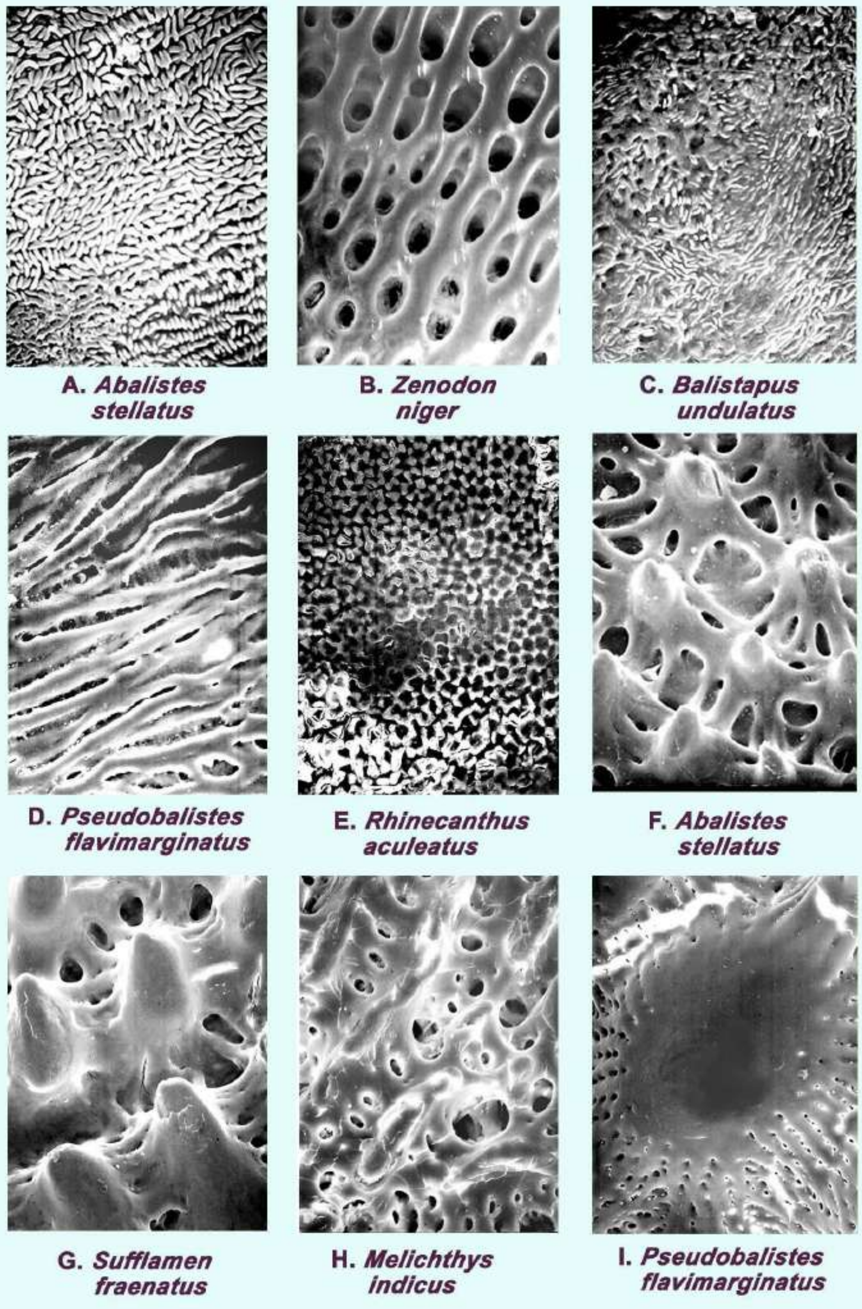


D. Thickest bottom layer (200x)

E. Posterior end of posterior margin (200x)

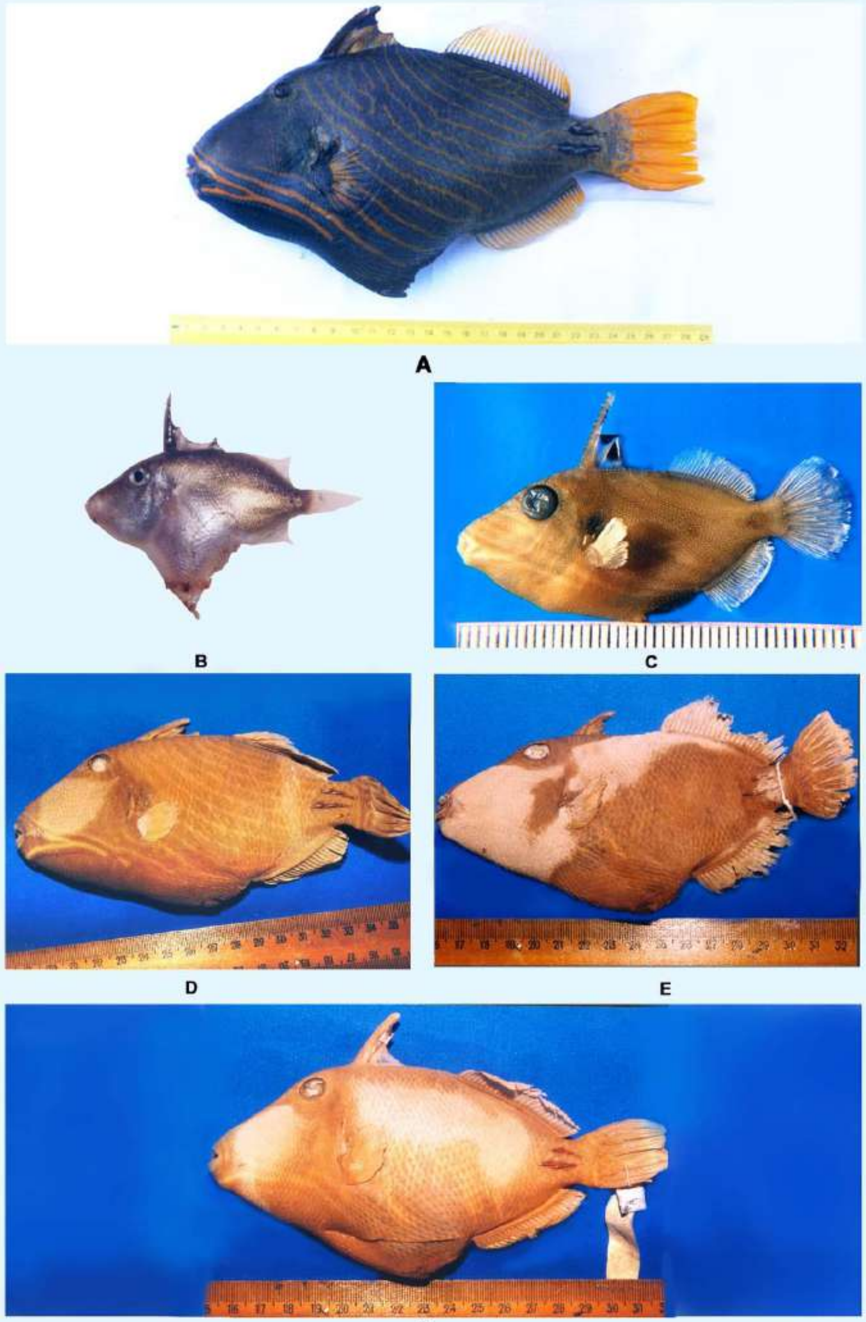
F. Central canal and lateral line canal (200x)

Figure 11. Ultra structure of body scale of *Abalistes stellatus*



A. *Abalistes stellatus*
B. *Zenodon niger*
C. *Balistapus undulatus*
D. *Pseudobalistes flavimarginatus*
E. *Rhinecanthus aculeatus*
F. *Abalistes stellatus*
G. *Sufflamen fraenatus*
H. *Melichthys indicus*
I. *Pseudobalistes flavimarginatus*

Figure 12. The ultra structure of the body scale of the fishes of the family Balistidae, A-E the anterior margin, F-I the posterior margin



F
Figure **13**. *Balistapus undulatus* (Mungo Park, 1797): A. From Tuticorin, 274mm TL, B. From Kavartti 20 mm TL, C. From Kavartti 41 mm TL, D. From Andaman ZSI Reg. No. 2256, 167 mm TL, collected by Dr. F. Day, E. ZSI Reg. No. 2737, 177mm TL, F. ZSI Reg. No. 8899, 170 mm TL.

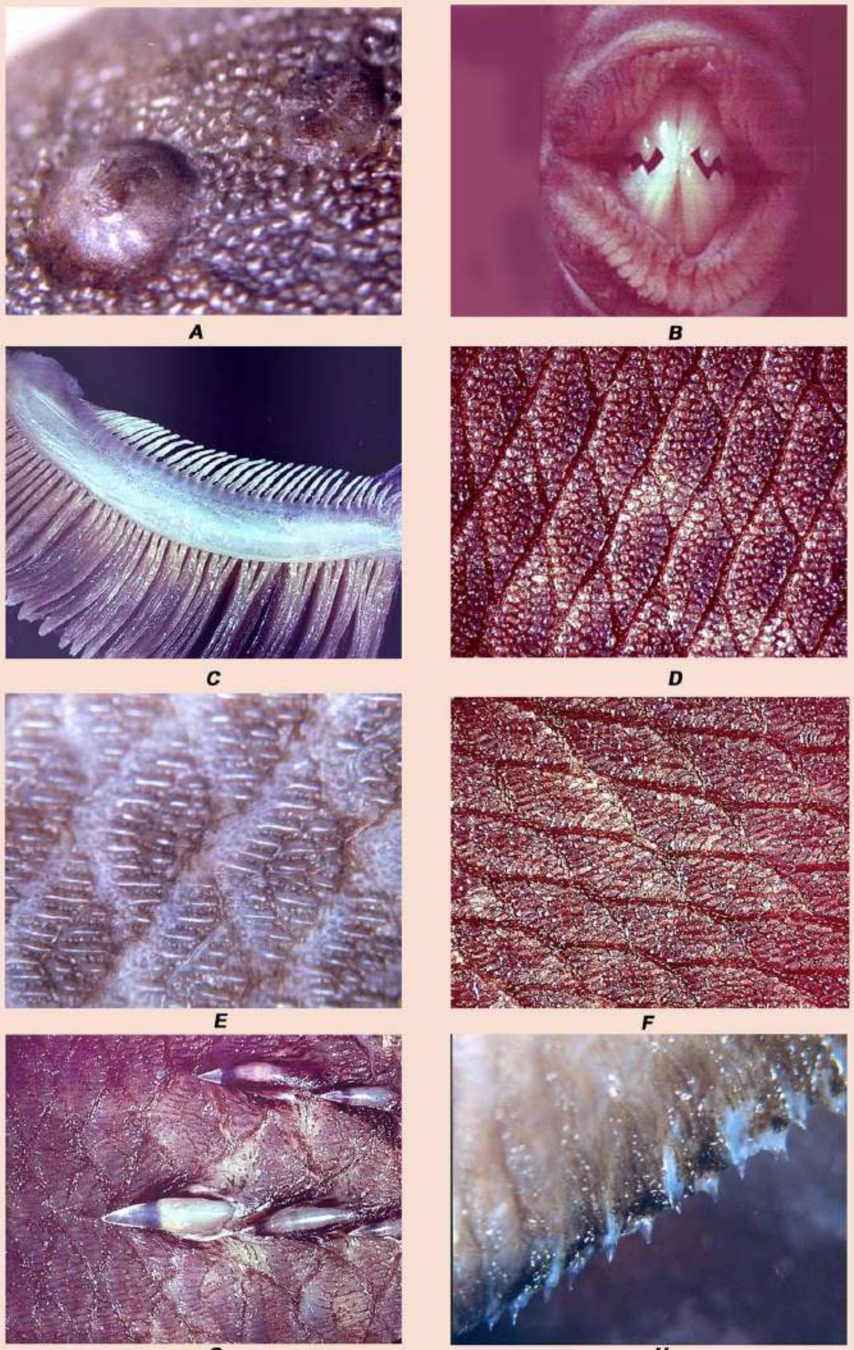


Figure 14. *Balistapus undulatus* (Mungo park, 1797), A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

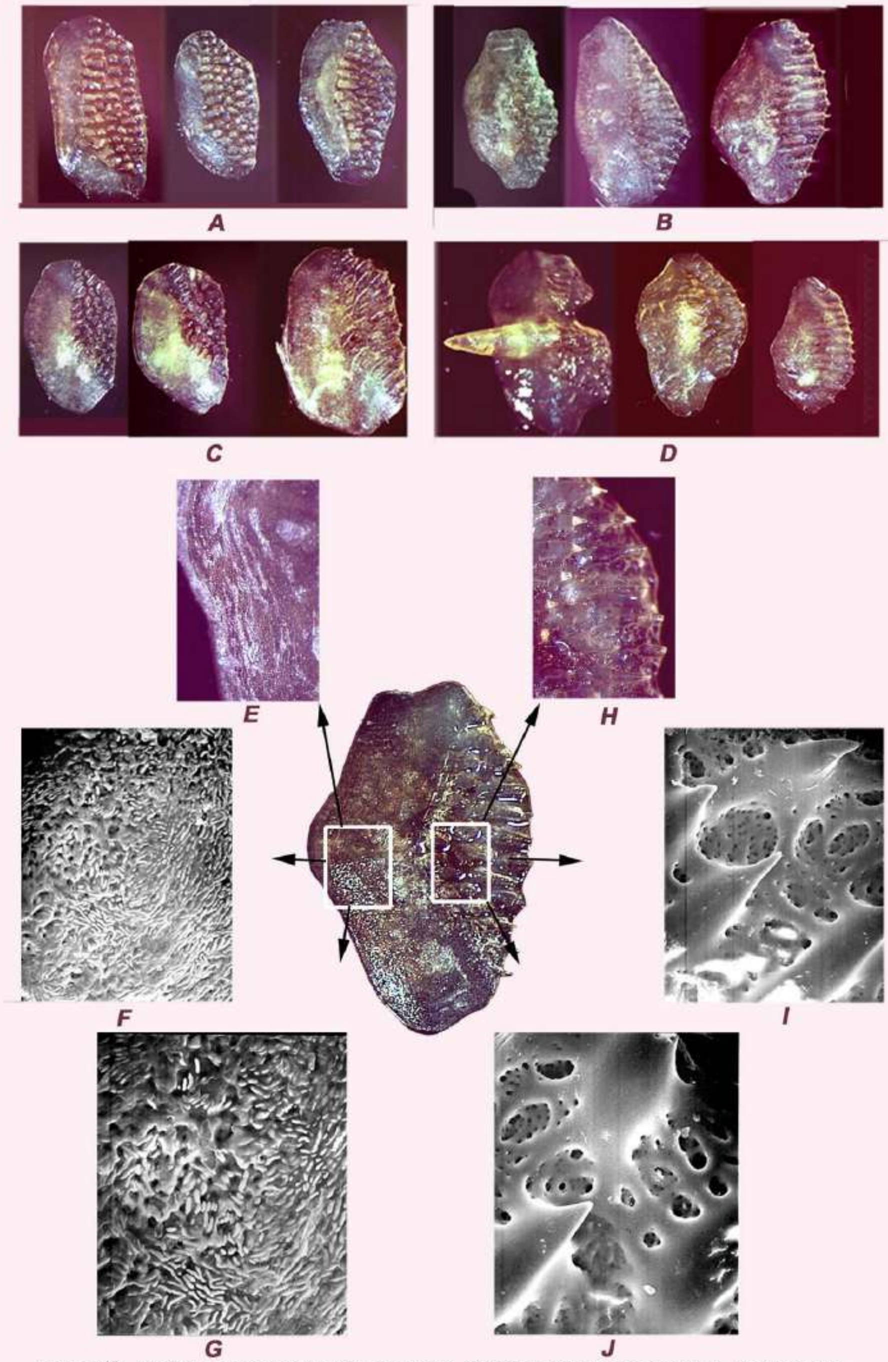


Figure 15 . *Balistapus undulatus* (Mungo Park, 1797): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E - G. Anterior margin of body scale 40x,100x, 200x, H - J. Posterior margin of body scale 40x, 100x, 200x.

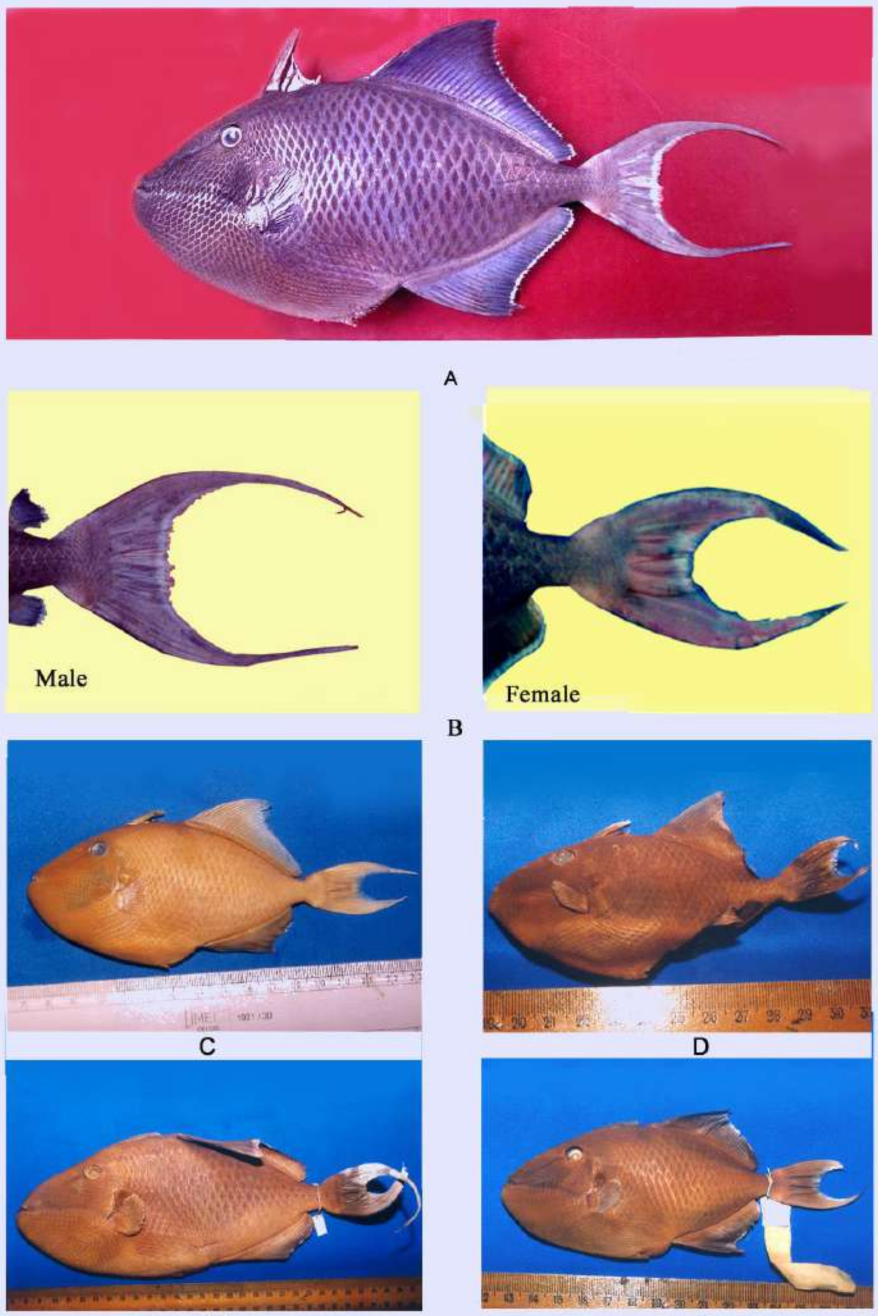


Figure 16. *Zenodon niger* (Ruppell, 1835): A. From Colachel 265 mm TL, B. Caudal fin of male and female, C. From Vizihinjam CMFRI-F. 154/440, 162 mm TL, D. From Trivandrum ZSI Reg. No.F2611/2, 130 mm TL, E. From Madras ZSI. Reg. No. 8063, 366 mm TL, F. From Andaman ZSI Reg. No. 7250, 164 mm TL.

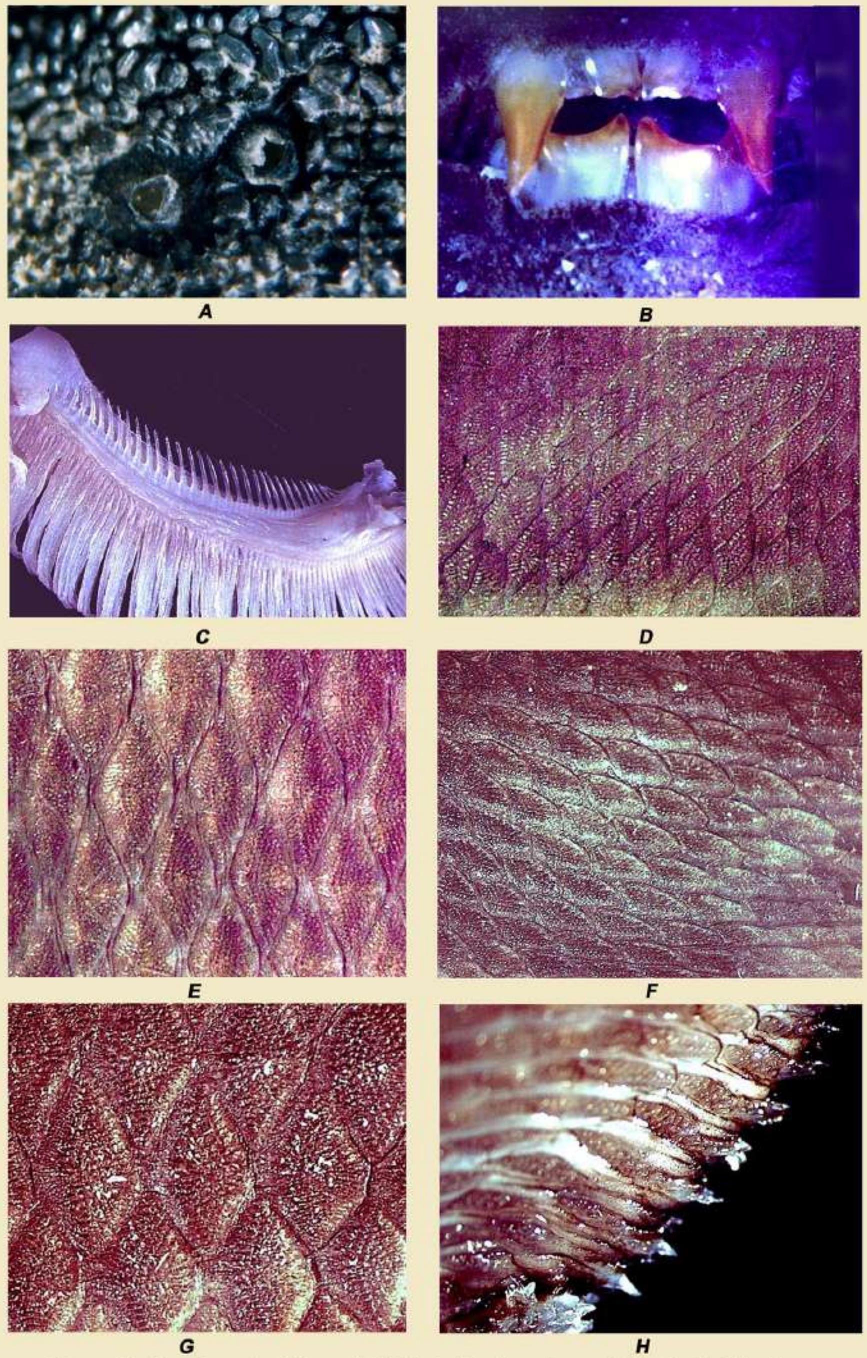


Figure 17. *Zenodon niger* (Ruppell,1835): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on abdomen, G. Scales on caudal peduncle, H. Ventral spines.

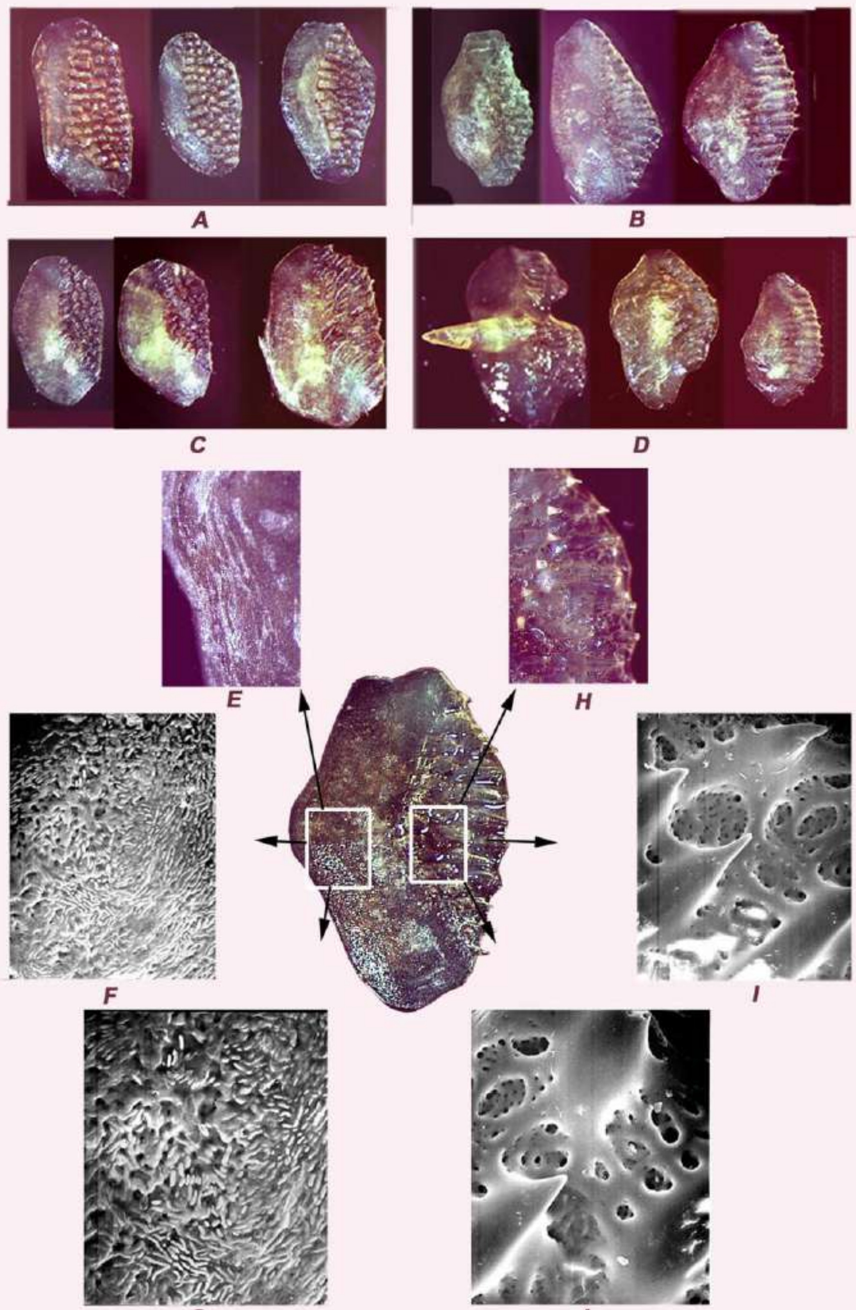


Figure 18. *Balistapus undulatus* (Mungo Park, 1797): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E - G. Anterior margin of body scale 40x,100x, 200x, H - J. Posterior margin of body scale 40x, 100x, 200x.

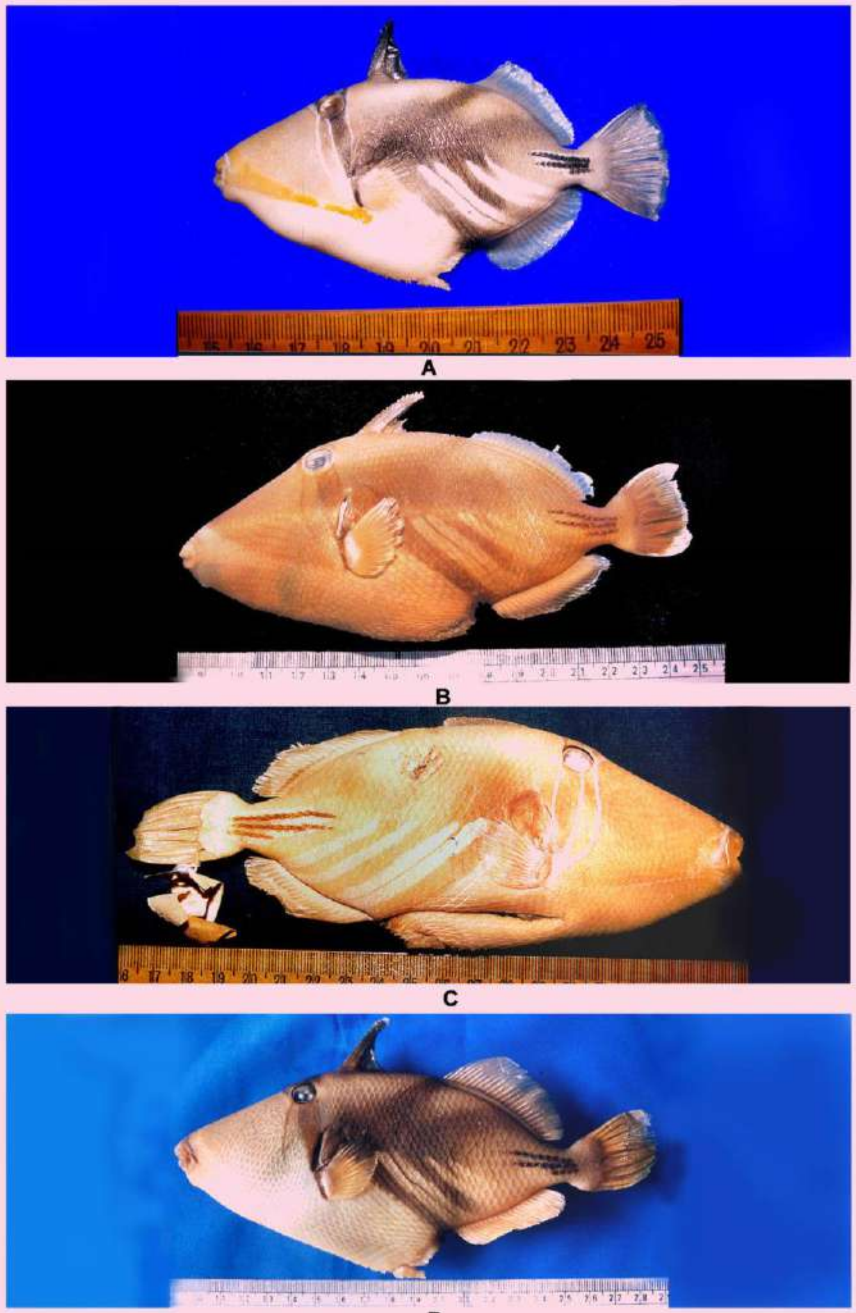


Figure 19. *Rhinecanthus aculeatus* (Linnaeus,1758): A. From Minicoy 110 mm TL, B. From Kavaratti CMFRI-LA-154/480 162 mm TL, C. From Andaman ZSI Reg. No. 2253 191 mm TL, collected by Dr. F. Day, D. From Agatti 203 mm TL.

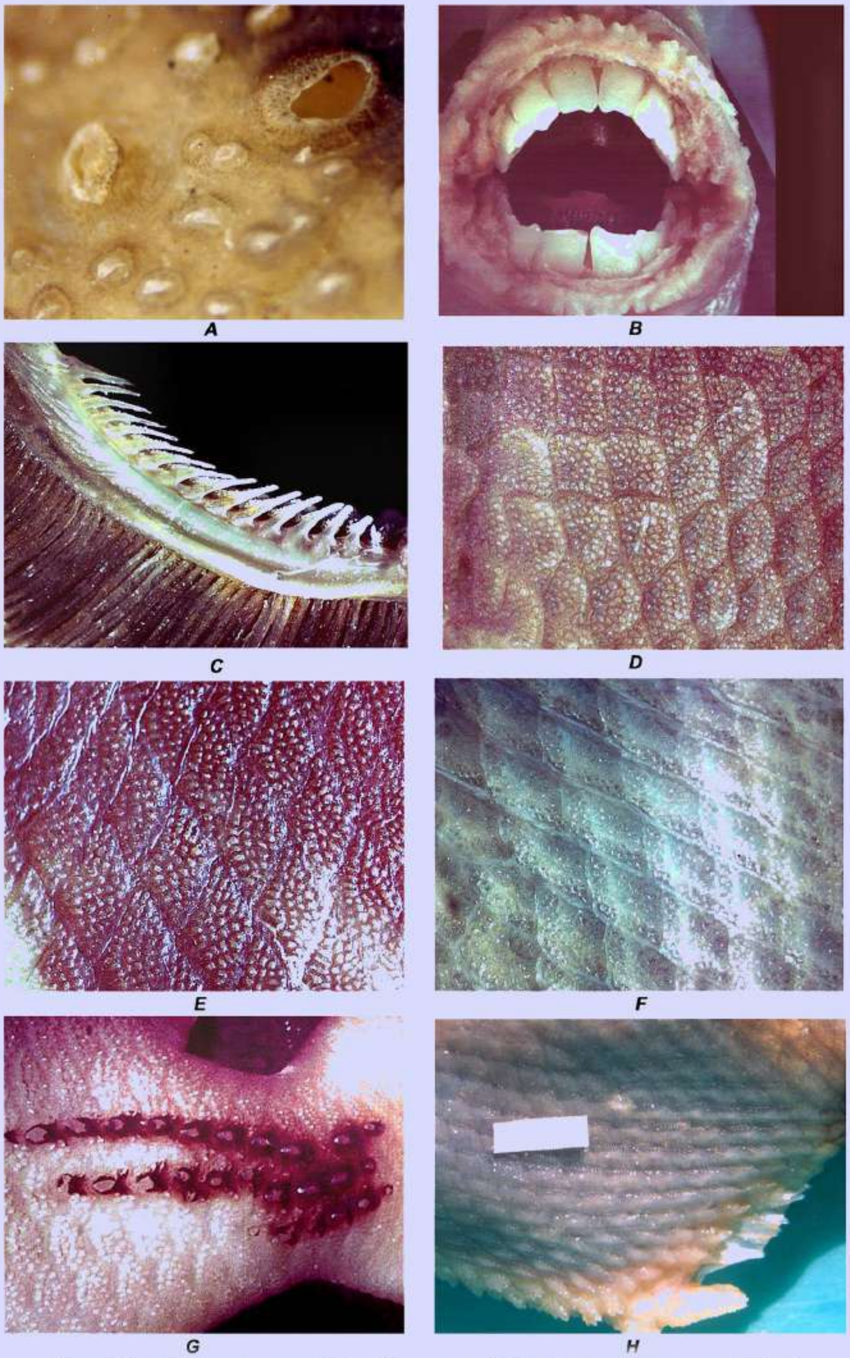


Figure 20. *Rhinecanthus aculeatus* (Linnaeus, 1758): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on abdomen, G. Scales on caudal peduncle, H. Ventral spines.

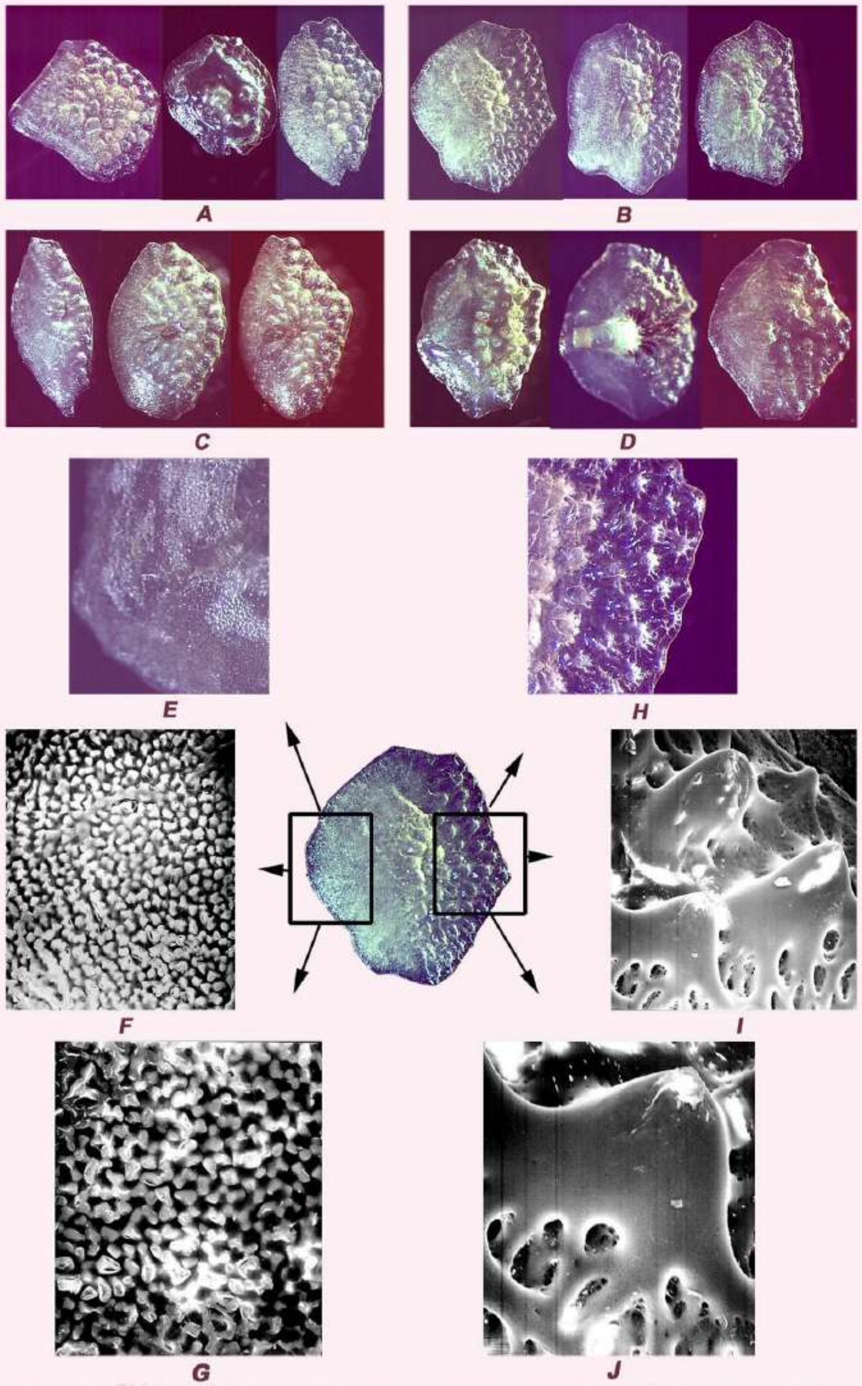
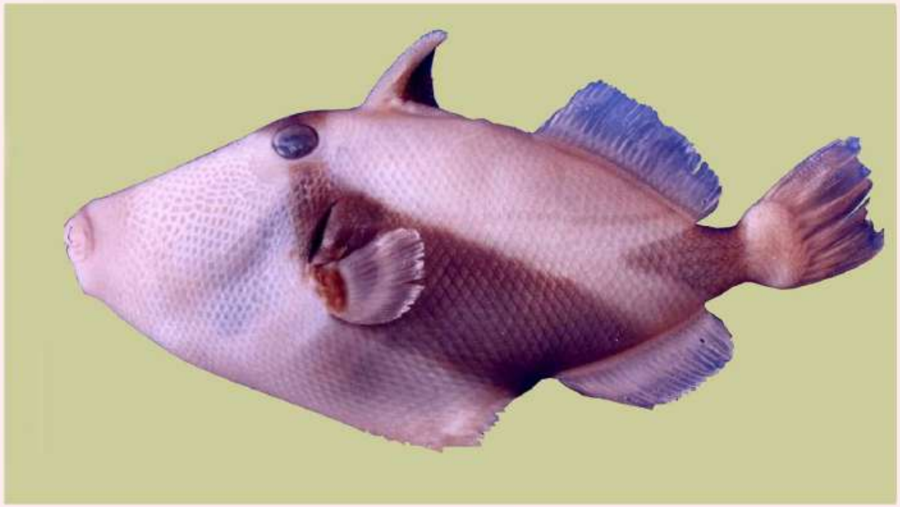


Figure 21. *Rhinecanthus aculeatus* (Linnaeus, 1758): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E - G. Anterior margin of body scale 40x,100x, 200x, H - J. Posterior margin of body scale 40x, 100x, 200x.



A

B

Figure 22. *Rhinecanthus echarpe* (Lacepede,1798): A. From MInicoy 152 mm TL, B. From Malay Archipelago ZSI Reg. No. 2252 179 mm TL, collected by Dr. F. Day.

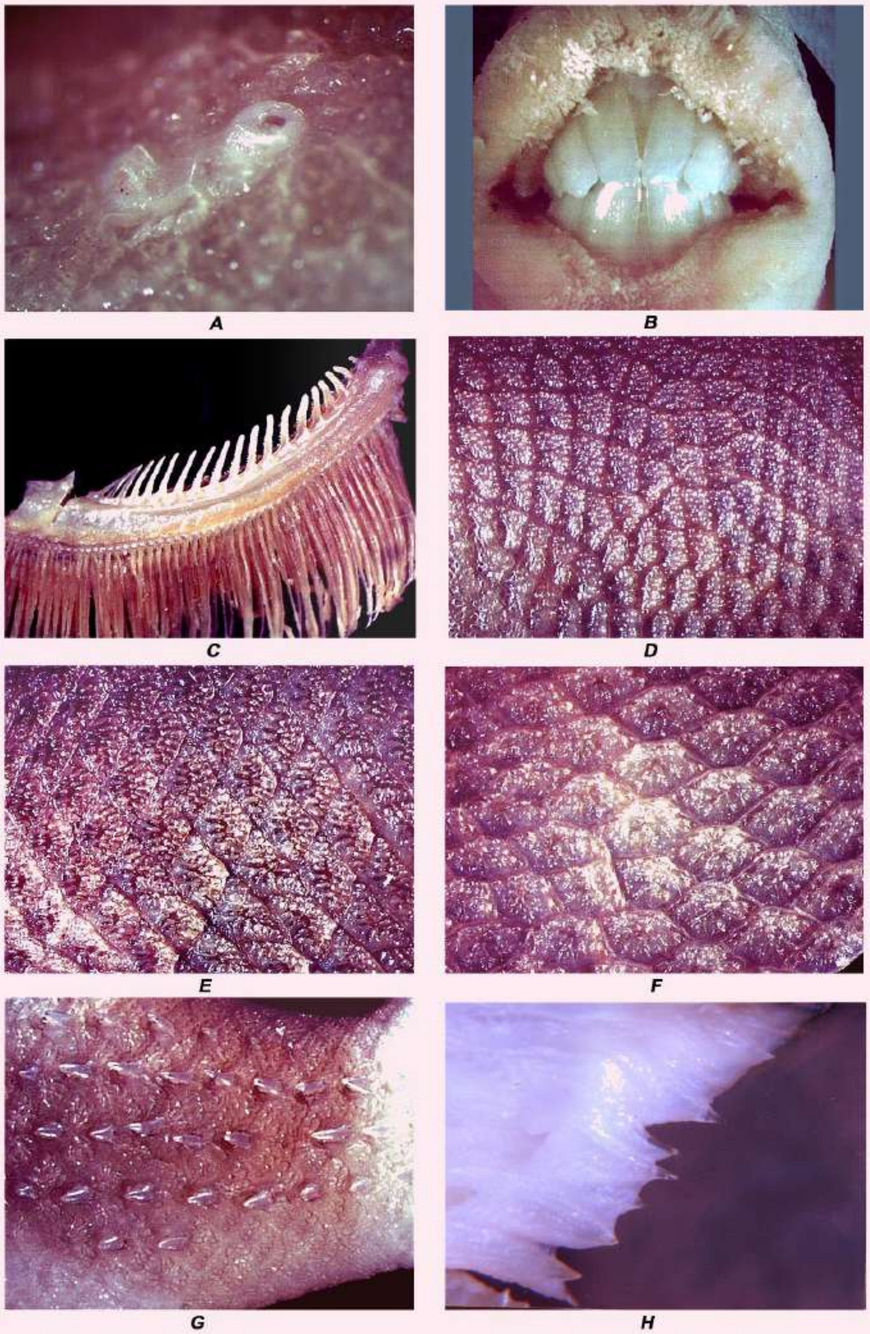


Figure 23. *Rhinecanthus echarpe* (Lacepede,1798): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on abdomen, G. Scales on caudal peduncle, H. Ventral spines.

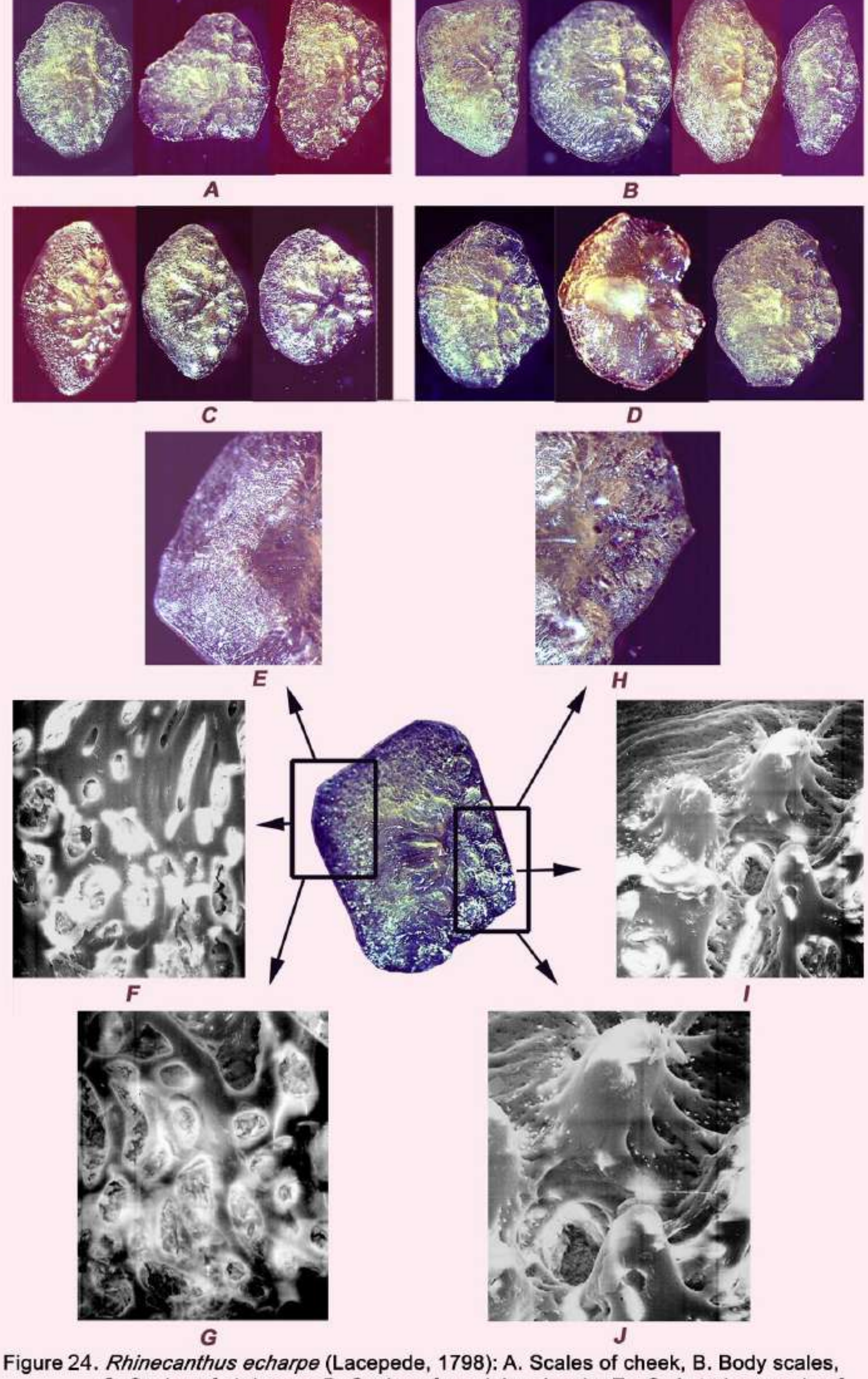


Figure 24. *Rhinecanthus echarpe* (Lacepede, 1798): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E - G. Anterior margin of body scale 40x,100x, 200x, H - J. Posterior margin of body scale 40x, 100x, 200x.

A

B

Figure 25. *Melichthys indicus* Randall and Klausewitz, 1973: A. From MInicoy 182 mm TL, B. From Minicoy CMFRI Reg. No. 554 200 mm TL.

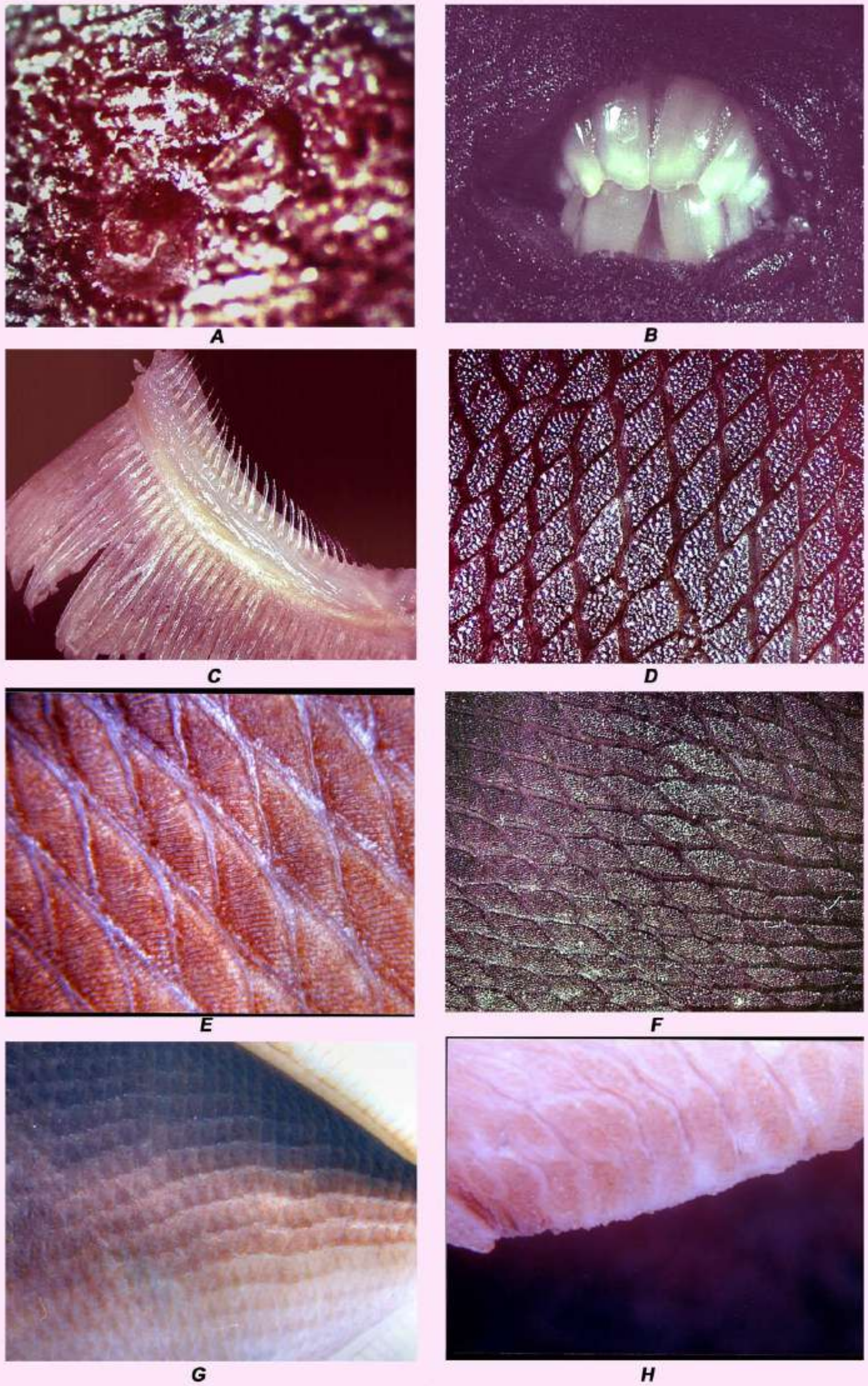


Figure 26. *Melichthys indicus* Randall and Klausewitz, 1973: A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on abdomen, G. Scales on caudal peduncle, H. Ventral spines.

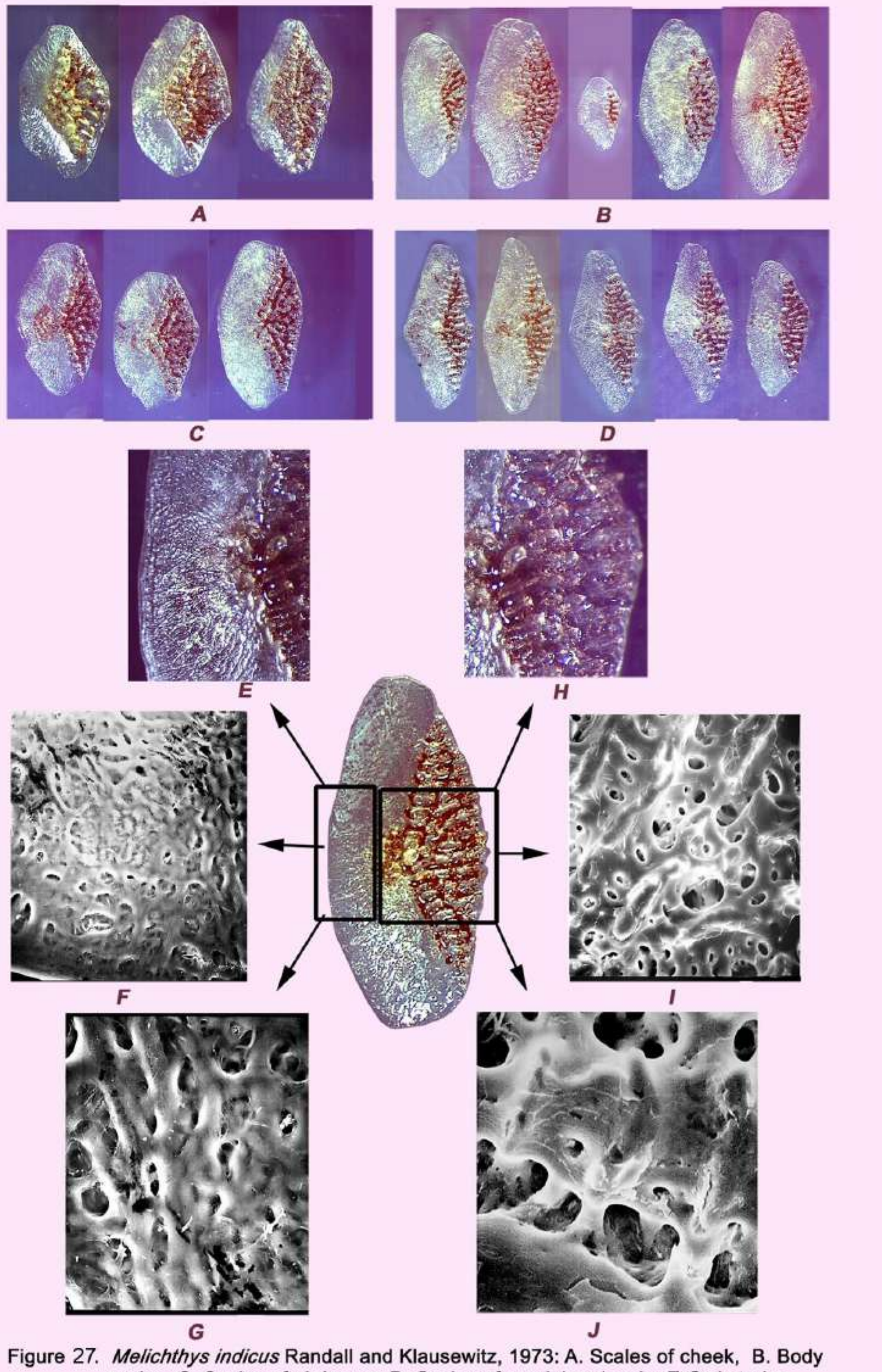


Figure 27. *Melichthys indicus* Randall and Klausewitz, 1973: A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x, 100x, 200x.

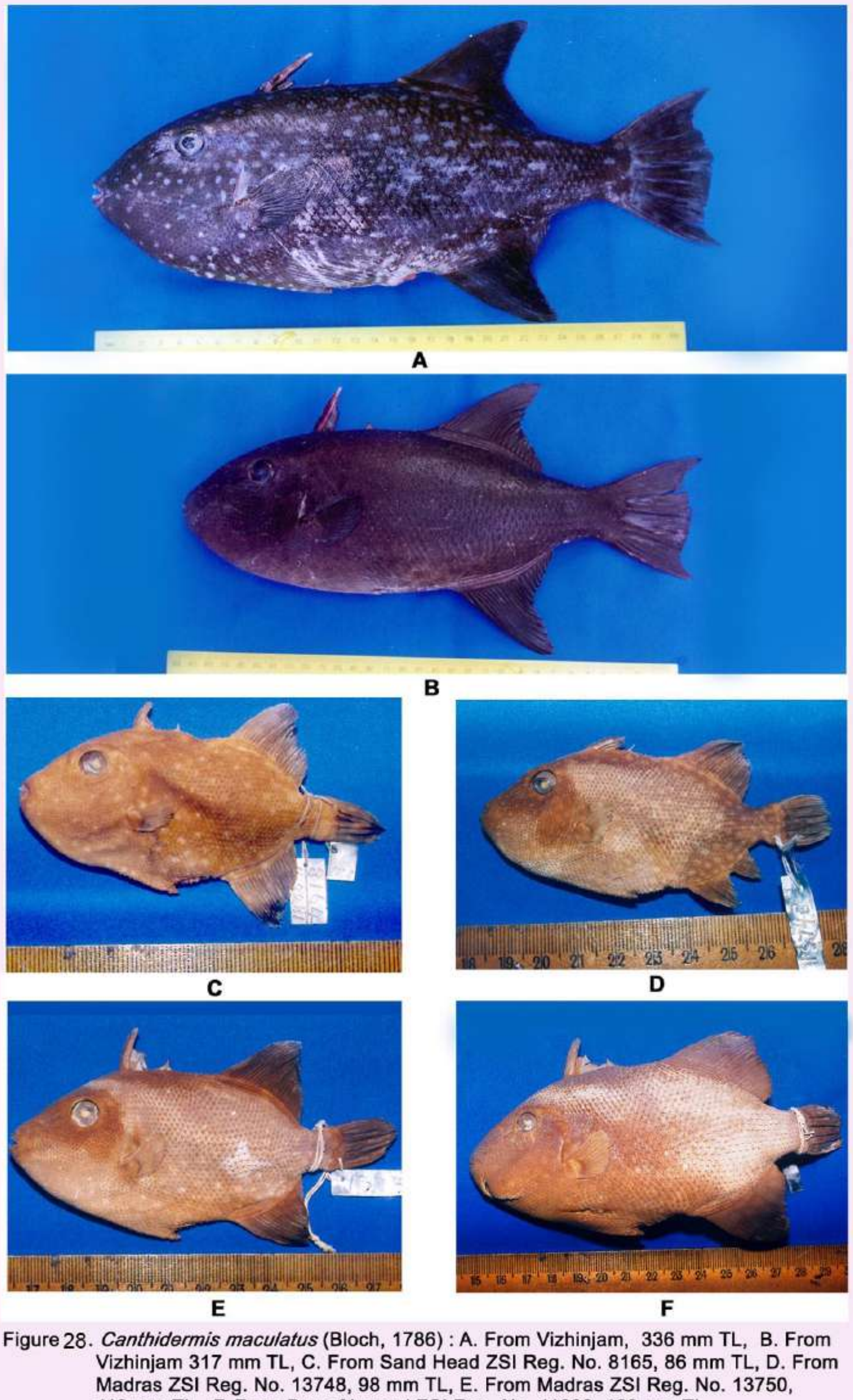


Figure 28. *Canthidermis maculatus* (Bloch, 1786) : A. From Vizhinjam, 336 mm TL, B. From Vizhinjam 317 mm TL, C. From Sand Head ZSI Reg. No. 8165, 86 mm TL, D. From Madras ZSI Reg. No. 13748, 98 mm TL, E. From Madras ZSI Reg. No. 13750, 113 mm TL, F. From Bay of bengal ZSI Reg. No. 11882, 163 mm TL.

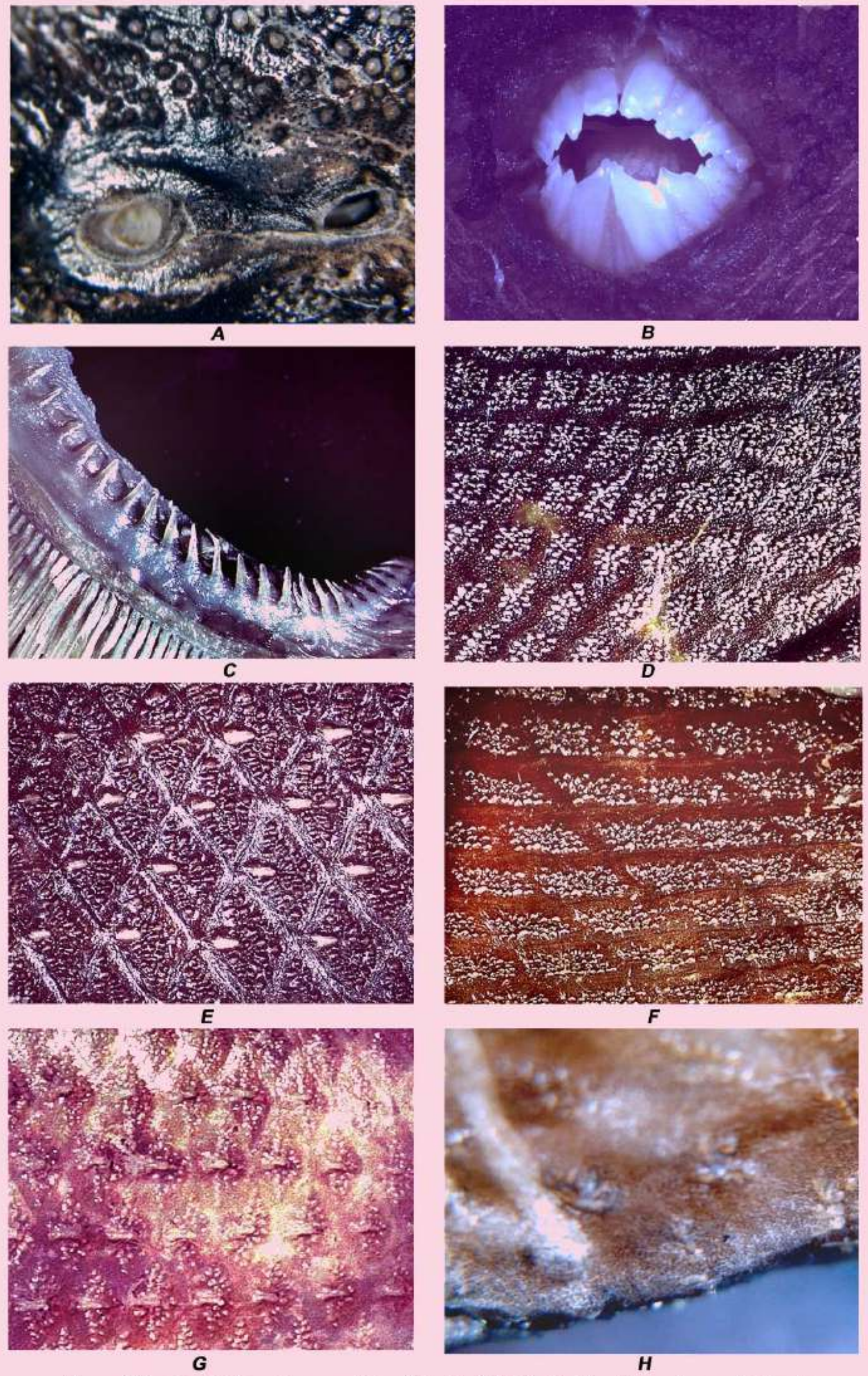


Figure 29. *Canthidermis maculatus* (Bloch, 1786): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

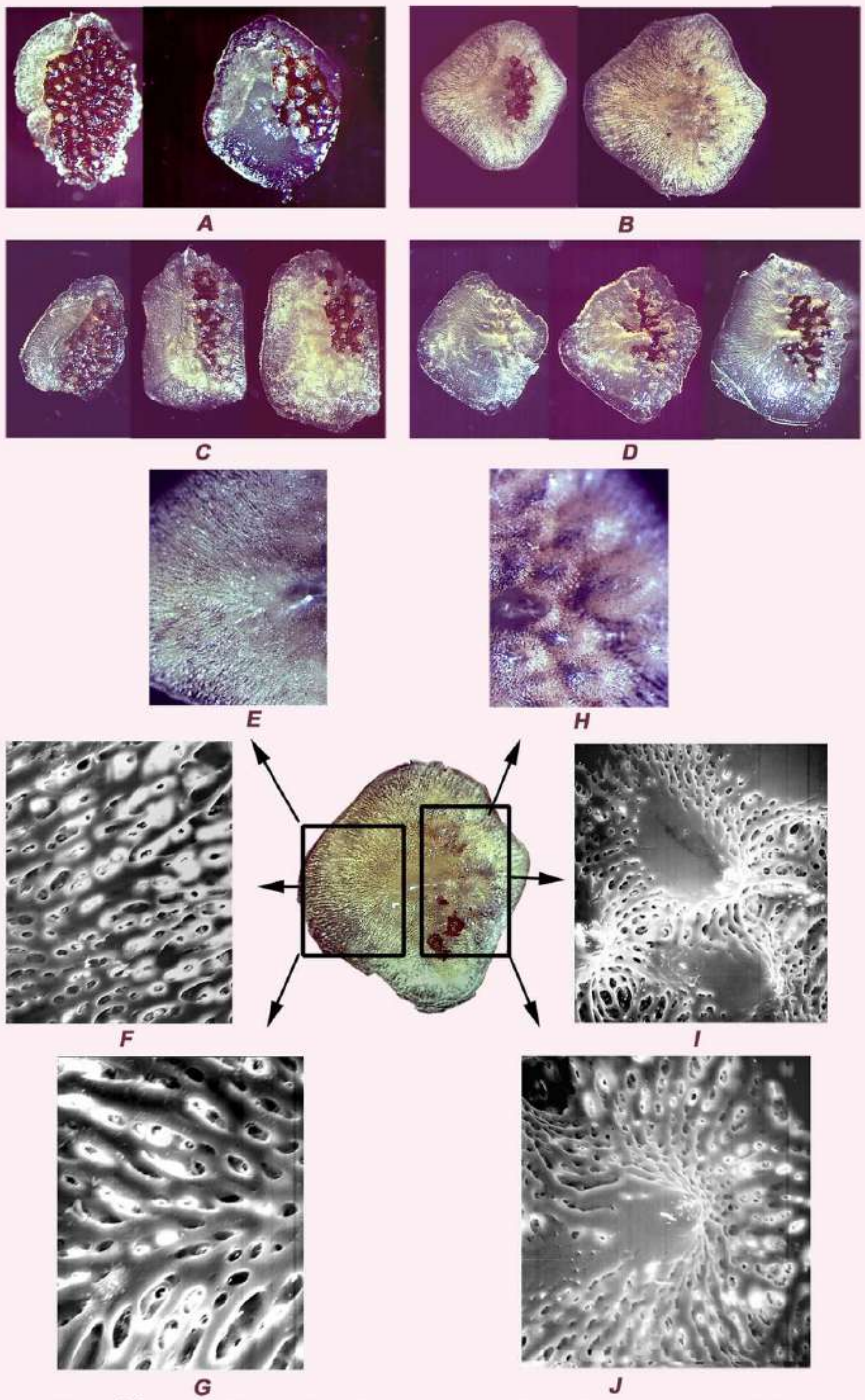


Figure 30. *Canthidermis maculatus* (Bloch, 1786) : A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.

A

B

Figure 31. *Parabalistes fuscus* (Bloch and Schneider, 1801) : A. From Agatti, 145 mm TL, B. From south west coast of India CMFRI Reg. No. 1025, 362 mm TL.

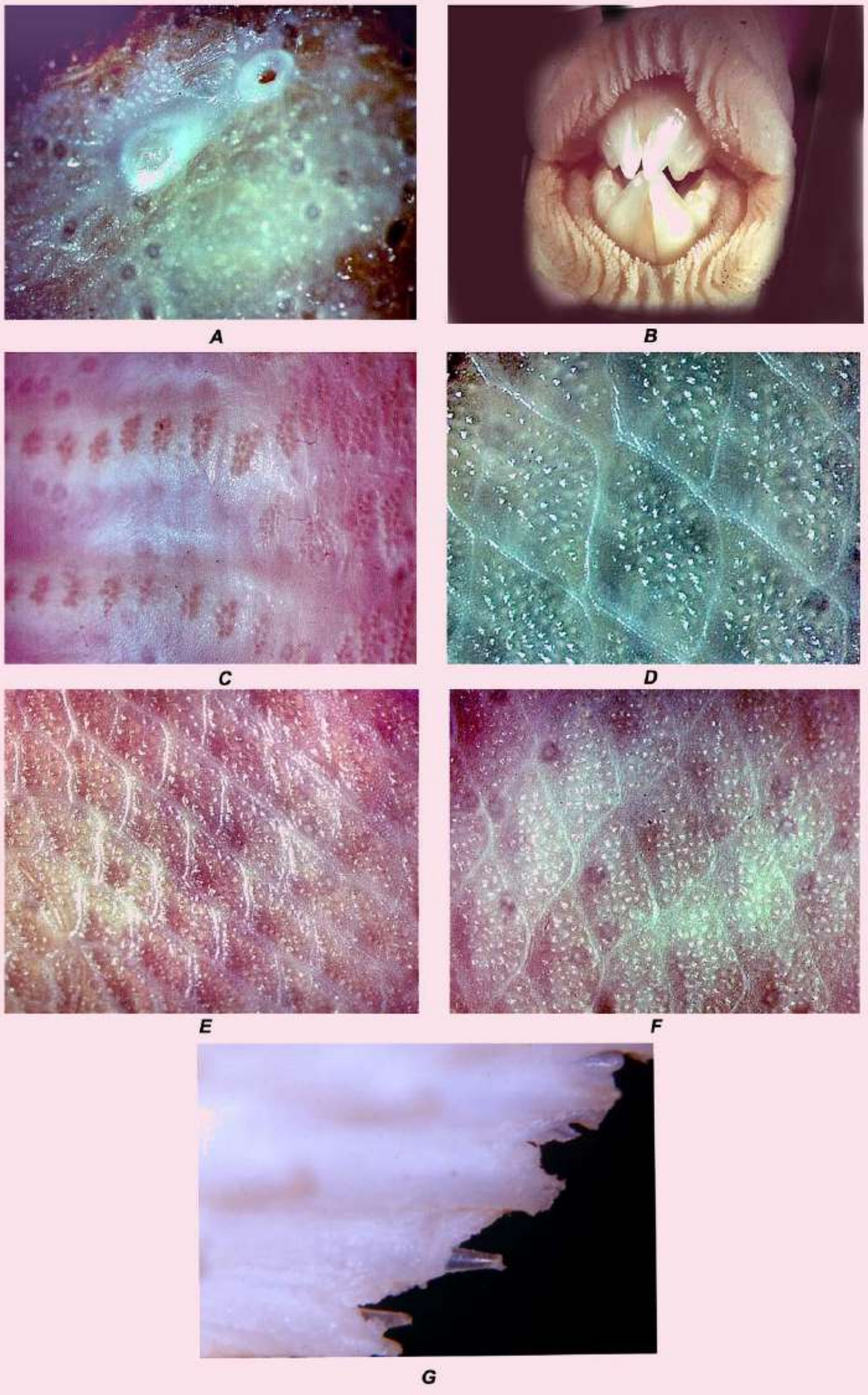
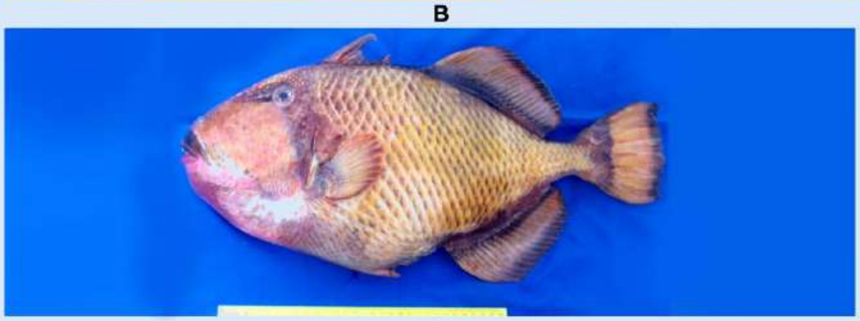


Figure 32. *Parabalistes fuscus* (Bloch and Schneider, 1801): A. Nasal apertures, B. Teeth, C. Scales on cheek, D. Body scales, E. Scales on Abdomen, F. Scales on caudal peduncle, G. Ventral spines.

A

B



C

D

Figure 33. *Pseudobalistes viridescens* (Bloch and Schneider, 1801) : A. From Mandapam 316 mm TL, B. From Kelakarai 326 mm TL, C. From Tuticorin 527 mm TL, D. From Minicoy 455 mm TL.

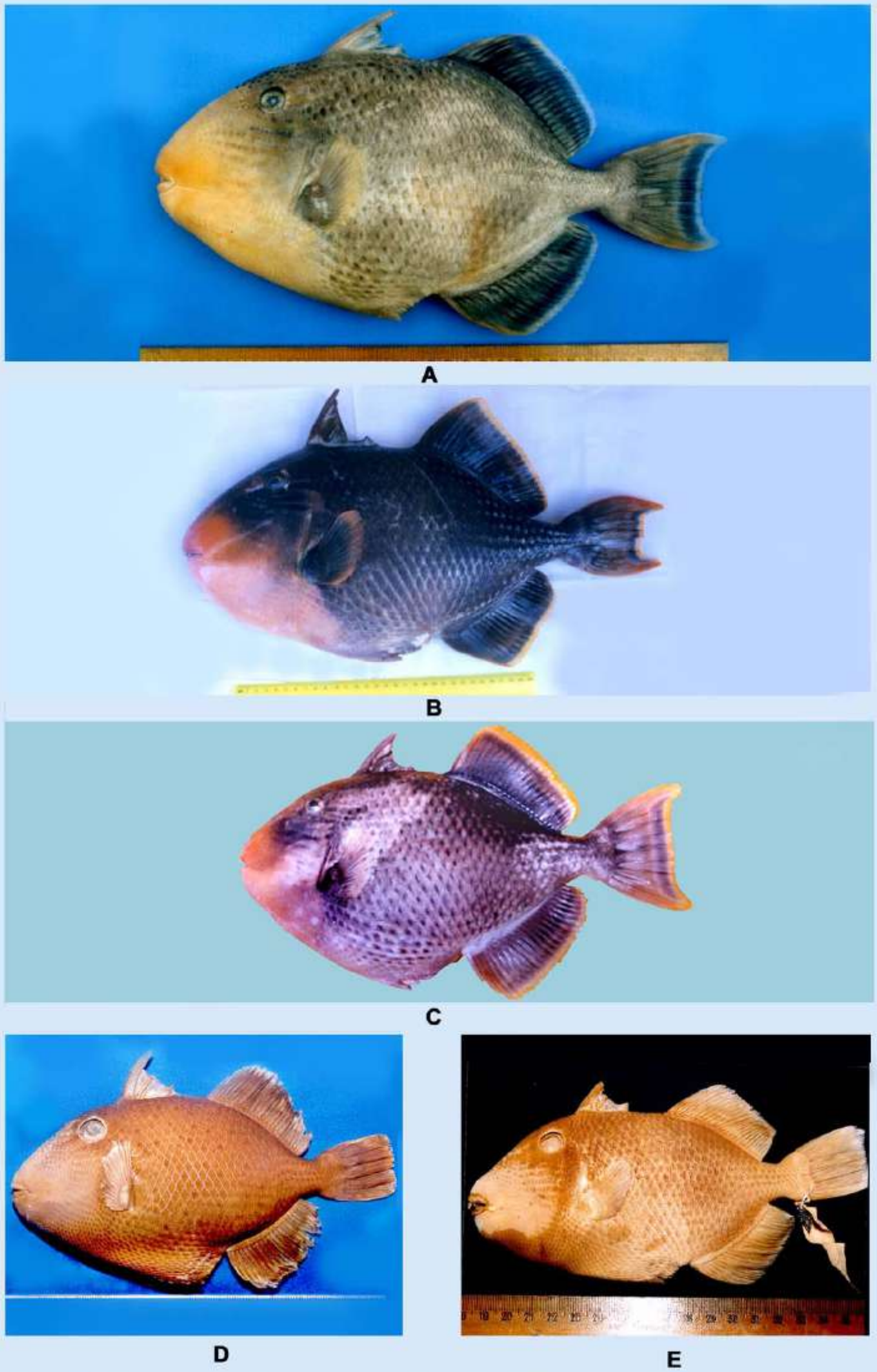


Figure 33. *Pseudobalistes flavimarginatus* (Ruppell, 1828): A. From Minicoy 435 mm TL, B. From Tuticorin 490 mm TL, C. From Mandapam 345 mm TL, D. From Agatti CMFRI-F.154/443, 317 mm TL, E. From Andaman ZSI Reg. No. 2251, 183 mm TL, collected by Dr. F. Day.

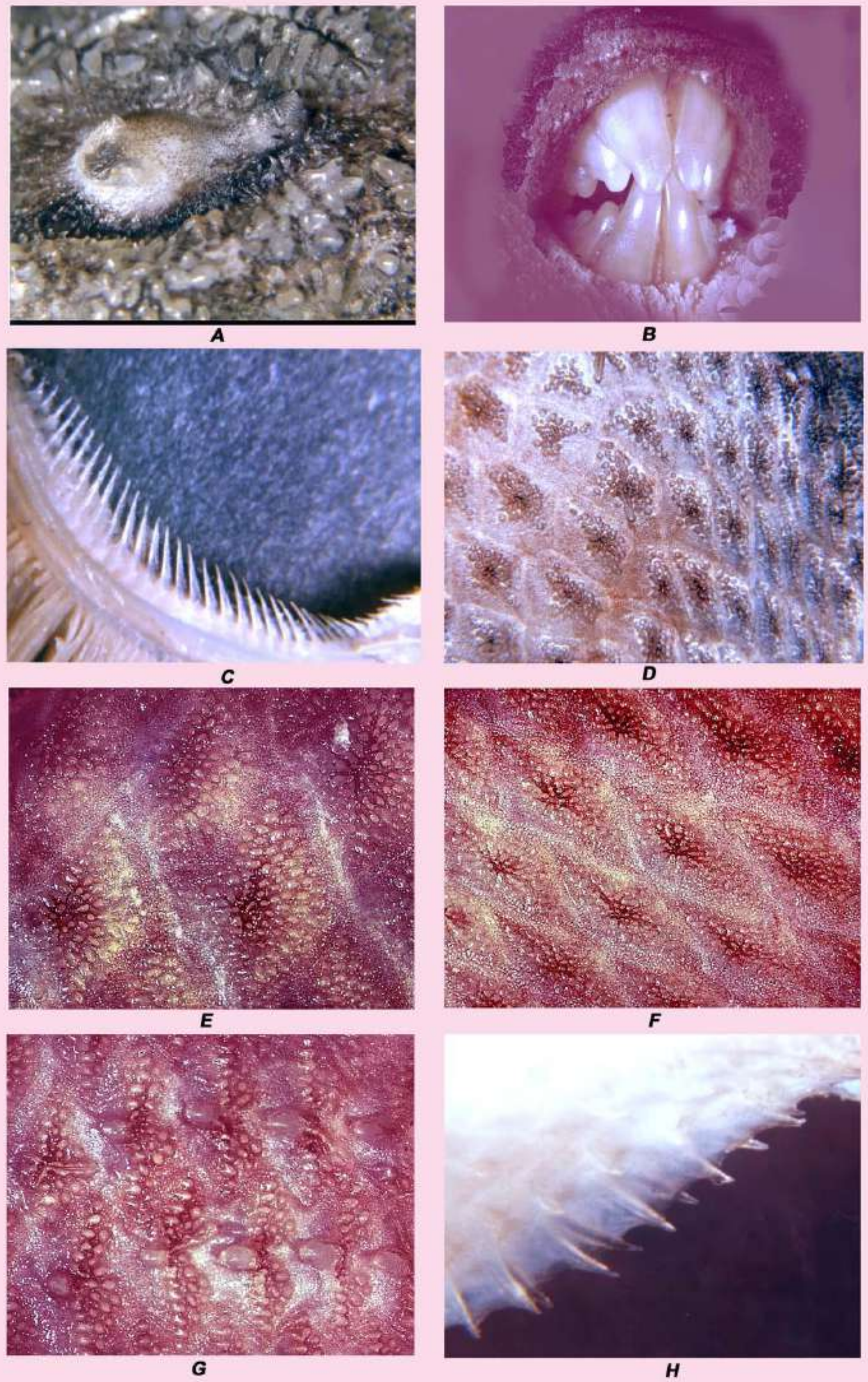


Figure 34. *Pseudobalistes viridescens* (Bloch and Schneider,1801): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

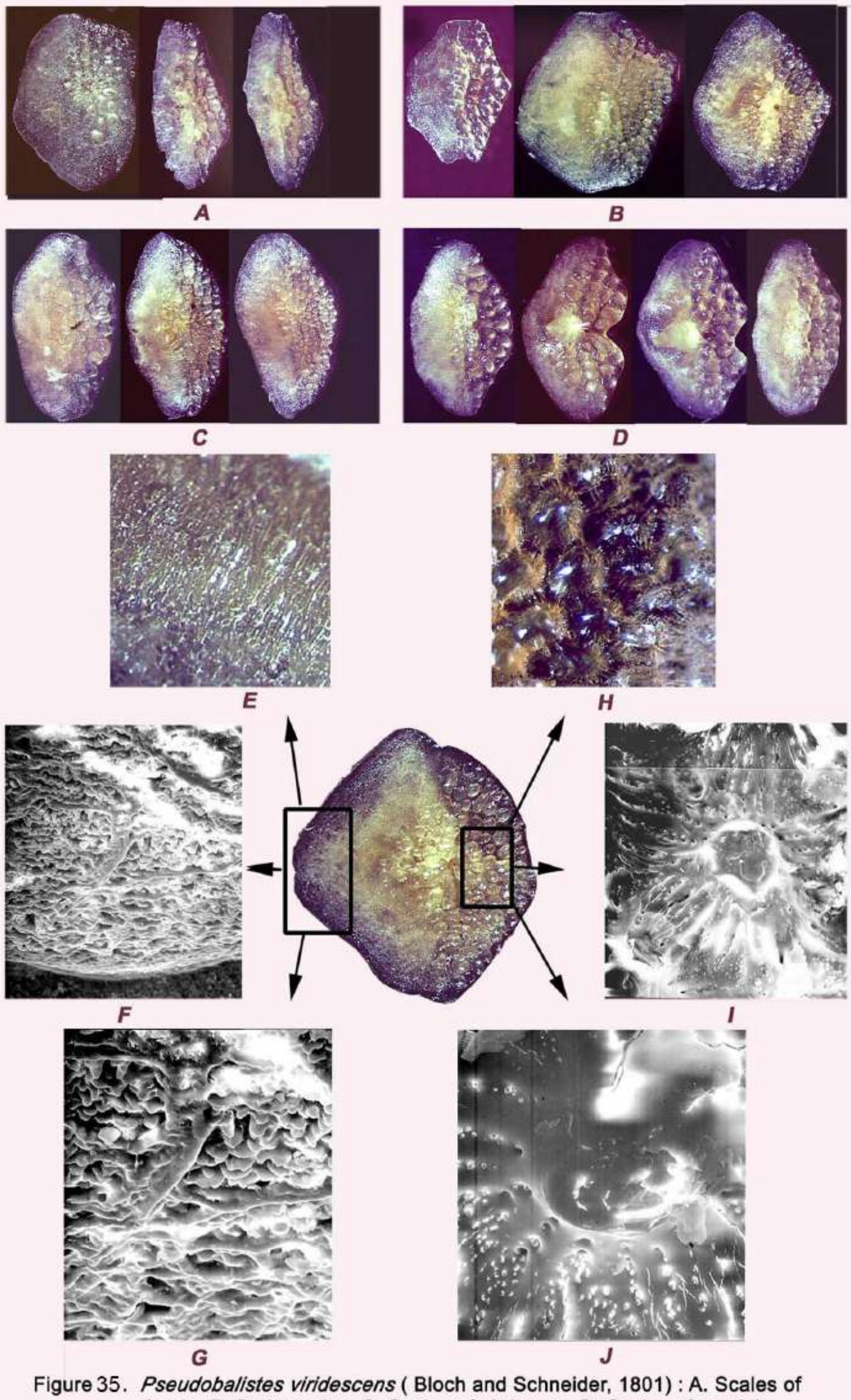


Figure 35. *Pseudobalistes viridescens* (Bloch and Schneider, 1801) : A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.

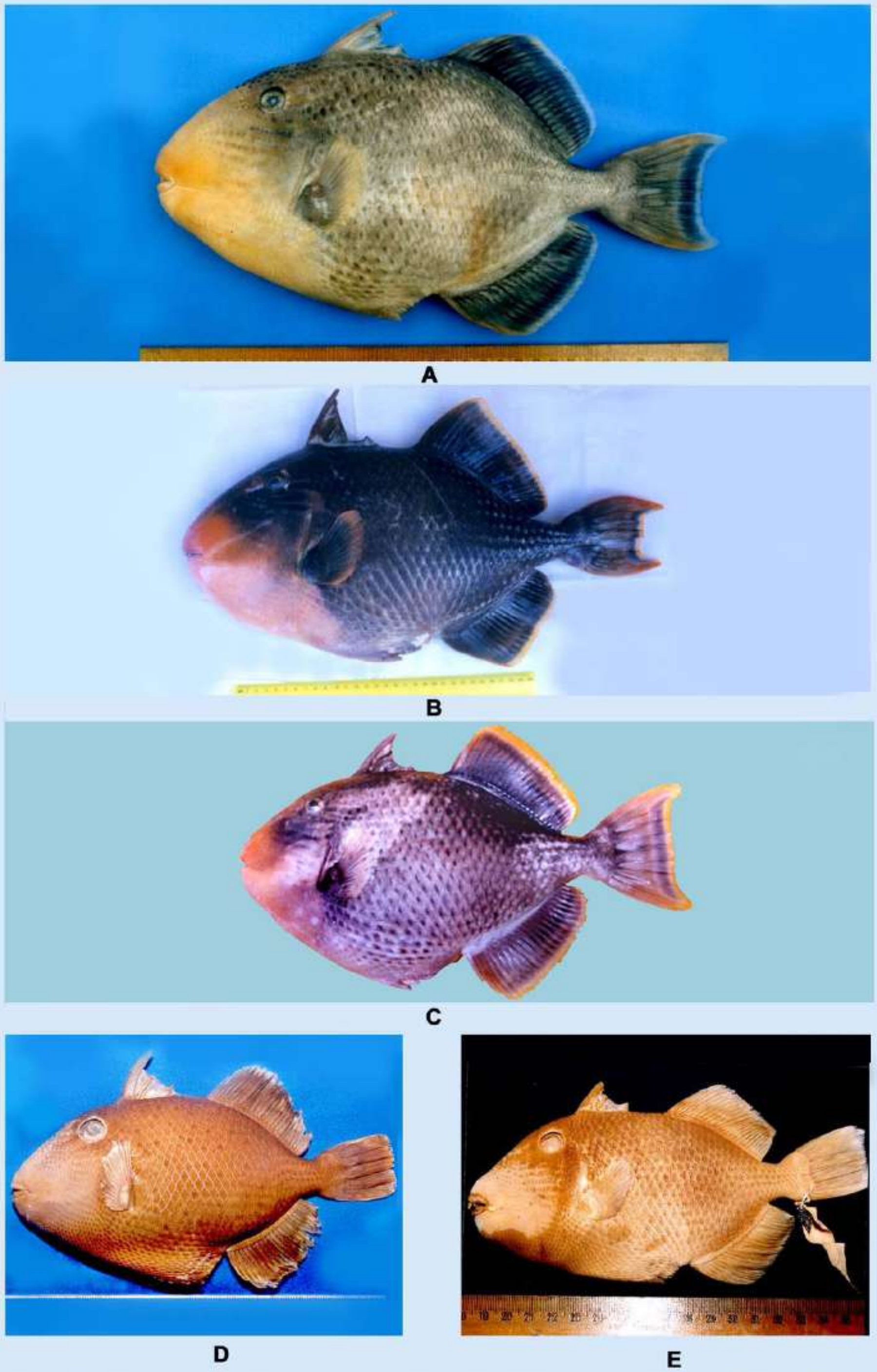


Figure 36. *Pseudobalistes flavimarginatus* (Ruppell, 1828): A. From Minicoy 435 mm TL, B. From Tuticorin 490 mm TL, C. From Mandapam 345 mm TL, D. From Agatti CMFRI-F.154/443, 317 mm TL, E. From Andaman ZSI Reg. No. 2251, 183 mm TL, collected by Dr. F. Day.

Figure 37. *Pseudobalistes flavimarginatus* (Ruppell, 1828): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

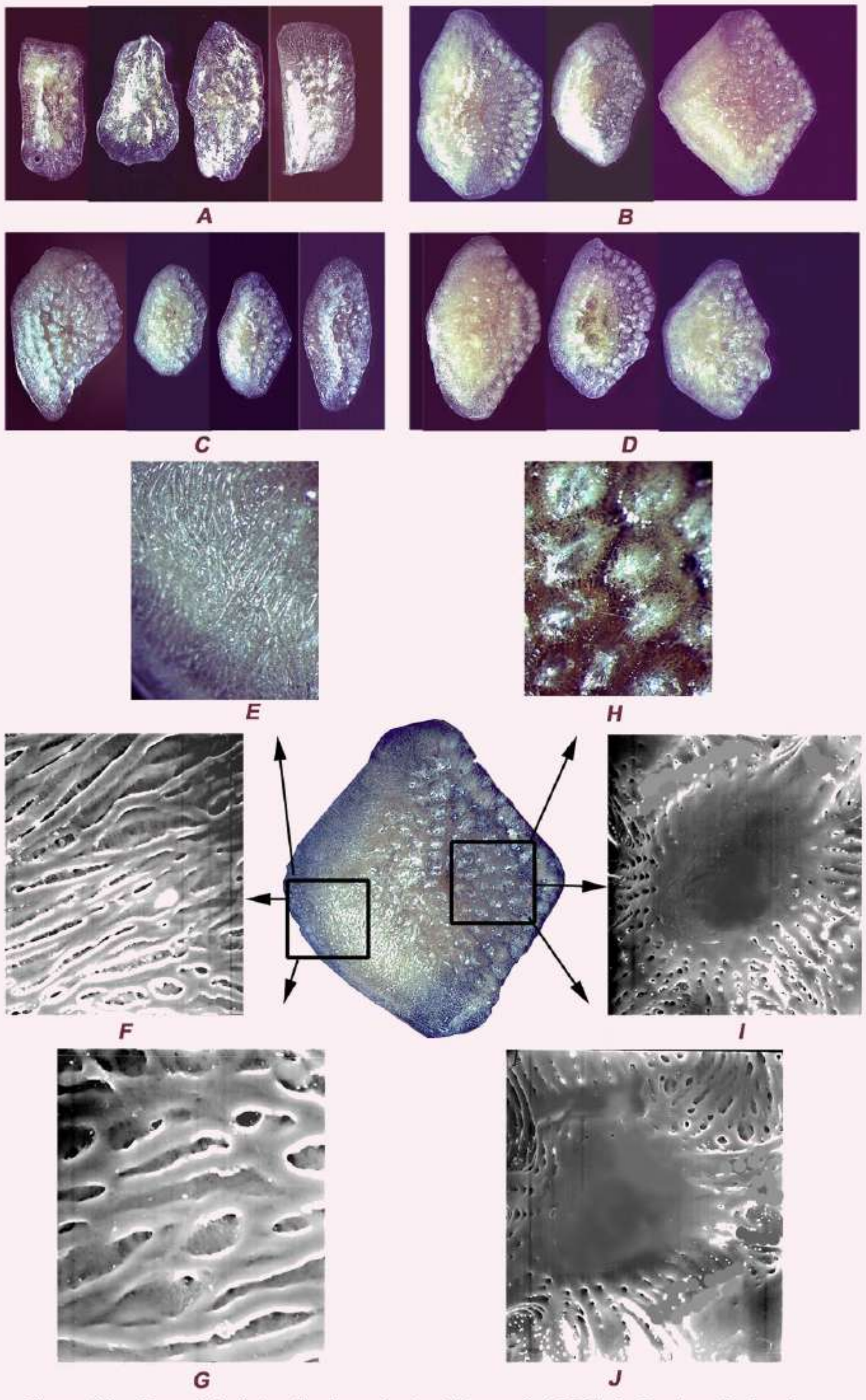


Figure 38. *Pseudobalistes flavimarginatus* (Ruppell, 1828): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.

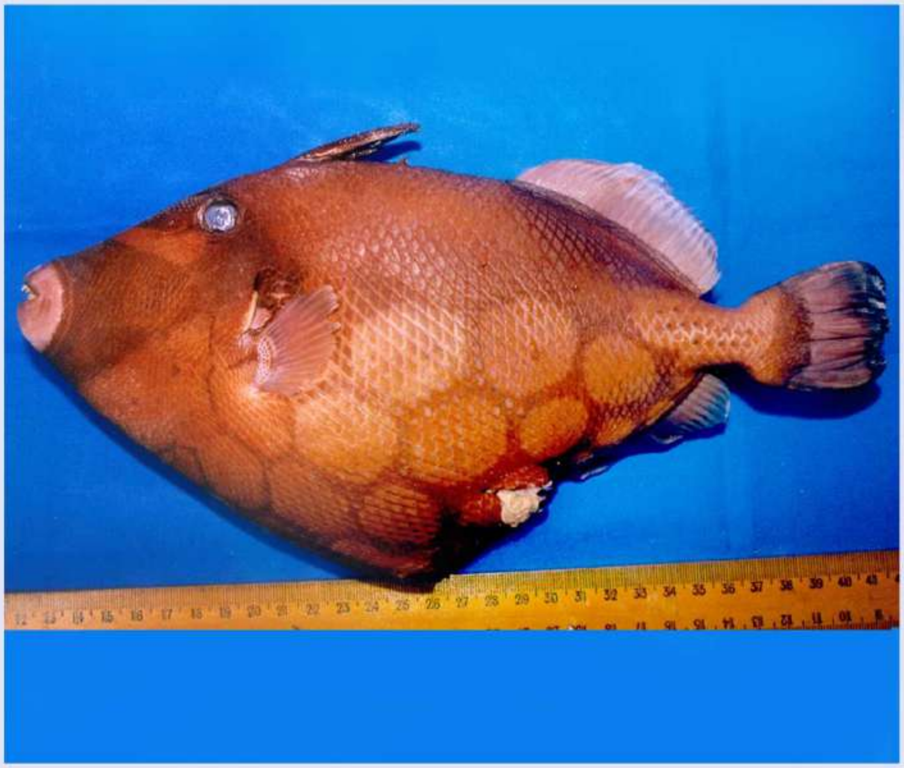
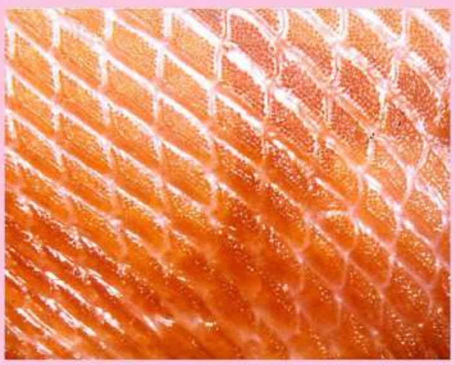


Figure 39. *Pseudobalistes conspicillum* (Bloch and Schneider, 1801) : From Lakshadweep 282 mm TL.

A *B*



C *D*

E

Figure 40. *Pseudobalistes conspicillum* (Bloch and Schneider,1801): A. Scales on cheek, B. Body scales, C. Scales on Abdomen, D. Scales on caudal peduncle, E. Ventral spines.

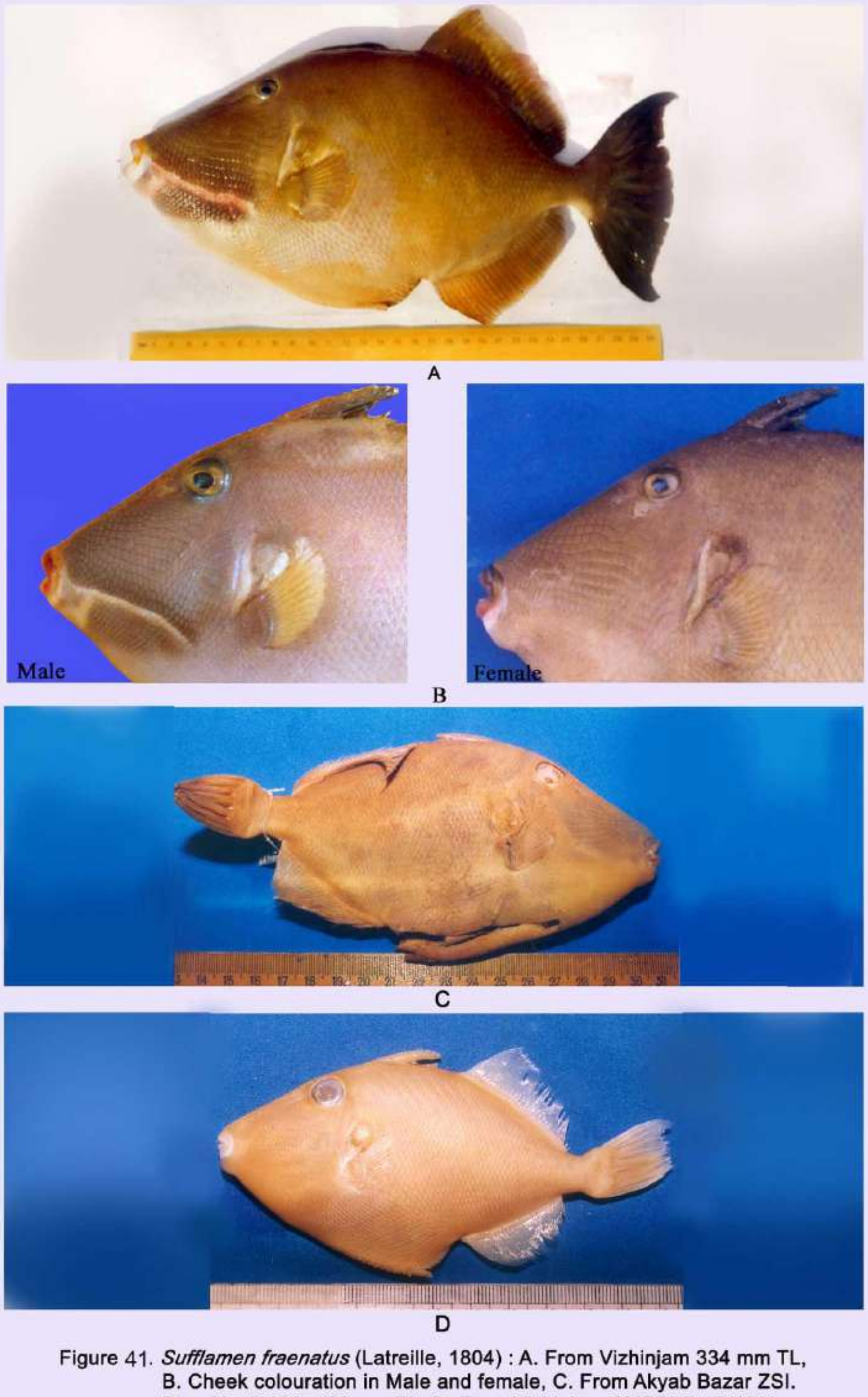


Figure 41. *Sufflamen fraenatus* (Latreille, 1804) : A. From Vizhinjam 334 mm TL, B. Cheek colouration in Male and female, C. From Akyab Bazar ZSI. Reg. No.10622, 182 mm TL, D. From Vizhinjam CMFRI-F 154/441, 120 mm TL.

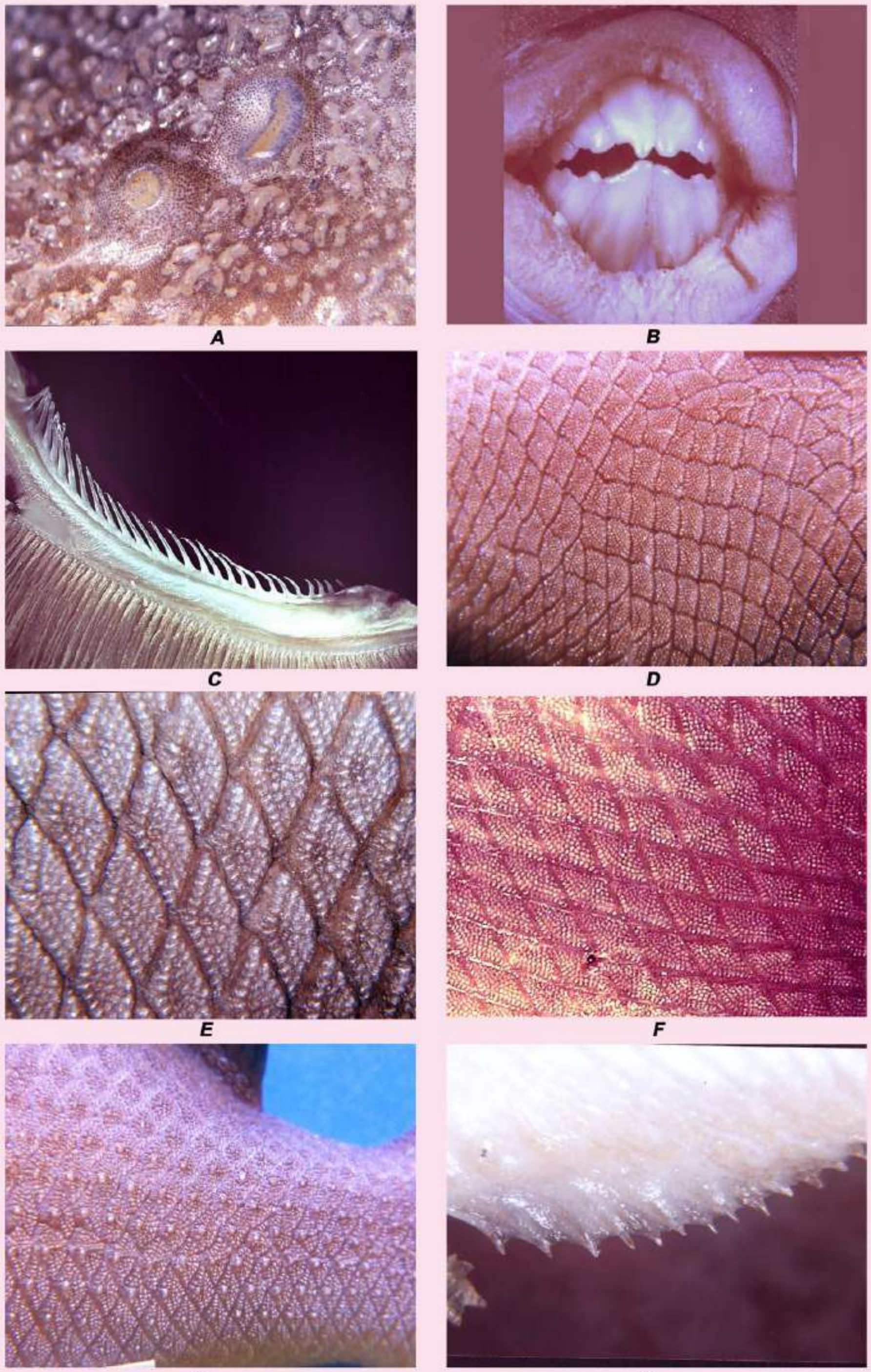


Figure 42. *Sufflamen fraenatus* (Latreille, 1804): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

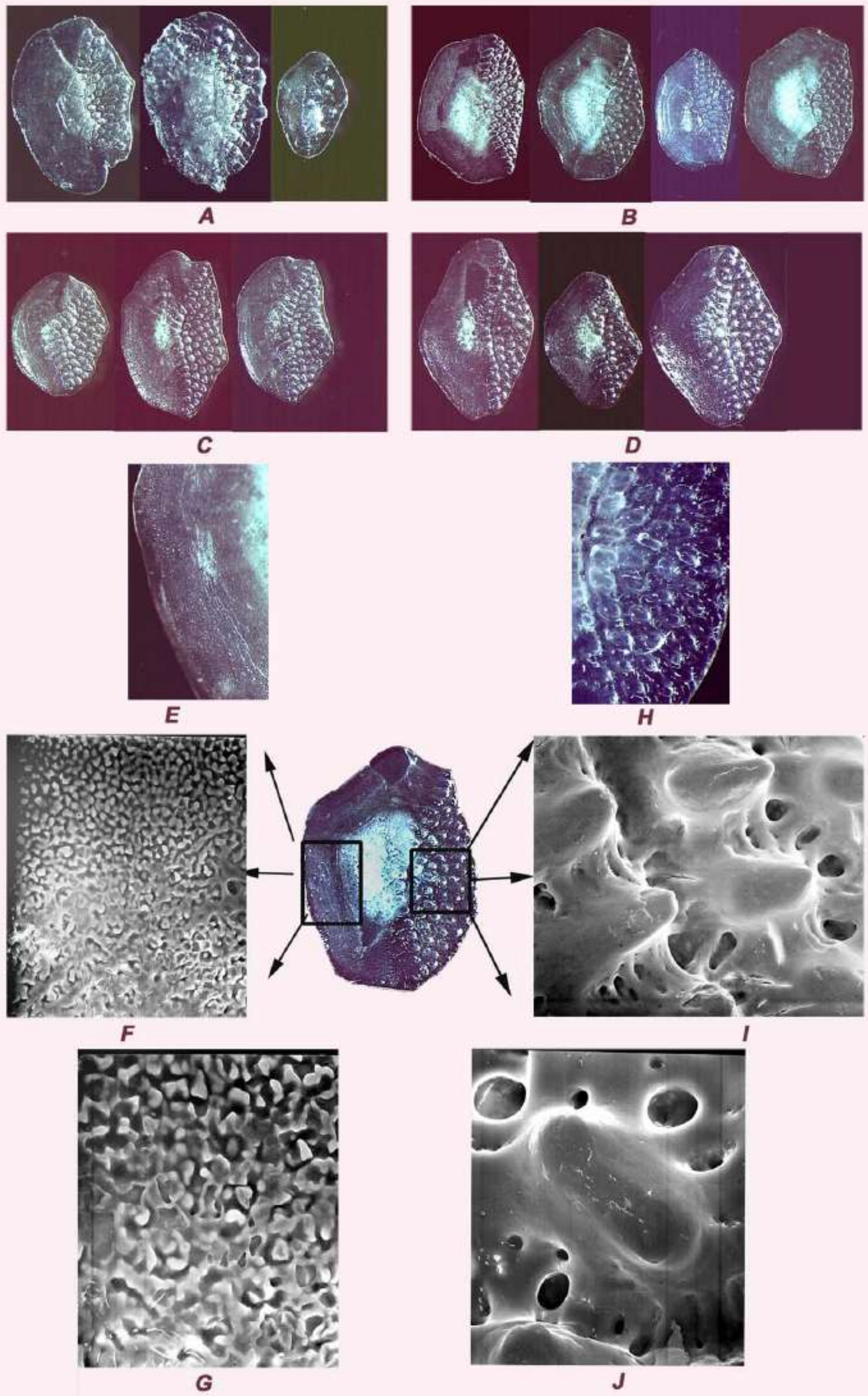


Figure 43. *Sufflamen fraenatus* (Latreille, 1804): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.

A

B

Figure 44. *Sufflamen chrysopterus* (Bloch and Schneider, 1801) : A. From Minicoy 110 mm TL, B. ZSI Reg. No. F.4124/2 154 mm TL.

Figure45. *Sufflamen chrysopterus* (Bloch and Schneider, 1801): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

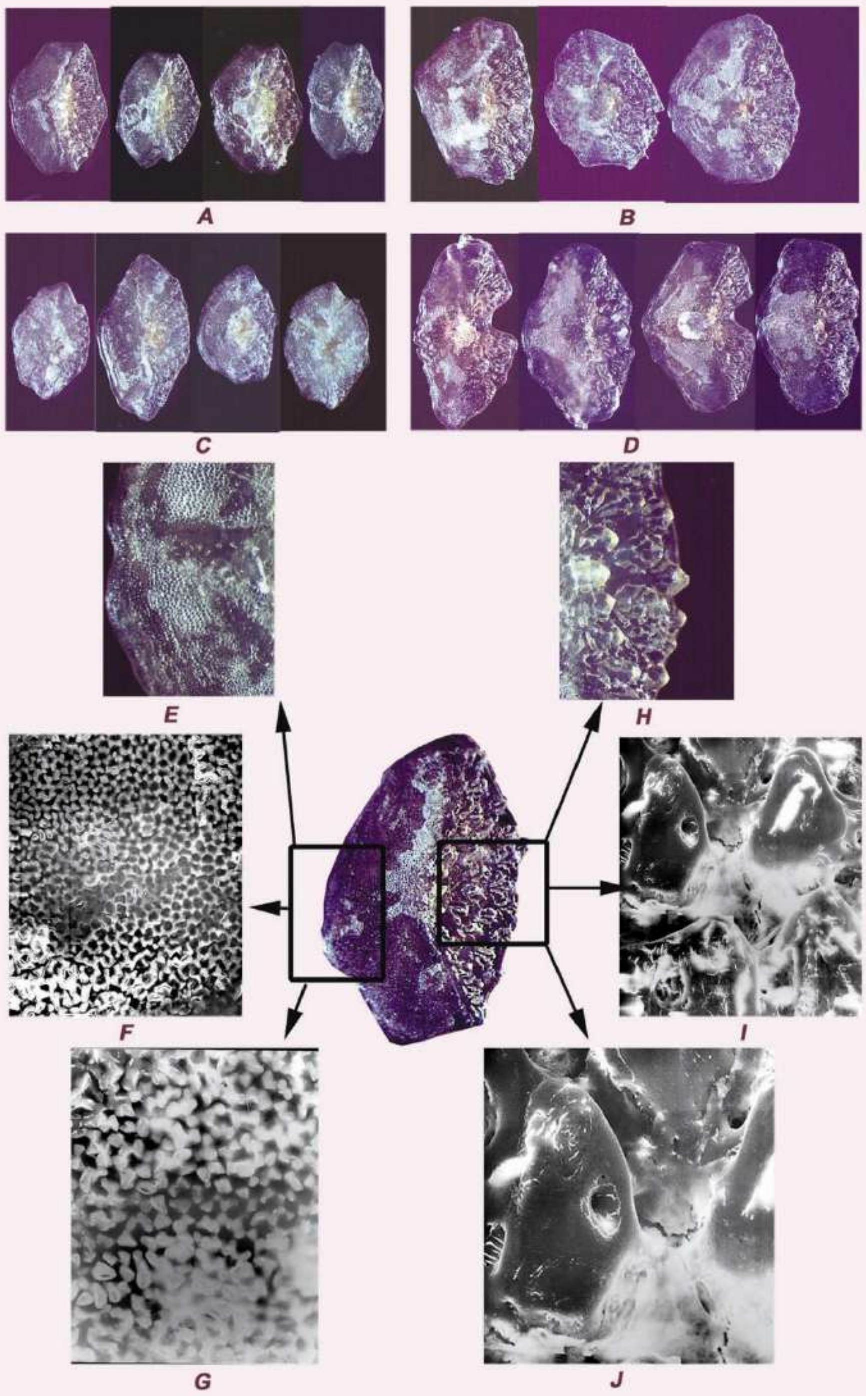


Figure 46. *Sufflamen chrysopterus* (Bloch and Schneider,1801): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.

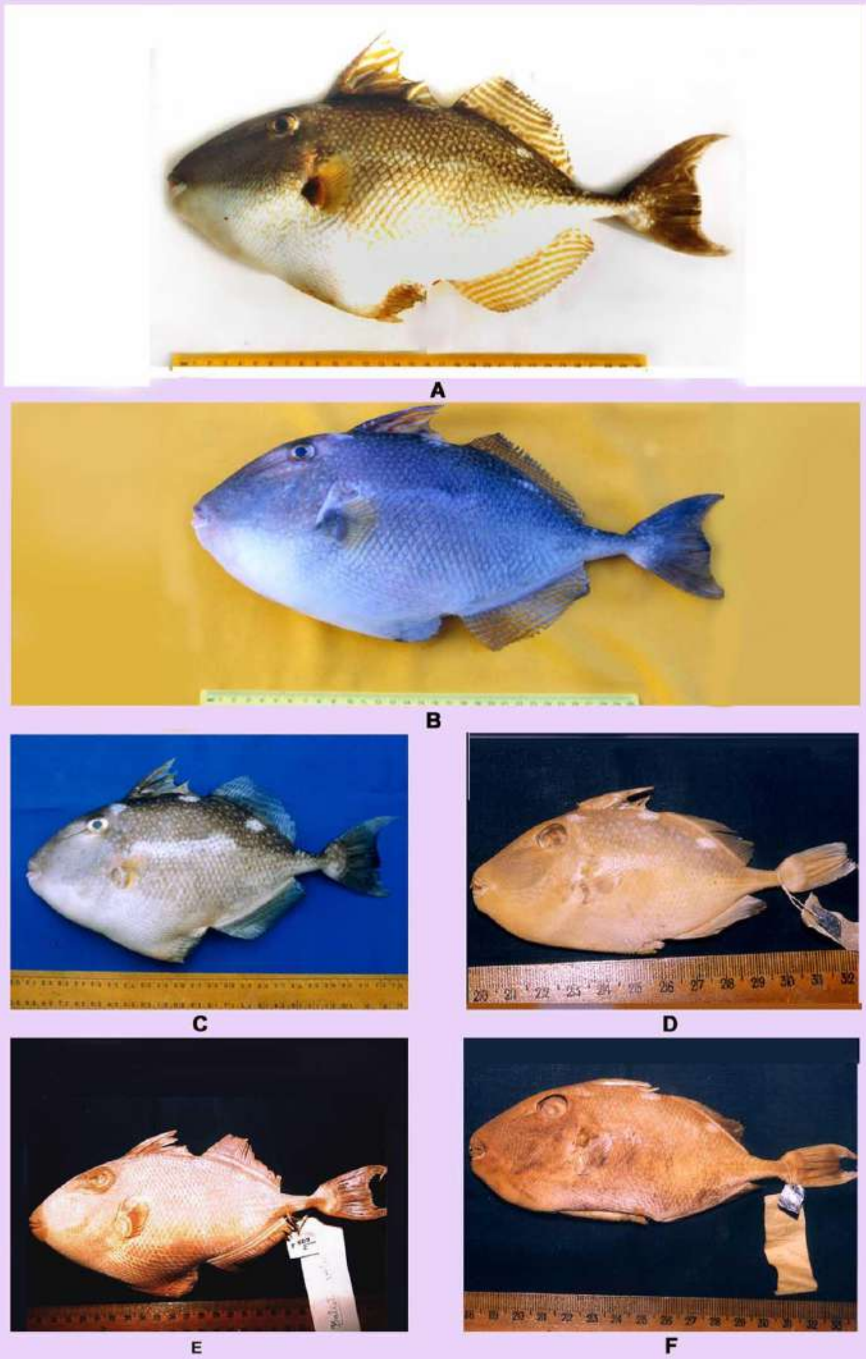


Figure 47. *Abalistes stellatus* (Lacapede, 1798) : A. From Colachel 380 mm TL, B. From Tuticorin 345 mm TL, C. From Vizihinjam 228 mm TL, D. From Madras ZSI. Reg. No. 2717, 135 mm TL, collected by Dr. F. Day, E. From Bay of Bengal ZSI Reg. No. F. 603/2, 246 mm TL, F. From Madras ZSI Reg. No. 2254, 166 mm TL, collected by Dr. F. Day.

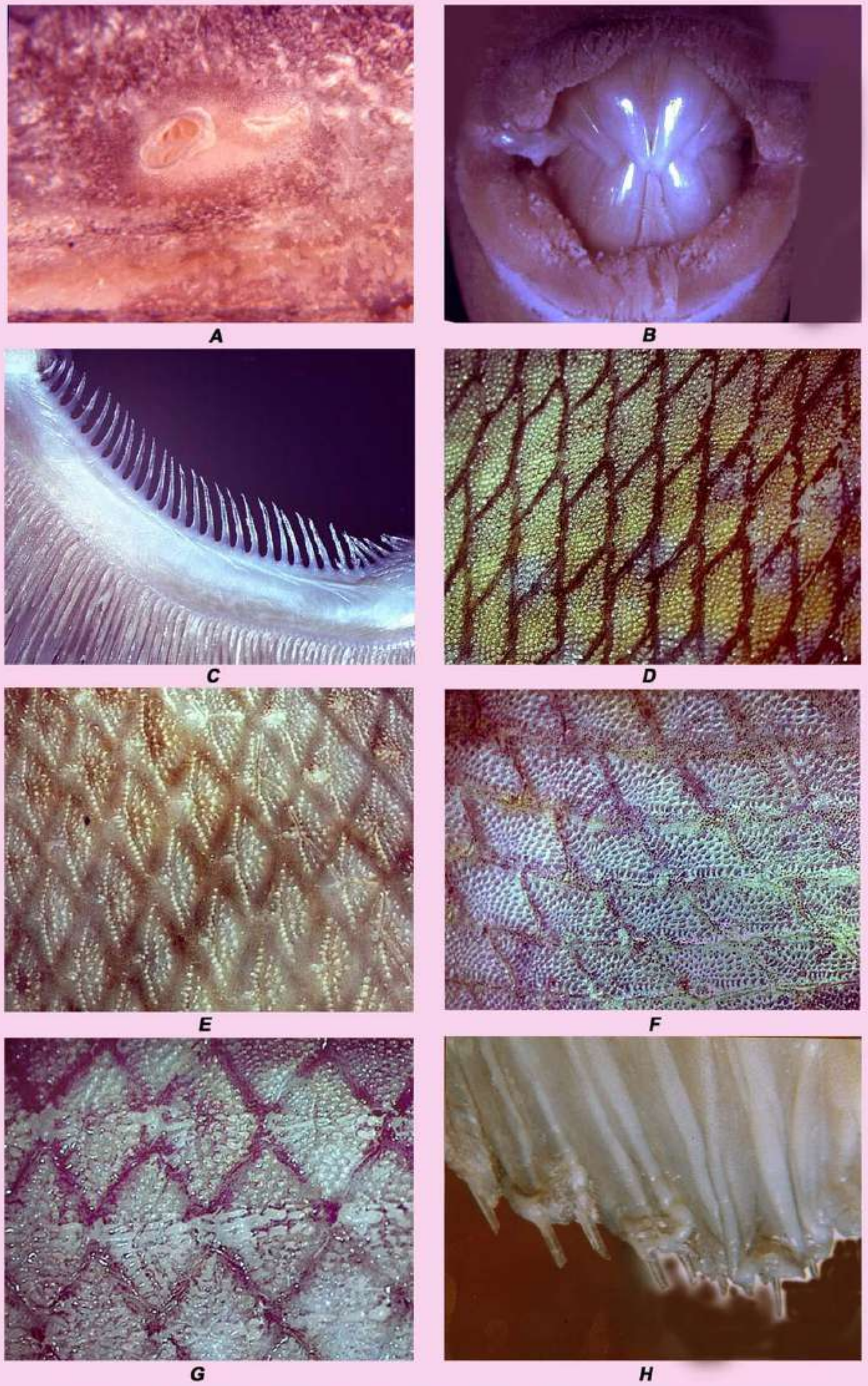


Figure 48. *Abalistes stellatus* (Lacepede, 1798): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

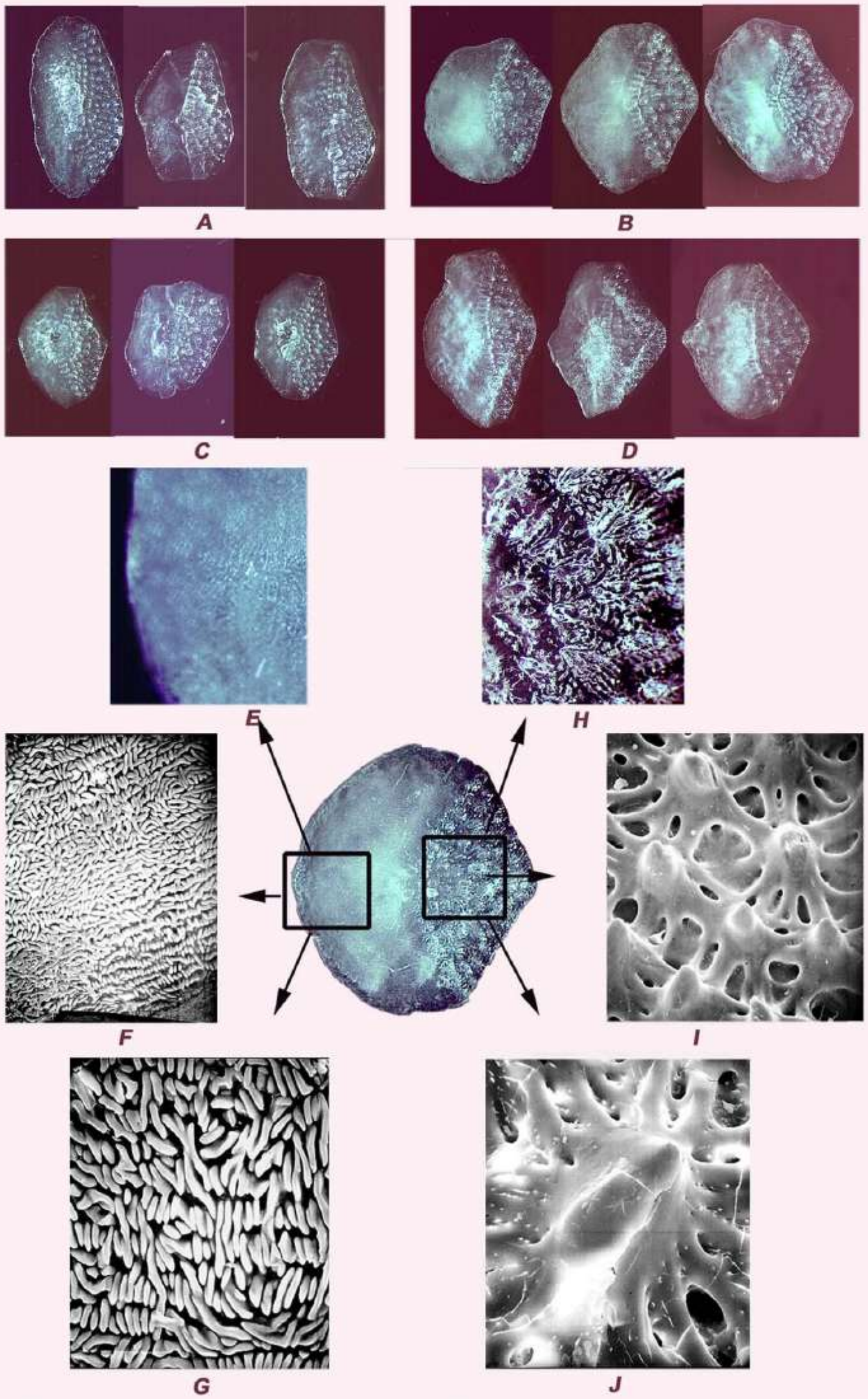


Figure 49. *Abalistes stellatus* (Lacepeda,1798) : A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.

CHAPTER 26

Field Identification of Nemipteridae: Threadfin Breams

Introduction

The fishes of family Nemipteridae are popularly known as threadfin breams. They are of high economic interest throughout their distribution in tropical Indo-Pacific (Russell, 1990). Globally the family is represented by 71 species across 5 genera. From Indian waters as many as 29 species are reported across 4 genera. (Froese and Pauly, 2021). The family is characterized by a single dorsal fin with X spines and 9 soft rays, anal fins with III spines and usually 7 soft rays, the last soft rays is usually branched (Fig. 1 & 2). Pectoral fins have 2 unbranched and 12-17 unbranched rays. Pelvic fins have single spine and 5 soft rays (Fig. 3) and placed in thoracic region. Body is covered with moderate sized scales with fine ctenii (Fig. 4). Some also have prominent and strong sub-orbital spine. Threadfin breams contributed 153066 tonnes to the total marine fish landings of India in 2019 which forms 4.3% of the total fish landings (NMFDC, 2021). The major species contributing to the commercial fishery belongs to the genus *Nemipterus* and they forms the major raw materials for the surimi based processing plants of India owing to high quality white meat with excellent textural properties.

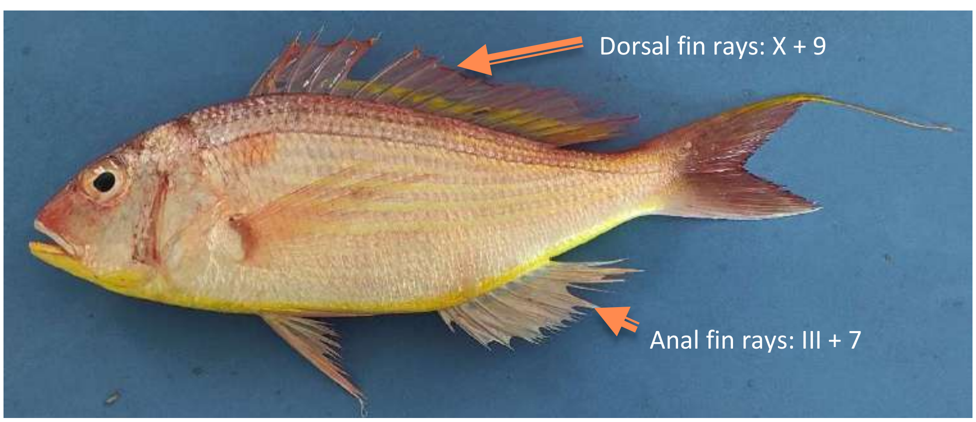


Fig 1: An illustration of a typical nemipterid fish

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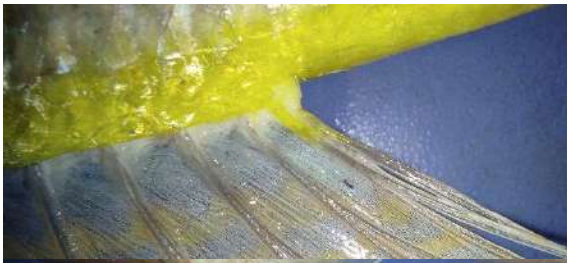


Fig 2. Last anal fin rays branched

Fig 3. Pelvic fin with I + 5 rays

Fig 4. Body covered by moderate sized scale with fine ctenii

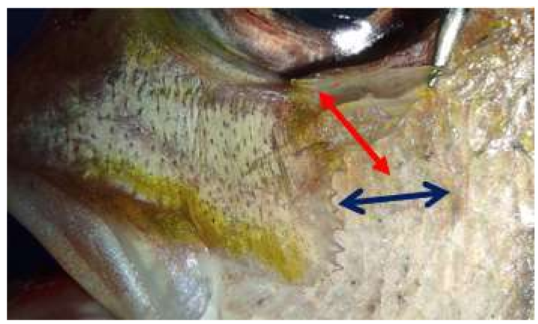


Fig 5. Presence of sub-orbital spine (red arrow) and serration (blue arrow) along the posterior margin

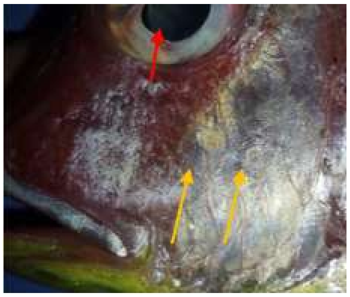
Key to the genera of Nemipterids of India

1a. Sub-orbital without scales having prominent spine (Fig. 5), posterior margin with serration or series of spines …………………………………….………………… ***Scolopsis***

1b. Sub-orbital either naked or with scales having no or weak spine, posterior margin finely serrate……………………………………………………………………. **2**

2a. Sub-orbital spine absent, 3 transverse rows of scales (Fig. 6) present on pre-opercular region……………………………………………………..…………. ***Nemipterus***

2b. Sub-orbital spine either weak or absent, 4-6 transverse rows of scales (Fig. 7) present on pre-opercular region ……………..……...………………………………………….. **3**



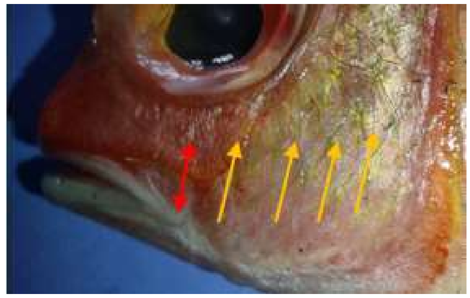


Fig 6. **Fig 7.**

3a. 2nd anal spine short and weaker than the 3rd, a single pair large canine teeth on both side of the lower jaw (Fig.8) ………………………………………..………. ***Pentapodus***

3b. 2nd anal spine larger and stronger than the 3rd (Fig. 9), canine teeth in jaws absent ……. ***Parascolopsis***

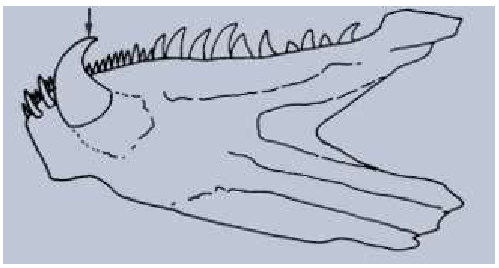


Fig. 8. Enlarged teeth on lower jaw

Fig. 9. Large and robust 2nd anal spine

Key to the species of genus *Nemipterus* from Indian waters

1a. 1st two dorsal spine close together and extended in to long filaments (Fig. 10) ………………………………………………………………………***N. nematophorus***

1b. 1st two dorsal spine separate and not extended in to long filaments (Fig. 10) ....…..... **2**

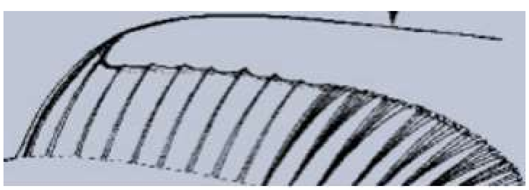


Fig. 10. Extension of 1st two dorsal spine

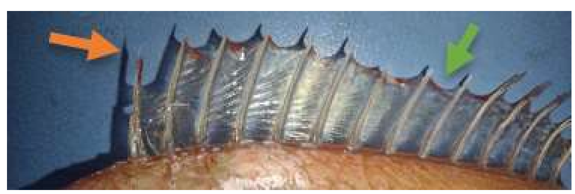


Fig. 10. Normal dorsal fin without extension (red arrow) & normal incision (orange arrow)

2a. Deep incision in the membranes of dorsal spine …………………………....…***N. peronii***

2b.Membranes between dorsal spine normal (Fig10) **3**

3a. Upper lobe of caudal fin extended in prominent filaments (Fig. 11) ....………..… **4**

3b. Upper lobe of caudal fin not-extended in prominent filaments (Fig. 12) ....………... **8**

4a. Pelvic fins very long, reaching up to or beyond anal fin origin (Fig. 14) ………………..…….. **5**

4b. Pelvic fins short or moderate, not reaching up to anal fin origin (Fig. 13) ......……………….. **6**

Fig. 11. Filamentous upper lobe of caudal fin

Fig. 12. Non-filamentous upper lobe of caudal fin

Fig. 13. Pelvic fin not going beyond anal origin
fin origin

Fig. 14. Pelvic fin going beyond anal fin

5a. Pectoral fin long, reaching up to or beyond anal fin origin (Fig. 15)… ***N. randalii***
5b. Pectoral fin short, not going beyond anal fin origin …………… ***N. marginatus***
6a. Pectoral fin short, reaching up to or beyond anal fin origin ………***N. japonicus***
6b. Pectoral fin short, not going beyond anal fin origin (Fig. 16) ………………**7**

Fig. 15. Pectoral fin going beyond anal fin origin

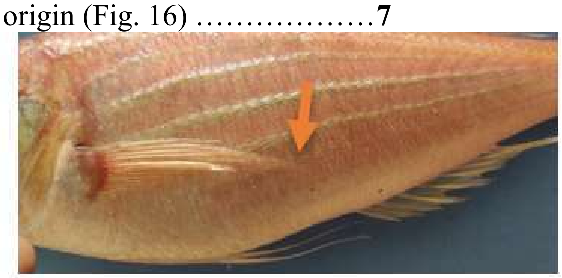


Fig. 16. Pectoral fin not reaching anal fin origin

7a. Body elongate, 21.7% to 26.3% of standard length ……………………..…***N. zysron***
7b. Body moderately deep, 25% to 34.5% of standard length ……………...…***N. nemurus***
8a. Dorsal fin with stripes (Fig. 17)……………………………………..……. ***N. hexadon***
8b. Dorsal fin without any stripes (Fig.18)……………………….………..………. **9**

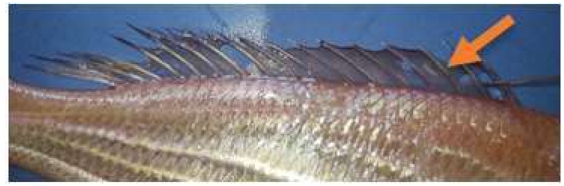


Fig. 17. Dorsal fins with stripes

Fig. 18. Dorsal fin without any stripes

9a. Anal fin with 2-5 undulating yellow stripes (Fig. 19)……………….… ***N. bipunctatus***
9b. Anal fin without any stripes on it ……………………………………… ***N. furcosus***

Fig. 19. Anal fins with stripes on it

Key to the species of genus *Parascolopsis* from Indian waters

1a. Gill rakers on 1st gill arch more than 15 **(Fig. 20**) …………….***P. akatamae****
1b. Gill rakers on 1st gill arch less than 15 (**Fig. 21**) …………… **.2**

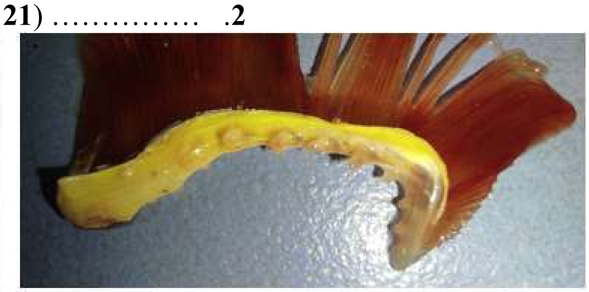


Fig. 20. 1st arch of gill with > 15 gill rakers

Fig. 21. 1st arch of gill with < 15 gill rakers

2a. Sub-orbital with scales ……………………………… ***P. townsendi***
2b. Sub-orbital and maxilla without scales (Fig. 22).……..**3**

Fig 22. Sub-orbital and maxilla without scales

3a. Scales on head reaching forward to or up to anterior margin of the eye(Fig.23)… **4**
3b. Scales on head not reaching forward to or up to anterior margin of the eye (Fig. 24) ……………………,,,,,,,,,,,,,,,,,,,,,,,,,,……………………………………   ***P. inermis***

Fig 23. Head scales reaching up to anterior of eye.

Fig 24. Head scales not reaching up to anterior of eye.

4a. Posterior margin of sub-orbital smooth or with few tiny spinules; black blotch on base of middle of dorsal fins (Fig. 25)………………………………….……***P. aspinosa***
4b. Posterior margin of sub-orbital denticulate; reddish blotch on middle of dorsal fins (Fig. 26) ……………………………………………………………….……. **5**

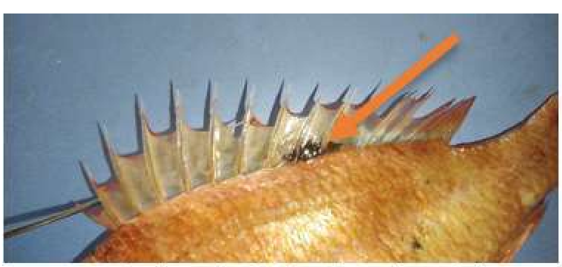


Fig. 25. Black or dark blotch on dorsal fin

Fig. 26. Red or orange blotch on dorsal fin

5a. Body depth < Head length, pectoral fin extended up to vent (Fig. 26)……***P. boesmani***
5b. Body depth = Head length, pectoral not reaching up to vent …………… ***P. baranesi***

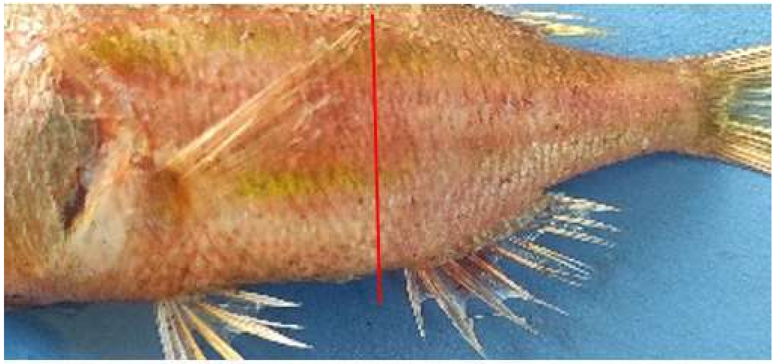


Fig. 27. Pectoral fins long reaching up to vent

***Note:** Miyamoto et al. (2020) described a new species *Parascolopsis akatamae* with close resemblance to *P. eriomma* and inferred that previous records of *P. eriomma* from Indian waters are in fact *P. akatamae*

Key to the species of Genus *Scolopsis* from Indian waters

1a. Antrorse spine or bony ridge present below eye (Fig. 28) ……………. **2**
1b. Antrorse spine or bony ridge below eye absent ………………………. **5**

Fig. 28.

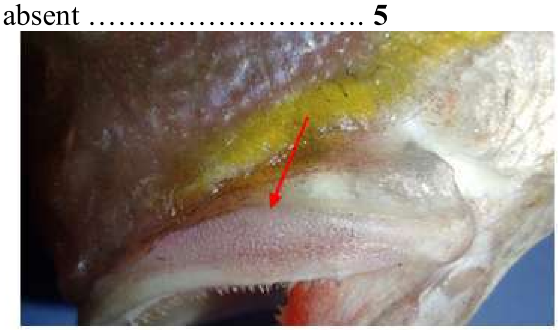


Fig. 29

2a. Maxilla denticulate on its external edge ……………………….……… ***S. ciliata***
2b. Maxilla smooth along its external edge (Fig. 28) ……………………….……. **3**
3a. Scales on the top of the head not extending up to posterior nostril **………………………………………………………………,,,,,,,,,,,,,,……… *S. xenochrous***
3b. Scales on the top of the head not extending up to posterior nostril ………..………. **4**
4a. Pectoral fin reaching up to anus & anterior part of anal fin dark ……….. ***S. bilineatus***
4b. Pectoral fin not reaching up to anus & anterior part of anal fin not dark (Fig. 30) …………………………………………….………………………..….. ***S. vosmeri***

Fig. 30.

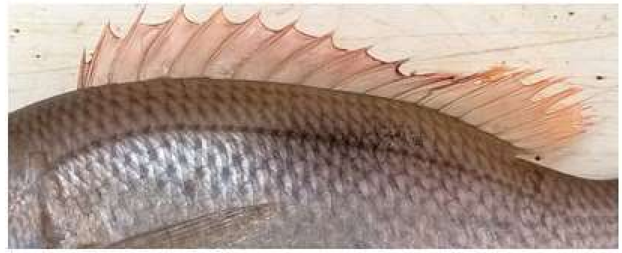


Fig. 31. Oval dark spot on the upper half of the body

5a. Head scales reaching forward up to mid of orbit …………………… ***S. ghanam***
5b. Head scales reaching forward up to anterior margin of eye ………………….. **6**
6a. Large, dark and oval shaped spot on upper half of body intersected by lateral line below dorsal fin (Fig. 31) ………………..……………………………………… ***S. bimaculatus***
6b. No dark oval spots on the upper half of the body …………………………….. 7

7a. Line joining snout and upper base of pectoral fin above lower margin of eye (Fig. 32) ……………………………………………….………….…………….. ***S. frenatus***
7b. Line joining snout and upper base of pectoral fin below lower margin of eye (Fig. 32) ……………………………………………………………………….. **8**

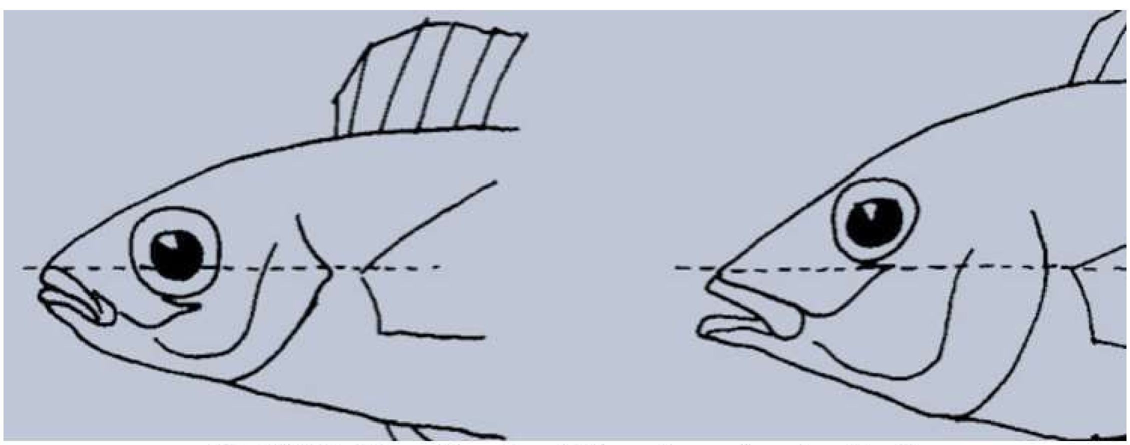


Fig. 32. Position of eye in relation of snout-pectoral axis

8a. Head scales reaching to the level of posterior nostrils ………..… ***S. taeniatus***
8b. Head scales not reaching to the level of posterior nostrils ……..…. ***S. auratus***

COMMON THREADFINBREAMS AVAILABLE IN INDIA

Scientific name: *Nemipterus japonicus* (Bloch, 1791)
Common Name: Japanese threadfin bream
Distribution: Indo Pacific
Key diagnostic features (Fig 33)

- Dorsal fin rays: X +9; Anal fin rays: III + 7
- Pelvic fins short or moderately long, not reaching the origin of anal.
- Pectoral fins long, reaching to or beyond the origin of anal fin.
- Upper lobe of caudal fin yellow in cooler filamentous
- 11-12 yellow stripes on the body from head till caudal region.
- Margin of dorsal fin yellow, edged with red and a yellow stripe near base of dorsal fin.

Scientific Name: *Nemipterus randalli* Russell, 1986 [Fig. 34]
Common Name: Randall's threadfin bream
Distribution: Western Indian Ocean
Key diagnostic features

- Dorsal fin rays: X +9; Anal fin rays: III + 7
- Upper lobe of caudal fin filamentous and pinkish or reddish in colour
- Dorsal fin not noticeably elevated &1st dorsal spine short.
- Pectoral and pelvic fins very long, reaching to or beyond the origin of anal fin.
- Body whitish-pink with 3 or 4 light yellow stripes on sides below lateral line

Scientific Name: *Nemipterus bipunctatus* (Valenciennes, 1830) [Fig. 35]
Common Name: Delagoa threadfin bream
Distribution: Indian Ocean
Key diagnostic features

- Dorsal fin rays: X +9; Anal fin rays: III + 7
- Upper lobe of caudal fin not produced in to filaments rather rounded in profile.
- Dorsal fin rosy, with reddish or yellowish margin, but lacks stripes
  Anal fin with 2 to 5 yellowish stripes.
- Body with 5 to 7 greenish-yellow bands on body
- Scales below lateral line in ascending rows anteriorly

Scientific Name: *Parascolopsis akatamae* Miyamoto, McMahan & Kaneko, 2020 [Fig. 36]
Common Name: Rosy dwarf monocle bream
Distribution: Indo-West Pacific
Key diagnostic features

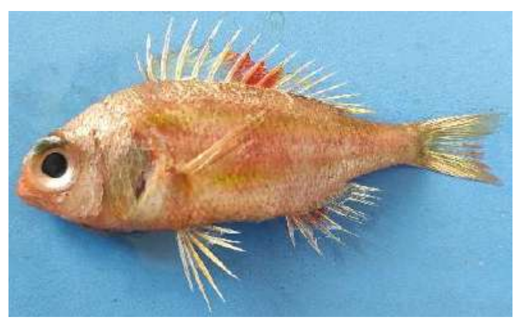
- Dorsal fin rays: X +9; Anal fin rays: III + 7
- Gillrakers on first arch: 16-19.
- Length of forked part of caudal fin 5.8–6.5 times in SL.
- Eye diameter 1.3–1.8 times in length of longest dorsal-fin spine.
- Pale yellow stripe present from lower edge of the eye to posterior edge of the preopercle.
- Strong bio-fluorescence emission observed on isthmus and branchiostegal region

Scientific Name: *Parascolopsis aspinosa* (Rao & Rao, 1981) [Fig. 37]
Common Name: Smooth dwarf monocle bream
Distribution: Indian Ocean
Key diagnostic features

Photo credit @ Rekha Nair

- Dorsal fin rays: X +9; Anal fin rays: III + 7
- Cheek scales: 4 or 5 transverse rows.
- Lower limb of preopercle without scales.
- Posterior margin of suborbital smooth.
- Black Spot at base of dorsal fin between 8th spine and 1^{st} soft ray.
- Dorsal fin with orange emargins; pectoral fin yellowish ; anal fin rosy

Scientific Name: *Parascolopsis boesemani* (Rao & Rao, 1981) [Fig. 38]
Common Name: Redfin drawf monocle bream
Distribution: Indian Ocean
Key diagnostic features



- Dorsal fin rays: X +9; Anal fin rays: III + 7
- Cheek scales: 4 or 5 transverse rows; sub orbital margin finely serrate.
- Predorsal scales reaching up to posterior nostrils.
- Lower limb of preopercle without scales
- 4 light reddish saddles on the body
- Red blotch on dorsal fin between 7^{th} and 10^{th} spines.
- Pectoral and pelvic fins long, reaching to beyond level of anus
- Body depth less than head length

Scientific Name: ***Scolopsis vosmeri*** **(Bloch, 1792) [Fig. 39]**
Common Name: Whitecheek monocle bream
Distribution: Indo-West Pacific

Key diagnostic features
- Dorsal fin rays: X +9; Anal fin rays: III + 7
- Body compressed with very convex dorsal profile.
- Small antrorse spine below eye (and prominent sub-orbital spine
- Scales on top of head extending forward to between snout and anterior nostril
- Anal fin with 3 strong spines (2nd spine very broad and longer than the 3rd spine).
- Pectoral fin short with 2 unbranched and 16 or 17 branched rays.
- A bright (whitish) vertical band from top of head onto gill covers.

Scientific Name: ***Scolopsis bimaculata*** **Ruppel, 1828 [Fig. 40]**
Common Name: Thumbprint monocle bream
Distribution: Indian Ocean

Key diagnostic features
- Dorsal fin rays: X +9; Anal fin rays: III + 7
- Pectoral fin with 2 unbranched and 16 branched rays.
- No antrorse spine below eye.
- Predorsal scales reaching up to posterior nostrils.
- Lower limb of preopercle with 1 or 2 rows of small scales.
- A dark oval patch on upper side originating below 7th or 8th dorsal fin spine.
- A blue stripe present along the line joining eyes

***Note:** *The line diagrams are adopted from Fisher and Bianchi (1984) and Russel (1990 & 2001) and for character demonstration.*

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CHAPTER 27

Taxonomy of Family Sciaenidae

Family Sciaenidae (croakers) is one of the largest family under Order Perciforms are small to moderately sized fishes, widespread in the Atlantic, Indian and Pacific oceans. These fishes are usually reported off beaches, estuaries, sheltered bays and bar mouths. Family Sciaenidae includes many commercially and recreationally important species. A total of 584 nominal species belonging to 289 valid species and 69 genera is reported worldwide. Their common name derives from their ability to produce drumming or croaking sounds through specialized body muscles connected to the swim bladder, which acts as a resonating chamber. The sound production could play a role during spawning season.

The coloration varies from silvery to yellowish or dark brown; dark spots, vertical bars and longitudinal stripes are often present; tip of spinous dorsal fin is dark edged in many species; abdominal and lower fins are yellowish in many instances; a dark blotch is often present at pectoral-fin bases. Drums are oblong to moderately elongate and moderately compressed, with conspicuous pores on snout and chin, and lateral line extending to margin of caudal fin. Snout is rounded to slightly pointed. Eye is small to moderate in size. Mouth is terminal, sub terminal, or slightly superior; small to rather large; and nearly horizontal to moderately oblique. Jaw teeth are usually small, conical, and arranged in bands. Occasionally canine teeth occur at tips of jaws. Snout possesses three to seven rostral pores along anterior margin, and two to five marginal pores along edge of rostral fold. Chin has two to six mental pores, one pore at midline, and remaining pores paired and located along each side. Barbels may be associated with pores on chin and may also occur on sub operculum. Branchiostegal rays number 7.Pectoral fin inserts on lower half of flank, has a nearly vertical base, and has 15 to 25 rays. Dorsal fin is long and single, with a deep notch between spinous and rayed sections in most genera but separated into separate spinous and rayed sections in one genus. Spinous section of dorsal fin has 7 to 13 (usually 10) spines, and rayed section has 1 to 4 spines and 18 to 46 rays. Pelvic fin inserts below or slightly posterior to pectoral fin insertion and consists of 1 spine and 5 rays. Anal fin has 1 or 2 spines and 6to 20 rays. Caudal fin is slightly emarginated, truncate, rounded, or pointed and consists of 17 principal rays. Ctenoid or cycloid scales cover body and part of head. In some species, scales are ctenoid on body and cycloid on head and breast. Scaly sheaths cover bases of dorsal and anal fins in some species. Gas bladder is present, is highly modified in some species, and is associated with muscles that cause it to vibrate and produce drumming or croaking sounds. Drums occur worldwide in tropical to warm temperate between the shoreline and about 600 m. Most species live in coastal marine habitats, many species are associated seasonally or year-round with estuaries, and some species are limited to freshwater. Many

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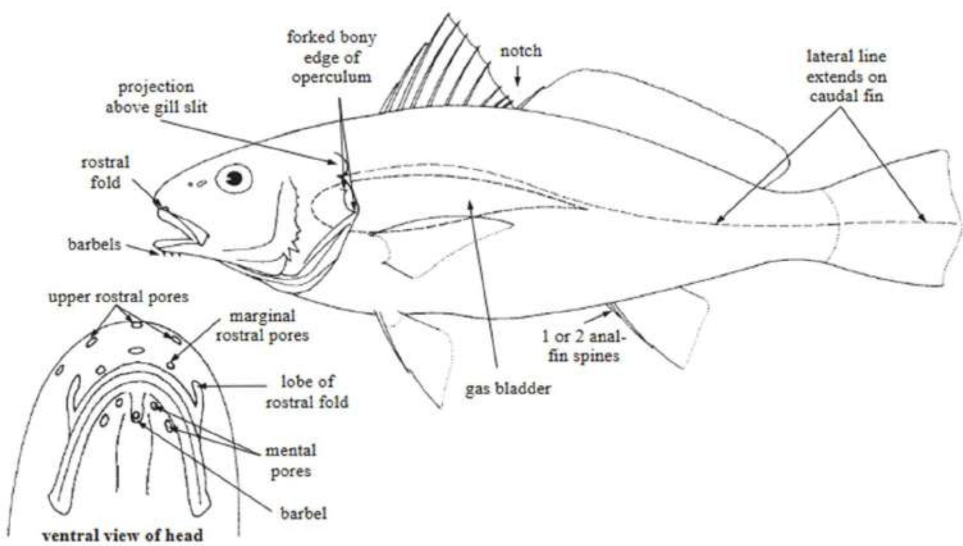
species utilize estuaries as nursery grounds. Most species are associated with sandy and muddy bottoms in the vicinity of river mouths; others are found on coral reefs and in surf zones. Sciaenid mainly feeds on benthic invertebrates and ray-finned fishes.

KINGDOM	- Animalia
PHYLUM	- Chordata
SUBPHYLUM	- Vertebrate
CLASS	- Actinopteri
SUBCLASS	- Teleostei
ORDER	- Perciformes
FAMILY	- Sciaenidae

Family: **Sciaenidae- Croakers**

- sensory pores present at tip of snout
- tip of lower jaw (chin) with 2 to 6 mental pores, some with barbels
- dorsal fin is long and continuous having a deep notch between spinous and soft portions
- anal fin with 2 spines
- caudal fin never forked, usually pointed in juveniles, becoming emarginate, truncate, rounded to rhomboidal, or S-shaped in adults
- a single continuous lateral line extending to hind margin of caudal fin.

Identification note- Correct identification of genera of this family is possible only by the examination of swimbladder and the otoliths.



(Source: FAO,WIO)

Diversity and Distribution of Sciaenids

Lal Mohan (1981) reported 36 species from 17 genera from Indian waters. Talwar (1995) in his book "Fauna of India and the Adjacent Countries" has reported the presence of 40 species of sciaenids in 20 genera. Nelson et al., (2016) in his book "Fishes of the World" listed 283 species in 67 genera. A recent work by Parenti (2020) listed 289 valid species in 69 genera. Trewavas (1977) grouped 65 species into 27 genera in his work The Sciaenid fishes of Indo-West –Pacific. From FishBase 18 species are reported from Arabian sea and 27 species from Bay of Bengal.

Key to the genera

Body elongated; carrot shaped swimbladder with 28-35 pairs of arboresent appendage; two pairs of canine teeth is present in anterior most of lower and upper jaws …………………………………………………………………………………..***Otolithes***

Mental pore a pair separated by symphysis; carrot shaped swimbladder with 17-22 pairs of appendages; "tail" of tadpole-shaped impression of otolith only slightly curve……………………………………………………………………………..…***Pennahia***

Mental pore 3 pairs; carrot shaped swimbladder ………………………….………***Nibea***

Air bladder simple, with a pair of tubules originate from posterior end of air bladder extending to the base of cranium…………………………………………………….………. ***Otolithoides***

First pair of swimbladder not cephalic; upper parts of the body, dorsal and caudal fins usually black spots about size of pupil……………………………………………..…… ***Protonibea***

Mental pore 3 pairs; hammer shaped swimbladder; barbel may present or absent; sagitta with the head of the tadpole pattern and the tail expanded and deepened as hollow cone…………………………………………………………….…………..***Johnius***

A single, tapering mental barbel; second anal spine very strong; teeth of lower jaw uniform…………………………………………………………………… ***Dendrophysa***

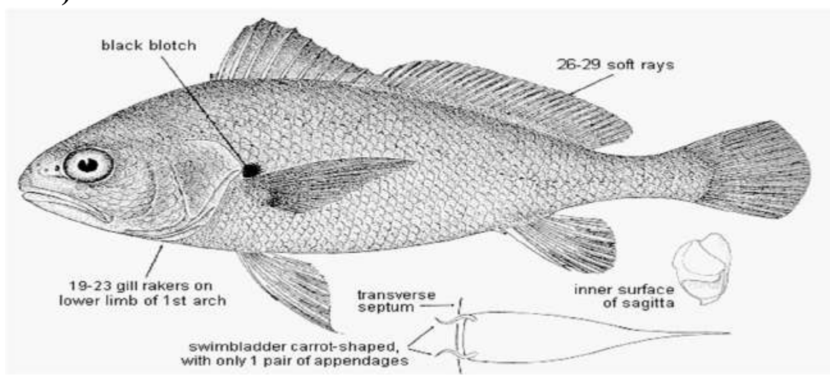
Teeth of the lower jaw are enlarged and spaced; a pair of barbels present; golden yellow color body……………………………………………………………..…..….***Daysciaena***

Gas bladder simple, round anteriorly, tapering posteriorly with a pair of short tubules on each side; lateral arborescent tubules absent. Sagitta with posterior depression; mental barbels absent……………………………………………………………..……..***Kathala***

Details of
Kathala axillaris **(Cuvier, 1830)**

Common name:
Kathala croaker

Carrot-shaped swimbladder; black blotch on pectoral fin axil; caudal fin rhomboid; gillraker count 20 to 23 and a dissimilar form of swimbladder.

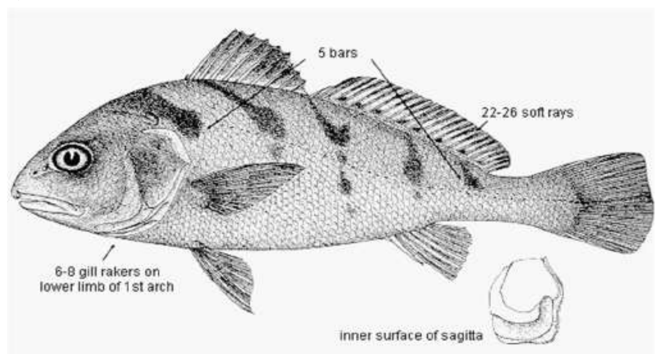


(Source: FAO, WIO)

Nibea maculata **(Bloch & Schneider, 1801)**

Common name: Blotched croaker

Tadpole shaped impression on sagitta (large earstone); a typical colour pattern of 5 dark bars extending obliquely from the back to the lower part of flanks and a sixth dark blotch on top of caudal peduncle.

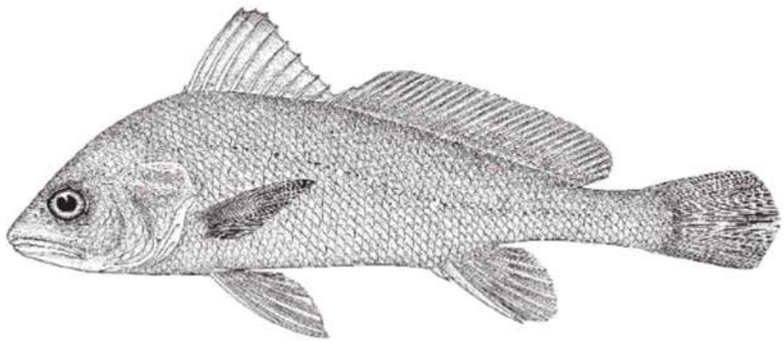


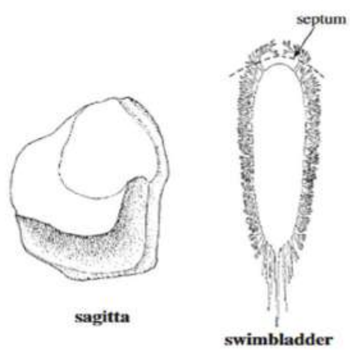
(Source: FAO, WIO)

Nibea soldado **(Lacepède, 1802)**

Common name: Soldier croaker

Carrot-shaped swim bladder, sharply constricted posteriorly to its tubeshaped end, with about 18 to 22 pairs of appendages; soft dorsal fin rays 28 to 31; no barbels on chin.



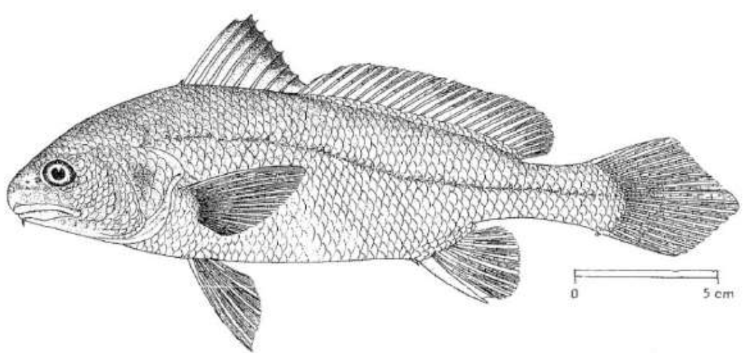


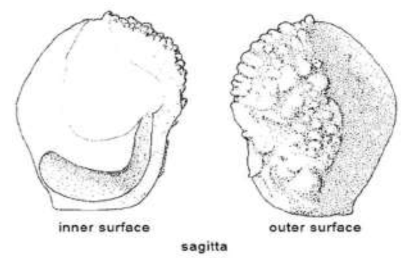
(Source: FAO, WIO)

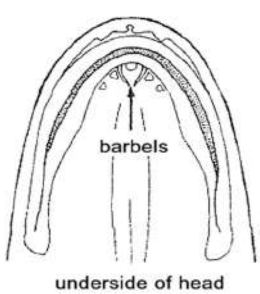
***Daysciaena albida* (Cuvier, 1830)**

Common name: Two-bearded croaker

A pair of small tapering barbels on chin; 23 to 26 dorsal soft rays; spinous portion of dorsal fin black.





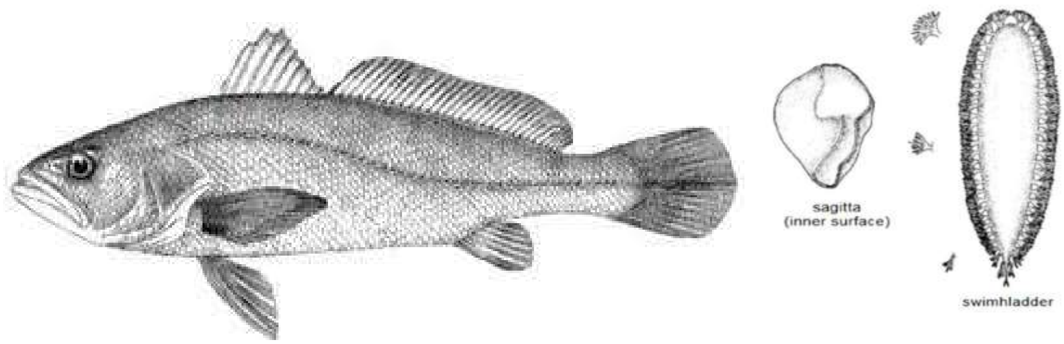


(Source: FAO, WIO)

Otolithes cuvieri **(Trewavas, 1974)**

Common name: Lesser tigertooth croaker

The body depth 3 1/4 to 4 ½ times in standard length. 1 or 2 pairs of robust canines in upper jaw and 1 pair at tip of lower jaw; gillrakers on lower limb of first arch 12 to 17; Carrot-shaped swimbladder, with about 28 pairs of arborescent appendages.

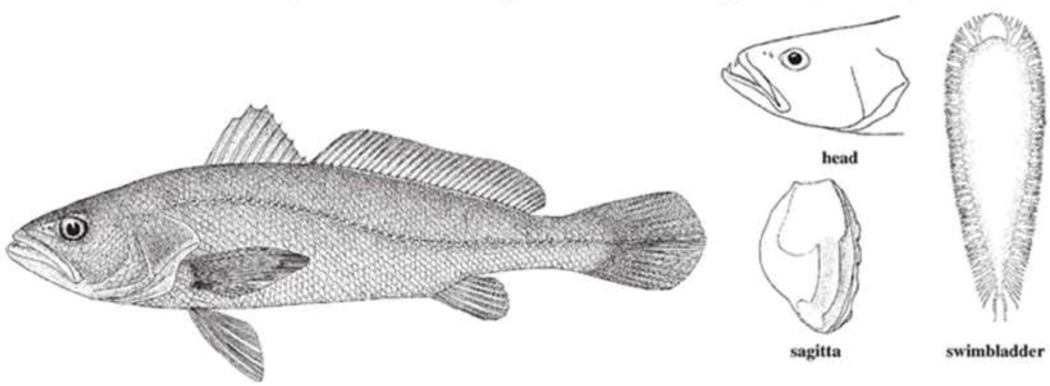


(Source: FAO, WIO)

Otolithes ruber **(Bloch & Schneider, 1801)**

Common name: Tigertooth croaker

Medium-sized to large species with a slender, cylindrical body. Snout not swollen or projecting; its dorsal profile rising evenly to origin of dorsal fin; ; teeth differentiated into large and small in both jaws; 1 or 2 pairs of strong canines at front of one or both jaws. Swimbladder carrot-shaped with 32 to 36 pairs of fan-like appendages along sides.

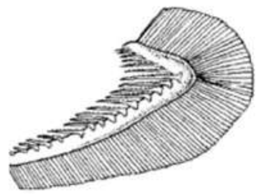


(Source: FAO, WIO)

Distinguishing characters of ***Otolithes ruber*** **and** ***Otolithes cuvieri***

Otolithes ruber ***Otolithes cuvieri***

Ist gill arch

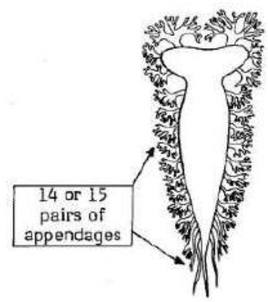


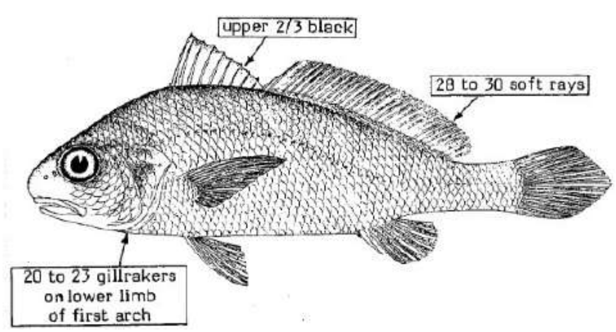
(Source: FAO, WIO)

Johnius glaucus **(Day, 1876)**

Common name: Pale spotfin croaker

Small to medium sized species; large eyes; hammer shaped swimbladder with 14-15 pairs of appendage; snout broadly rounded when seen from above and without strong anterior teeth and scales on spinous dorsal fin; caudal fin rhomboidal.



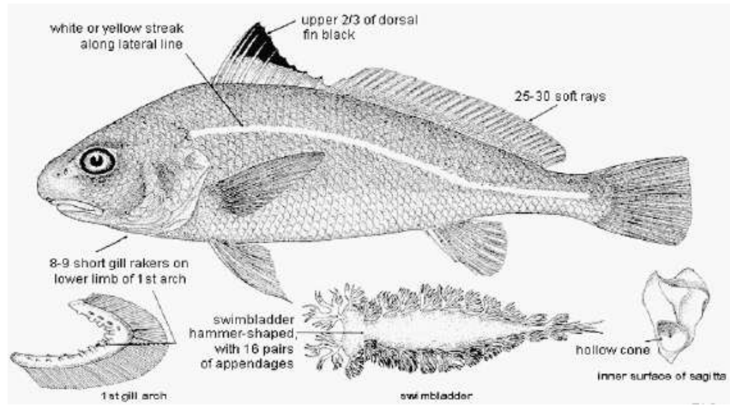


(Source: FAO, WIO)

Johnius carutta **(Bloch, 1793)**

Common name: Karut croaker

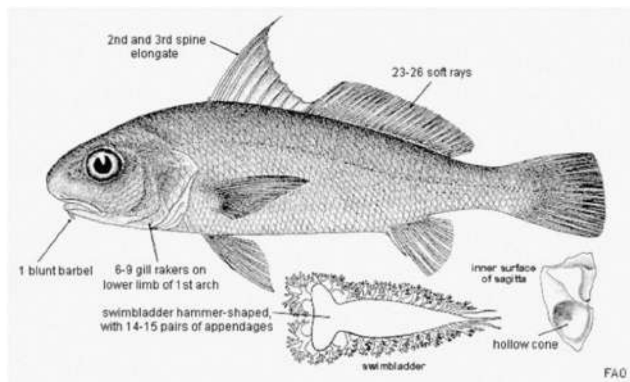
Rounded snout; Dorsal fin with 9 to 10 spines, trailed by a deep notch, second part of the fin with 1 spine and 25 to 28 soft rays; Teeth distinguished into large and small in upper jaw only.



(Source: FAO, WIO)

Johnius amblycephalus **(Bleeker, 1855)**
Common name: Bearded croaker

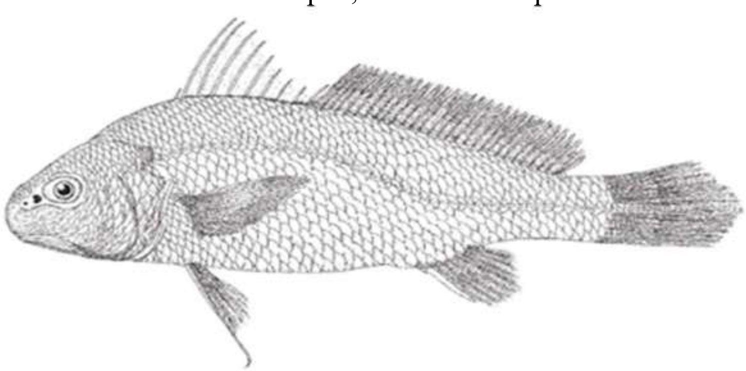
A small to medium-sized species with a moderately deep body; a stiff, blunt barbel on chin; caudal fin slightly rhomboidal, S-shaped or truncate; Swimbladder hammer-shaped, with 14 or 15 pairs of arborescent appendages; back and flanks black or dark brown.



Johnius carouna **(Cuvier, 1830)**

Common name: Caroun croaker

A small to medium-sized species with a moderately deep body; Snout bluntly rounded, slightly projecting in front of upper jaw; teeth differentiated into large and small in upper jaw only. Swimbladder hammer-shaped, with 14 or 15 pairs of arborescent appendages.



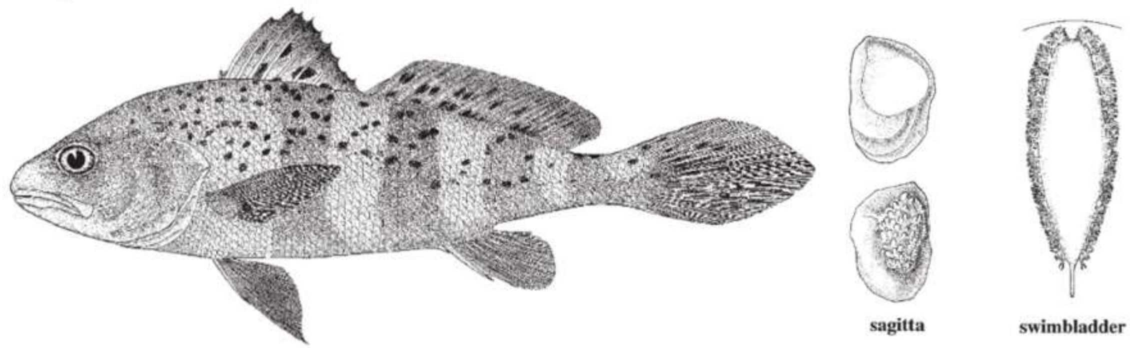
swimbladder

(Source: FAO, WIO)

Protonibea diacanthus **(Lacepède, 1802)**

Common name: Spotted croaker

A large species with a slender body; Snout acutely pointed; mental pores in 3 pairs, the first small, close together, united by a crescent-shaped groove just behind symphysis; Swimbladder carrot-shaped, with 16 to 20 pairs of arborescent appendages; 3 to 5 dark bars along back and many small black spots (about size of pupil) on top of head, upper half of body and caudal fin; in larger fishes, bars and spots obscure or absent.

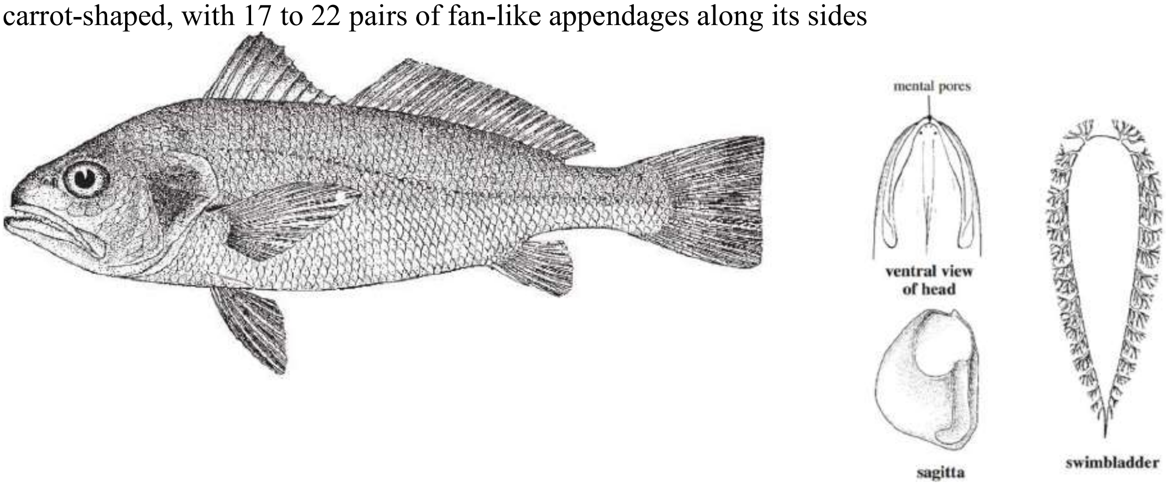


(Source: FAO,WIO)

Pennahia anea **(Bloch, 1793)**

Common name: Donkey croaker

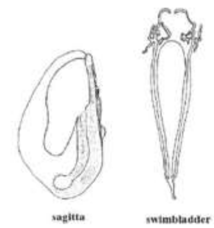
A fairly small, moderately deep-bodied species; Snout pointed; ; mental pores in 2 pairs, both small, the first pair at front of chin, separated by symphysis; caudal fin truncate; swimbladder carrot-shaped, with 17 to 22 pairs of fan-like appendages along its sides

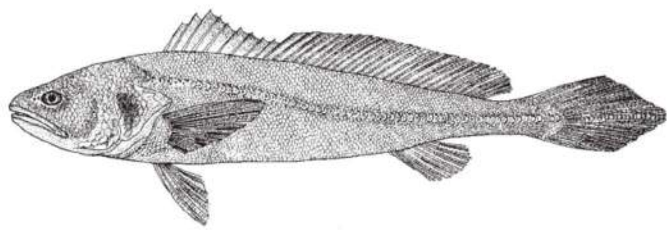


(Source: FAO, WIO)

***Otolithoides biauritus* (Cantor, 1849)**

Common name: Bronze croaker A large species with a slender, cylindrical body; mental pores in 2 pairs, the first small, at
front of chin, separated by symphysis; Swimbladder carrot-shaped, with a single pair of tube-like appendages arising from posterior end of bladder and running forward beside main body of bladder and in front of it into head beyond transverse septum, where they branch under skull.



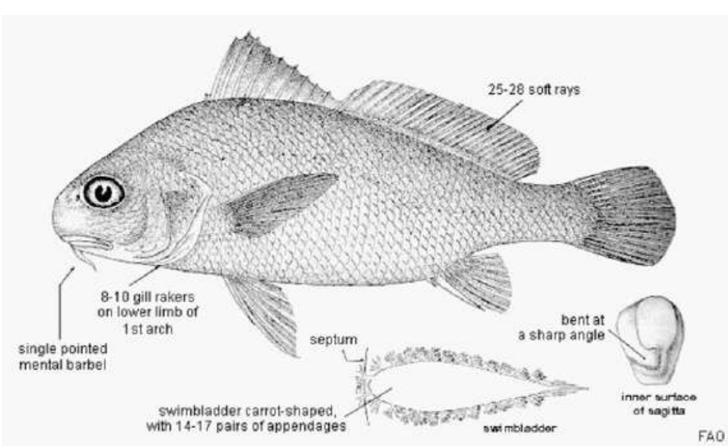


(Source: FAO, WIO)

***Dendrophysa russelii* (Cuvier, 1829)**

Common name: Goatee croaker

Mouth inferior; upper jaw villiform teeth band, outer row slightly enlarged; teeth on lower jaw uniformly small;5mental pores; swimbladder carrot shaped with 14-17 pairs of arborescent appendages along sides, none entering the head; sagittal(large earstone) with tadpole-shaped impression of which the "tail" is bent at a sharp angle; caudal fin rhomboid.



(Source: FAO, WIO)

Genus	List of species reported from India (Lal Mohan, 1981)
Bahaba (Herre,1935)	*Bahaba chaptis* (Hamilton, 1822)
Macrospinosa (Lal Mohan ,1969)	*Macrospinosa cuja* (Hamilton, 1822)
Kathala(Lal Mohan ,1969)	*Kathala axillaris* (Cuvier, 1830)
Otolithoides (Fowler, 1933)	*Otolithoides biauritus* (Cantor, 1849)
	Otolithoides pama (Hamilton, 1822)
Argyrosomus (De la Pylaie, 1835)	*Argyrosomus hololepidotus* (Lacepède, 1801)
	Argyrosomus amoyensis (Bleeker, 1863)
*Atrobucca (*Chu , Lo & Wu 1963)	*Atrobucca nibe* (Jordan & Thompson, 1911)
	Atrobucca trewavasae Talwar & Sathiarajan, 1975
Chrysochir (Trewavas & Yazdani 1966)	*Chrysochir aurea* (Richardson, 1846)
Otolithes (Oken ,1817)	*Otolithes ruber* (Bloch & Schneider, 1801)
	Otolithes cuvieri Trewavas, 1974
Pterotolithus (Fowler, 1933)	*Pterotolithus maculatus* (Cuvier, 1830)
Protonibea (Trewavas,1971)	*Protonibea diacanthus* (Lacepède, 1802)
Dendrophysa (Trewavas,1964)	*Dendrophysa russelii* (Cuvier, 1829)
Nibea (Jordan & Thompson 1911)	*Nibea semiluctuosa* (Cuvier, 1830) *Nibea maculata* (Bloch & Schneider, 1801)
	Nibea chui Trewavas, 1971
	Nibea soldado (Lacepède, 1802)
Johnius (Bloch, 1793)	*Johnius carutta* Bloch, 1793 *Johnius elongatus* Lal Mohan, 1976
	Johnius belangerii (Cuvier, 1830)
	Johnius dussumieri (Cuvier, 1830)
	Johnius mannarensis Lal Mohan, 1971
	Johnius coitor (Hamilton, 1822)
	Johnius glaucus (Day, 1876)
	Johnius macropterus (Bleeker, 1853)
	Johnius macrorhynus (Lal Mohan, 1976)

	Johnius dussumieri (Cuvier, 1830)
Pennahia (Fowler,1926)	*Pennahia anea* (Bloch, 1793) *Pennahia macrocephalus* (Tang, 1937)

References:

- Fischer, W., & Bianchi, G. (1984). *FAO* species identification sheets for fishery purposes: Western Indian Ocean (Fishing Area 51). v. 1: Introductory material. Bony fishes, families: Acanthuridae to Clupeidae.-v. 2: Bony fishes, families: Congiopodidae to Lophotidae.-v. 3:... families: Lutjanidae to Scaridae.-v. 4:... families: Scatophagidae to Trichiuridae.-v. 5: Bony fishes, families: Triglidae to Zeidae. Chimaeras. Sharks. Lobsters. Shrimps and prawns. Sea turtles. v. 6: Alphabetical index of scientific names and vernacular names.
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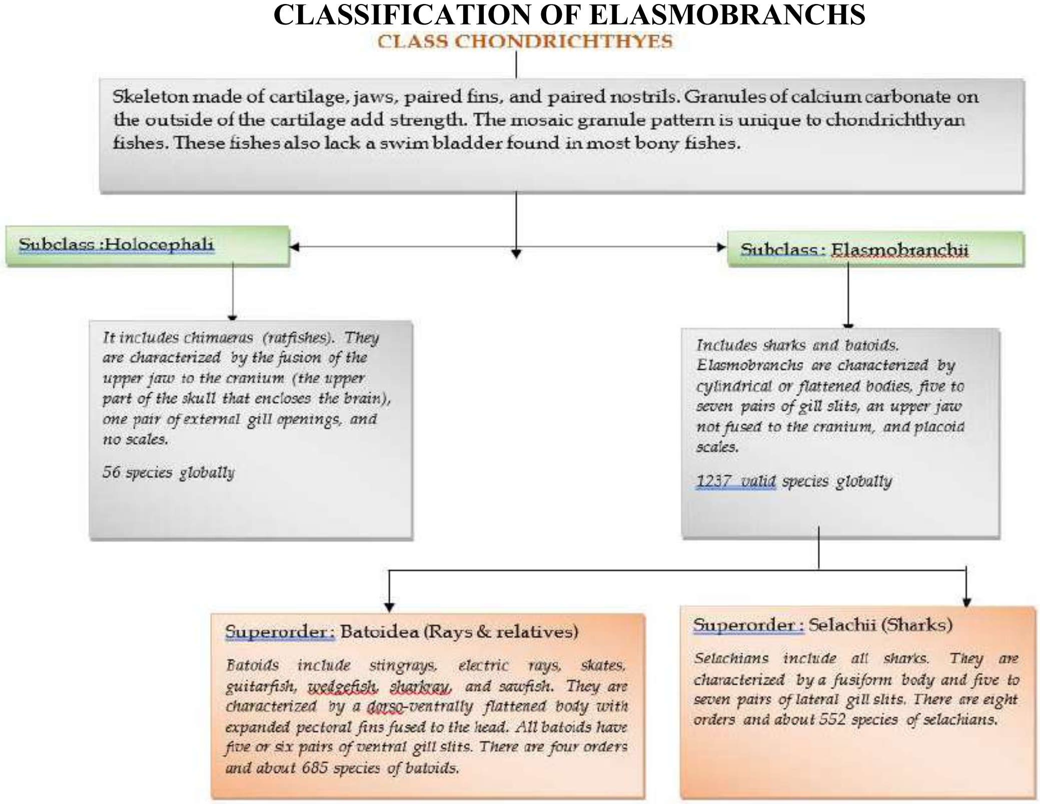
CHAPTER 28

Taxonomy of Sharks

Sharks, along with skates, guitarfishes, rays (batoids) and chimaeras belong to the Phylum Chordata, and the Class Chondrichthyes. Species in the class Chondrichthyes can be characterized by their cartilaginous skeleton, allowing their skeletal structure greater flexibility than rigid bone would. Chondrichthyes have placoid scales, sometimes referred to as dermal denticles; tiny hard modified teeth that aid in the movement of the fish through the water by reducing drag. Other anatomical features that all Chondrichthyes share are paired pectoral fins and ampullae of Lorenzini, which are used to sense electrical fields within their environment.

CLASSIFICATION OF ELASMOBRANCHS



Class Chondrichthyes are divided into the subclass Elasmobranchii separate from subclass Holocephali containing chimaeras. Based on several anatomical and functional differences. Unlike chimaeras with only four gill slits, species in the Subclass Elasmobranchii have at least

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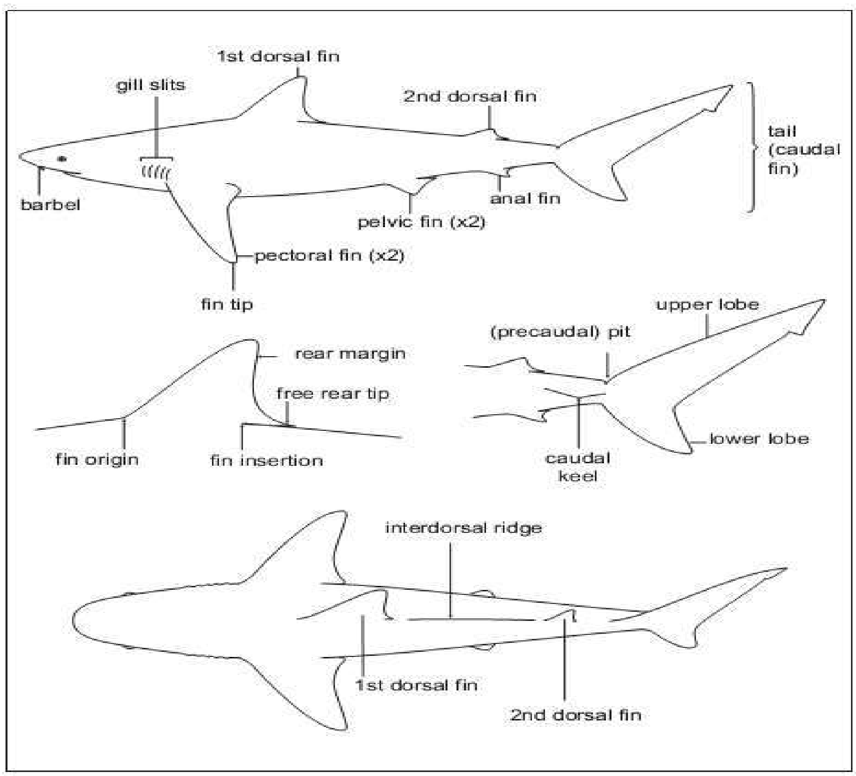
five gillslits. And unlike chimaeras whose upper jaw is fused to their cranium, the sharks jaw is not fused and contains rows of replaceable teeth, not found in chimaeras.

Some of the key differences between sharks, skates and rays are in the shape and function of homologous body parts. The pectoral fins on skates and rays are much wider and used for movement and propulsion, while the pectoral fins on sharks are used for lift and directional changes while swimming. Sharks also have a shorter caudal fin with an upper and lower lobe used for propulsion, while the elongated and much narrower tail fin on skates and rays is used to help steer. And while sharks, skates and rays all have, for the most part, 5 gill slits, the gills on sharks are located on either side of the body, while the gills on skates and rays are found on the ventral side of the fish.

Compagno (2001) lists 60 families within the living orders of chondrichthyans. There are nearly 500 species of living sharks, over 600 species of batoids and 50 species of chimaeras, with new species constantly being described. For understanding the identification keys, the morphological characters should be known. Major morphological identifications are given in Fig 1 & 2.

Anatomy of sharks



Source: FAO,1984

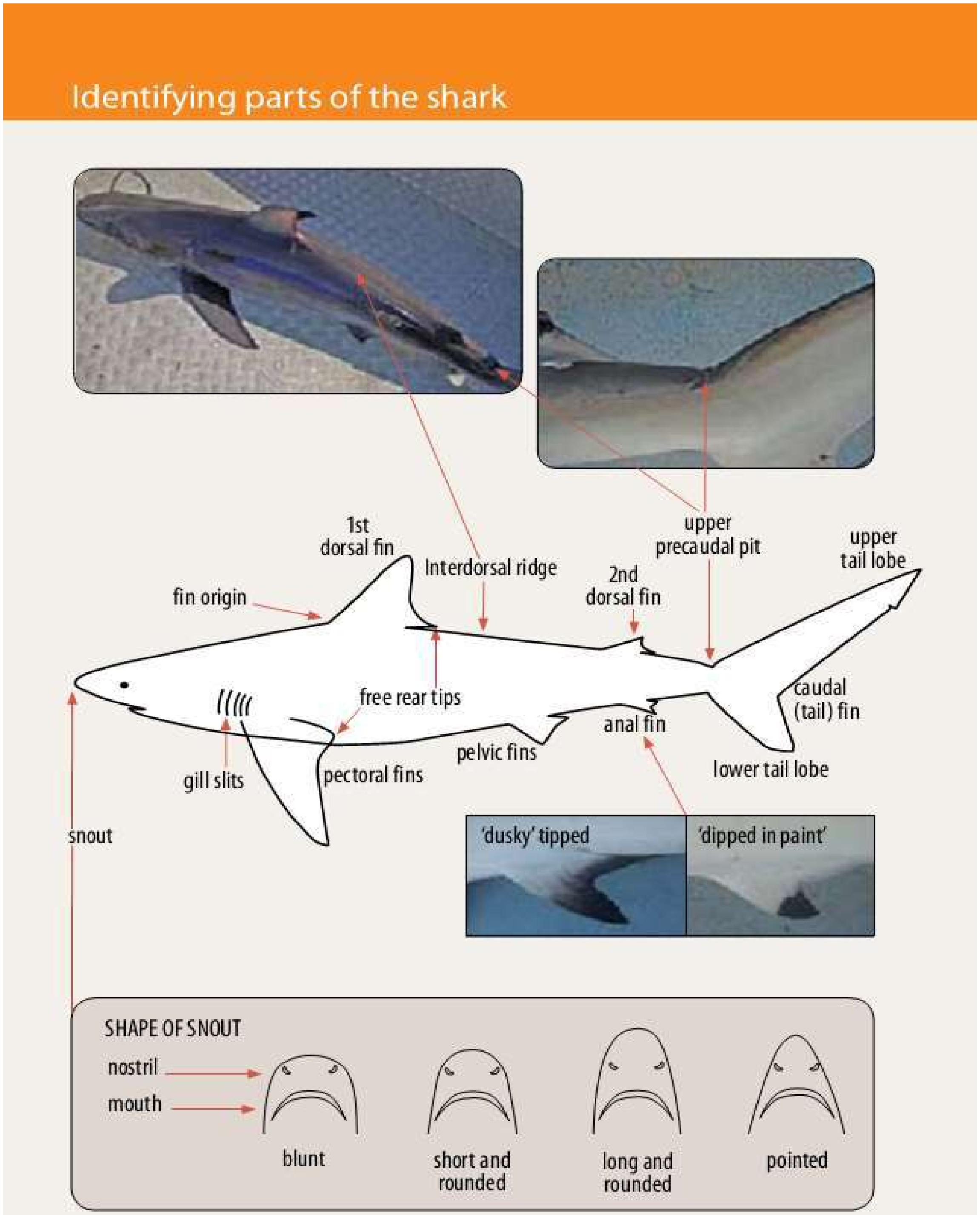


Illustration Source: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/264775/Identifying-sharks-and-rays.pdf

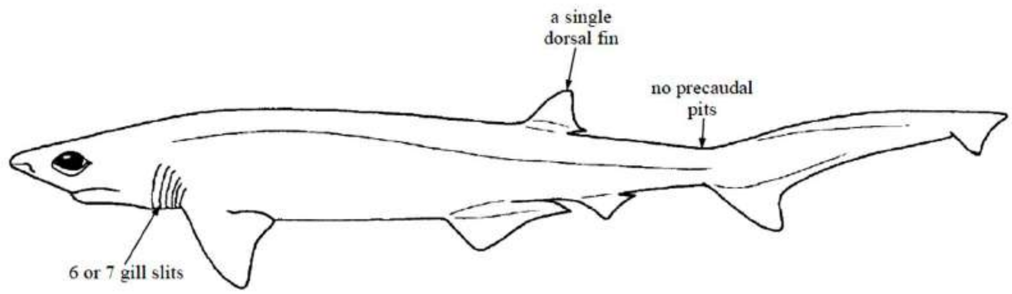
Sharks can be grouped into nine orders and 37 families according to their distinctive characters.

S. No	Order	Families
1	Hexanchiformes (frilled and cow sharks	Chlamydoselachidae
		Hexanchidae
2	Squaliformes (dogfish sharks)	Squalidae
		Centrophoridae
		Etmopteridae
		Somniosidae
		Oxynotidae
		Dalatiidae
3	Pristiophoriformes (saw sharks)	Pristiophoridae
4	Squantiniformes (angel sharks)	Squatinidae
5	Heterodontiformes (bullhead sharks)	Heterodontidae
6	Orectolobiformes (carpet sharks)	Parascylliidae
		Brachaeluridae
		Orectolobidae
		Hemiscylliidae
		Ginglystomatidae
		Stegostomatidae
		Rhincodontidae
7	Lamniformes (mackerel sharks)	Odontaspididae
		Pseudocarchariidae
		Mitsukurinidae
		Megachasmidae
		Alopiidae
		Cetorhinidae
		Carchariidae
		Lamnidae
8	Echinorhiniformes (bramble and prickly sharks)	Echinorhinidae
9	Carcharhiniformes (ground sharks)	Pentanchidae
		Scyliorhinidae
		Proscylliidae
		Pseudotriakidae
		Leptochariidae
		Triakidae
		Hemigaleidae
		Carcharhinidae
		Galeocerdonidae
		Sphyrnidae

The key characters of the orders and major families from Indian waters and species in each order reported is given below

1. **ORDER HEXANCHIFORMES (frilled and cow sharks)**

   Key characters: Trunk cylindrical or somewhat compressed, not flattened and raylike. Head conical to slightly depressed, not expanded laterally; 6 or 7 pairs of gill slits present on sides of head, with the posterior most in front of pectoral fin origins. A single spineless dorsal-fin present, with origin over or behind pelvic fin insertions.



Major families in the order are

Family Chlamydoselachidae - Frilled sharks

Mouth terminal on head; teeth tricuspidate, six pairs of gill slits,first pair connected across the underside of the throat; body elongated and eel-like.

Family Hexanchidae - Cowsharks, Sixgill sharks, Sevengill sharks

Mouth subterminal on head; front teeth unicuspidate in upper jaw and comb-shaped and blade-like in lower jaw, six or seven pairs of gill slits, first not connected across underside of throat; body fairly stocky, not eel-like.

Species from Indian waters:

1. *Heptranchias perlo*
2. *Hexanchus griseus*

2. **ORDER SQUALIFORMES (dogfish sharks)**

Two dorsal fins (with or without spines); no anal fin. Caudal fin with vertebral column elevated into a moderately long upper lobe; lower lobe absent to strong. Five gill slits, all in front of pectoral fin origins.

Family: Squalidae (Dogfish Sharks)

Teeth blade-like and similar in both jaws, with a deflected horizontal cusp, caudal peduncle usually with an upper precaudal pit (weak orabsent in Cirrhigaleus); Caudal peduncle with strong lateral keels dorsal fin spines without grooves; caudal fin without subterminal notch.

Major species from Indian waters:

1. *Squalus mitsukurii*
2. *Squalus hemipinnis*

Family: Etmopteridae (Lanternsharks)

Hook-like or with cusps and cusplets teeth in both jaws, blade-like and more or less overlapping; underside of body, flanks, and tail usually with more or less conspicuous, dense, black markings with light organs (photophores).

Species from India waters:

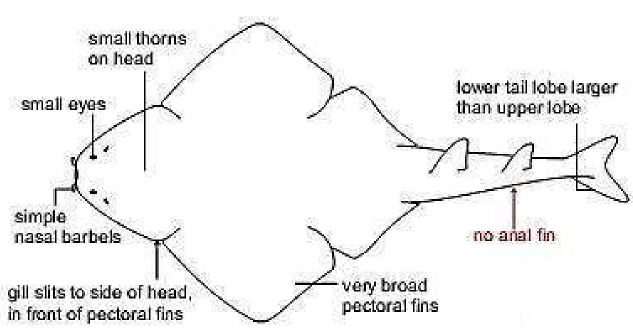
1. *Centroscyllium ornatum*
2. *Etmopterus pusillus*

Family: Centrophoridae (Gulper Sharks)
Upper teeth relatively broad and blade-like; lower teeth low, wide and blade-like. compressed, blade-like and overlapping, much larger than uppers underside of body, flanks and tail without conspicuous, dense, black markings that have light organs, though light producing organs may be present elsewhere.
Species from Indian waters:
1. *Centrophorus atromarginatus*
2. *Centrophorus granulosus*
3. *Centrophorus moluccensis*
4. *Centrophorus squamosus*
5. *Centrophorus uyato*
6. *Deania profundorum*

Family: Somniosidae (Sleeper Sharks)
Moderately broad head and somewhat flattened or conical; snout flat and narrowly rounded to elongate-rounded in dorsoventral view; abdomen usually with lateral keels; both dorsal fins either with or without (Somniosus, Scymnodalatias) fin spines.
Species from Indian waters:
1. *Centroscymnus crepidator*
2. *Zameus squamulosus*
3. *Scymnodon ichiharai*

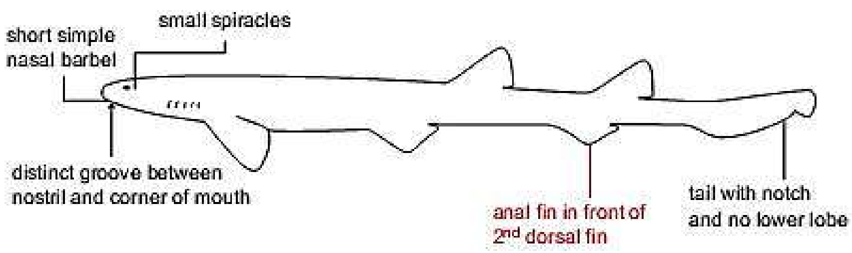
3. ORDER: SQUANTINIFORMES (Angelsharks)
Mouth at end of head body flat and ray-like; very large pectoral fins with triangular anterior lobes that overlap gill slits; caudal fin with base slanted ventrally (hypocercal)

Family: Squatinidae (Angelsharks)
Similar to rays, with a broad flattened body, short snout and large fins, but with gill openings on the sides of the head, not beneath, and very large pectoral fins not attached to the head opposite the gills (the hindmost gill opening is in front of pectoral fin origins, but covered by triangular anterior fin lobes).

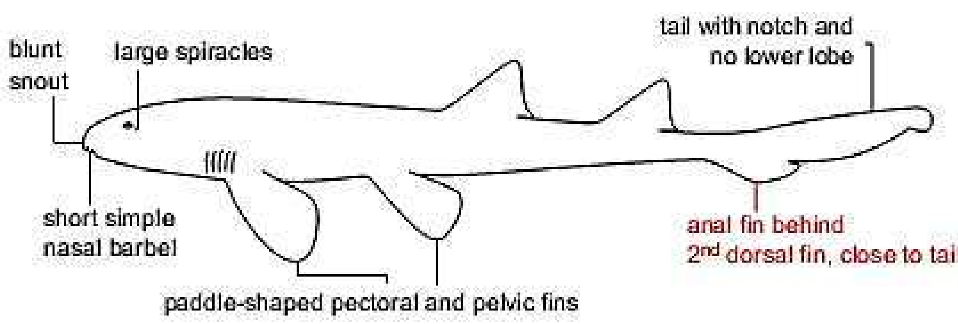


Species from Indian waters:
1. *Squatina africana*

4. ORDER
ORECTOLOBIFORMES (carpet sharks)
Eyes behind mouth; deep nasoral grooves connecting nostrils and mouth; a pair of barbels just medial to incurrent apertures of nostrils (rudimentary in Family Rhincodontidae).

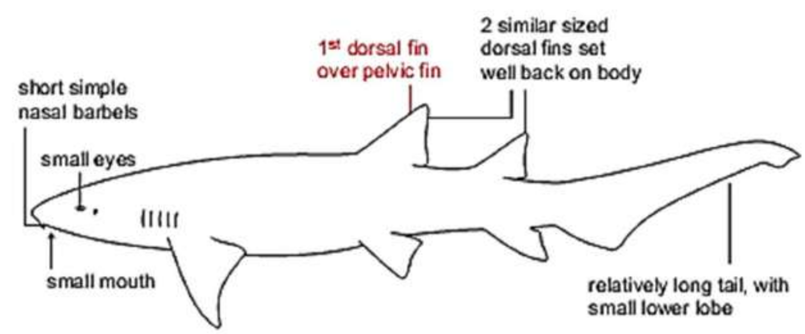


Family: Hemiscylliidae (Longtailed carpetsharks)
Nasal barbels short; distance from vent to lower caudal origin longer than distance from snout to vent; anal fin low, rounded and keel-like.



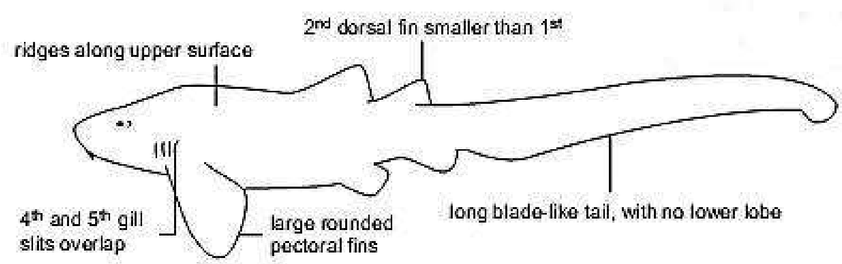
Species from Indian waters*:*
1. *Chiloscyllium arabicum*
2. *Chiloscyllium indicum*
3. *Chiloscyllium plagiosum*
4. *Chiloscyllium punctatum*
5. *Chiloscyllium griseum*
6. *Chiloscyllium burmer*

Family: Ginglystomatidae (Nurse sharks)
Head and body cylindrical or moderately flattened, head without skin flaps; teeth small. No circumnarial lobe and groove around outer edges of nostrils



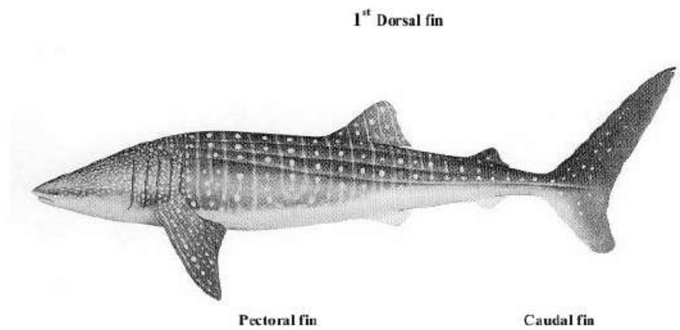
Species from Indian waters:
1. *Nebrius ferrugineus*

Family: Stegostomatidae (Zebra Shark)
Mouth smaller and subterminal; external gill slits small; caudal peduncle without strong lateral keels; caudal fin with a weak lower lobe or none, but with a strong terminal lobe and subterminal notch, Caudal fin about as long as rest of shark.



Species from Indian waters:
1. *Stegostoma fasciatum*

Family: Rhincodontidae (Whale shark)
Mouth huge and nearly at end of head; external gill slits very large; caudal pedunclewith strong lateral keels; caudal fin with a strong lower lobe, but without a subterminal notch.



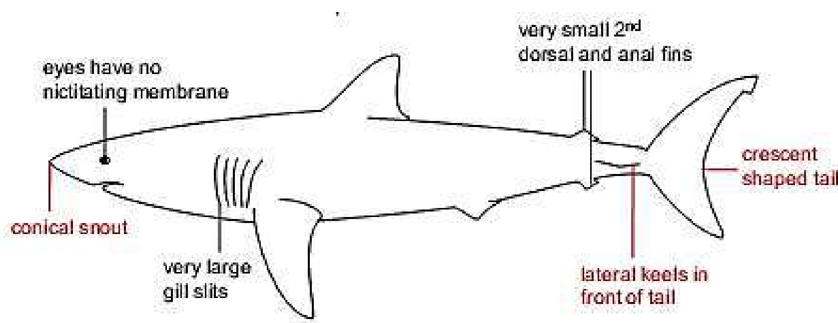
Species from Indian waters :
1. *Rhincodon typus*

5. ORDER: LAMNIFORMES (Mackerel sharks)

Eyes partly or entirely over mouth; nasoral grooves usually absent, when present (a few members of the Family Scyliorhinidae) broad and shallow; barbels, when present, developed from anterior nasal flaps of nostrils, not separatefrom them. No nictitating eyelids; largest teeth in mouth usually are two or three rows of anteriors on either side of upper and lower jaw symphyses.

Family: Lamnidae (Mackerel sharks)

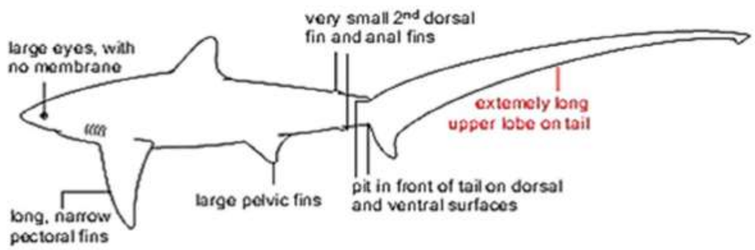
A strong keel present on each side of caudal peduncle; caudal fin crescentic and nearly symmetrical, with a long lower lobe. Teeth large and few, sharp-edged; gill openings large but not extending onto upper surface of head; no gill rakers on internal gill arche



Species from Indian waters:
1. *Isurus oxyrinchus*
2. *Isurus paucus*

Family:Alopiidae (Thresher Shark)

Snout conical or flattened, short and not blade-like; anal fin subequal todorsal fins in size or smaller than them; upper and sometimes lower precaudal pits present; caudal fin with strong lower lobe. Caudal fin about as long as rest of shark.



Major species from Indian water*:*

1. *Alopias pelagicus*
2. *Alopias superciliosus*
3. *Alopias vulpinus*

Family: Pseudocarchariidae (Crocodile Shark)

Subterminal small mouth, behind snout tip; teeth blade-like with large anterior teeth, intermediate teeth, and lateral teeth in upper jaw; internal gill openings without gill rakers. Eyes very large; gill slits extending onto upper surface of head; both upper and lower precaudal pits present; a low keel on each side of caudal peduncle.

Major Species from Indian waters:

1. *Pseudocarcharhias kamoharai*

Family: Odontaspididae (Sandtiger Sharks)

Eyes smaller; gill slits not extending onto upper surface of head; lower precaudal pit absent; no keels on caudal peduncle. long conical snout, fairly large eyes; first dorsal fin closer to pectoral fins than pelvic fins, first dorsal fin larger than second dorsal and anal fins.

Species from Indian waters:

1. *Carcharias taurus*
2. *Odontaspis ferox*
3. *Odontaspis noronhai*

6. ORDER: ECHINORHINIFORMES (bramble and prickly sharks)

Flat broad head with tiny spiracles; similar sized dorsa lfin placed close together well back, Anal fin absent; large thorn-like skin denticles.

Family: Echinorhinidae (bramble sharks)

Very large and thorn-like skin denticles. Cylindrical stout, body. Five gill openings in front of pectoral fin, fifth one larger than others., flat broad head and snout,; origin of first dorsal slightly behind pelvic fin origin. Lower caudal lobe poorly developed in adults, absent in young, subterminal caudal notch lacking or not obvious.

Species from Indian waters:

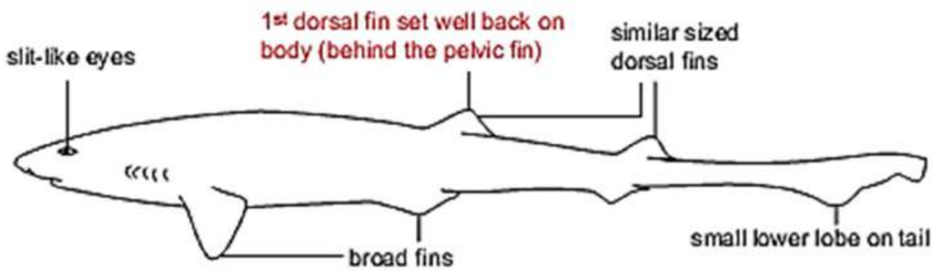
1. *Echinorhinus brucus*

7. ORDER: CARCHARHINIFORMES (GROUND SHARKS)

This order is the largest, most diverse and widespread group of sharks. It contains at least 291 species in 10 families. Very wide range of appearances, from strange bottom-dwelling deepsea sharks, to typical large sharks. All have two spineless dorsal fins and an anal fin. A long mouth extends to or behind the eyes, Nasoral grooves are usually absent (or broad and shallow, when present in a few catsharks). If barbels are present, these are developed from the anterior nasal flaps of nostrils. Largest teeth are distinctly lateral on dental band, with no gap or intermediate teeth separating the large anterior teeth from even larger teeth in upper jaw.

Family: Scyliorhinidae (Catsharks)

Supraorbital crest present on cranium above eyes. (Crest can be felt by running your fingers over the eye orbits)



Species from Indian waters: *Cephaloscyllium silasi,*

Family: Pentanchidae (Halaelurus catsharks)

1. *Apristurus investigatoris*
2. *Bythaelurus hispidus*
3. *Halaelurus quagga*

Family: Proscylliidae (Finback catsharks)

Rounded-parabolic snout or subangular in dorsoventral profile, without a deep groove in front of eye; internarial space less than 1.3 times nostril width; inside of mouth and edges of gill arches with papillae; first dorsal fin short, base closer to pelvic fins than pectoral fins.

Species from Indian waters:

1. *Eridacnis radcliffei*
2. *Proscyllium magnificum*

Family: Pseudotriakidae (False catsharks)

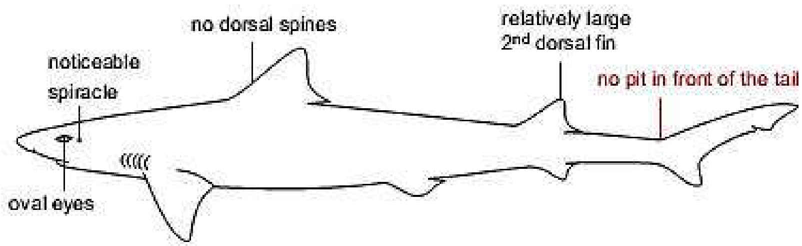
Bell-shaped snout in dorsoventral profile, with a deep groove in front of eye, internarial space over 1.5 times nostril width; inside of mouth and edges of gill arches without papillae; first dorsal fin more or less elongated, base closer to pectoral fins.

Species from Indian waters:

1. *Planonasus indicus*

Family: Triakidae (Houndsharks)

Anterior nasal flaps usually not barbel-like (except for Furgaleus); upper labial furrows shorter, considerably less than internarial width and less than half of mouth width; intestinal valve with 4 to 10 turns; supraorbital crests present on cranium.

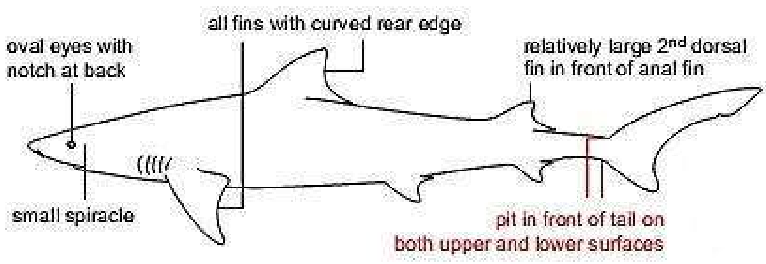


Species from Indian waters:

1. *Iago omanensis*
2. *Iago mangalorensis*
3. *Mustelus mosis*

Family: Hemigaleidae (Weasel sharks)

Posterior nasal flaps well developed on rear edges of excurrent apertures of nostrils, symphysial tooth rows well developed in upper and lower jaws; second dorsal fin height about 0.4 to 0.7 times first dorsal fin height; intestine with a spiral valve containing 4 to 6 turns.



Species from Indian waters:

1. *Chaenogaleus macrostoma*
2. *Hemigaleus microstoma*
3. *Hemipristis elongata*

Family: Carcharhinidae

Two dorsal fins and one anal fin, Precaudal pit present,Caudal fin with strong ventral lobe Medium to large size; some small Long arched mouth with blade-like teeth No nasoral grooves or barbels Round eyes with internal nictitating eyelidsUpper labial furrows short to long, but not extending to front of eyes; spiracles usually absent; posterior nasal flaps poorly developed on rear edge of excurrent apertures of nostrils; lateral keels usually absent (except weak ones) on Prionace caudal peduncle.

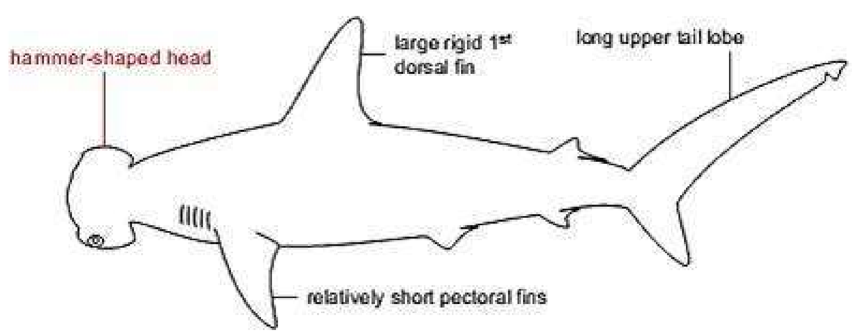
Major species from Indian waters:

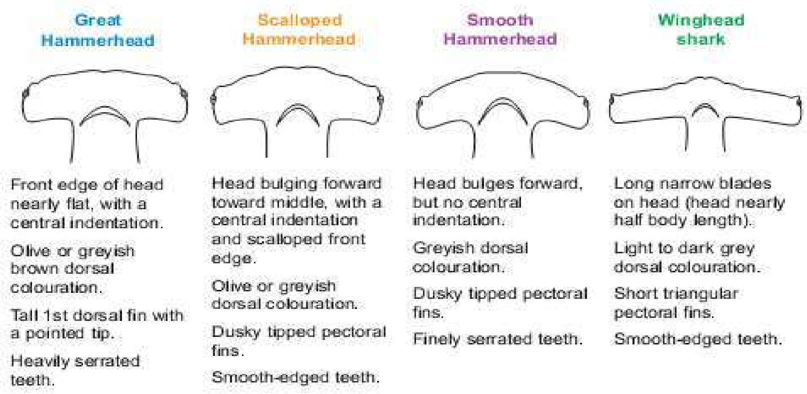
1. *Carcharhinus albimarginatus*
2. *Carcharhinus altimus*
3. *Carcharhinus amblyrhynchoides*
4. *Carcharhinus amblyrhynchos*
5. *Carcharhinus amboinensis*
6. *Carcharhinus brachyurus*

7. *Carcharhinus brevipinna*
8. *Carcharhinus dussumieri*
9. *Carcharhinus falciformis*
10. *Carcharhinus galapagensis*
11. *Carcharhinus hemiodon*
12. *Carcharhinus leucas*
13. *Carcharhinus limbatus*
14. *Carcharhinus longimanus*
15. *Carcharhinus macloti*
16. *Carcharhinus melanopterus*
17. *Carcharhinus obscurus*
18. *Carcharhinus plumbeus*
19. *Carcharhinus sealei*
20. *Carcharhinus sorrah*
21. *Glyphis gangeticus*
22. *Glyphis glyphis*
23. *Lamiopsis temminckii*
24. *Loxodon macrorhinus*
25. *Negaprion acutidens*
26. *Prionace glauca*
27. *Rhizoprionodon acutus*
28. *Rhizoprionodon oligolinx*
29. *Scoliodon laticaudus*
30. *Triaenodon obesus*

Family: Sphyrnidae (Hammerhead sharks)

Head with lateral expansions or blades, like a double-edged axe.





Species from Indian waters:

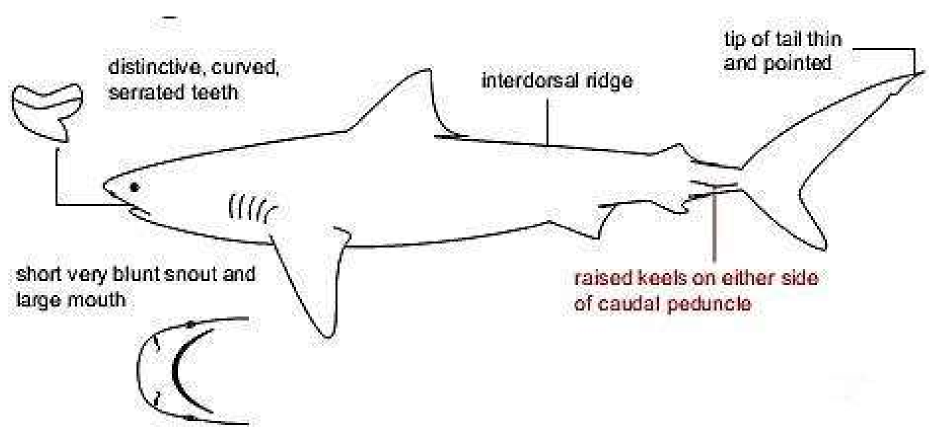
1. *Eusphyra blochii*
2. *Sphyrna lewini*
3. *Sphyrna mokarran*
4. *Sphyrna tudes*
5. *Sphyrna zygaena*

Family: Galeocerdidae. Tiger sharks

Upper labial furrows very long, extending to front of eyes; spiracles present and relatively large; posterior nasal flaps well developed on rear edge of excurrent apertures of nostrils; prominent lateral keels on caudal peduncle

Species from Indian waters:

1. *Galeocerdo cuvier*



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CHAPTER 29

Taxonomy of Wedgefishes and Guitarfishes in Indian Waters

Introduction

Interest in elasmobranch biodiversity and taxonomy has grown in recent years (since 2000). Recognizing the importance of accurate species-level taxonomy in biodiversity studies, fisheries management, to understand the composition, now additional efforts have been included in fisheries monitoring. Fisheries scientists are ever more keenly aware of the need for accurate species-level assessments of catches to manage fisheries effectively. Finally, conservation biologists are beginning to recognize how critically important it is to have an accurate understanding of species compositions based on careful taxonomy to prioritize and manage units of biodiversity for conservation (Naylor et al., 2012). The Cartilaginous fishes, consisting of sharks, rays and chimeras belongs to class Chondrichthyes. Today, more than 1,400 species live in the seas and freshwater and estuarine systems of the world. In India, the Chondrichthyes are represented by around 160 species under 67 genera, 28 families and 10 Orders in the Indian region (Kizhakudan et al., 2015). The Bar coding of elasmobranchs is standard for molecular identification of species. Unfortunately, some of the specimens from which tissue samples are derived are misidentified when collected, and because there is no expertly curated reference dataset against which to compare sequences, many are added to GenBank with their original incorrectly assigned identities. Therefore, the combination of molecular and the classical taxonomy (based on morphology) of elasmobranchs is essential to conduct the phylogenetic analysis and avoids incorrect phylogenetic inferences. Globally, 536 shark species, 611 rays and 52 chimeras were assessed by International Union for Conservation of Nature (IUCN) Red List assessment process. Now, 391 (32.6%) species are threatened with extinction. Overfishing is the universal threat affecting all 391 threatened species and is the sole threat for 67.3% of species and interacts with three other threats for the remaining third: loss and degradation of habitat (31.2% of threatened species), climate change (10.2%), and pollution (6.9%). Species are disproportionately threatened in tropical and subtropical coastal waters (Dulvy et al., 2021). Elasmobranchs are characterized by a life-history of slow growth, late maturity, and low fecundity, making them extremely susceptible to population decline from overexploitation.

As part of conservation programme in India, ten species of sharks and rays, including *Rhincodon typus* (Whale shark), *Anoxypristis cuspidata* (Knifetooth sawfish), *Carcharhinus hemiodon* (Pondicherry shark), *Glyphis gangeticus* (Gangetic shark), *G. glyphis* (Speartooth shark), *Himantura fluviatilis* (Ganges stingray), *Pristis microdon* (= *P. pristis*) (Freshwater sawfish), *P. zijsron* (Green sawfish), *Rhynchobatus djiddensis* (Giant guitarfish), and

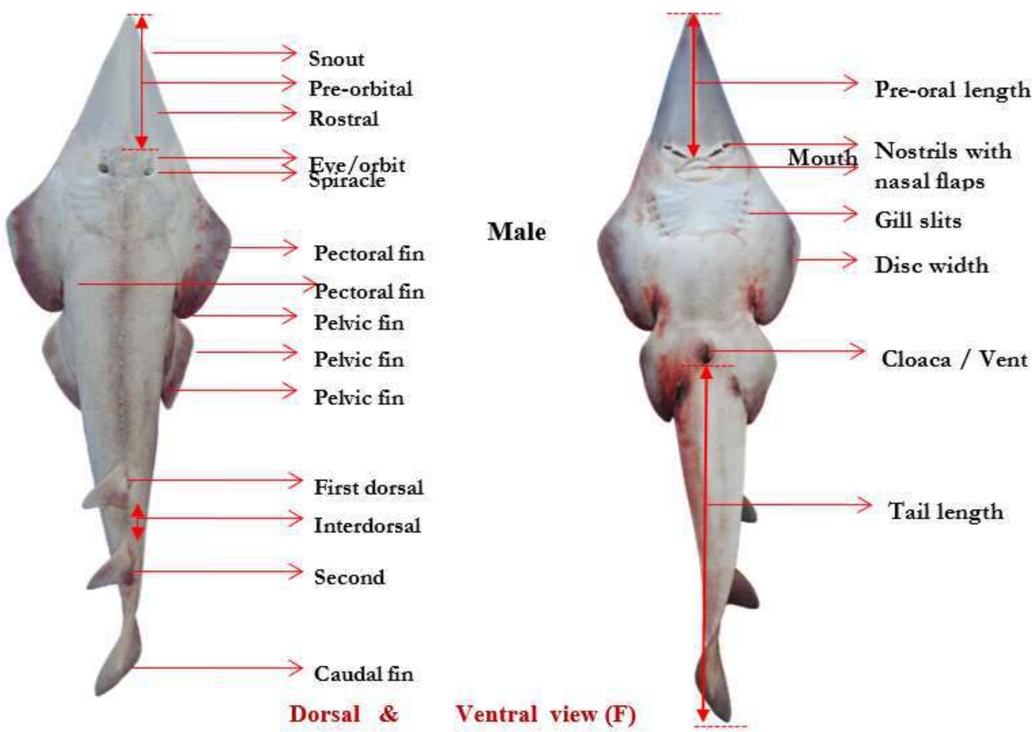
G B Purushottama, Sujitha Thomas, Shoba Joe Kizhakudan and K V Akhilesh *ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala*

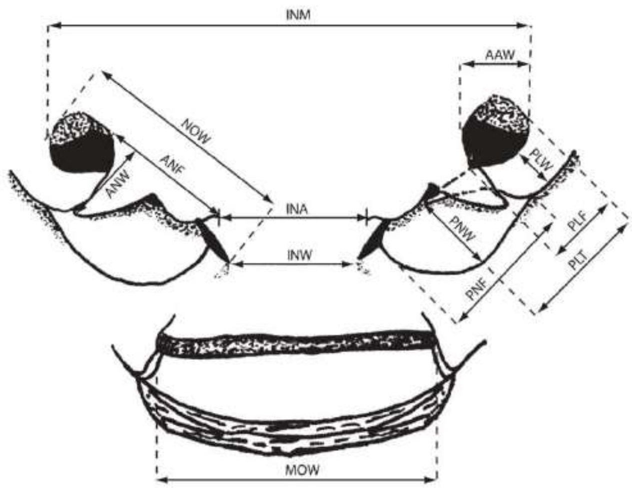
Urogymnus asperrimus (Porcupine ray) were listed under Schedule-I Part 2(A) of the Indian Wildlife (Protection) Act, 1972 during 2001.

Classification of shark-like batoids

Sixty-three species from five families are recognized within the order Rhinopristiformes: the sawfishes (Pristidae), wedgefishes (Rhinidae), giant guitarfishes (Glaucostegidae), guitarfishes (Rhinobatidae), and banjo rays (Trygonorrhinidae). Their flattened body is perfectly adapted for life on the seabed, either swimming close to the bottom or resting and lying concealed within the sediments. Of these five families, only the Rhinobatidae is not inferred to be monophyletic. The classical and molecular taxonomy confirmed the family Pristidae (sawfishes) as monophyletic. Rhina forms a strongly supported monophyletic group with *Rhynchobatus*, which we recognize as a family level grouping, the Rhinidae. Members of the genus *Glaucostegus* all formed a strongly supported group in the tree, now recognized as the family Glaucostegidae. Finally, the Trygonorrhinidae, comprising the genera *Trygonorrhina*, *Aptychotrema*, and *Zapteryx* (previously included in the family Rhinobatidae) is strongly forms the basal group within Rhinopristiformes (Last et al., 2016).

Technical terms and field identification characters



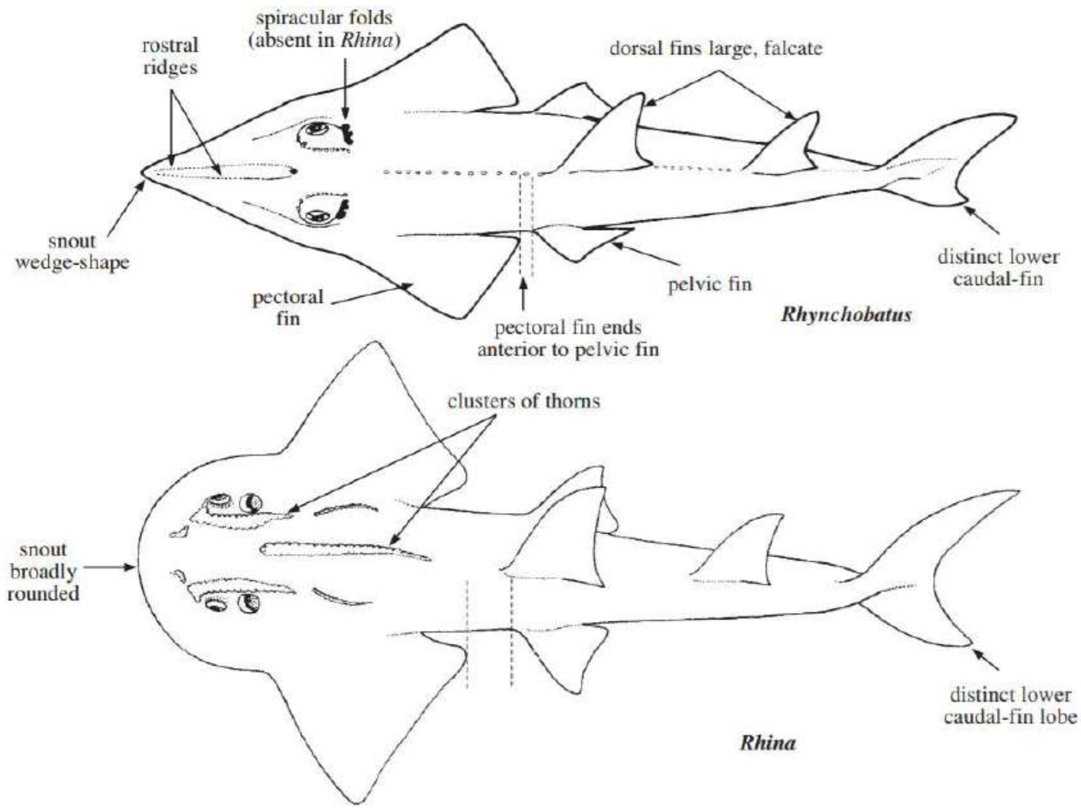


Ventral view (M)

Measurements of the oronasal region of the genus *Rhinobatos*.
AAW, anterior aperture width; ANF, anterior nasal-flap base length; ANW, anterior nasal-flap base width; INA, distance between insertions of anterior nasal flaps; INM, distance between lateral margins of anterior apertures; INW, internarial distance; MOW, mouth width; NOW, nostril length; PLF, posterolateral nasal-flap anterior exposed base length; PLT, posterolateral nasal-flap total length; PLW, posterolateral nasal-flap width; PNF, posterior nasal-flap base length; PNW, posterior nasal-flap width (**Source**: Last et al., 2004)

Wedgefishes (Family Rhinidae)

Wedgefishes are medium to large, shark-like rays with a variably depressed trunk, weakly formed disc, and a head either thickened and broadly domed, or flattened wedge-shaped or rounded. Pectoral fins are triangular and join the body behind eye level. The nostrils are long and narrow, and usually lie oblique to a small horizontal mouth with rounded to oval teeth that lack distinct cusps. The anterior nasal flaps are poorly developed and do not form a nasal curtain. The spiracles are large with 0–3 skin folds along their hind margin. A robust tail is slightly longer than the disc, and has two upright dorsal fins (the first above the pelvic fins), and a well-developed bilobed caudal fin with a strongly concave posterior margin. Its pelvic fins are moderately sized, angular and are not divided into two lobes. The skin is covered with minute denticles and there is a variably developed series of thorns along the dorsal mid-line, and usually 2–3 short series on each shoulder. Dorsal surface mainly yellowish to greyish brown and white ventrally. Often with rows of white spots or ocelli, and often a black blotch on each pectoral fin (pectoral marking) that is variably surrounded by white spots (marking generally most obvious in young). The undersurface of the snout can have a blackish marking. The family now includes 10 valid species from 3 genera: *Rhina, Rhynchobatus* and *Rhynchorhina*, is most diverse in the Indo-West Pacific. Historically, the genera Rhina and *Rhynchobatus* have been either placed together in the Rhinidae or assigned to separate families. However, recent molecular research has provided evidence that they belong to the same family (Rhinidae), including the newly named genus *Rhynchorhina* which is based on an unusual Eastern Atlantic species having a wedge-shaped body with a rounded snout. Wedgefishes are amongst the bulkiest of all bottom-dwelling rays, and some species reach in excess of 3 m in length (Last et al. 2016).



(**Source**: FAO, 1999)

- ***Rhina* Bloch & Schneider, 1801**
  - *Rhina ancylostoma* Bloch & Schneider, 1801 (Shark ray)

- ***Rhynchobatus* Müller & Henle, 1837**
  - *Rhynchobatus australiae* Whitley, 1939 (Bottlenose wedgefish)
  - *Rhynchobatus cooki* Last, Kyne & Compagno, 2016 (Roughnose wedgefish)
  - *Rhynchobatus djiddensis* (Forsskål, 1775) (Whitespotted wedgefish)
  - *Rhynchobatus immaculatus* Last, Ho & Chen, 2013 (Taiwanese wedgefish)
  - *Rhynchobatus laevis* (Bloch & Schneider, 1801) (Smoothnose wedgefish)
  - *Rhynchobatus luebberti* Ehrenbaum, 1915 (African wedgefish)
  - *Rhynchobatus mononoke* Koeda, Itou, Yamada & Motomura, 2020 (Japanese wedgefish)
  - *Rhynchobatus palpebratus* Compagno & Last, 2008 (Eyebrow wedgefish)
  - *Rhynchobatus springeri* Compagno & Last, 2010 (Broadnose wedgefish)

- ***Rhynchorhina* Séret & Naylor, 2016**
  - *Rhynchorhina mauritaniensis* Séret & Naylor, 2016 (False shark ray)

Rhina ancylostoma **Bloch & Schneider, 1801 (Shark ray)**

Shark like ray with a large and heavy body, ridges of large thorns on head region, snout broadly rounded and distinct from pectorals, first dorsal-fin origin slightly anterior to pelvic-fin origin, caudal fin lunate, upper and lower lobes almost symmetrical, dorsal colour bluish grey/brown, white ventrally; numerous white spots dorsally on fins, body and tail; dark bands between eyes and spiracles. Young ones brightly coloured, Maximum size: 270 cm

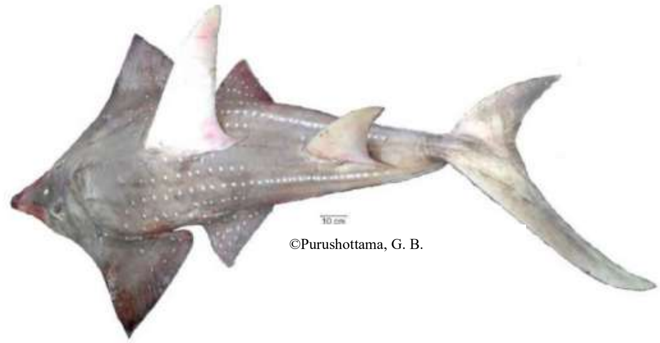
A.*Rhina ancylostoma* (Adult) **B.** *Rhina ancylostoma* (Juvenile)

Rhynchobatus australiae **Whitley, 1939 (Bottlenose wedgefish)**

Large sized wedgefish with bottle-shaped snout, first dorsal-fin falcate, origin slightly posterior to pelvic-fin origin, black spot on each pectoral fin in juveniles, becoming faint or absent in large adults, a line of 3 white spots usually anterior to black pectoral spot, 2 white spots seen below, caudal fin deeply concave, colour pale grey to yellowish, Maximum size: 300 cm TL.

Rhynchobatus laevis (Bloch & Schneider, 1801) (Smoothnose wedgefish)

Large sized wedgefish with bottle-shaped snout, prominent black spot on each pectoral fin surrounded by 4-5 white spots, spiracle with two skin folds, outer slightly larger than inner, pre-dorsal spot pattern not reaching to midline between pectoral marking, greyish dorsally in young, brown in adults, white ventrally, Maximum size: 300 cm TL.



B. *Rhynchobatus laevis* (Sub-adult)

Guitarfishes (Rhinobatidae)

Guitarfishes, otherwise known as shovelnose rays, are small to large rays. They have a flattened wedge- or shovel-shaped disc with a strongly depressed trunk. The snout is often elongate and its tip varies from narrowly pointed to broadly rounded. Eyes and spiracles vary from medium to large, the latter with 1–2 variably developed folds. Nostrils rather short and very oblique with fewer than 68 lamellae. All species lack a nasal curtain, and the anterior nasal flaps are often broad and joined posteriorly to either close to the inner edge of the nostril or slightly within the interspace between the nostrils. Mouth profile is straight. The skin is usually covered with fine denticles (sometimes partly naked), and small thorns and thornlets are variably developed in a row along dorsal mid-line of body, in small patches near eyes, and on shoulder and snout. Long-based pelvic fins are positioned laterally and posteriorly to the disc. Two upright or tilted dorsal fins are well separated, with the first positioned well to slightly behind rear tips of the pelvic fins. The small caudal fin lacks an obvious ventral lobe. Dorsal coloration varies from plain (usually greyish or brownish) to having a strong pattern of lines, bars, spots and/or blotches. The cranium and rostral cartilage are not usually sharply demarcated at their edges with the snout. The undersurface is usually white but a black blotch is often present on the snout. Until recently, the family Rhinobatidae included the giant guitarfishes (Glaucostegidae) and banjo rays (Trygonorrhinidae) but recent molecular analyses have shown that members of these three groups are distinct from each other. Guitarfishes, as defined herein, are provisionally represented by 3 genera (*Acroteriobatus, Rhinobatos* and *Pseudobatos*) and 31 valid species. However, based on mitochondrial DNA sequence comparisons, the amphi-American genus (*Pseudobatos*) is strongly divergent from the other genera and may belong within a separate family. Guitarfishes occur in all warm temperate and tropical oceans, inshore to well offshore on continental and insular shelves and slopes, to depths of at least 400 m. None of the species occurs in freshwater. As bottom-dwellers, they usually rest on, or lie partly concealed within soft mud or sandy sediments, rather than swimming actively in mid-water. Viviparous (aplacental) producing litters of up to 16 young. They feed mainly on small benthic invertebrates and fishes (Last et al., 2016).

- **Genus *Acroteriobatus* Giltay, 1928**

  - *Acroteriobatus andysabini* (2021) (Malagasy blue-spotted guitarfish)
  - *Acroteriobatus annulatus* (Müller & Henle, 1841) (Lesser guitarfish)
  - *Acroteriobatus blochii* (Müller & Henle, 1841) (Bluntnose guitarfish)
  - *Acroteriobatus leucospilus* (Norman, 1926) (Grayspotted guitarfish)
  - *Acroteriobatus ocellatus* (Norman, 1926) (Speckled guitarfish)
  - *Acroteriobatus omanensis* Last, Hendeson & Naylor, 2016 (Oman guitarfish)
  - *Acroteriobatus salalah* (Randall & Compagno, 1995) (Salalah guitarfish)
  - *Acroteriobatus stehmanni* (Weigmann, Ebert & Séret, 2021) (Socotra blue-spotted guitarfish)
  - *Acroteriobatus variegatus* (Nair & Lal Mohan, 1973) (Stripenose guitarfish)
  - *Acroteriobatus zanzibarensis* (Norman, 1926) (Zanzibar guitarfish)

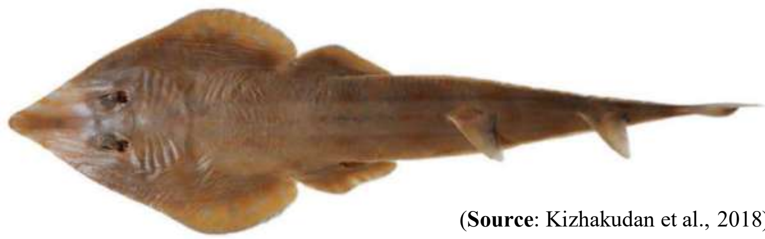
- **Genus *Pseudobatos* Last, Seret, and Naylor, 2016**

  - *Pseudobatos buthi* Rutledge, 2019 (Spadenose guitarfish)
  - *Pseudobatos glaucostigmus* (Jordan & Gilbert, 1883) (Speckled guitarfish)
  - *Pseudobatos horkelii* (Müller & Henle, 1841) (Brazilian guitarfish)
  - *Pseudobatos lentiginosus* (Garman, 1880) (Atlantic guitarfish)
  - *Pseudobatos leucorhynchus* (Günther, 1867) (Whitesnout guitarfish)
  - *Pseudobatos percellens* (Walbaum, 1792) (Chola guitarfish)
  - *Pseudobatos planiceps* (Garman, 1880) (Pacific guitarfish)
  - *Pseudobatos prahli* (Acero & Franke, 1995) (Gorgona guitarfish)
  - *Pseudobatos productus* (Ayres, 1854) (Shovelnose guitarfish)

- **Genus *Rhinobatos* Linck, 1790**

  - *Rhinobatos albomaculatus* Norman, 1930 (White-spotted guitarfish)
  - *Rhinobatos annandalei* Norman, 1926 (Annandale's guitarfish)
  - *Rhinobatos borneensis* Last, Séret & Naylor, 2016 (Borneo guitarfish)
  - *Rhinobatos holcorhynchus* Norman, 1922 (Slender guitarfish)
  - *Rhinobatos hynnicephalus* Richardson, 1846 (Ringstreaked guitarfish)
  - *Rhinobatos irvinei* Norman, 1931 (Spineback guitarfish)
  - *Rhinobatos jimbaranensis* Last, White & Fahmi, 2006 (Jimbaran shovelnose ray)
  - *Rhinobatos lionotus* Norman, 1926 (Smoothback guitarfish)
  - *Rhinobatos nudidorsalis* Last, Compagno & Nakaya, 2004 (Bareback shovelnose ray)
  - *Rhinobatos penggali* Last, White & Fahmi, 2006 (Indonesian shovelnose ray)
  - *Rhinobatos punctifer* Compagno & Randall, 1987 (Spotted guitarfish)
  - *Rhinobatos rhinobatos* Linnaeus, 1758 (Common guitarfish)
  - *Rhinobatos sainsburyi* Last, 2004 (Goldeneye shovelnose ray)
  - *Rhinobatos schlegelii* Müller & Henle, 1841 (Brown guitarfish)
  - *Rhinobatos whitei* Last, Corrigan & Naylor, 2014 (Philippine guitarfish)

***Acroteriobatus variegatus* (Nair & Lal Mohan, 1973) (Stripenose guitarfish)**



(**Source**: Kizhakudan et al., 2018)

Medium-sized guitarfish with flattened, wedge-shaped disc with strongly depressed trunk and triangular snout, anterior nasal flaps extending well into internasal space (barely separated), denticles along midline of dorsal surface distinct, dorsal fins widely separated, 2.7-2.9 of first dorsal fin base, tail 1.4-1.6 times disc length, dorsal surface yellow-brown with pale blotches, snout pale translucent with yellow bars/spots, rear margin of disc yellow with bluish lines, Maximum size: 80 cm TL.

***Rhinobatos annandalei* Norman, 1926 (Annandale's guitarfish)**

Medium sized guitarfish with a broad, flattened wedge shaped disc with strongly depressed trunk and triangular snout, denticles along midline of dorsal surface and around eyes, anterior nasal flaps extending slightly into internasal space, disc broader in females than in males, dorsal fins separated by 2.2-2.4 times first dorsal fin base, tail 1.2-1.3 times disc length, body greyish-brown, with numerous round, whitish spots; white ventrally, Maximum size: 95 cm TL.

***Rhinobatos lionotus* Norman, 1926 (smoothback guitarfish**

Medium sized guitarfish with a broad, flattened wedge shaped disc with strongly depressed trunk, snout triangular, thin disc, 1.2-1.4 times the width, rostral ridge present, anterior nasal flaps well into internasal space, dorsal fins moderately separated by 2.4-2.8 times first dorsal base length, body greenish-brown, with numerous dark brown spots; dorsal fin margins dusky posteriorly; white ventrally, Maximum size: 85 cm TL.

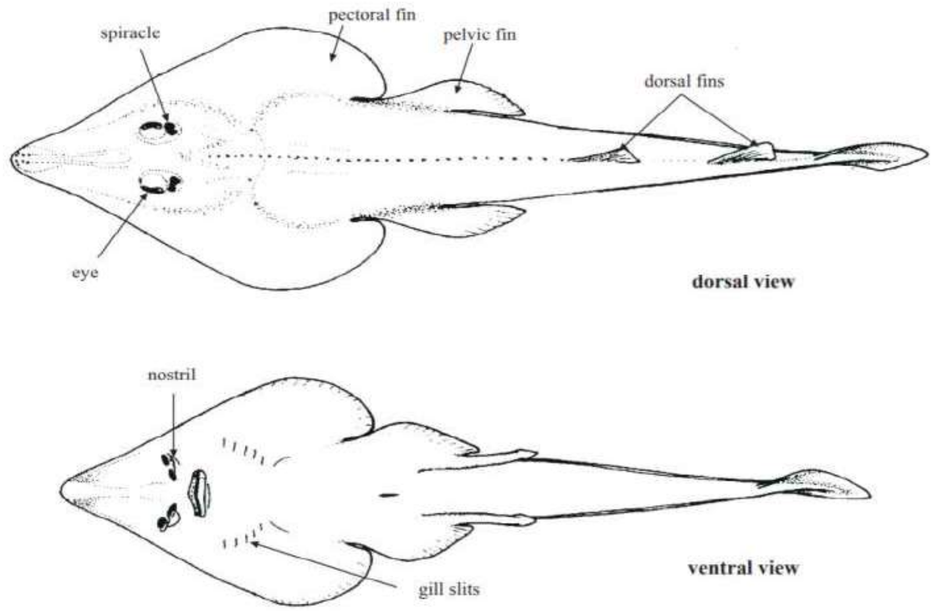
Rhinobatos lionotus

***Rhinobatos punctifer* Compagno & Randall, 1987 (spotted guitarfish)**

Medium sized guitarfish with a broadly angular wedge shaped disc with a strongly depressed trunk, triangular snout, small denticles on midline of body, anterior nasal flaps slightly into internasal space, dorsal fins widely separated, 2.4-2.5 times first dorsal fin base, tail 1.5 times disc length, dorsal surface yellow brown to greyish, often with numerous small white spots; white ventrally, Maximum size: 90 cm TL.

Giant guitarfishes (Glaucostegidae)

Giant guitarfishes are large to very large rays with a flattened, spade-like to wedge-shaped disc and a robust, depressed shark-like trunk. Their snout is typically long and its tip varies from being acute or bluntly rounded, to protruding forward as a large bulbous lobe. Eyes typically small and widely separated, spiracles also small with 1–2 variably developed folds. Nostrils are long and almost transverse to oblique with many lamellae (up to 94). They lack a nasal curtain and the anterior nasal flaps are relatively narrow and joined posteriorly to the inner edge of the nostril. Mouth profile is straight. The skin is covered with fine denticles, with small thorns variably confined to a row along mid-line of body, and small patches near eyes, on shoulder and sometimes on snout (often better developed in young than adults). Longbased pelvic fins are positioned laterally, posterior to the disc. Two similarly shaped, upright dorsal fins are well separated, and the first is positioned well behind the tips of the pelvic fins. A small, posteriorly directed caudal fin lacks an obvious ventral lobe typical of wedgefishes (Rhinidae). Colour is plain brownish or greyish dorsally with anterior cranium and rostral cartilage sharply demarcated from a much paler translucent snout. None of the species has spots, stripes or blotches. The undersurface is usually white but the ventral snout appears weakly translucent and its tip can have a black blotch. Giant guitarfishes were only recently recognized as a separate family, with a single genus and 6 valid species. The group was once classified with guitarfishes (Rhinobatidae) but molecular analyses have shown that they are more closely related to sawfishes (Pristidae). Giant guitarfishes are primarily inhabitants of subtropical and tropical inshore continental and insular seas of the Indo–Pacific and Eastern Atlantic, including the Mediterranean Sea. They occur in intertidal habitats and some species have been recorded from fresh and brackish waters. Bottom-dwellers, often resting on soft mud or sandy bottoms, they are also strong swimmers. All species are ovoviviparous. They feed mainly on benthic invertebrates, but their diet includes small benthic fishes. Most are large, reaching 1.7–3 m (5.6–9.8 ft) in length depending on the exact species involved, except for the small *G. obtusus* that is less than 1 m (3.3 ft) (Last et al., 2016).



(**Source**: FAO, 1999)

- *Glaucostegus cemiculus* (Geoffroy St. Hilaire, 1817) (Blackchin guitarfish)
- *Glaucostegus granulatus* Cuvier, 1829 (Sharpnose guitarfish)
- *Glaucostegus halavi* Forsskål, 1775 (Halavi guitarfish)
- *Glaucostegus obtusus* (Müller & Henle, 1841) (Widenose guitarfish)
- *Glaucostegus thouin* (Anonymous, 1798) (Clubnose guitarfish)
- *Glaucostegus typus* (Bennett, 1830) (Giant guitarfish)
- *Glaucostegus granulatus* Cuvier, 1829 (Sharpnose guitarfish)

***Glaucostegus granulatus* Cuvier, 1829 (Sharpnose guitarfish)**

Large sized guitarfish with flattened, narrow, wedge shaped disc with a strongly depressed trunk, snout elongate, narrowly triangular and bluntly pointed tip, rough skin, denticles enlarged on back and top of head and mostly joined along their entire length in midline, spiracular folds short and widely separated, dorsal fins closely located, interspace 1.3-1.6 times first dorsal fin base, tail 1- 1.4 times disc length, dorsal uniformly yellow or brown in colour, fin margins pale, snout translucent except rostral cartilage; white ventrally, Maximum size: 230 cm TL.

Glaucostegus granulatus

Glaucostegus obtusus

Glaucostegus obtusus **(Müller & Henle, 1841) (Widenose guitarfish)**

Small sized guitarfish with a flattened, broad shovel-shaped disc strongly depressed trunk, snout short and broadly triangular, denticles enlarged on back and thorns on snout tip and around orbit, One small spiracular fold, nasal flaps barely penetrating into interdorsal space, dorsal fins short, closely located, dorsal uniformly grey or grey brown, white ventrally, fin margins pale, snout translucent, Maximum size: 93 cm TL.

Glaucostegus thouin **(Anonymous, 1798) (Clubnose guitarfish)**

Large sized guitarfish with a flattened, large wedge-shaped disc; strongly depressed trunk, snout elongated with a bulbous tip, projecting well forward, denticles on back along their entire length, spiracular folds short and widely separated, dorsal fins closely located, interspace 2-2.5 times first dorsal fin base length, dorsal uniformly yellow or brown without blotches or spots, fin margins pale, snout margins translucent; snout tip greyish, disc white ventrally, Maximum size: 300 cm TL.

Glaucostegus thouin (**Source**: Kizhakudan et al., 2018)

Banjo rays (Family Trygonorrhinidae)

Banjo rays are small to large guitarfishes with a broad, flattened sub-oval to wedge-shaped disc, and a rather narrow, depressed trunk. The snout varies from very long and pointed to rather short and broadly rounded. Eyes and spiracles are small to medium-sized, and the spiracle has either 1 well-developed fold or none. Nostrils short and almost horizontal. Anterior nasal flaps are very broad, extending over entire length of nostril, with a long median lobe. A broad nasal curtain is present in one genus (Trygonorrhina). Mouth profile is weakly convex to strongly arched. The skin is covered with fine to very coarse denticles, with small to very large thorns in row along mid-line of body, and usually small patches near eyes and on shoulders. Short- to long-based pelvic fins are positioned laterally behind disc. Two tilted dorsal fins are well separated with the first well to slightly behind tips of the pelvic fins. Caudal fin small and lacks a prominent ventral lobe. All species have strong colour patterns consisting of lines, bars, spots and blotches on the dorsal surface, but the cranium and rostral cartilage are not usually sharply demarcated at their edges with the snout. The undersurface is mainly white but black blotches are sometimes present on the snout and posterior disc. Until recently, banjo rays were included in the guitarfishes (Rhinobatidae), but molecular research has shown that members of these groups are distinct from each other. Banjo rays are represented by 3 genera (*Aptychotrema, Trygonorrhina and Zapteryx*) and 8 valid species. They occur in temperate and tropical seas, primarily inshore on continental shelves but also to ~220 m depth. None of the species occurs in freshwater. Bottom-dwellers, they rest on soft and hard substrates, including seagrasses. Viviparous (aplacental) producing large litters of up to 18 pups. Diet consists primarily of small benthic invertebrates and fishes. They grow up to 1.5 m TL (Last et al., 2016).

- ***Aptychotrema* Norman, 1926**
  - *Aptychotrema rostrata* Shaw, 1794 (Eastern shovelnose ray)
  - *Aptychotrema timorensis* Last, 2004 (Spotted shovelnose ray)
  - *Aptychotrema vincentiana* Haacke, 1885 (Western shovelnose ray)

- ***Trygonorrhina* J. P. Müller & Henle, 1838**
  - *Trygonorrhina dumerilii* (Castelnau, 1873) (Southern fiddler ray)
  - *Trygonorrhina fasciata* J. P. Müller & Henle, 1841 (Eastern fiddler ray)

- ***Zapteryx* D. S. Jordan & C. H. Gilbert, 1880**
  - *Zapteryx brevirostris* J. P. Müller & Henle, 1841 (Shortnose guitarfish)
  - *Zapteryx exasperata* D. S. Jordan & C. H. Gilbert, 1880 (Banded guitarfish)
  - *Zapteryx xyster* D. S. Jordan & Evermann, 1896 (Southern banded guitarfish)

Additional families

Two additional families are associated with the order but their phylogenetic relationships have not been fully resolved:

- Family Platyrhinidae (fanrays)
- Family Zanobatidae (panrays)

Platyrhinidae

The Platyrhinidae are a family of rays, commonly known as thornbacks due to their dorsal rows of large thorns. They resemble guitarfishes in shape. Though traditionally classified with stingrays, molecular evidence suggests they are more closely related to electric rays in the order Torpediniformes.

- **Genus *Platyrhina* J. P. Müller & Henle, 1838**

  - *Platyrhina hyugaensis* Iwatsuki, Miyamoto & Nakaya, 2011 (Hyuga fanray)
  - *Platyrhina sinensis* Bloch & J. G. Schneider, 1801 (fanray)
  - *Platyrhina tangi* Iwatsuki, J. Zhang & Nakaya, 2011 (yellow-spotted fanray)

- **Genus *Platyrhinoidis* Garman 1881**

  - *Platyrhinoidis triseriata* D. S. Jordan & Gilbert, 1880 (thornback guitarfish)

Zanobatidae

The panrays are a genus, *Zanobatus*, of rays found in coastal parts of the warm East Atlantic Ocean, ranging from Morocco to Angola. It is the only genus in the family Zanobatidae, which traditionally has been included in the Myliobatiformes order, but based on genetic evidence it is now in Rhinopristiformes or a sister taxon to Rhinopristiformes.

The two species of panrays are generally poorly known and one of the species was only scientifically described in 2016. They are up to about 60 cm (2 ft) long, and brownish above with a heavily mottled, blotched or barred dark pattern. They are ovoviviparous and feed on benthic invertebrates.

There are two recognized species in the genus:

- *Zanobatus maculatus* Séret, 2016 (Maculate panray)
- *Zanobatus schoenleinii* (J. P. Müller & Henle, 1841) (Striped panray)

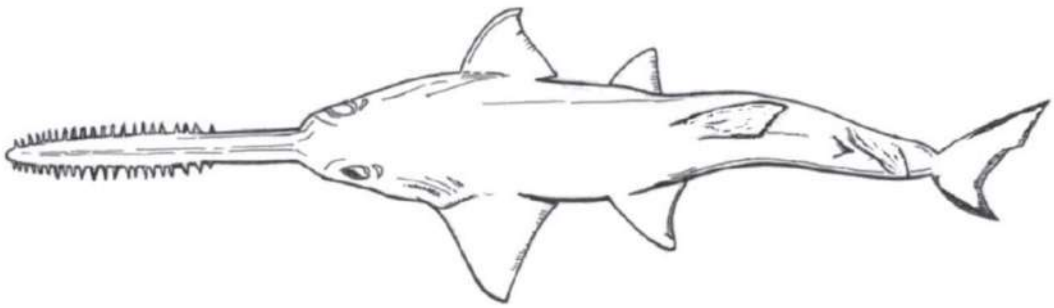
Sawfishes (Family Pristidae)

Sawfishes are amongst the largest of all rays. Their snout is greatly extended to form a hard, flattened blade armed along each edge with a row of sharp, tooth-like denticles – hence the common name 'sawfishes'. The shape of the rostrum and the number, size and position of these rostral teeth differ between species. A shark group, the sawsharks (Pristiophoridae), resemble sawfishes in having a highly modified blade-like snout edged with rostral teeth, but have barbels on the snout and their gills located on the side of the head rather than its undersurface. Unlike other ray groups, the pectoral fins of sawfishes are not fused to the body to form an obvious disc. A sawfish's body is strong, elongate and more or less sub-cylindrical with a slightly flattened head projecting well forward of the pectoral fins. Eyes are positioned near the sides of the head. Nostrils lie posterior to the toothed part of the rostrum and the mouth is broad and transverse. The two dorsal fins are similar in shape and rather tall, with the first dorsal fin located fully or partly above the pelvic fins. Caudal fin is well developed and its ventral lobe is variably extended depending on the species. All species are plain coloured varying from yellowish, brownish, greyish or greenish above. The family includes 2 genera and 5 valid species. Sawfishes once occurred worldwide in warm temperate to tropical rivers and inshore continental waters, but their abundance and distribution globally has declined dramatically over the last century. Some species are now regionally extinct and all are considered endangered. Sawfishes are largely benthic, resting on or feeding near the bottom. Their highly modified rostrum is used to stun prey such as invertebrates and small fishes. All species are viviparous (aplacental). Most species are large, reaching up to 7 m TL.

- *Anoxypristis cuspidata* (Latham, 1794) (Knifetooth sawfish)
- *Pristis clavata* Garman, 1906 (Dwarf sawfish)
- *Pristis pectinata* Latham, 1794 (Smalltooth sawfish)
- *Pristis zijsron* Bleeker, 1851 (Green sawfish)
- *Pristis pristis* (Linnaeus, 1758) (Largetooth sawfish)

Anoxypristis cuspidata **(Latham, 1794) (Knifetooth sawfish)**

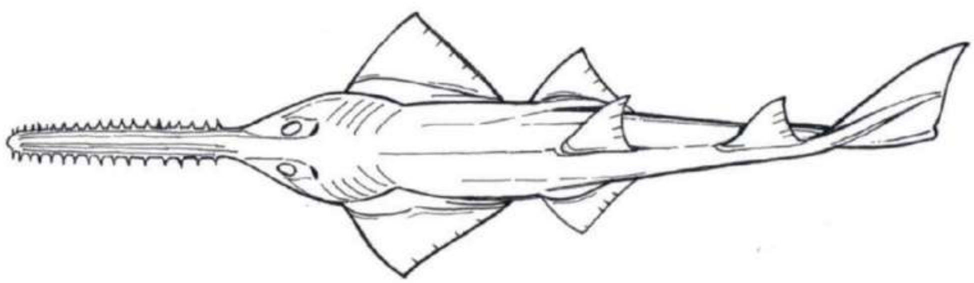
Medium sized sawfish with smooth skin, rostral saw very long and narrow, nearly 31% TL, rostral teeth absent on saw base, teeth slightly close together near tip than at middle of saw, first dorsal-fin origin posterior to pelvic-fin origin, caudal fin lunate, ventral lobe of caudal fin well developed, size >1/2 of upper. Small fleshy lobe in the outer margin of upper lobe, two lateral keels on caudal fin base, dorsal colour grey/yellowish brown with a bluish tinge, white ventrally, fins pale, Maximum size: 470 cm TL.



Anoxypristis cuspidata (**Source**: Kizhakudan et al., 2018)

Pristis zijsron **Bleeker, 1851 (Green sawfish)**

Very large and heavy sized sawfish with rough denticles on body, rostrum narrow and slender, nearly 23-33% TL, 23–37 pairs of rostral teeth (other Indian sawfishes 14-26), rostral teeth close together at tip of rostrum than base, first dorsal fin origin slightly posterior to pelvic fin origin, nearly half way across the base of pelvic, posterior margin of caudal fin straight in adult and convex in young, no fleshy lobe on the outer margin of upper lobe, no ventral lobe, single large median keel on caudal fin base, no short keel below this, dorsal colour uniformly olive to greenish brown, white ventrally, Maximum size: 730 cm TL.

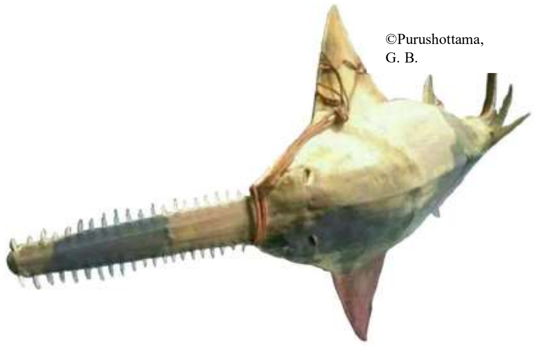


Pristis zijsron (**Source**: Kizhakudan et al., 2018)

Pristis pristis **(Linnaeus, 1758) (Largetooth sawfish)**

Very large and heavy sized sawfish with rough denticles on body, rostrum narrow and slender, nearly 23-33% TL, 23–37 pairs of rostral teeth (other Indian sawfishes 14-26), rostral teeth close together at tip of rostrum than base, first dorsal fin origin slightly posterior to pelvic fin origin, nearly half way across the base of pelvic, posterior margin of caudal fin straight in adult and convex in young, no fleshy lobe on the outer margin of upper lobe, no ventral lobe, single large median keel on caudal fin base, no short keel below this, dorsal colour uniformly olive to greenish brown, white ventrally, Maximum size: 730 cm TL

Pristis pristis



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CHAPTER 30

Myctophids in the Arabian Sea And its Systematics

Fish Stocks in the Arabian Sea

The northern Arabian Sea is the habitat of large mid-water fish stocks (Gjøsæter, 1984). These stocks reside all along the outer edges of the coastal zone of the Arabian Peninsula, off Pakistan, and the Gulf of Oman. Doubtless there are also sizeable stocks off Somalia and northern India. Off the Arabian Peninsula and in the Gulf of Oman these stocks are dominated by myctophids, mostly by *Benthosema pterotum*, although *Benthosema fibulatum*, *Diaphus arabicus* (Kinzer et al.1993), *Myctophum spinosum*, and *Symbolophorus evermanni* are occasional large contributors. Possibly the *B. pterotum* population is the largest, localized fish stock in the world, amounting to 100 million tons! It has been suggested that this very large stock of the one species derives from the very small stocks of all other fish; for some reason *B. pterotum* and other myctophids are the competitive dominants (GLOBEC, 1993).

Myctophiformes

Lantern fishes the order myctophiforms belongs to the Class Actinopterygii (ray-finned fishes). It contains two families: Myctophidae & Neoscopelidae

Characters of family Myctophidae: Head and body compressed. Eyes large and lateral. Mouth terminal extending beyond vertical through the middle of eye. Upper edge of jaw formed by premaxillary only. Teeth small. Rudimentary spine at base of dorsal, anal and upper-most pectoral and outermost ventral fin ray. Adipose fin present. Anal fin origin under or close behind base of dorsal fin. Scales cycloid or ctenoid. Photophores present, arranged in distinct groups on head and trunk. Small secondary photo pose on head, trunk and fins in some species. Luminous organs of various shapes and the size are present on head or caudal peduncle, and at base of adipose fin in some species.

Characters of family Neoscopelidae: Body elongate; head and body compressed. Mouth terminal; jaws extending to or beyond rear margin of orbit. Maxilla vomer and palatines. Pectoral fins well-developed, reaching to about anus. Origin of ventral fins well behind vertical through pectoral fin base. Origin of dorsal fin above vendor base; anal fin

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posterior to dorsal fin. Adipose fin present. Luminous organs on head absent. Photophores on body present or absent.

General characters of the order are, Head and body compressed; eye lateral (dorsolateral in the myctophids Hierops); mouth usually large and terminal; adipose fin present; usually 8 pelvic fin rays; usually 7-11 branchiostegal rays. Lantern fishes live all over the world except the Arctic Ocean. All are deep-and benthopelagic fishes as adults live in the middle depths of the open ocean, usually between 660 and 3,3300 ft (200 and 1000 m). Some may enter the upper part of the deep water region. Several lantern fishes are thought to live near, but not in contact with the bottom at the same point in life. Larval or young lantern fishes live near the surface, mainly between about 150 and 800 feet (50 - 2580 m)

Family – Myctophidae

Myctophidae belongs to the Class - Osteichthyes, Order - Myctophiformes. Worldwide there are more than 30 genera (230-250 species) of myctophid fishes with a size range of 3-30cm, most being under 15cm.

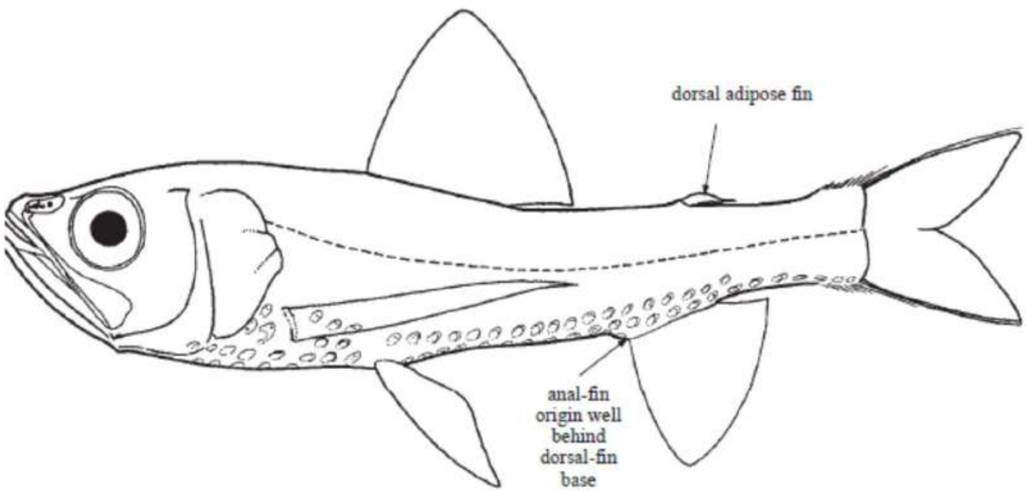
Systematics

Myctophids have a slender, compressed body covered with deciduous, cycloid or ctenoid scales, a prominent, bluntly rounded head with large elliptical to round eye and terminal mouth with rows of small teeth. Fins are generally small with a single dorsal fin, adipose fin, anal fin (with adipose plates at its base), paired fins (pectoral and pelvic; pectorals absent in some) and a forked caudal fin. Majority of the myctophids possess a gas bladder (that reflects sound and also helps in buoyancy), which become filled with lipids or degenerates during maturation (helps in egg production) in some species. An important characteristic of myctophids is the presence of non bacterial luminescent organs called photophores present along their ventral body surface and head. The presence of photophores forms an important diagnostic feature in identifying different species of various genera and also to distinguish between the male and female of the same genus. Though all the myctophids species have photophores, one species, *Taaningichthys paurolychnus,* completely lacks these organs. Interestingly all other members of this genus have these organs. The photophores emit blue, green or yellow light by chemical reaction. Each photophore is covered by a modified scale which acts as a lens to focus light. In *Diaphus sp*. There are two pairs of well developed light organs situated immediately in front of the eyes (and hence the name 'headlight fish'). The photophores are sexually dimorphic in nature especially the luminous glands present in the dorsal and ventral surface of caudal peduncle – supra caudal (dorsal) in male and infra caudal (ventral) in female; although male and female of some species *(Lampanyctus sp.* etc) possess both glands. The colour of the myctophids vary from bluegreen to silver in shallow dwelling species, while deep water species are dark brown to black.

Neoscopelids

Diagnostic characters: Small fishes, usually 15 to 30 cm as adults. Body elongate with no photophores (*Scopelengys*) or with 3 rows of large photophores when viewed from below (*Neoscopelus*). Eyes variable, small to large. Mouth large, extending to or beyond vertical from posterior margin of eye; tongue with photophores around margin in ***Neoscopelus***. Gill rakers 9 to 16. Dorsal fin single, its origin above or slightly in front of pelvic fin, well in front of anal

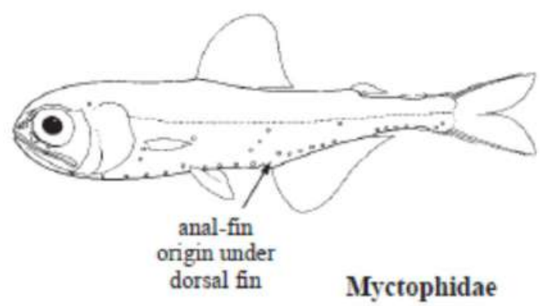
fins;11 to 13 soft rays. **Dorsal adipose fin** over end of anal fin. **Anal-fin origin well behind dorsal-fin base**, anal fin with 10 to 14 soft rays. Pectoral fins long, reaching to about anus, anal fin with 15 to 19 rays.Pelvic fins large, usually reaching to anus.Scales large, cycloid, and deciduous.
Colour: reddish silvery in *Neoscopelus*; blackish in *Scopelengys*.



Habitat, biology, and fisheries: Large adults of *Neoscopelus* usually benthopelagic below 1 000 m, but subadults mostly in midwater between 500 and 1 000 m in tropical and subtropical areas. *Scopelengys* mesoto bathypelagic. No known fisheries.

Remarks: Three genera and 5 species with *Solivomer* not known from the Atlantic. All Atlantic species probably circumglobal.

Similar families in occurring in area
Myctophidae: photophores arranged in groups not in straight horizontal rows (except *Taaningichthys paurolychnus* which lacks photophores). Anal-fin origin under posterior dorsal-fin base.



Gonostomatidae, Phosichthyidae, Sternoptychidae: certain genera with similar body form to, and might be confused with, neoscopleids. Almost all with 1 or 2 horizontal rows of photophores on body but lack median ventral row. Lack edentulate maxilla that is expanded posteriorly.

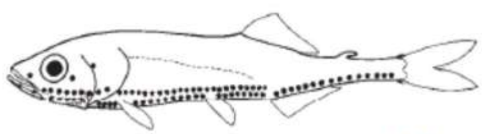
Key to the species of Neoscopelidae in the area

1a. Photophores present; eye large, about 1 in snout; upper jaw extending to about posterior margin of eye (Fig. 1)**. .** ***(Neoscopelus) _ 3***

1b. Photophores absent; eye small, about 3 in snout; upper jaw extending at least 1 eye diameter beyond eye (Fig. 2) **.** ***Scopelengys tristis***

2a. Upper lateral series of photophores extends well past midpoint of anal-fin base (Fig. 1); gill rakers usually 14 (rarely 15 or 16) **. . . . .** ***Neoscopelus microchir***

2b. Upper lateral series of photophores extends only to about anus (Fig. 3); gill rakers usually 11 (rarely 12 to 14)**. . . . .** ***Neoscopelus macrolepidotus***



Phosichthyidae

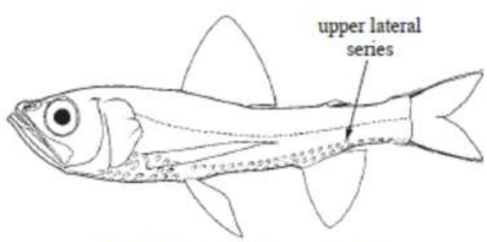


Fig. 1 *Neoscopelus microchir*

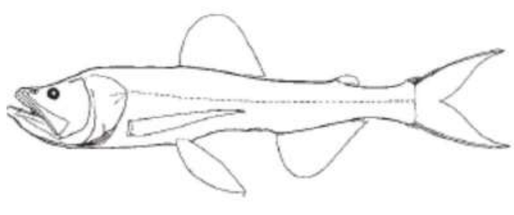


Fig. 2 *Scopelengys tristis*

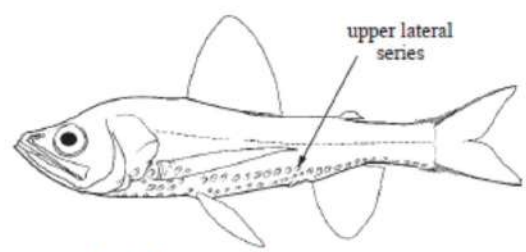


Fig. 3 *Neoscopelus macrolepidotus*

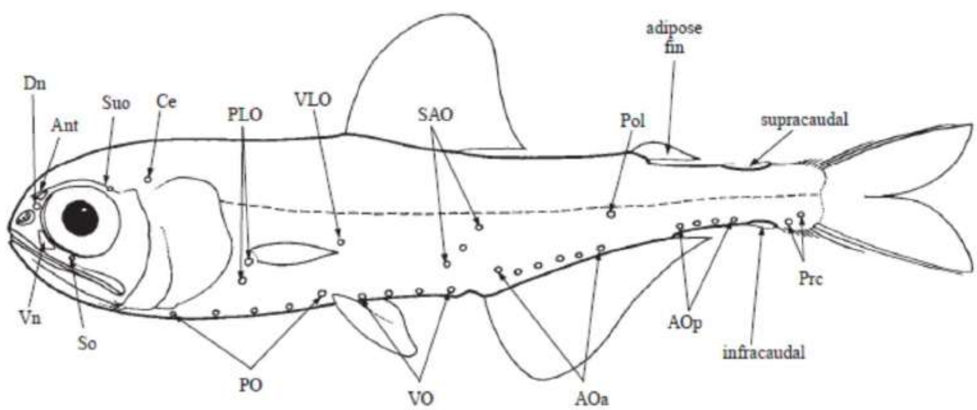
List of species occurring in the area

Neoscopelus macrolepidotus Johnson, 1863. To 23 cm. Tropical-subtropical.
Neoscopelus microchir Matsubara, 1943. To 30 cm. Tropical-subtropical.
Scopelengys tristis Alcock, 1890. To 20 cm. Tropical-subtropical.

MYCTOPHIDAE

Lanternfishes

Diagnostic characters: Small fishes, from 2 to 30 cm as adults. Body typically elongate although 2 area species, *Electrona risso* and *Myctophum selenops*, quite deep-bodied. Head large with jaws reaching posterior margin of eye and beyond. Eye large. Small teeth in bands on the premaxillaries and dentaries, sometimes flattened but seldom enlarged. Gill rakers well developed but absent in *Centrobranchus*. Dorsal- fin base at midbody, fin sometimes relatively high; posterior dorsal-fin base nearly above or behind anal-fin origin; 10 to 26 soft rays. Dorsal adipose fin present. Anal fin under or just behind base of dorsal fin;12 to 27 soft rays.Principal caudal-fin rays 10 + 9 = 19.Pectoral fins rudimentary to very long; 10 to 18 soft rays. Pelvic fins under or just before anterior base of dorsal fin; pelvic-fin soft rays usually 8 but 6 in *Notolychnus* and sometimes 7 in *Gonichthys*. Scales deciduous. Photophores present in groups on head and body in all but 1 area species, *Taaningichthys paurolychnus*. Additional luminous tissue may be found on head, scales, fins, and as glands on the upper and/or lower caudal peduncle. Colour: mainly brown to black in deeper water species, silvery in shallower water species; often with metalic blue or green scales.



Dn	-	dorso-nasal	Vn	-	ventronasal
And	-	antorbital	So	-	suborbital
Suo	-	supraorbital	PO	-	thoracic
Ce	-	cervical	VO	-	ventral
PLO	-	suprapectoral	AOa	-	anterior anal
VLO	-	supraventral	AOp	-	posterior anal
SAO	-	supra-anal	Prc	-	precaudal

general distribution and terminology of the luminous organs (photophores)

Habitat, biology, and fisheries: Typically,myctophids are pelagic fishes of the open ocean. Most species are found in the upper 1 000 m of the water column (mesopelagic). A few species live deeper than 1 000 m (bathypelagic).Some species are associated with continental and island slopes (pseudoceanic). Daily vertical migrations from about 400 to 1 000 m during the day into the upper 200 m at night are common; some species reach the surface.The light produced by the various light-producing organs is the result of relatively simple oxidation of luciferin in the presence of the enzyme luciferase. Myctophids are abundant in some areas, making up a large portion of the total biomass. Many myctophid species are found in Area 31 because it includes elements of tropical, sub-tropical, and even temperate faunas. Myctophids are very important food for larger fishes, sea birds, and marine mammals. The only myctophid fisheries have been in the South Atlantic, Gulf of Oman, and Persian Gulf.

Remarks: Thirty-three genera and at least 240 species worldwide;20 genera and 77 species in the area. It is possible that certain species with wide distributions are, in fact, species complexes. The life histories of many lanternfish species are poorly known, especially of those species larger than 10 cm. Distributions given in the list of species apply only to the Atlantic; space does not allow discussion of extra-Atlantic occurrences.

Similar families occurring in area

Separated from most other families in the area by a lack of photophores and a dorsal adipose fin. Further distinguishing characters of these families are the following: Neoscopelidae: posterior dorsal-fin base well in advance of the anal-fin origin. *Neoscopelus* as large photophores in 3 longitudinal rows on body and along edge of tongue. *Scopelengys* lacks photophores and has a very small eye. Gonostomatidae, Phosichthyidae (Photichthyidae), Sternoptychidae: teeth conical or needle-like on both premaxilla and maxilla, never in bands. Almost all have 1 or 2 horizontal rows of photophores on body. None with a set of 3 photophores (SAO) at midbody, elaborate head photophores (Ant, Dn, Vn), or the supra- or infracaudal glands of myctophids.

Key to the genera and monotypic species of Myctophidae occurring in the area

Note: Identification and taxonomy of Myctophidae are based heavily on the arrangement of the various photophore groups as shown above.Caremust be taken in identifying the location and number of photophores. Photophores are often lost or damaged in nets so identification may be impossible.

1a. Two Prc photophores (Fig. 1a) **. . . . . . . _** ***2***

1b. Three or more Prc (1 may be at or above lateral midline at base of caudal peduncle) or none in *Taaningichthys paurolychnus* (Fig. 1b) **. . . . . _** ***12***

2a. Four photophores (VLO, SAO3, Pol, Prc2) well above the midlateral line (Fig. 2); specimens usually skinned and photophores often lost; small species, never over 2.5 cm **. . . . .** ***Notolychnus valdiviae***

2b. No photophores above lateral line**. . . . . . _** ***3***

3a. AO in a single uninterrupted series (Fig. 3, 4); Pol absent **. . . . . _** ***4***

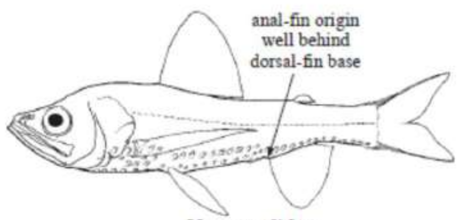
3b. AO divided into 2 groups, AOa and AOp (Fig. 5); Pol present (Fig. 5) **. . . . . . _** ***5***

4a. PVO1-2 inclined, in line with PO1 (Fig. 3); interorbital wide; eye normal, pointing laterally. . . . . ***Electrona risso***

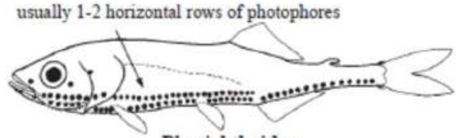
4b. PVO1-2 in an almost horizontal line (Fig. 4), a line through them markedly above PO1; interorbital very narrow; eyes pointed upward, almost telescopic. . . . . ***Protomyctophum arcticum*** (not in Area 31)

5a. Mouth terminal, snout not projecting (Fig. 5); jaws short, extending less than 1/2 eye diameter behind orbit. . . . . _ ***6***

5b. Mouth subterminal, snout projecting (Fig. 10); jaws moderate, extending 1/2 eye diameter behind orbit . . . . _ ***10***



Neoscopelidae



Phosichthyidae

Fig. 1 Prc photophores

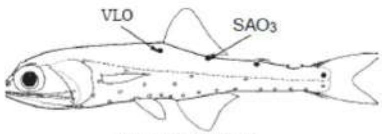


Fig. 2 *Notolychnus*

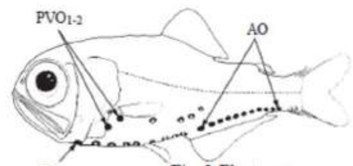
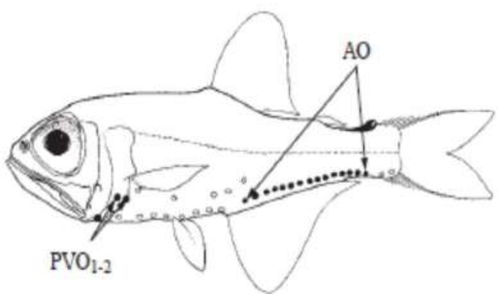


Fig. 3 *Electrona*



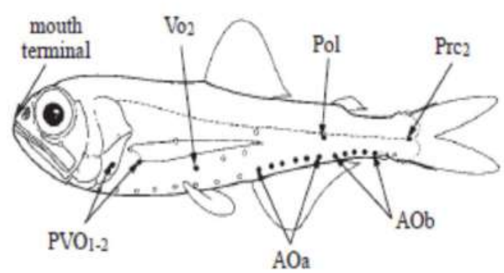


Fig. 4 *Protomyctophum arcticum*

Fig. 5 *Benthosema*

6a. PVO1-2 in a horizontal line (Fig. 5); VO2 elevated **. . . . . _** ***7***

6b. PVO1-2 in an inclined line (Fig. 7), with PVO2 usually more than 1 photophore diameter above PVO1; all VO level (Fig. 7)**. . . . . _** ***8***

7a. Prc2 high, from 1 to 2 photophore diameters below, or on, midlateral line (Fig. 5); teeth simple, never hooked **. . . . .** ***Benthosema***

7b. Prc2 low, level with Prc1 (Fig. 6); outer dentary teeth flattened and hooked forward **. . . . .** ***Diogenichthys atlanticus***

8a. Two Pol (Fig. 7) **. . . . .** ***Hygophum***
8b. One Pol (Fig. 8) **. . . . . _** ***9***
9a. SAO forming an almost right angle with SAO1 over or in advance of VO3 (Fig. 8) **. . .** ***Symbolophorus***
9b. SAO in an almost straight or slightly angled line with SAO1 well behind VO3 (Fig. 9) **. . .** ***Myctophum***
10a. Gill rakers absent (Fig. 10) **. . . . .** ***Centrobranchus nigroocellatus***

10b. Gill rakers present . . . . _ ***11***

11a. AOp 7 or fewer, at most 1 over anal base (Fig. 11); anal-fin origin about under middle of dorsal-fin base. . . . . . . ***Loweina***

11b. AOp 10 or more, with 5 to 7 over anal-fin base (Fig. 12); anal-fin origin under end of dorsal-fin base . . . ***Gonichthys cocco***

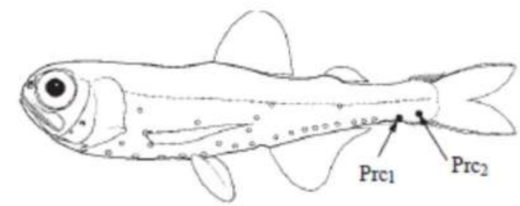


Fig. 6 *Diogenichthys atlanticus*

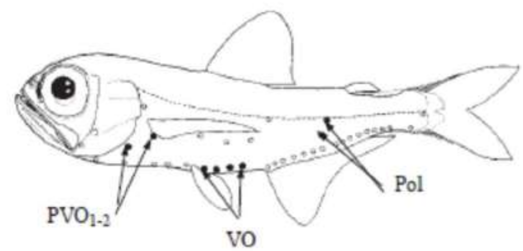


Fig. 7 *Hygophum*

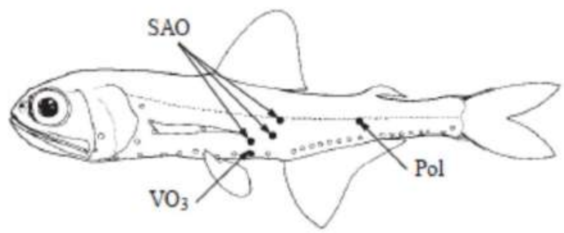


Fig. 8 *Symbolophorus*

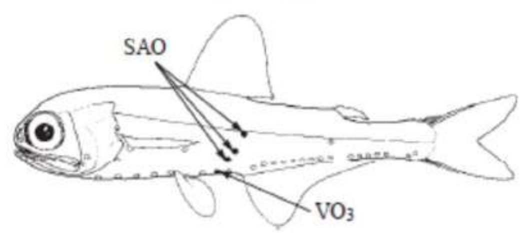


Fig. 9 *Myctophum*

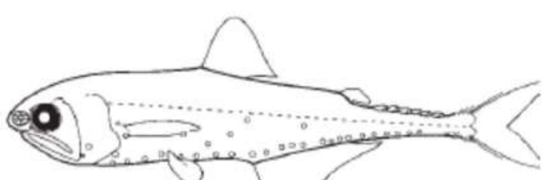


Fig. 10 *Centrobranchus nigroocellatus*

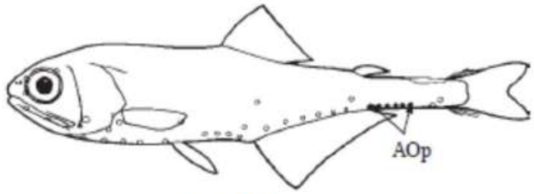


Fig. 11 *Loweina*

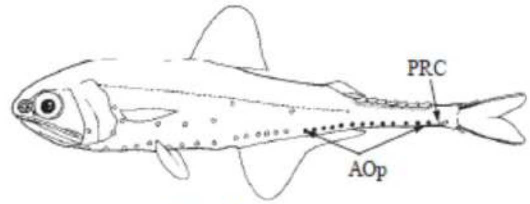


Fig. 12 *Gonichthys*

12a. Dn absent; VO and Pol never arranged as in 12b . . . . _ ***13***

12b. Dn present; either 2 horizontal Pol (Fig. 13) near lateral line or VO1-3 on a straight ascending line with VO4-5 level (Fig. 14). . . . . _ ***19***

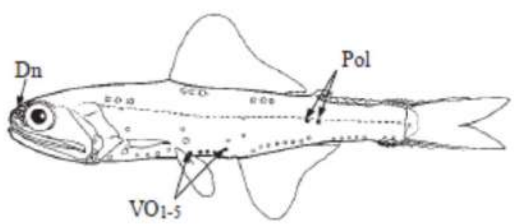


Fig. 13 *Notoscopelus*

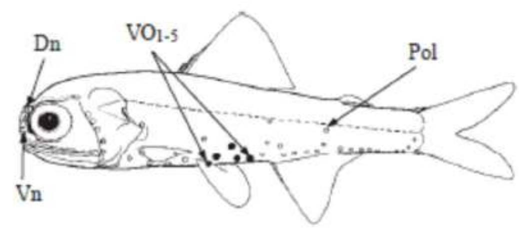


Fig. 14 *Diaphus*

13a. Supra- and infracaudal glands single organs bordered by heavy jet-black pigment (Fig. 15a). . . . . _ ***14***

13b. Supra- and infracaudal glands overlapping scale-like plates, never bordered by jet-black pigment (Fig. 15b) . . . . _ ***15***

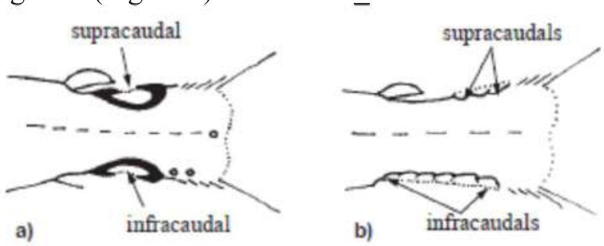


Fig. 15 caudal peduncle

14a. A large white crescent on posterior half of eye; dorsal-fin origin behind base of pelvic fin; only 1 SAO (at midbody) or none in *T. paurolychnus* (Fig. 16) . . . . ***Taaningichthys***

14b. No large white crescent on posterior half of eye; dorsal-fin origin over or slightly in front of pelvic fin; 3 SAO (Fig. 17) . . . . ***Lampadena***

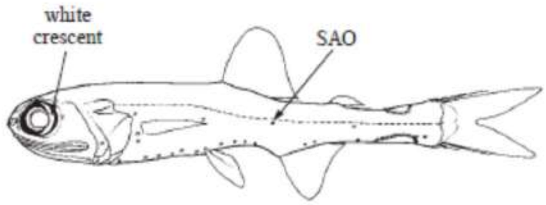


Fig. 16 *Taaningichthys*

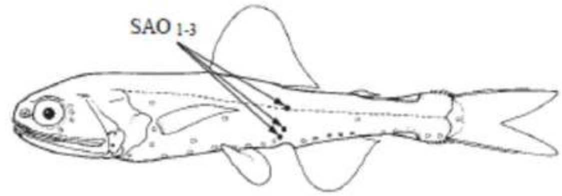


Fig. 17 *Lampadena*

15a. Luminous tissue restricted to caudal luminous glands and occasionally at base of adipose fin (Fig. 18) . . . . _ ***16***

15b. Luminous tissue over base of anal or dorsal fins and on other portions of body (Figs. 19, 20, 21) . . . . _ ***17***

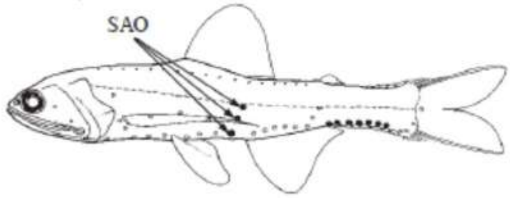


Fig. 18 *Lampanyctus*

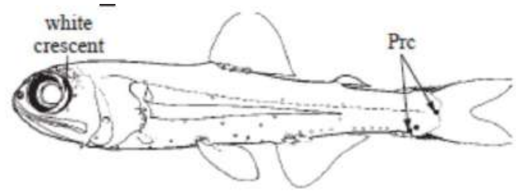


Fig. 19 *Bolinichthys*

16a. Pectoral fin long, at least reaching SAO photophores, often to anterior anal fin. (Fig. 18) . . . . ***Lampanyctus***

16b. Pectoral fin rudimentary or short, seldom reaching PO4 (note that *L. macdonaldi* is the onlyAtlantic *Lampanyctus* with a short pectoral fin but it has 21 or more gill rakers vs. fewer than21 in all *Nannobrachium*) . . . . ***Nannobrachium***

17a. Three (2+1) Prc; a whitish crescent on posterior half of eye; luminous tissue above eyes insome species (Fig. 19) . . . . ***Bolinichthys***

17b. Four (3+1) Prc; eye without whitish crescent; no luminous tissue above eyes (Figs. 20, 21) . . . . _ ***18***

18a. PO4 elevated; VO2 elevated (Fig. 20); no medial luminous tissue either at bases of pelvic fins or between pelvic fins and anal-fin origin; pectoral fin long, reaching adipose origin**.** ***Lepidophanes***

18b. PO4 not elevated; VO only slightly arched (Fig. 21); medial luminous tissue present at bases of pelvic fins or between pelvic fins and anal-fin origin; pectoral fins moderate, not reaching adipose fin . . . . ***Ceratoscopelus***

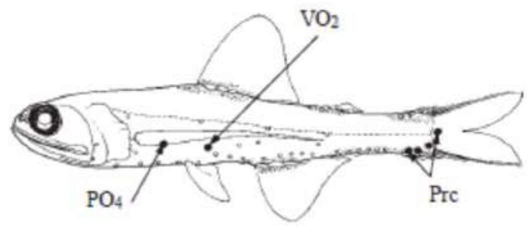


Fig. 20 *Lepidophanes*

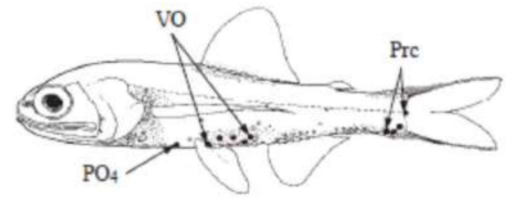


Fig. 21 *Ceratoscopelus*

19a. VO1-5 level; both supra- and infracaudal glands present in both sexes; 2 horizontal Pol near lateral line (Fig. 22) **. . . . .** ***Notoscopelus***

19b. VO1-3 on a straight, inclined, ascending line with VO4-5 level (Figs 23, 24); no caudal glands (*Diaphus*) or only 1 caudal gland (*Lobianchia*); 1 Pol **. _** ***20***

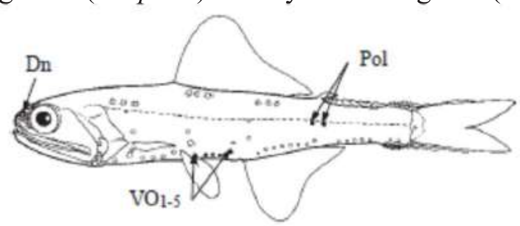


Fig. 22 *Notoscopelus*

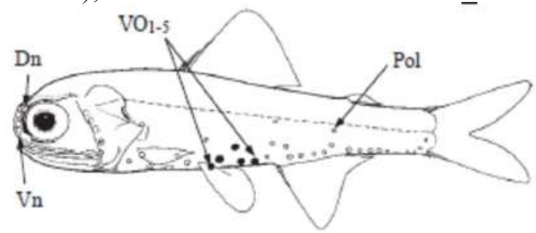


Fig. 23 *Diaphus*

20a. Caudal glands absent; more than 1 pair of luminous glands on head (Ant, Dn, Vn, or So); usually a luminous scale at PLO (Fig. 23) **. . .** ***Diaphus***

20b. Supracaudal (males) and infracaudal (females) well developed; 1 pair (Dn) of luminous organs on head; luminous scale at PLO absent (Fig. 24) **. . . . .** ***Lobianchia***

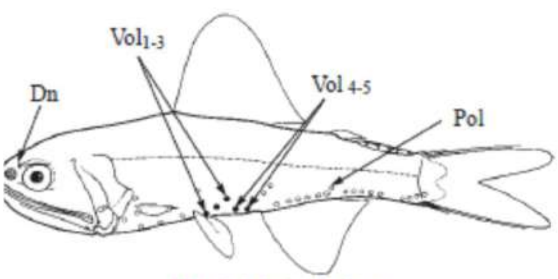


Fig. 24 *Lobianchia*

List of species occurring in the area

Benthosema glaciale (Reinhardt, 1837). To 7 cm. Subarctic S to N31.
Benthosema suborbitale (Gilbert, 1913). To 3.8 cm. Widespread, tropical to temperate.
Bolinichthys distofax Johnson, 1975. To 8.5 cm. Rare, tropical and S subtropical.
Bolinichthys indicus (Nafpaktitis and Nafpaktitis, 1969). To 4.5 cm. Bipolar subtropical.
Bolinichthys photothorax (Parr, 1928). To 6.5 cm. Tropical-subtropical, rarely N to Slope Water (SW21).
Bolinichthys supralateralis (Parr, 1928). To 11 cm. Widespread, tropical to temperate.
Centrobranchus nigroocellatus (Günther, 1873). To 5 cm. Widespread, tropical to temperate.

Ceratoscopelus maderensis (Lowe, 1839). To 7 cm. N temperate S to N 31.

Ceratoscopelus warmingii (Lütken, 1892). To 7.5 cm. Widespread, tropical to temperate.

Diaphus adenomus Gilbert, 1905. To 18 cm. Rare, pseudoceanic, W31 (and SE27).

Diaphus anderseni Tåning, 1932. To 3 cm. S subtropical, rare to SE31.

Diaphus bertelseni Nafpaktitis, 1966. To 8 cm. Rare, tropical-subtropical.

Diaphus brachycephalus Tåning, 1928. To 6 cm. Tropical-subtropical.

Diaphus dumerilii (Bleeker, 1856). To 8.6 cm. Tropical, common N to Slope Water (SW21).

Diaphus effulgens (Goode and Bean, 1896). To 15 cm. Bipolar subtropical.

Diaphus fragilis Tåning, 1928. To 9 cm. Tropical, rare N to Slope Water (SW31).

Diaphus garmani Gilbert, 1906. To 6 cm. Tropical, possibly pseudoceanic as adult.

Diaphus lucidus (Goode and Bean, 1896). To 12 cm. Tropical, rare N to Slope Water (SW21).

Diaphus luetkeni (Brauer, 1904). To 6 cm. Tropical, rare N to Slope Water (SW21).

Diaphus metopoclampus (Cocco, 1829). 7.5 cm. Bipolar temperate-subtropical.

Diaphus minax Nafpaktitis, 1968. To 6.6 cm. Extremely rare, pseudoceanic, only W31.

Diaphus mollis Tåning, 1928. To 6 cm. Widespread.

Diaphus perspicillatus (Ogilby, 1898). To 7 cm. Tropical, N to Slope Water (SW21).

Diaphus problematicus Parr, 1928. To 9 cm. Tropical.

Diaphus rafinesquii (Cocco, 1838). To 9 cm. Temperate, rare S to Gulf of Mexico.

Diaphus roei Nafpaktitis, 1974. To 11 cm. Rare, pseudoceanic, only 31.

Diaphus splendidus (Brauer, 1904). To 5.5 cm. Tropical-subtropical.

Diaphus subtilis Nafpaktitis, 1968. To 8.5 cm. Uncommon, tropical-subtropical.

Diaphus taaningi Norman, 1930. To 7 cm. Pseudoceanic, W31, Slope Water and off Africa.

Diaphus termophilus Tåning, 1928. To 7.5 cm. Tropical.

Diogenichthys atlanticus (Tåning, 1928). To 3 cm. Widespread, tropical to temperate.

Electrona risso (Cocco, 1829). To 8 cm. E Atlantic but rare stray to SE31.

Gonichthys cocco (Cocco, 1829). To 6 cm. Widespread, tropical to temperate.

Hygophum benoiti (Cocco, 1838). To 5.5 cm. N temperate-subtropical.

Hygophum hygomii (Lütken, 1892). To at least 6 cm. Bipolar temperate-subtropical.

Hygophum macrochir (Günther, 1864). To 6 cm. Tropical and S subtropical.

Hygophum reinhardtii (Lütken, 1892). To at least 5 cm. Probably tropical-subtropical.

Hygophum taaningi Bekker, 1965. To 5 cm. N tropical-subtropical.

Lampadena anomala Parr, 1928. To 15 cm. Rare, bathypelagic, tropical-subtropical.

Lampadena chavesi Collett 1905. To 7.5 cm. Bipolar subtropical.

Lampadena luminosa (Garman, 1899). To 18 cm. Tropical-subtropical.

Lampadena speculigera Goode and Bean, 1896. To 13 cm. Bipolar temperate to N31.

Lampadena urophaos atlantica Maul, 1969. To 23 cm. N subtropical.

Lampanyctus alatus Goode and Bean ,1896. To 6 cm. Widespread, mostly tropical.

Lampanyctus crocodilus (Risso, 1810). To 30 cm. N temperate to N31 and E 34.

Lampanyctus festivus Tåning, 1928. To 12 cm. Bipolar subtropical.

Lampanyctus intricarius Tåning, 1928. To 17 cm. Bipolar temperate, extremely rare N31.

Lampanyctus macdonaldi (Goode and Bean, 1896). To 14 cm. Bipolar temperate rare to N31.

Lampanyctus nobilis Tåning, 1928. To 11 cm. Tropical.

Lampanyctus photonotus Parr, 1928. To 7 cm. Widespread, tropical to temperate.

Lampanyctus pusillus (Johnson, 1890). To 4.3 cm. Bipolar, temperate-subtropical.

Lampanyctus tenuiformis (Brauer, 1906). To 12 cm. Tropical.

Lampanyctus vadulus Hully, 1981. To 9.9 cm. E tropical, W to SE31.

Lepidophanes gaussi (Brauer, 1906). To 4.8 cm. Bipolar subtropical.

Lepidophanes guentheri (Goode and Bean, 1896). To 7 cm. Widespread, tropical to temperate.

Lobianchia dofleini (Zugmayer, 1911). To 5 cm. Bipolar temperate-subtropical.
Lobianchia gemellarii (Cocco, 1838). To 11 cm. Tropical-subtropical.
Loweina interrupta (Tåning, 1928). To 3.9 cm. Extremely rare, temperate-subtropical.
Loweina rara (Lütken, 1892). To 4.5 cm. Rare, widespread.
Myctophum affine (Lütken, 1892). To 8 cm. Tropical, N in Slope Water.
Myctophum asperum Richardson, 1845. To 8.5 cm. Tropical, rare to Slope Water.
Myctophum nitidulum Garman, 1899. To 9.9 cm. Widespread, tropical to temperate.
Myctophum obtusirostre Tåning, 1928. To 9 cm. Tropical, rare to Slope Water.
Myctophum punctatum Rafinesque, 1810. To 10 cm. N subpolar-temperate.
Myctophum selenops Tåning, 1928. To 7.5 cm. Widespread, usually tropical-subtropical.
Nannobrachium atrum (Tåning, 1928). To 14 cm. Bipolar, temperate-subtropical.
Nannobrachium cuprarium (Tåning, 1928). To 11 cm. Bipolar, subtropical.
Nannobrachium isaacsi (Wisner, 1974). To 13 cm. E tropical to SE31.
Nannobrachium lineatum (Tåning, 1928). To 24 cm. Tropical-subtropical.
Notolychnus valdiviae (Brauer, 1904). To 2.5 cm. Widespread, tropical to temperate.
Notoscopelus caudispinosus (Johnson, 1863). To 14 cm. Tropical-subtropical.
Notoscopelus resplendens (Richardson, 1845). To 7.7 cm. Widespread, tropical to temperate.
Symbolophorus rufinus (Tåning, 1928). To 8.7 cm. Tropical-subtropical.
Symbolophorus veranyi (Moreau, 1888). To 5.8 cm. N temperate, rare to N31.
Taaningichthys bathyphilus (Tåning, 1928).To 8 cm. Bathypelagic, tropical-subtropical.
Taaningichthys minimus (Tåning, 1928). To 6.5 cm. Tropical-subtropical.*Taaningichthys paurolychnus* Davy 1972. To 9.5 cm. Extremely rare, bathypelagic.

Distribution

The myctophids, together with Gonostomatidae forms one of the most dominant fish species in the mesopelagic realm of the world oceans, from Arctic to Antarctic. Other fish groups include Neoscopelidae (Blackchins), Sternoptychidae (Hatchet fishes), Chiasmodontidae (Swallowers), Nomeidae (Man-of-War fishes), Bathylagidae (Deep-sea smelts) etc. Though mesopelagic fish are found in all oceans, their annual production and species diversity is found to be more in tropical
and sub-tropical waters. Myctophids are distributed throughout the world oceans from Arctic to Antarctic waters. Though many are meso or bathypelagic species, some were found to inhabit the continental slope regions. Larval forms of many deep water species are also found to inhabit inshore waters. Worldwide, myctophid larvae make up at least 50% of all fish larvae taken in open water plankton tows. Species distribution is related to the currents and other physical and chemical characteristics of ocean.

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CHAPTER 31

Overview of Crustacean Fisheries & Crab Taxonomy in India

Introduction

Crustaceans are one of the most valuable resources in the marine fishery in India and contributed an overall average of 14.9 % to the total landings during 1996-2019. Marine commercial crustacean resources mainly comprised of penaeid prawns, non-penaeid prawns, crabs, lobsters and stomatopods. Many species are exploited along the east and west coasts of India, mainly in trawls, seines and gill nets. The state of Gujarat was leading in overall Crustacean production contributing 30.2% of all India landings, followed by States of Maharashtra (22.5%) and Kerala (12.9%). The overall trend of the fishery (1981-2020) showed increase at national level, recording a maximum landing of 532851 tonnes during 2011 and the lowest, 192324 tonnes during 1981 with an overall average of 390063 tonnes. Resource-wise trend also, showed increase except for lobsters and stomatopods. The details are presented in the figures (Figs. 1- 5).

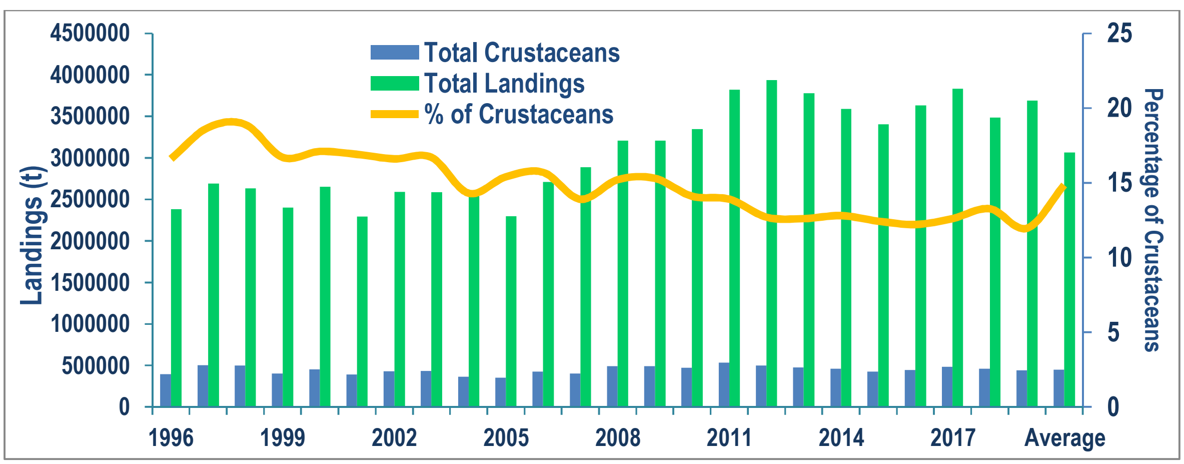


Fig. 1. Total marine fish and crustacean landings (t) in India during 1996-2019.

Jose Josileen *ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala*

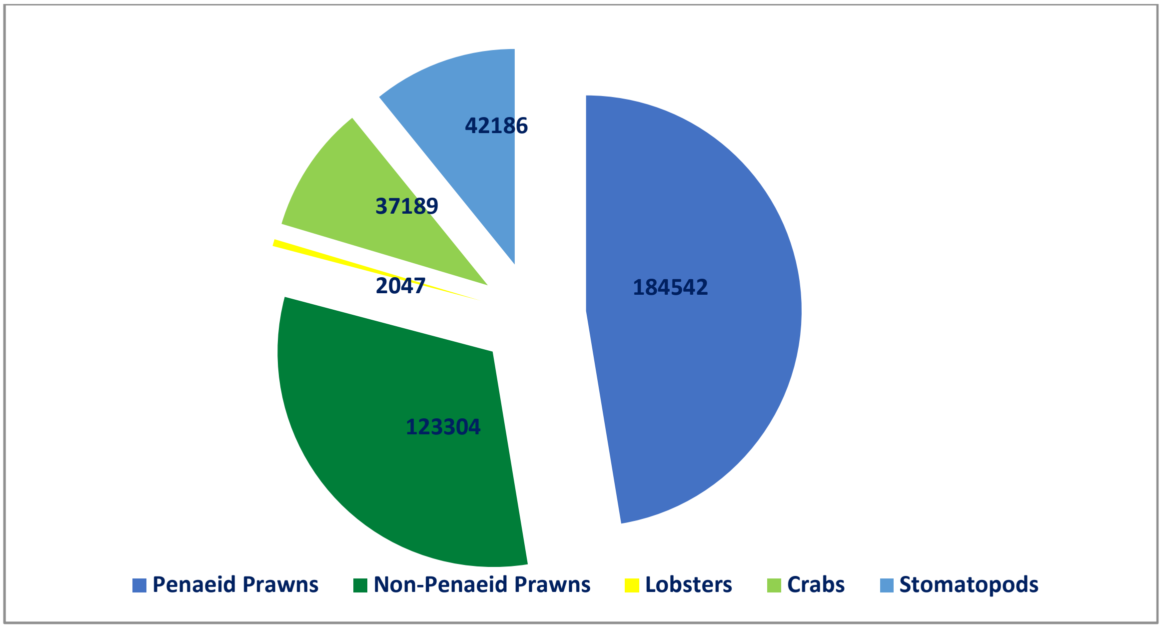


Fig. 2. Average production (t) of crustacean resources in India during 1981-2020.

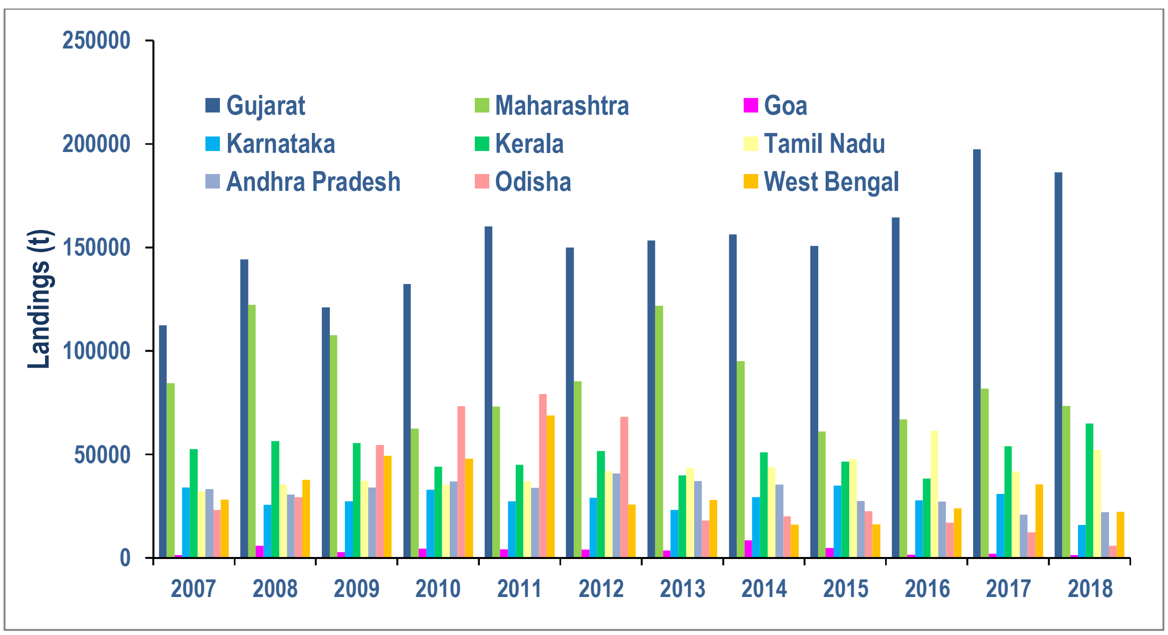


Fig. 3. State-wise Crustacean landings (t) in India during 2007-2018.

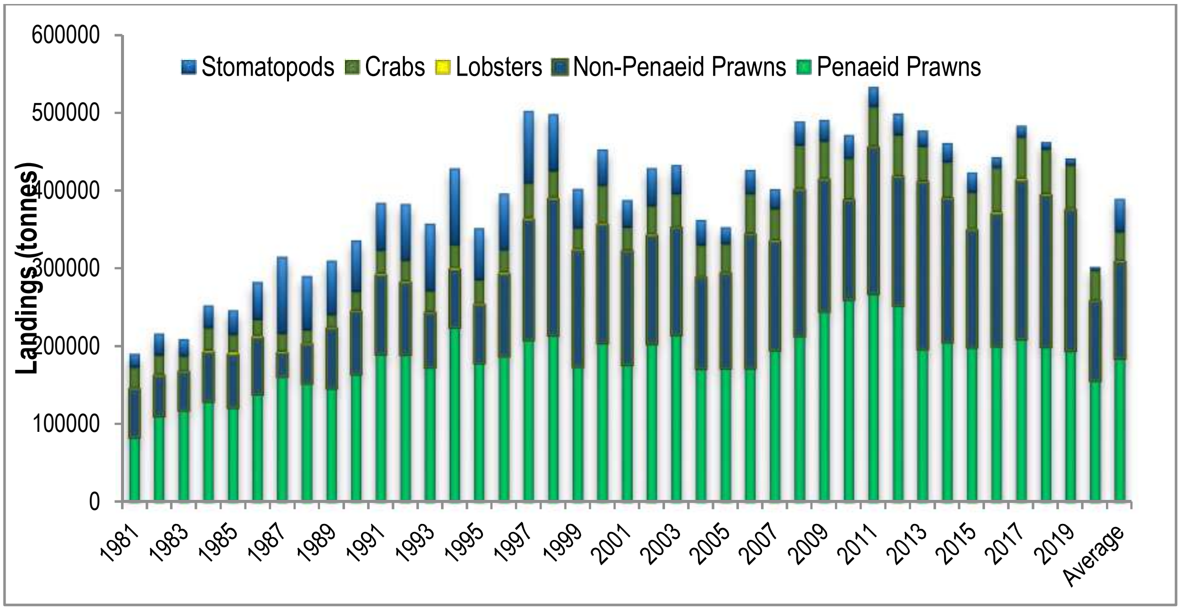


Fig.4. Annual production (t) of crustacean resources in India during 1981-2020.

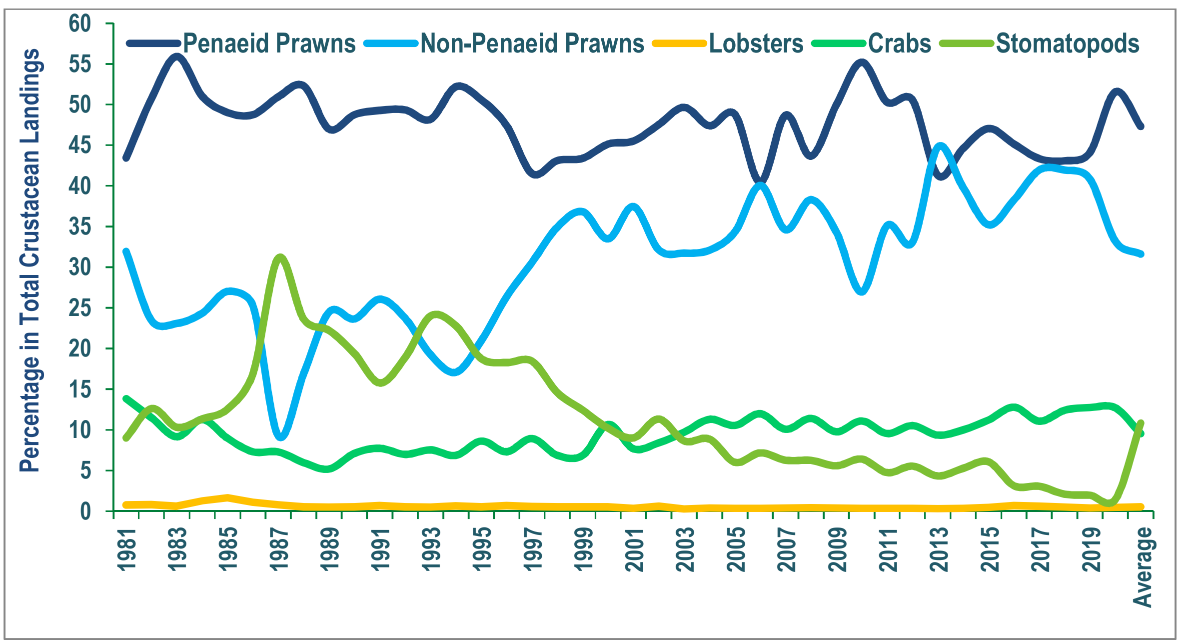


Fig.5. Percentage of various crustacean resources in India during 1981-2020.

Prawn Fisheries of India

Most of the commercial species of prawns* belong to the penaeoidea. Studies on penaeoids are more comprehensive and at present 5 families, 23 genera and 121 species (including the introduced species) are known to occur along the Indian coast including the Lakshadweep and Andaman and Nicobar Islands, with the penaeidae being the most important family (Radhakrishnan et al., 2011). As species of penaeidae are generally of moderate to large in size occupying large quantities in shallow waters along the continental shelf in trawlable bottoms, they are fished extensively by trawls, gillnets and seines.

About 16 genera and 73 species of penaeids are known to occur along the Indian coast and adjoining seas. Among these, the genus *Penaeus* is of great economic importance followed by *Metapenaeus, Parapenaeopsis* and *Kishinouyepenaeopsis*. The other genus seems to be less abundant, although *Metapenaeopsis* and *Trachysalambria* are frequently found among prawn landings and have some commercial value (Radhakrishnan and Josileen, 2013). Total penaeid prawn landings during 1981-2020 and major commercial species are presented in the figure 6 and table 1.

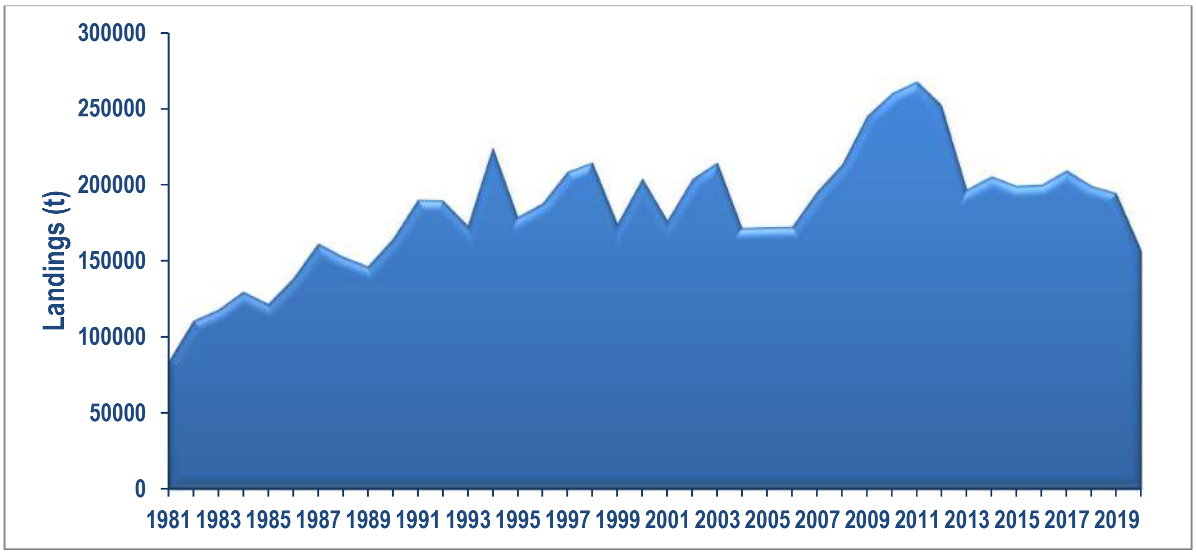


Fig. 6. Total penaeid prawn landings (t) in India during 1981-2020.

[*The terms 'shrimp' and 'prawn' are not related to any known taxonomic group. Although the term 'shrimp' is applied to smaller species, and 'prawn' to large forms, there is no clear distinction between both terms and their usage is often confused or reverse in different countries or regions (Chan, 1998)].

Non-penaeids contributed 31.6% of the total crustacean production in India during 1981-2020. Although non-penaeid prawns are found all along the coastline, they form fisheries of commercial importance only along the northwest and the northeast coasts contributed mainly by states of Maharashtra, Gujarat, Andhra Pradesh and West Bengal. The non-penaeid prawns are generally caught by the fixed bag nets, called 'dol' nets, in Maharashtra and Gujarat and by a variety of gears, such as stake nets, scoop nets, shore seines, boat seines and drag nets in other states. Besides these gears, they are occasionally caught in the trawls also. The total non-penaeid landings during 1981-2020 is presented in the figure 7.

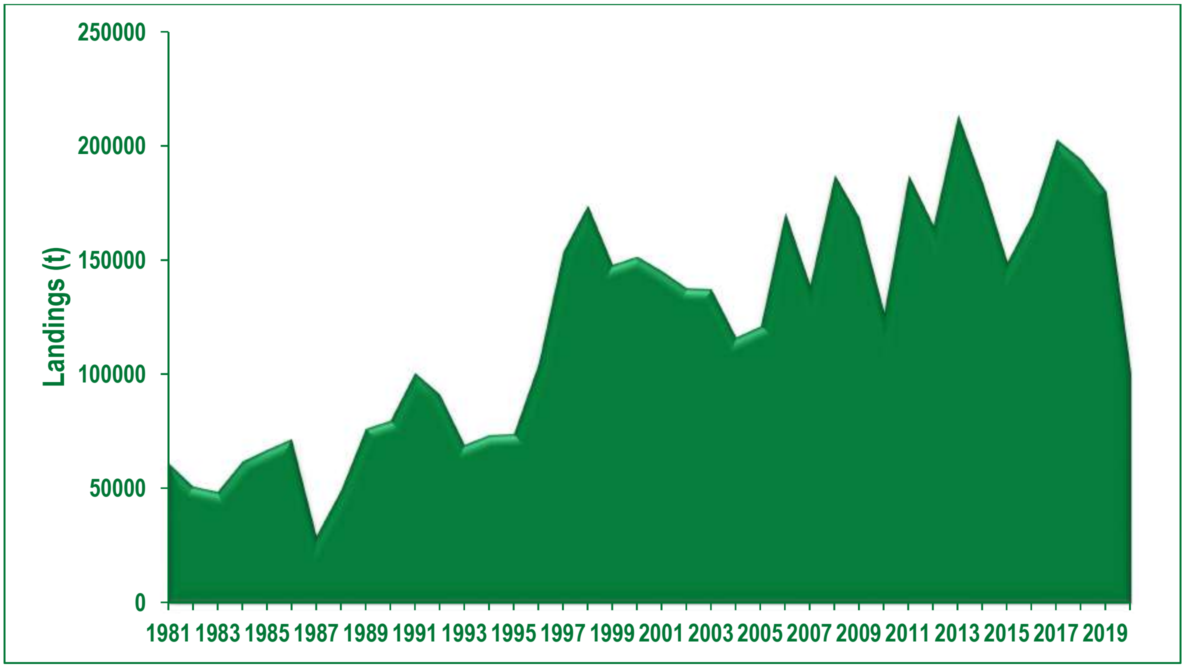


Fig. 7. Total non-penaeid prawn landings (t) in India during 1981-2020.

Deep-sea prawn fishery

In Indian waters, deep sea fishery is seasonal and major species is known to occur in south-east and southwest coast of India. The main fishing ground occurs off Kollam in Kerala and less abundant area off Mangalore, in Karnataka. Along east coast main fishing ground is off Toothukudi in Tamil Nadu. The depth of fishing occurring is mainly between 250 - 400 m. The details of species and landings are presented in table-2 and figures 8-9.

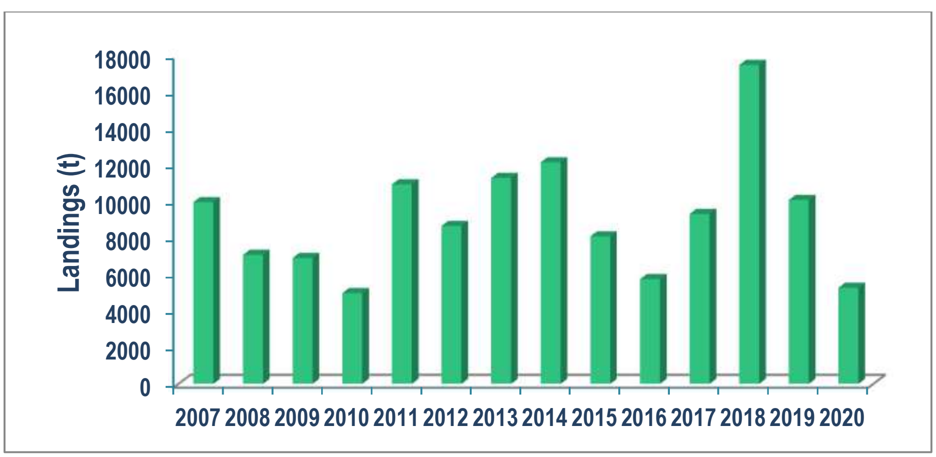


Fig. 8. Total deep-sea prawn landings (t) in India during 2007-2020.

Table -1. Commercially important prawns of India.

Penaeid Prawns
Penaeus canaliculatus (Olivier, 1811)
Penaeus indicus H.Milne Edwards, 1837
Penaeus japonicus Bate, 1888
Penaeus latisulcatus Kishinouye, 1896
Penaeus merguiensis De Man, 1888
Penaeus monodon Fabricius, 1798
Penaeus pencillatus Alcock, 1905
Penaeus semisulcatus De Haan, 1844
Metapenaeus affinis (H.Milne Edwards, 1837)
Metapenaeus brevicornis (H.Milne Edwards, 1837)
Metapenaeus dobsoni (Miers, 1878)
Metapenaeus kutchensis George, George and Rao, 1963
Metapenaeus monoceros (Fabricius, 1798)
Metapenaeus moyebi (Kishinouye, 1896)
Ganjampenaeopsis uncta (Alcock,1905) [*Parapenaeopsis uncta*]
Kishinouyepenaeopsis cornuta (Kishinouye, 1900) [*Parapenaeopsis cornuta*]
Kishinouyepenaeopsis maxillipedo (Alcock,1905) [*Parapenaeopsis maxillipedo*]
Mierspenaeopsis hardwickii (Miers,1878) [*Parapenaeopsis hardwickii*]
Mierspenaeopsis sculptilis (Heller,1862) [*Parapenaeopsis sculptilis*]
Parapenaeopsis stylifera (H.Milne Edwards, 1837)
Metapenaeopsis barbata (De Haan, 1844)
Metapenaeopsis stridulans (Alcock, 1905)
Megokris granulosus (Haswell, 1879) [*Trachypenaeus granulosus*]
Megokris sedili (Hall, 1961) [*Trachypenaeus sedili*]
Solenocera choprai (Nataraj, 1945)
Solenocera crassicornis (H.Milne Edwards, 1837)
Trachysalambria aspera (Alcock, 1905) [*Trachypenaeus asper*]
Non-penaeid
Acetes indicus H. Milne Edwards, 1830
Nematopalaemon tenuipes (Henderson, 1893)
Palaemon styliferus H. Milne Edwards, 1840 (in H. Milne Edwards, 1840) [*Exopalaemon styliferus*]
Exhippolysmata ensirostris (Kemp, 1914) [*Exhippolysmata ensirostris ensirostris*]
Lysmata vittata (Stimpson, 1860) [*Hippoysmata vittata*]

*Note: Species names are provided as following the **World Register of Marine Species** (WoRMS) and old names in [ ].

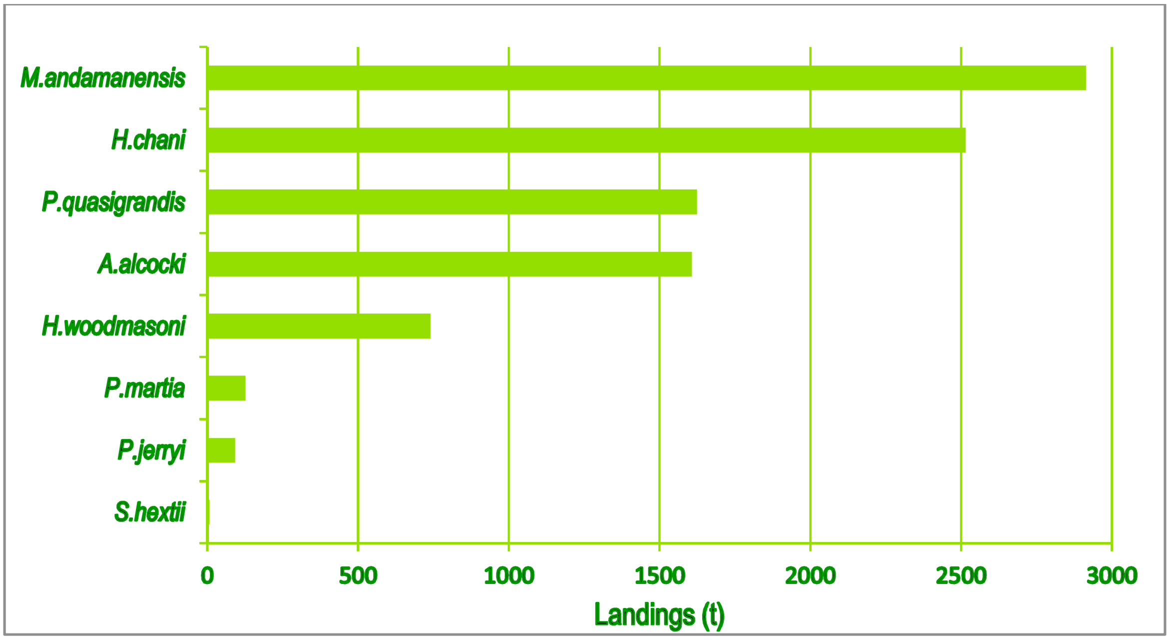


Fig. 9. Species composition of deep-sea prawn landings (t) in Kerala during 2013-2020.

Table-2. Major deep-sea prawns of India

Deep-sea prawns
Acanthephyra armata (A. Milne-Edwards, 1881)
Acanthephyra sanguinea (Wood-Mason in Wood-mason & Alcock, 1892)
Aristeus alcocki Ramadan, 1938
Heterocarpus chani Bate, 1888
Heterocarpus ensifer (A. Milne Edwards,1881)
Heterocarpus laevigatus (Spence Bate,1888)
Heterocarpus longirostris (Macgilchrist,1905)
Heterocarpus sibogae (De Man,1917)
Heterocarpus tricarinatus (Alcock &Anderson,1894)
Heterocarpus woodmasoni Alcock, 1901
Metapenaeopsis andamanensis (Wood-Mason, 1891)
Parapenaeus investigatoris Alcock and Anderson, 1899
Penaeopsis jerryi Pérez Farfante, 1979
Plesionika martia (A.Milne Edwards, 1883)
Plesionika quasigrantis (Bate, 1888)
Sicyonia fallax (De Man,1907)
Sicyonia lancifer (Olivier,1811)
Sicyonia longicauda (Rathbun, 1906)
Sicyonia parajaponica (Crosnier, 2003)
Solenocera alfonso (Perez farfante, 1981)
Solenocera hextii (Wood-Mason & Alcock, 1891)

Crab Fishery and Species composition

Edible crabs landed in India belong to the family Portunidae and around 61% of the landings were recorded by three species of marine crabs *Portunus sanguinolentus* (28.2%), *Portunus pelagicus* (25%) and *Charybdis feriata* (7.7%). The overall trend of the fishery indicated an increase at the national level, recording a maximum landing of 57354 tonnes (t) during 2018 and the lowest record of 14202 t during 1978 and the bulk of the estimated landings (59%) were from Tamil Nadu and Gujarat. The dominant species recorded in different states during 2018-2020 overall landings are presented in table 3 and all India (1981-2020) & state-wise estimates of marine crab landings during 2007-2020 are presented in figures 10 & 11. The other important edible species included in the fishery in appreciable quantities were *Charybdis lucifera*, *Charybdis natator*, *Charybdis smithii*, *Charybdis annulata*, *Portunus gladiator* (revised as *Monomia gladiator*), *Podophthalmus vigil*, *Scylla serrata* and *Scylla olivacea*.

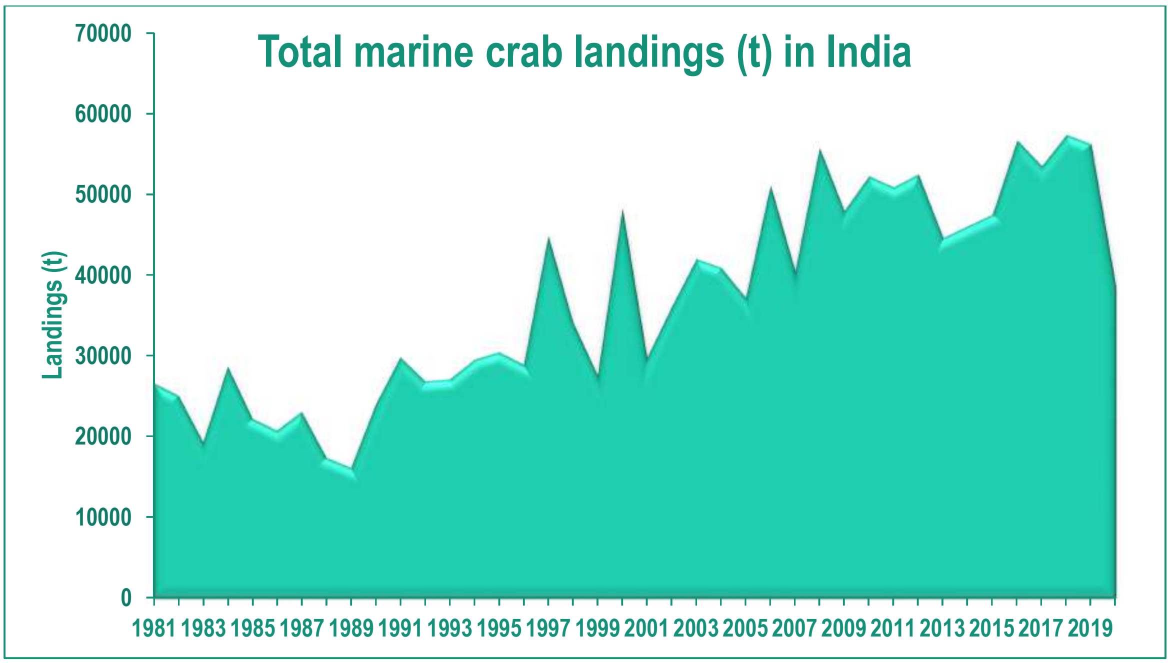


Fig. 10. Total marine crab landings (t) in India during 1981-2020.

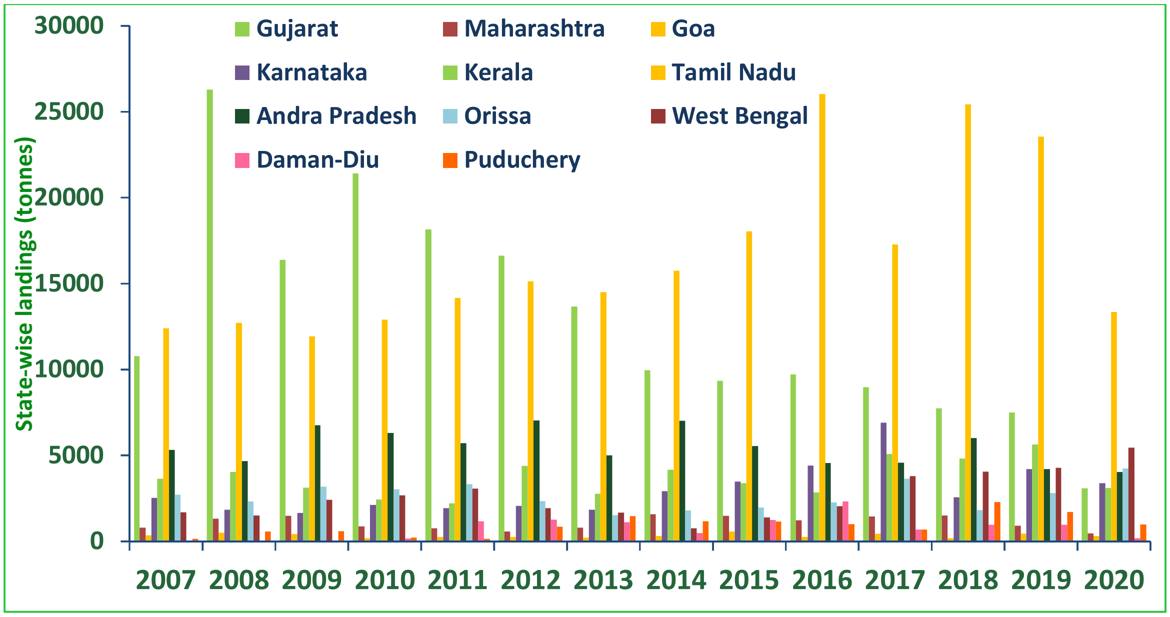


Fig. 11. State-wise estimates of marine crab landings during 2007-2020

Table-3. The dominant species recorded in the marine crab landings of different maritime states during 2018-2020.

State	Dominant species (2018-20)
Gujarat	*P. sanguinolentus*
Maharashtra	*P. sanguinolentus*
Goa	*P. sanguinolentus*
Karnataka	*P. pelagicus*
Kerala	*P. sanguinolentus*
Tamil Nadu	*P. sanguinolentus* & *P.pelagicus*
Andhra Pradesh	*P. sanguinolentus*
Odisha	*P. sanguinolentus*
West Bengal	*P. sanguinolentus*
Daman-Diu	*C. feriata*
Puducherry	*P. sanguinolentus*

Lobster fishery

In India, lobster landings recorded an average estimate of 2047 tonnes while for the last forty years (1981-2020). The overall trend of the lobster fishery in India indicated a decrease at the national level, recording a maximum landing of 4074 tonnes (t) during 1985 and the lowest record of 1201 t during 2005. The bulk of the estimated landings in recent years contributed by four states, Gujarat, Tamil Nadu, West Bengal and Maharashtra. The lobsters are mainly landed in trawlers, gillnet and traps. The lobsters are categorised into spiny or rock lobsters, sand lobsters and deep sea lobsters. The most important spiny lobsters are *Panulirus homarus, P. polyphagus, P. ornatus, P. penicillatus* and *P. versicolor. Thenus unimaculatus* forms the fishery of sand lobster and *Puerulus sewelli* is the major species among the deep sea lobsters. The details of all India landings during 1981-2020 is given in figure 12.

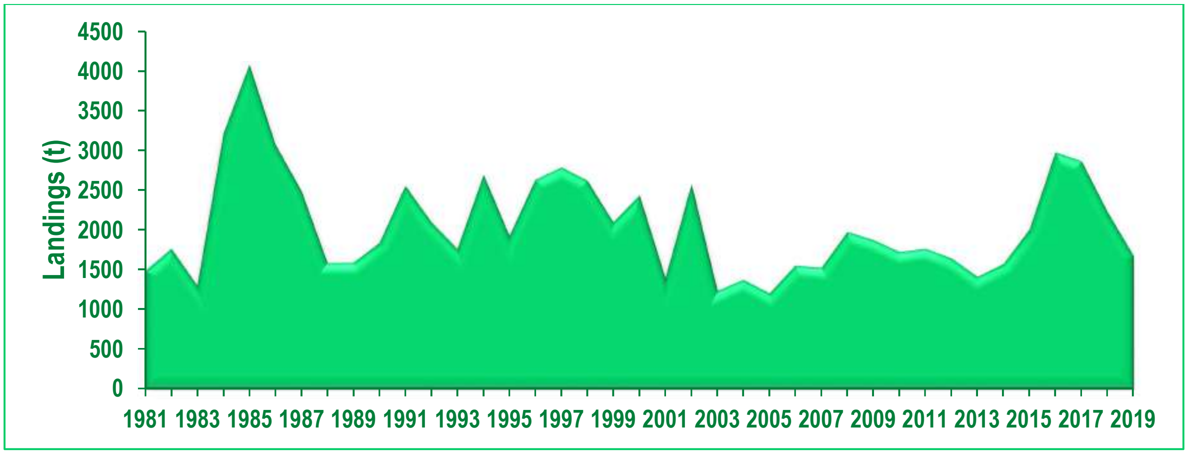


Fig. 12. Total lobster landings (t) in India during 1981-2020.

Taxonomy of Commercially Important Marine crabs of India

Introduction

Kathirvel (2008) reported 990 species of marine brachyuran crabs belonging to 281 genera and 36 families from Indian waters. Trivedi et al., (2018) published an annotated checklist of the marine brachyuran crabs occurring in Indian waters, with a total of 910 species belonging to 361 genera and 62 families. which has 446 species (218 genera and 51 families). Highest species diversity recorded in Kerala (183 species, 117 genera and 35 families) followed by Maharashtra (92 species). However, genetic diversity is more in Maharashtra (64 genera) than in Kerala (63 genera).

Classification

Crabs belong to the order Decapoda and they can be can be classified into two main groups, brachyuran crabs (infraorder Brachyura) and anomuran crabs (infraorder Anomura). Most species of Brachyura, or true crabs, can easily be separated from the so-called "false crabs" belonging to the infraorder Anomura by having five pairs of locomotory appendages of a crab (the pereiopods) are made up of a pair of usually powerful chelipeds (legs carrying a chela or pincer) and normally of four pairs of walking (or ambulatory) legs. The first appendage is referred to as the cheliped and the last four appendages (walking legs) as legs. The claw (or chela) itself consists of a palm (or manus) and two fingers, one of which is movable (the dactylus or movable finger), whereas the other one (Propodus/pollex) is fixed. The tips or edges of the fingers may be pectinated. In some families the last pair or all walking legs are modified for swimming or burrowing, as seen in the Portunidae (Carpenter and Niem, 1998).

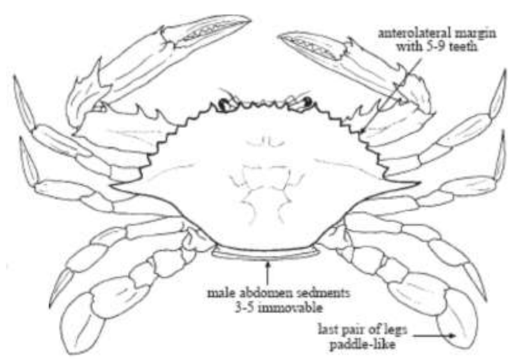
Most of the edible crabs caught from marine and brackish water environments belong to the family Portunidae, Rafinesque, 1815. This family includes seven subfamilies; Caphyrinae Paul'son, 1875, Carcininae MacLeay, 1838, Carupinae Paul'son,1875, Podophthalminae Dana, 1851, Polybiinae, Ortmann, 1893, Portuninae Rafinesque, 1815, Thalamitinae Paul'son, 1875. In the seas around India, five genera of Portuninae have been reported by various authors. They are *Scylla, Portunus*, *Charybdis, Lupocyclus* and *Thalamita*. Among them the first three genera mainly contribute to the commercial crab fishery.

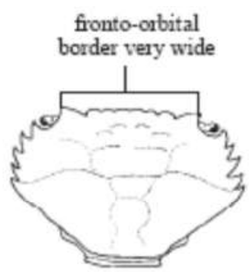
Portunidae

Carapace hexagonal, transversely ovate to transversely hexagonal, sometimes circular; dorsal surface relatively flat to gently convex, usually ridged or granulose; front broad, margin usually multidentate; usually 5 to 9 teeth on each anterolateral margin, posterolateral margins usually distinctly converging. Endopodite of second maxillipeds with strongly developed lobe on inner margin. Legs laterally flattened to varying degrees, last 2 segments of last pair paddle-like. Male abdominal segments 3 to 5 completely fused, immovable.

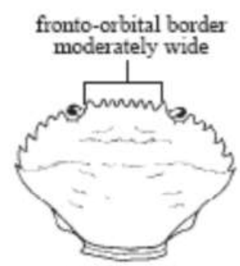
Sexuality

In crabs, sexes are separate and sexes can be distinguished from the shape of the abdomen. In males the abdomen is narrow, inverted 'T' shaped and in addition mature males have larger and broader chelae. The first and second abdominal appendages (pleopods) are highly modified to form an intromittant copulatory organ. Females possess a broad abdomen, conical/oval in shape (according to the stage of maturity) and bear four pairs of pleopods.





a) *Thalamita*



b) *Charybdis*

Shape of abdomen in male and female (different stages) crabs

Key to species of interest to fisheries occurring in the area

1a. Carapace with 2 anterolateral teeth; eyes very long, reaching lateral edge of carapace (Fig. 1) . . . . ***Podophthalmus vigil***
1b. Carapace with more than 2 anterolateral teeth; eyes normal in size ***2***

2a. Carapace rounded; ventral surface of palm with stridulatory (sound-producing) ridges (Fig. 2a) . . . . ***Ovalipes punctatus***
2b. Carapace transversely ovate; palm without any stridulatory (sound-producing) ridges (Fig. 2b) ***3***

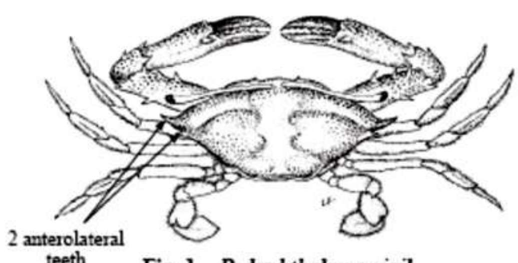


Fig. 1 *Podophthalmus vigil*

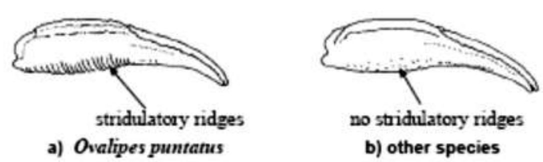


Fig. 2 chela in ventral view

3a. Five to 7 teeth on each anterolateral margin (Fig. 3a-c) ***4***
3b. Nine teeth on each anterolateral margin (Fig. 3d) ***12***

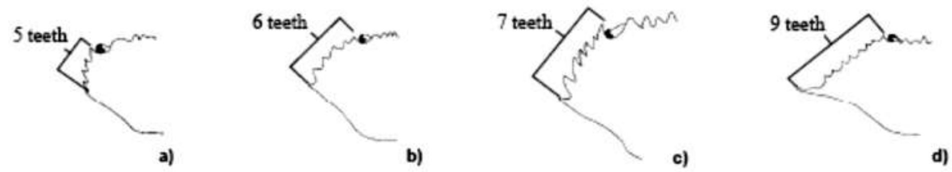


Fig. 3 lateral margin of carapace (dorsal view)

4a. Width of frontal-orbital border not much less than greatest width of carapace; 5 teeth on each anterolateral margin (first tooth sometimes with accessory denticle) (Fig. 4a) **. *5***
4b. Width of frontal-orbital border distinctly less than greatest width of carapace; 6 or 7 teeth on each anterolateral margin (Fig. 4b) **. *6***

5a. Basal antennal segment with a smooth or granulated ridge (Fig. 5a) **. . . *Thalamita crenata***
5b. Basal antennal segment with several sharp spines (Fig. 5b) **. . . . .. . *Thalamita spinimana***

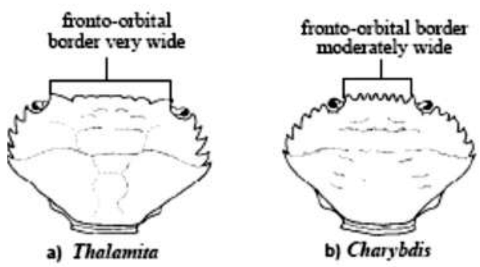


Fig. 4 carapace (dorsal view)

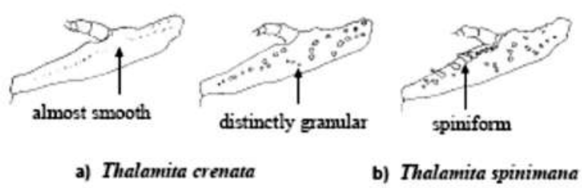


Fig. 5 basal antennal segment

6a. Posterior border of carapace forming an angular junction with posterolateral border (Fig. 6a); merus of cheliped without distal spine on posterior border **. .. . . *Charybdis truncate***
6b. Posterior border of carapace forming a curve with posterolateral border (Fig. 6b); merus of cheliped with distal spine on posterior border **. . . . .** *7*

7a. Carapace with distinct ridges or granular patches behind level of last pair of anterolateral teeth (Fig. 7a) **. . . . . *Charybdis natator***
7b. Carapace without distinct ridges or granular patches behind level of last pair of anterolateral teeth (Fig. 7b) **. *8***

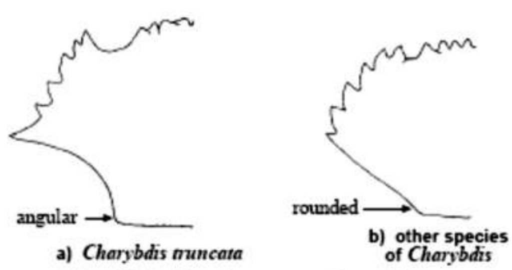


Fig. 6 left side of carapace (dorsal view)

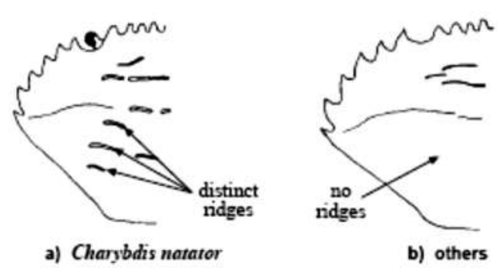


Fig. 7 left side of carapace (dorsal view)

8a. Merus of cheliped with 2 spines on anterior border; palm with 2 spines on upper surface

(Fig. 8a) . . . . ***Charybdis anisodon***
8b. Merus of cheliped with 3 or 4 spines on anterior border; palm with more than 2 spines on upper surface (Fig. 8b) ***9***

9a. First anterolateral tooth not truncate or notched (Fig. 9a) . . . . . . ***Charybdis annulata***
9b. First anterolateral tooth truncate or notched (Fig. 9b) ***10***

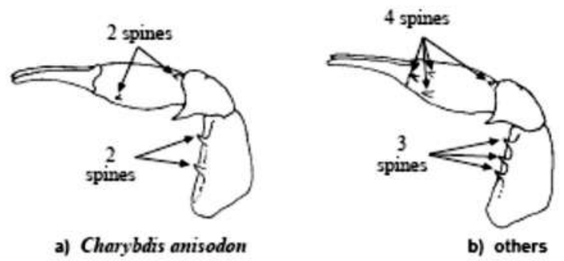


Fig. 8 right cheliped (dorsal view)

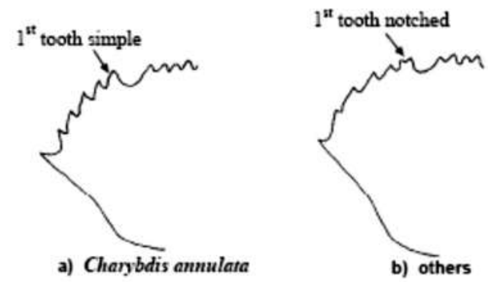


Fig. 9 lateral margin of carapace (dorsal view)

10a. Palm of cheliped with 4 spines on upper surface (Fig. 10a); male abdominal segment 4 keeled (Fig. 11a) . . . . ***Charybdis feriata***
10b. Palm of cheliped with 5 spines on upper surface (Fig. 10b); male abdominal segment 4 not keeled (Fig. 11b) ***11***

Fig. 10 right cheliped (dorsal view)

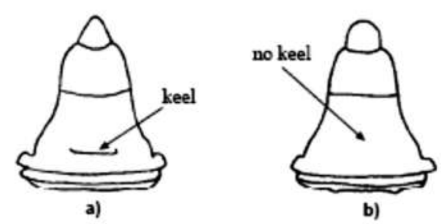


Fig. 11 male abdomen

11a. Palm with well-developed spines (Fig. 12a); male abdominal segment 6 with convex lateral borders (Fig. 13a); last anterolateral tooth smallest and spiniform, not projecting beyond preceding tooth (Fig. 14a) . . . . ***Charybdis japonica***
11b. Palm with poorly developed spines (Fig. 12b); male abdominal segment 6 with lateral borders parallel in proximal half (Fig. 13b); last anterolateral tooth elongate, projecting laterally beyond preceding tooth (Fig. 14b) . . . . ***Charybdis affinis***

12a. Last anterolateral tooth subequal in size to others (Fig. 15a) ***3***
12b. Last anterolateral tooth at least 2 times larger than others (Fig. 15b) ***16***

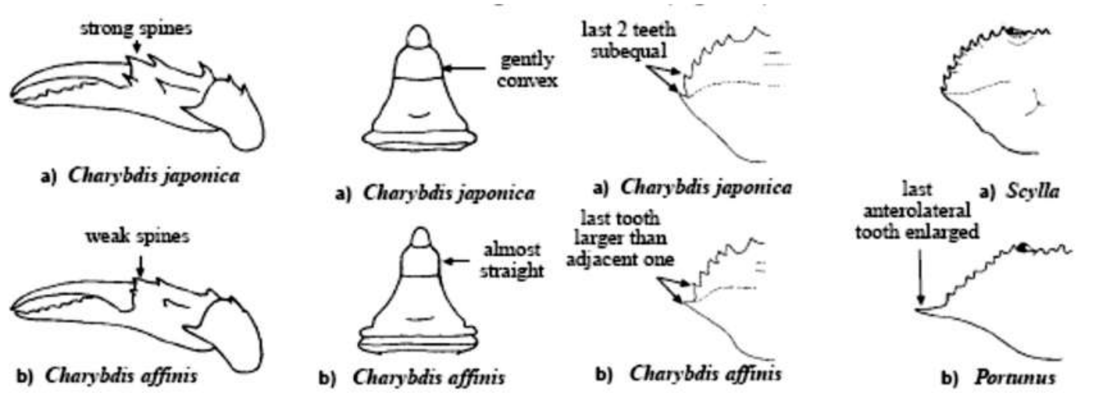


Fig. 12 right cheliped **Fig. 13 male abdomen** **Fig. 14 anterolateral teeth** **Fig. 15 anterolateral teeth**

13a. Carpus of cheliped with only 1 low to very low granule on outer surface, never spiniform (Fig. 16a); colour of palm usually with at least some patches of orange or yellow in life **. .. *14***

13b. Carpus of cheliped with 2 distinct spiniform or sharp granules or spines on outer surface (Fig. 16b); colour of palm in life green to purple **. *15***

14a. Frontal margin usually with sharp teeth (Fig. 17a); palm usually with distinct, sharp spines (Fig. 18a) **. . . . . *Scylla paramamosain***
14b. Frontal margin usually with rounded teeth (Fig. 17b); palm usually with reduced, blunt spines (Fig. 18b) **. . . . . *Scylla olivacea***

15a. Frontal margin usually with rounded teeth (Fig. 19a); sharp granules on palm and carpus never spiniform; colour in life: carapace usually very dark green to black, outer surface of palm purple and never with marbled pattern, last legs marbled only in males
. . . .Scylla tranquebarica

15b. Frontal margin usually with sharp teeth (Fig. 19b); sharp granules on palm and carpus often spiniform; colour in life: carapace usually green to olive-green, outer surface of palm green and often with marbled pattern, last legs marbled both in males and females
. . . . Scylla serrata

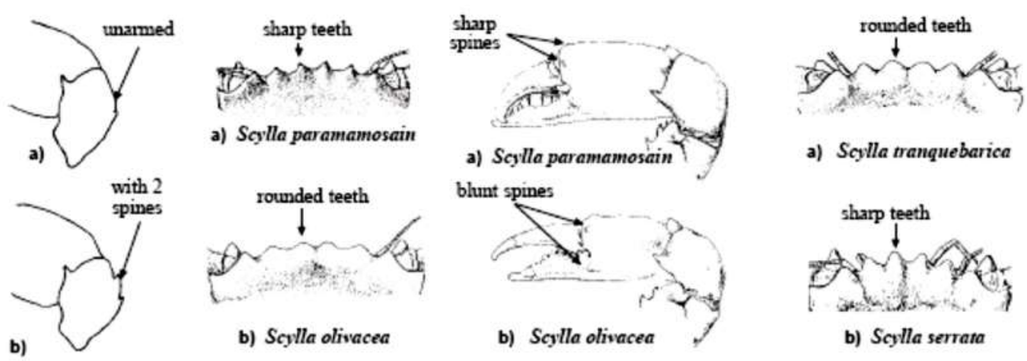


Fig. 16 carpus of cheliped **Fig. 17 frontal margin of carapace (dorsal view)** **Fig. 18 right cheliped** **Fig. 19 frontal margin of carapace (dorsal view)**

16a. Carapace with 3 purple to red spots on posterior half**. . .** ***Portunus sanguinolentus***
16b. Carapace marbled or with uniform coloration **. *17***

17a. Front with 4 teeth (Fig. 21a); inner margin of merus of cheliped with 3 spines (Fig. 22a) …………………… ***Portunus pelagicus***
17b. Front with 3 teeth (Fig. 21b); inner margin of merus of cheliped with 4 spines (Fig. 22b) **. . . . .*Portunus trituberculatus***

Fig. 21 frontal margin of carapace (dorsal view)

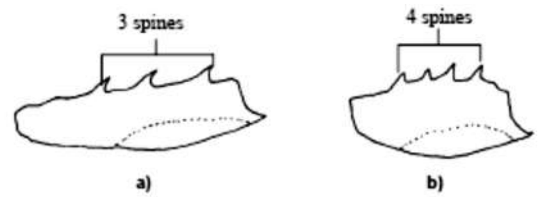


Fig. 22 merus of cheliped (inner margin)

Key – P.K.L.Ng .1998. FAO species identification guide for fishery purposes – Crabs – Portunidae .

<u>Species identification guide for fishery purposes – Crabs –Portunidae</u>

Portunus pelagicus (Linnaeus, 1758) (Flower crab).

Carapace rough to granulose, front with 4 acutely triangular teeth; 9 teeth on each anterolateral margin, the last tooth 2 to 4 times larger than preceding teeth. Chelae elongate in males; larger chela with conical tooth at base of fingers.
Colour: males with blue markings, females dull green/greenish brown.

Portunus sanguinolentus (Herbst, 1783)(Three-spot swimming crab).

Carapace finely granulose, regions just discernible; 9 teeth on each anterolateral margin, the last tooth 2 to 3 times larger than preceding teeth. Chelae elongated in males; larger chela with conical tooth at base of fingers; pollex ridged.
Colour**:** olive to dark green, with 3 prominent maroon to red spots on posterior 1/3 of carapace.

Charybdis feriata (Linnaeus, 1758) (Crucifix crab)

Carapace ovate; 5 distinct teeth on each anterolateral margin.
Colour: distinctive pattern of longitudinal stripes of maroon and white, usually with distinct white cross on median part of gastric region; legs and pincers with numerous scattered white spots.

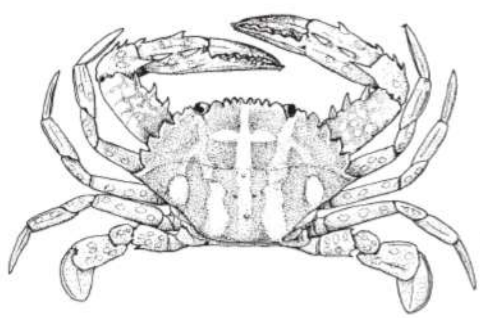
Charybdis natator (Herbst, 1789) (Ridged swimmimg crab)

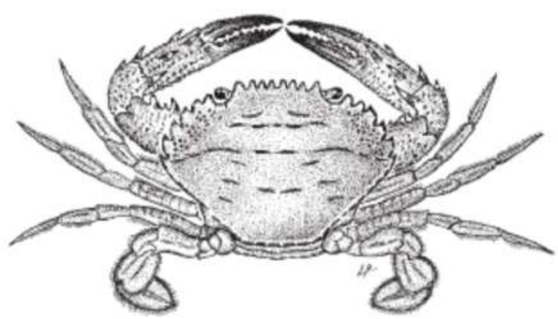
Carapace with densely covered with very short pubescence which is absent on several distinct transverse granulated ridges in anterior half.
Colour: orangish red overall, with ridges on carapace and legs dark reddish brown.

Podophthalmus vigil (Fabricius, 1798)

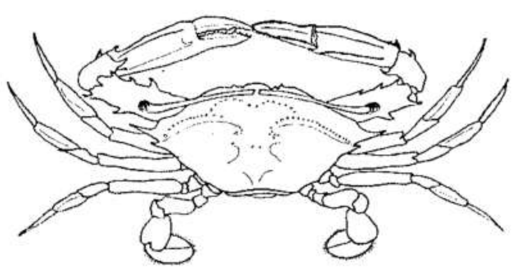
Carapace distinctly broader than long; anterior margin much broader than posterior margin, with posterolateral margins converging strongly towards narrow posterior carapace margin; orbits very broad. Eyes very long, reaching to or extending beyond edge of carapace.
Colour: carapace green; chelipeds and parts of legs violet to maroon in adults.

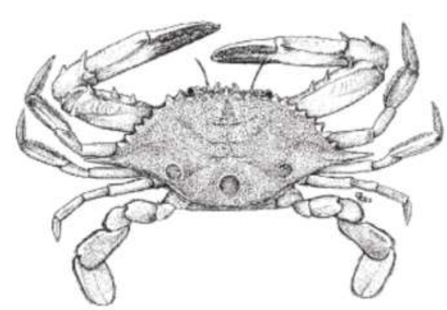
Charybdis feriatus (Linnaeus, 1758) ***Charybdis natator*** (Herbst, 1789)





Podophthalmus vigil (Fabricius, 1798) ***Portunus sanguinolentus*** (Herbst, 1783)





Portunus pelagicus (Linnaeus, 1758)

***Scylla* spp.**

The taxonomy of the genus *Scylla* has been terribly confused and is still difficult. Recent research in Australia (Keenan et al., 1998) has clearly shown, using morphological, DNA, and allozyme data, that there are 4 species of *Scylla*.

Scylla serrata (Forsskål, 1775) (Giant mud crab)

Carapace smooth, with strong transverse ridges; H-shaped gastric groove deep; relatively broad frontal lobes, all more or less in line with each other; broad anterolateral teeth, projecting obliquely outwards, colour green to greenish black; legs may be marbled. Well-developed spines present on outer surface of chelipedal carpus and anterior and posterior dorsal parts of palm.

Scylla tranquebarica (Fabricius, 1798) (Purple mud crab)

Colour varies from brown to almost black in coloration, and has very well-developed spines on the outer surfaces of the chelipedal carpus and the palm (as seen in *S. serrata*). It differs from *S. serrata*, however, by having the frontal teeth more acutely triangular, the median pair projecting slightly forwards of the lateral pair, and the anterolateral teeth gently curving anteriorly, giving the carapace a less transverse appearance.

Scylla olivacea (Herbst, 1796) (Orange mud crab)

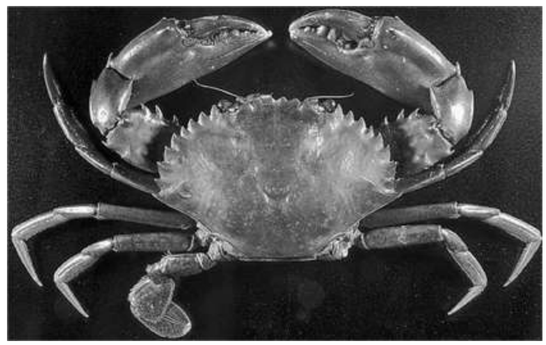
Carapace brownish to brownish green in colour (sometimes orangish), palm orange to yellow. It has a smoother, more evenly convex carapace with very low transverse ridges, a shallow H-shaped gastric groove, the median pair of the frontal lobes more rounded and projecting slightly forwards of the lateral ones, the anterolateral teeth gently curving anteriorly, giving the carapace a less transverse appearance. It also has very low spines on both the outer surface of the chelipedal carpus and the dorsal surface of palm.

Scylla paramamosain Estampador, 1949 (Green mud crab)

Carapace usually green to light green, palm green to greenish blue with lower surface and base of fingers usually pale yellow to yellowish orange. Frontal margin usually with sharp teeth, palm usually with distinct, sharp spines.

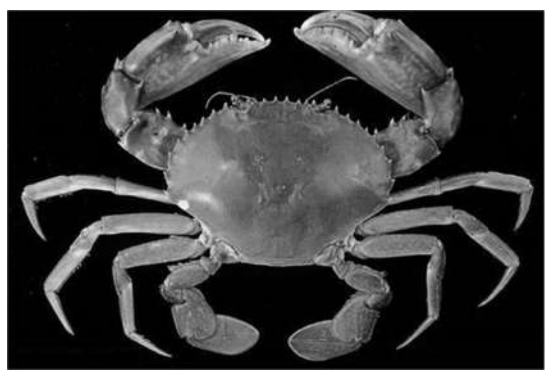
Scylla serrata (Forsskål, 1775)

Scylla tranquebarica (Fabricius, 1798)



Scylla olivacea (Herbst, 1796)

Scylla paramamosain Estampador, 1949



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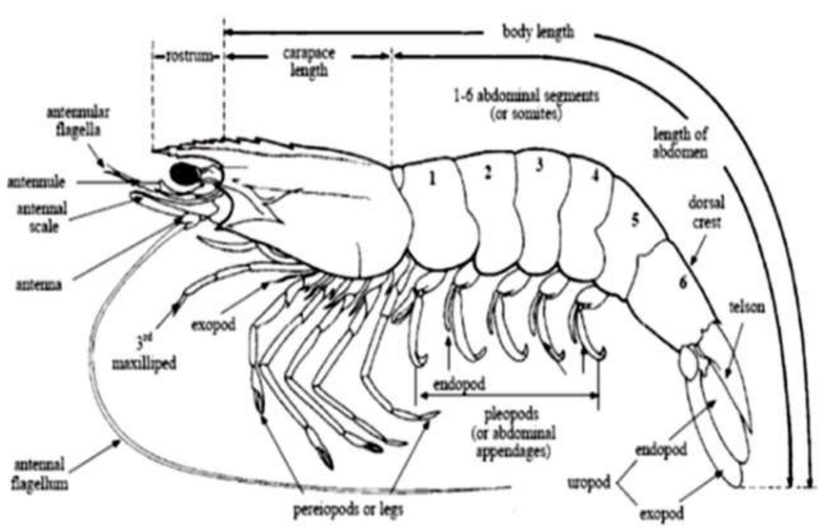
CHAPTER 32

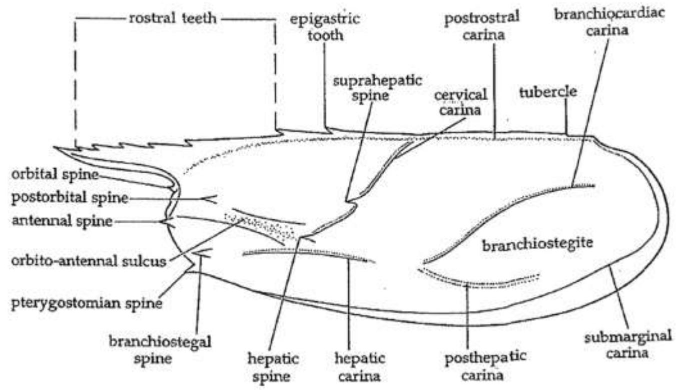
Morphological Characters for Identification of inshore Penaeid Prawns from Indian Waters

Penaeid prawns are distributed all along the Indian coast and inhabit inshore or offshore waters. They have a general life span of 2 to 2.5 years, maturing mostly between 6 – 8 months. They spawn in oceanic waters but the large number of eggs released by them develop through different stages and drift to estuaries. Here they develop into juvenile prawns. From the estuaries, they move to the sea to mature and spawn, and complete their life cycle. Most of the penaeid prawns spawn throughout their life. They are bisexual and mature females are larger than males. Petasma is the copulatory organ in males formed between the first pair of pleopods or swimming appendage and in females the genitalia termed thelycum consisting of the modifications of the posterior two or sometime three thoracic sternites, for the transfer or storage of sperms.

Fig.1.



Diagrammatic representation of penaeid prawn



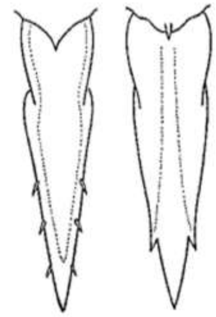


Fig.2. Carapace

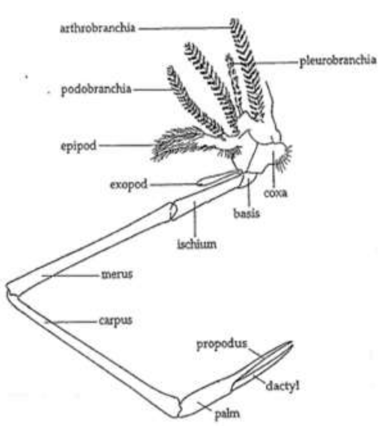


Fig.4. Pereopod

Important characters for identification of some important penaeid prawn species from Indian waters:

Metapenaeus dobsoni (Miers, 1878) Distomedian projections of petasma with a short filament on ventral surface and another on dorsal surface. Anterior thelycal plate tongue-like. Merus of fifth pereopod with 1-2 triangular teeth.

Fig.5. Petasma, thelycum and merus of fifth pereopod

Metapenaeus monoceros (Fabricius, 1798) Distomedian projections of petasma hood-like. Lateral thelycal plates with parallel ear-shaped lateral ridges; Merus of fifth pereopod with large spine.

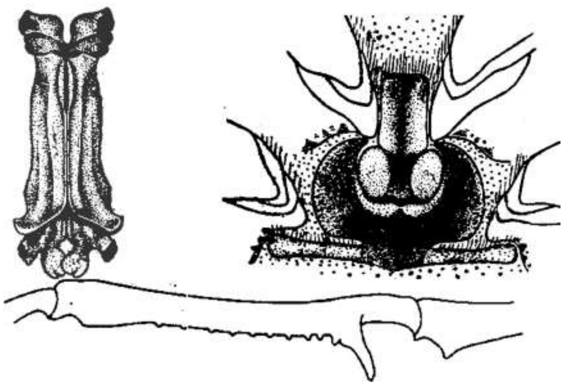


Fig.6. Petasma, thelycum and merus of fifth pereopod

Metapenaeus affinis (H. Milne Edwards, 1837) Distomedian projections of petasma crescent-shaped. Anterior thelycal plate longitudinally grooved, wider posteriorly than anteriorly; Merus of fifth pereopod with a proximal notch followed by a twisted keeled tubercle.

Fig.7. Petasma, thelycum and merus of fifth pereopod

Metapenaeus brevicornis (H. Milne Edwards, 1837) Distomedian projections of petasma with a long and slender apical filament. Anterior plate of thelycum large, square and grooved, lateral plates enclosing two pear shaped plates. Merus of fifth pereopod with spine like projection.

Fig.8. Petasma, thelycum and merus of fifth pereopod

Metapenaeus kutchensis (George, George and Rao, 1963) Distomedian petasmal lobes bifid. Anterior plates of thelycum lying in level with the coxal projections, posterior lateral plates large and round.

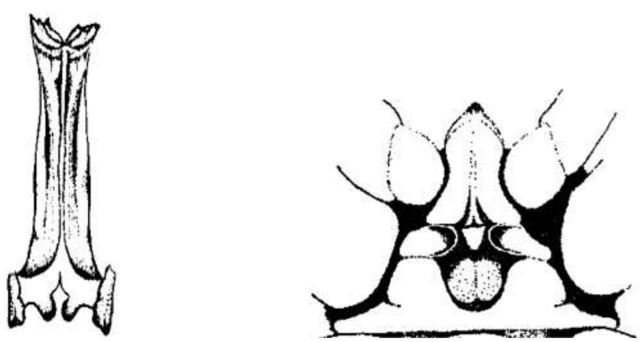
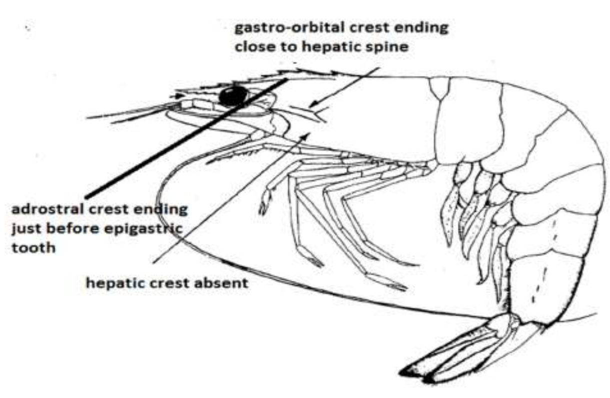
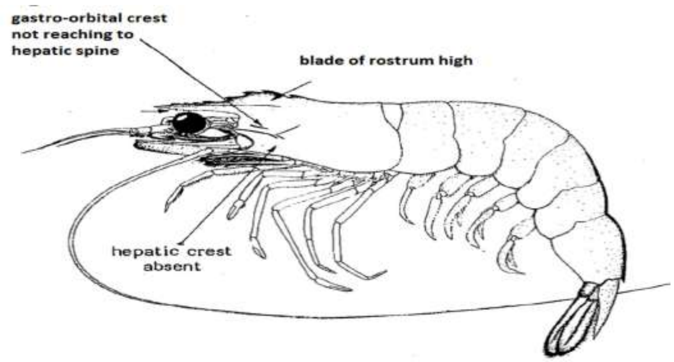


Fig.9. Petasma and thelycum

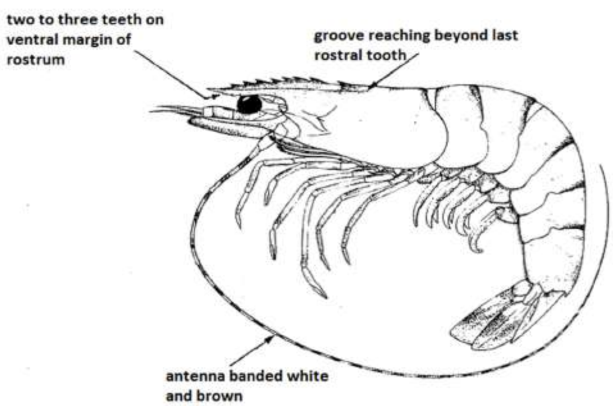
Penaeus indicus H. Milne Edwards, 1837 Rostrum with 7-8 dorsal and 5-6 ventral teeth. Adrostral carina ending just before epigastric tooth. Gastro-orbital crest ending close to hepatic spine.



Penaeus merguiensis De Man, 1888 Rostral crest triangular and high. Dorsal teeth on rostrum 6-9 and 3-5 ventral teeth. Gastro orbital crest not reaching up to the hepatic spine.

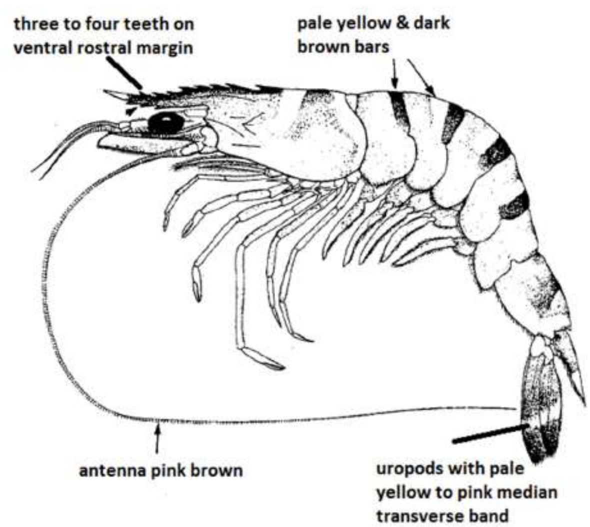


Penaeus semisulcatus De Haan, 1844

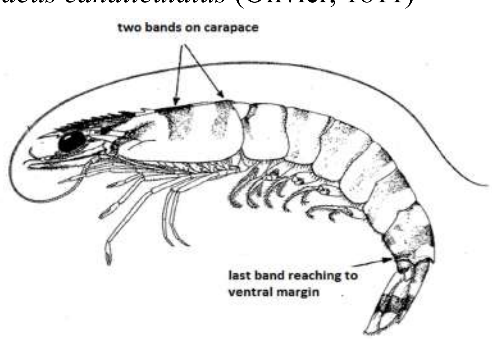


Rostrum with 7-8 dorsal and 3 ventral teeth. Adrostral carina reaches beyond the epigastric tooth. Body pale brown or greenish with yellow stripes on carapace and abdomen.

Penaeus monodon Fabricius, 1798 Rostrum has 6-8 dorsal and 3-4 ventral teeth. Adrostral carina reaches almost the epigastric tooth. Body with distinct black and yellow stripes on abdomen and uropods.

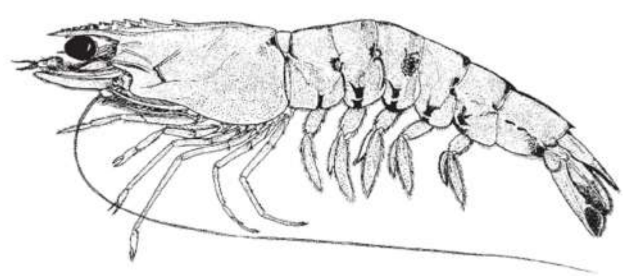


Penaeus canaliculatus (Olivier, 1811)

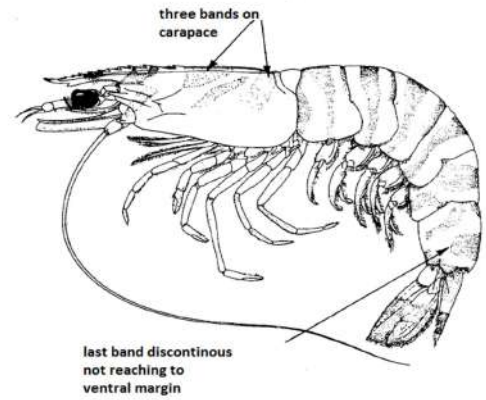


Adrostral crest extends almost to the posterior margin of carapace. Telson lack lateral spines. Two bands present on carapace and the band on the last abdominal segment complete.

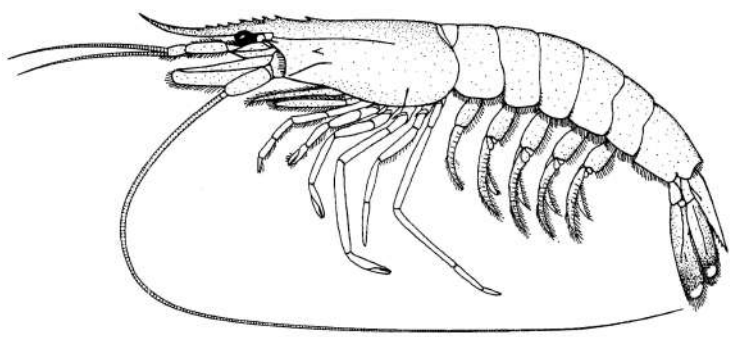
Penaeus latisulcatus Kishinouye, 1896 Adrostral crest extends almost to the posterior margin of carapace. Telson with 3 pairs of movable lateral spines. Black or brown dots on abdominal segments and black lines on pleuron.

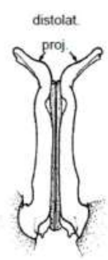


Penaeus japonicus Spence Bate, 1888 Adrostral crest extends to the posterior margin of carapace. Telson with 3 pairs of movable lateral spines. Three bands on carapace, band on last abdominal segment incomplete.



Parapenaeopsis stylifera (H.Milne Edwards, 1837) Telson armed with 4 pairs of lateral fixed spines. Distolateral projection of petama slender, horn like and straight, directed antero laterally. Anterior plate of thelycum square, concave; posterior plate deeply notched anteromedially.





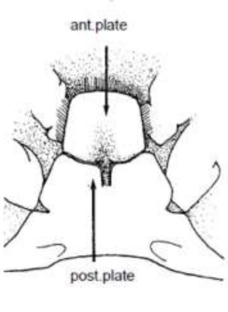
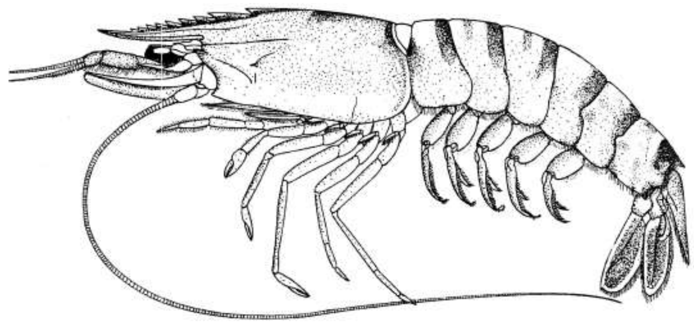


Fig.10. Petasma, thelycum and spines on telson

Kishinouyepenaeopsis maxillipedo (Alcock, 1905) Petasma with slender horn like distolateral projections curving inwards. Thelycum subquadrate, posteriorly depressed and medially fused to posterior plate. Dark brown spot on the last abdominal segment.



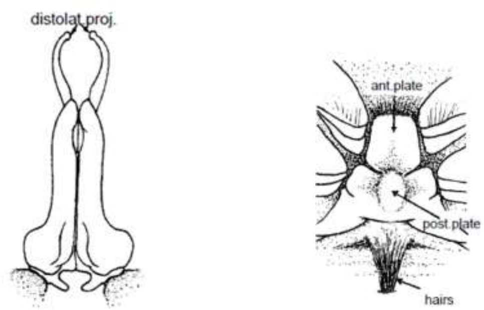
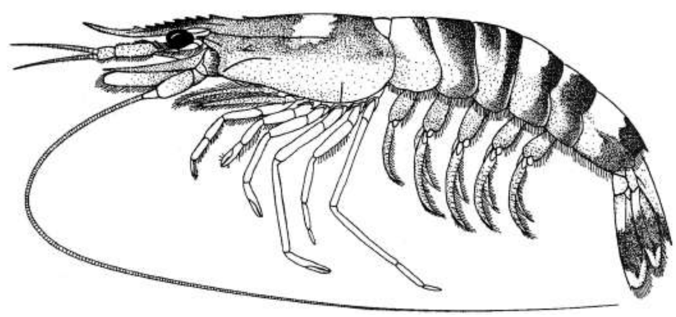


Fig.11. Petasma and thelycum

Mierspenaeopsis sculptilis (Heller, 1862) Petasma with long, rabbit ear-shaped distomedian projections, deeply concave ventrally; distolateral projections short, directed anterolaterally; proximolateral lobes very large, and curved dorsally. Thelycum with anterior plate distally rounded and broadly articulating with posterior plate.



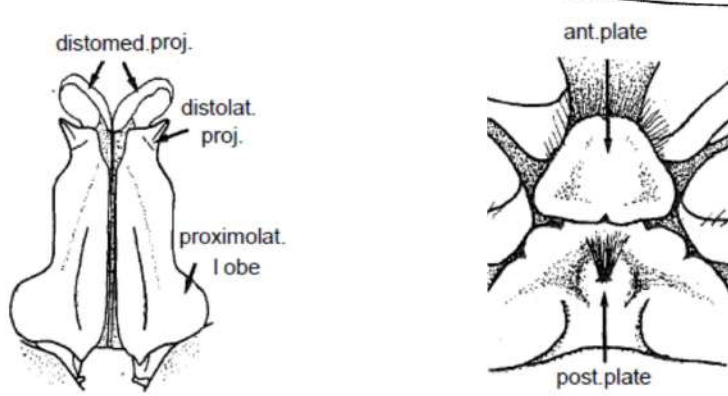


Fig.12. Petasma and thelycum

Kishinouyepenaeopsis cornuta (Kishinouye, 1900) Telson with 2 to 4 pairs of distolateral spinules. Petasma with long and slender, horn-like distolateral projection, diverging proximally and curving inward distally, each with a small dorsal spiniform process. Anterior plate of thelycum oblong and concave, fused posteromedially with posterior plate.

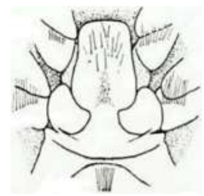
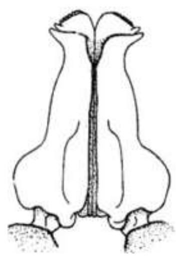


Fig.14. Petasma and thelycum

Mierspenaeopsis hardwickii (Miers, 1878) Petasma with distomedian projections wing-like, wider than long, their anterior margin often crenulate; distolateral projections short and directed laterally. Thelycum with anterior plate concave, rounded anteriorly; posterior plate flat, with a pair of anterolateral tooth-like projections.



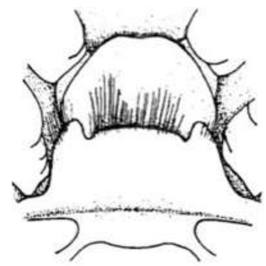


Fig.15. Petasma and thelycum

Ganjampenaeopsis uncta (Alcock, 1905) Distolateral projections of petasma tapering, ends with a long dorsornedian spine-like process. Anterior plate of thelycum wide and short, with curved anterior margin and with 2 longitudinal ridges, medially fused with the quadrate posterior plate. Dark brown patch on dorso posterior part of carapace.

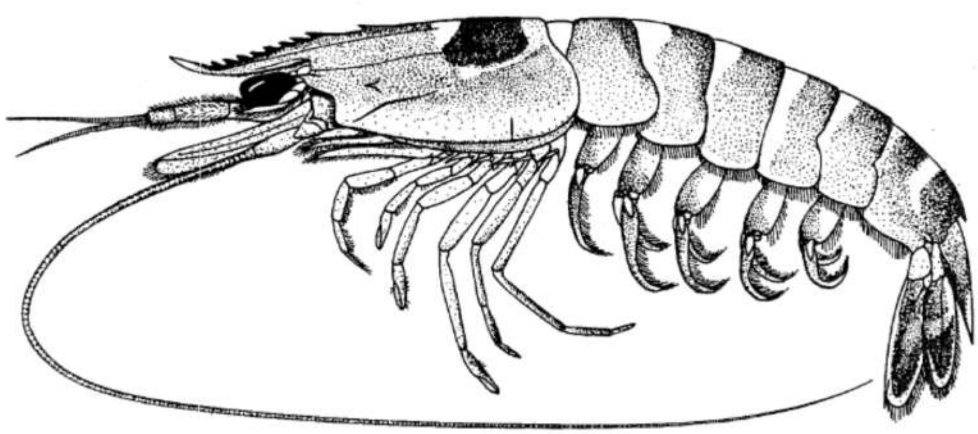


Fig.16. Petasma and thelycum

Metapenaeopsis stridulans Alcock, 1905 Carapace, abdomen and telson with dark brown mottlings. 5 to 7 strong stridulating ridges in a straight band on carapace. Left lobe of petasma sharply pointed and triangular. Thelycal plate square.

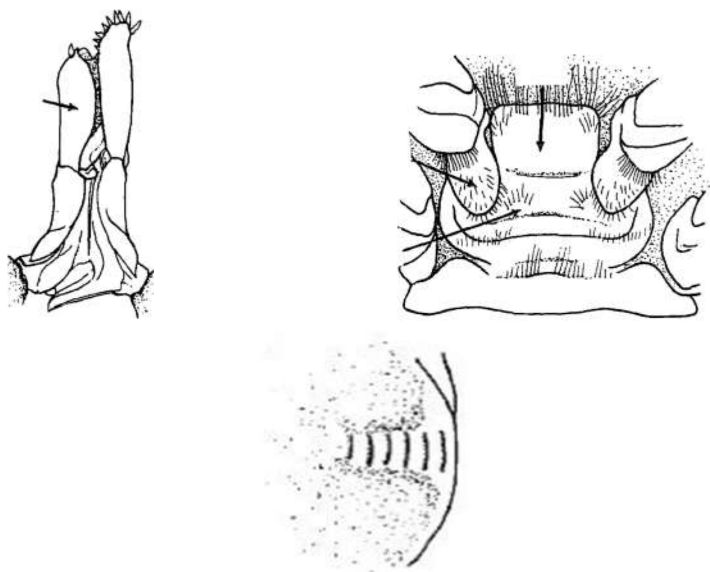


Fig.17. Petasma, thelycum and stridulating ridges

Metapenaeopsis toloensis Hall, 1962 Stridulating ridges 14 to 22 in curved band. Left distoventral projection of petasma swollen. Thelycal plates subquadrate with rounded corners.

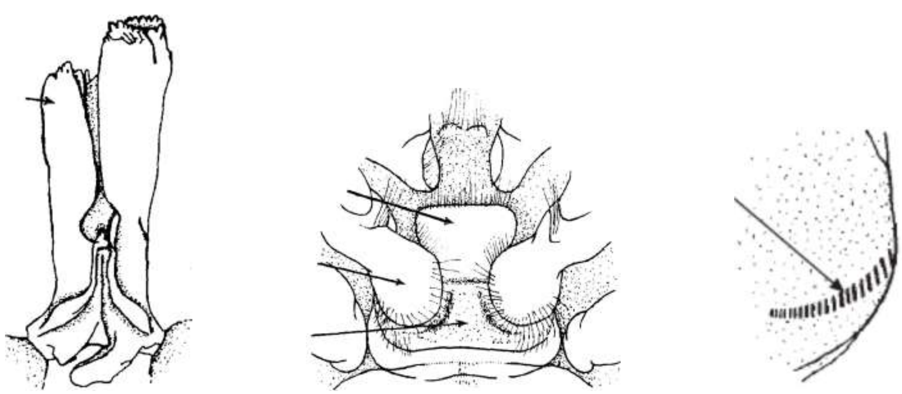


Fig.18. Petasma, thelycum and stridulating ridges

Trachysalambria aspera (Alcock, 1905) - Rostrum straight with 8- 9 dorsal teeth excluding the epigastric tooth. Carina on the second abdominal segment forms a tubercle. Carina on 3rd abdominal segment starting at 1/3rd, that on 6th abdominal segment ends in sharp spine. The median plate on the anterior portion of the thelycum semicircular, single transverse plate on the posterior portion.

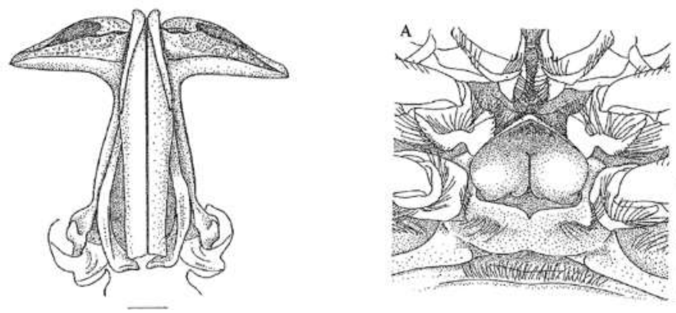


Fig.19. Petasma and thelycum

Solenocera crassicornis (H.Milne Edwards, 1837) - Rostrum with 8-10 dorsal teeth. Fifth pereopod without coxal spine. Telson unarmed.

Solenocera choprai Nataraj, 1945 - Rostrum with 6-9 dorsal teeth. Fifth pereopod with a coxal spine. Telson with a pair of fixed distolateral spine.

Solenocera crassicornis *Solenocera choprai*

Few important terms for identification of penaeid prawns

- **Adrostral carina**: Ridge flanking the rostrum, sometimes nearly reaching the posterior margin of the carapace.
- **Branchiostegal spine**: Short spine on or near anterior margin of the carapace ventral to the antennal spine and dorsal to the anteroventral angle of the carapace.
- **Distomedian projection**: Distal relatively narrow extension of the dorsomedian lobule of the petasma.
- **Epigastric tooth:** Tooth on the carapace situated above the gastric region behind the first (posterior most) rostral tooth.

- **Hepatic carina:** Longitudinally or obliquely disposed ridge of variable length lying ventral to the hepatic region, sometimes extending almost to the anterior margin of the carapace.
- **Hepatic spine:** Lateral spine situated near the anterior margin of the hepatic region of the carapace.
- **Pleuron (Pleura):** One of the lateral flaps on each of the anterior five abdominal somites.
- **Postorbital spine:** Spine situated near the orbital margin posterior to the antennal spine
- **Postrostral carina:** Dorso-median ridge extending posteriorly from the base of the rostrum, sometimes nearly reaching the posterior margin of the carapace.
- **Pterygostomian spine:** Marginal spine arising from the anteroventral angle or border of the carapace.
- **Sternum:** Ventral surface of the cephalothorax or abdomen.
- **Prahepatic spine**: Spine arising from the edge of the cervical carina dorsal to the hepatic spine.
- **Supraorbital spine:** Spine located posterior to the orbital margin of the carapace.
- **Telson:** Terminal unit of the abdomen bearing the anus.
- **Uropod:** Paired biramous appendage attached to the sixth abdominal somite, usually combining with the telson to form a tailfan.

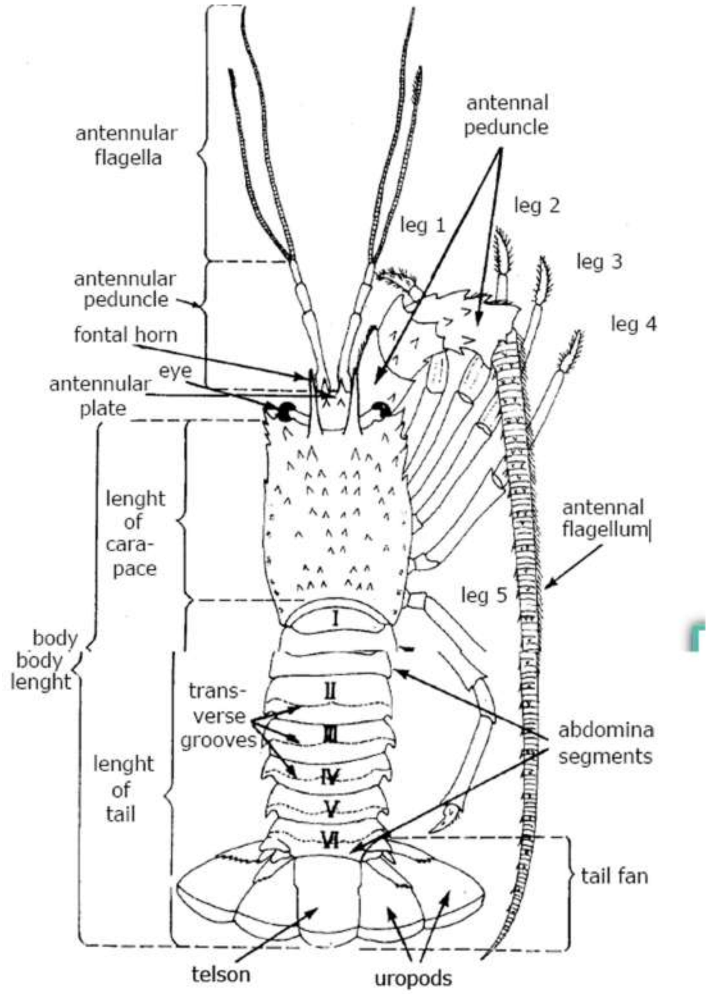
CHAPTER 33
Deep Sea Crustacean Taxonomy

Taxonomy is the practice and science of classifying organisms. Taxonomy uses taxonomic units known as taxa. Conventional classic taxonomy mainly classifies the organism based on their morphological features whereas integrative taxonomy is based on the molecular techniques such as gene sequencing and DNA barcoding with classical morphological features.

The term 'Systematics' is often used in taxonomy. The systematic zoology is the science that discovers names, determines relationships, classifies and studies the evolution of living organisms. It is an important branch in biology and is considered to be one of the major subdivisions of biology having a broader base than genetics, biochemistry and physiology. Shellfish systematics is the most unique one in fisheries science in view of its importance and implications in diversity. The shellfish includes two highly diversified phyla i.e. phylum Arthropoda and phylum Mollusca. These two groups are named as shellfishes because of the presence of exoskeleton made of chitin in arthropods and shells made of calcium in molluscs. These two major phyla are invertebrates. They show enormous diversity in their morphology, in the habitats they occupy and in their biology. Phylum Arthropoda includes economically important groups such as lobsters, shrimps, and crabs. Taxonomical study reveals numerous interesting phenomena in shellfish phylogeny and the study is most indispensable for the correct identification of candidate species for conservation and management of our fishery resources and aquaculture practices. On the whole taxonomic study on shellfishes furnishes the urgently needed information about species and it cultivates a way of thinking and approach for all biological problems, which are much needed for the balance and well-being of shellfish biology as a whole.

Lobster Resources

Lobsters are among the most prized of fisheries resources and of significant commercial interest in many countries. Because of their high value and esteemed culinary worth, much attention has been paid to lobsters in biological, fisheries, and systematic literature. They have a great demand in the domestic market as a delicacy and is a foreign exchange earner for the country.



general shape (dorsal view) of a spiny lobster
(Panulirus sp.Xno rostrum, no pincers)

Key to species of *Panulirus* recorded off the Indian coast and the island groups, Andaman Nicobar Island and the Lakshadweep Islands

1. Margin of transverse abdominal grooves with squamae varying from well-developed and even in size to minute and irregular in size. Overall colour ranges from brownish-red in specimens with large squamae to olive green in specimens with minute squamae …………………………………………………………………...***P.homarus***
2. Antennular plate (between the stridulating organs) with 2pairs (4) of subequal principle spines, fused at their bases. Supraorbital horns rounded in cross section. Overall colour olive-black…………………………………………………….....***P.pencillatus***
3. Antennular plate with 1 pair (2) of equal principle spines; supraorbital horns flattened bilaterally. Overall colour purplish-red with abdomen covered with conspicuous white spots………………………………………………………………***P.longipes***
4. Antennular plate with 1 pair of equal spines; white bands on each abdominal segment. Legs with white spots. Colour Olive green………………………...***P.polyphagus***

5. Conspicuous transverse white band posteriorly on each abdominal segment. Legs with longitudinal white stripes, juveniles have white antennae. Overall colour black and green………………………………………………………...…***P.versicolor***
6. No transverse white band on abdominal segments but above each pleural spur is a conspicuous white spots. Legs with irregular transverse mottling, no longitudinal stripes. Overall colour bluish green……………………………………….***P.ornatus***

***Panulirus homarus homarus* (Linnaeus, 1758)**

Biology: Maximum total length 31cm, carapace length 12cm. Average total length 20 to 25cm Major fisheries are on the southeast and southwest coast of India. The commercial fishery at Muttom, Kanyakumari district was found to be largely supported by 1st and 2nd year animals. At a given carapace length females are heavier than males. Females attain functional maturity at a carapace length (CL) of 55mm. Males attain maturity at 63mm CL on the basis of allometric growth of III walking leg. Peak breeding season is from November to December.

Genus *Puerulus* Ortmann, 1897

Key to species (after Berry, 1969)

1. Two teeth between frontal horns and the cervical groove
   1a. Median keel of carapace with 5 post-cervical and 2 or 3 intestinal teeth. Fifth pereopod of male not chelate……………………………………..… ***P.sewelli***

Biology: Maximum total body length 20cm, maximum carapace length about 8cm. Average total length about 15 cm. The species was commercially exploited along the southwest and southeast coast of India. A catch rate of 200-300kg/hr was reported from vessels opening off Mandapam. January to April is the peak period of abundance. During 1998-2000, 524t were landed at Sakthikulangara, Kollam, and Kerala. The sizes of *P.sewelli* ranged from 76-80mm to 176-180 TL in Males and from 81-85mm to 176-180mm in females. 26% of females were found in mature/berried stage. Due to coincidence of peak breeding and the fishery, the breeding population has been heavily exploited. The species has been overexploited and the current landing is around 2 tonnes/annum from Quilon Bank.

Family: Scyllaridae Latreille, 1825

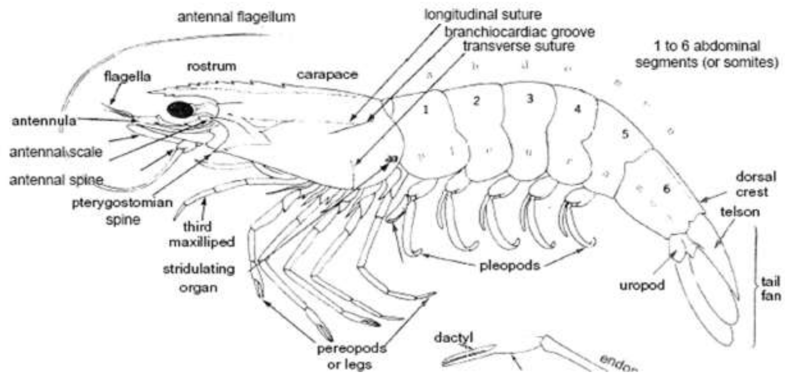
Key to Identification of the family

Antennal flagellum reduced to a single, flat plate which forms the sixth and final segment of the antenna. The shovel-like appearance of the antennae is responsible for the name shovel-nosed lobster

***Thenus unimaculatus* Burton & Davie, 2007**

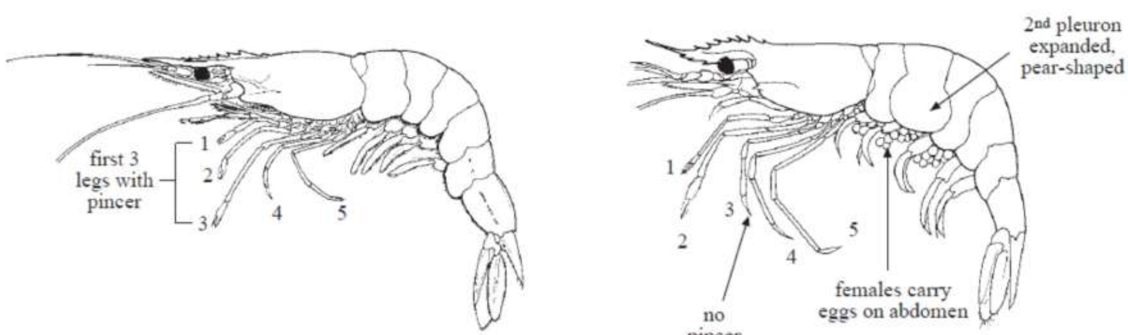
Biology: Maximum total body length about 25cm; often appears as bycatch in trawl; also caught in gillnets. At Kollam, Kerala peak fishery was observed from November to February. Total length varied between 61-230 mm in males and 46-250mm in females. Length at recruitment (Lr) was 48mm. Absolute fecundity varied from 14750 to 33250 mature eggs (Radhakrishnan *et al.,* 2013).

Shrimp Resources



Shrimp resources are available both from inshore and from offshore waters. As the fish resource from inshore waters remained static during the last two decades, fishing pattern underwent several changes in the previous decade, leading to the exploitation of deep sea resources either with deployment of large sized vessels or modified medium/small sized vessels. Deepwater shrimps appear to have a world-wide distribution in tropical waters. They have been caught in surveys using baited traps in depths between 200 m and 800 m off continents and at 200- 500 m depth in the Indian Ocean.

Deep sea decapod crustaceans constitute one of the dominant high price groups of invertebrates in the marine fishery sector of Kerala although the structure and organization of their community are not well known as that of coastal penaeid prawns. In view of the increasingly prominent role played by deep sea prawns and prawn products in the economy of the country, the taxonomic identity of various species exploited from the deep sea fishing grounds off Kerala is an essential prerequisite for the sustainable development and management of deep sea prawn wealth of Kerala. The deep sea prawns landed at various harbours of Kerala is an assemblage of wide array of species representing various families, the prominent being *Pandalidae, Aristeidae, Solenoceridae and Penaeidae while family Oplophoridae* contributes to only a minor portion of the deep sea trawl catches in Kerala.



Penaeoidea (after Liu, 1955) **Caridea**

Penaeid shrimps

Aristeus alcocki **Ramadan 1938**

Diagnostic characters: Large size red abdominal rings. Rostrum in female long and slender upper margin curved downwards till distal end of 2nd segment of antennular peduncle. Rostrum in males much shorter and seldom surpassing tip of antennular peduncle, armed with three teeth above orbit; **and no teeth on ventral side, lacks hepatic spine, upper antennular flagellum very short, Eyestalk with a tubercle.** Petasma simple, membranous, right and left halves united with each other along the whole length of dorsomedian with a papilla-like projection directed posteromedially. Thelycum represented by a shield shaped plate directed anteroventrally bordered by an oblique ridge on either side.

Colour: Pink with reddish bands on the posterior border of all abdominal segments.

Fishery & Biology: The catches were mainly composed of females and their size ranged from 78 mm to 188 mm in total length. The size distribution showed unimodal pattern with majority in size groups 146-165 mm. The males, which were very poorly represented in the catches were relatively smaller in size and their total length varied from 67 mm to 110 mm.

Distribution: Indian Ocean; Arabian Sea and Bay of Bengal, at depth of 350-450 m off Quillon and Alleppey.

Solenocera hextii **Wood-Mason & Alcock, 1891**

Family : Solenoceridae

Diagnostic characters: Flatenned rostrum with 7 teeth on dorsal side and no teeth on ventral side of the rostrum. Postrostral carina sharp but not laminose. Antennular flagella with red and white bands. The spines on the cervical groove situated ventral to the posteriormost rostral tooth which is well developed. The characteristic 'L' shaped groove on either side of the branchiostegal region is also clearly defined.

Colour: Pink to red

Distribution: Found all along the east and west coast of India at depths between 250 to 547 m.

Metapenaeopsis andamanensis **(Wood-Mason, 1891)**

Family: *Penaeidae*

Diagnostic characters: Rostrum more or less horizontal and straight with 6 to 7 teeth on dorsal side and no teeth on the ventral side. Lower antennular flagellum longer than the upper, much longer than the entire antennular peduncle but 0.7 times the carapace length. 3rd pereopod surpass the rostrum by the length of the entire chela. Assymetrical petasma. 3rd maxilliped and 1st pereopod with a basal spine, distal fixed pair of spines on telson.

Colour: Pale pink to red

Fishery & Biology: The total length of males varied from 67 mm to 115 mm and that of females from 68 mm to 130 mm.

Distribution: A penaeid prawn commonly encountered in the trawl catches at all depths ranges upto 400 m and was obtained from all areas.

Penaeopsis jeryii **Perez Farfante, 1979**

Family: *Penaeidae*

Diagnostic characters: Dagger shaped rostrum with teeth on dorsal side of the rostrum. Specimen appears to be pale red in color with white bands on the body. Cervical groove very prominent,

antennal scale as long as rostrum. Thelycum trilobed and sub elliptical in structure.

Fishery & Biology: Size range of female specimens ranged from 74-115 mm and males ranged from 70-110 mm.
Distribution: All along the southwest coast of India particularly off Cochin, Quillon and Alleppey at depth of 275-350 m

Caridean / Non-Penaeid shrimps

Heterocarpus woodmasoni Alcock, 1901
Family : ***Pandalidae***
Diagnostic characters: Carapace with 2 longitudinal crests on each side, extending over full length of carapace – post antennal crest and branchiostegal crest. A conspicuous elevated, sharp tooth at middle of dorsal crest of 3rd abdominal segment, telson bears 5 pairs of dorsolateral spinules besides those at the tip.
Fishery & biology: Size in the catches ranged from 72 to 135 mm in total length but dominated by 111-120 mm size groups in both the sexes. The fertilized eggs on the pleopods and the head-roe are light orange and this colour stands out in contrast with the pink colour of the prawn. The berry becomes greyish in advanced stages of development.
Distribution: Andamans, Southwest of India off Cochin and Alleppey at depths of 250-400 m

Heterocarpus chani Li, 2006
Diagnostic characters: The teeth on the dorsal crest and the rostrum together vary from 8 to 10. Teeth on the rostrum proper varying from 2 to 4 and 13-15 on ventral side. The dactyli of the 3 posterior legs short, median carination of the 3rd abdominal tergum is quite prominent. Carapace with 2 longitudinal crests on each side, extending over full length of carapace- post-ocular crest and branchiostegal crest. Post antennal crest very short.
Fishery & biology: The size of the individual prawn varied from 67 to 140 mm in total length and the catches were represented by all groups of the females. Males are mostly in 90-100 mm size groups. The colour of the berry is light **orange** and turns dirty grey as embryo develops.
Distribution: Southeast and Southwest coast off Cochin, off Alleppey at depths of 250-400 m. immature specimens were found in greater numbers in shallow waters while the bigger prawns seemed to prefer deeper grounds beyond 350 m.

Plesionika quasigrandis **(Bate, 1888)**
Pandalidae
Diagnostic characters: Rostrum upturned at the tip. Rostrum is armed with 46 teeth on the dorsal side and 31 teeth on the ventral side., very long slender legs, Telson is double the length of the 5th abdominal somite. Lower antennular flagellum longer than the upper and about 5.4 times the carapace length. 3rd maxilliped extends beyond the antennal scale by the length of its dactylus. Second pereopod exceeds the tip of antennal scale by its chela and 1/8 length of carpus. Minute tubercle on the dorsal surface of the carapace at about 1/6th of its length from the hinder edge which corresponds in position to the small blunt median spine which is present in all the specimens.
Colour: Body pale red in colour
Fishery & biology: The size of this prawn in the catches ranged from 63 to 125 mm but the size groups 95-110 mm in both sexes predominated. Berry is greenish-blue in colour with ovoid shape of fertilized eggs.
Distribution: In Indian waters this species is known to occur in south-east and south-west coast of India abundantly noticed from Quilon and Mangalore regions from the depth of 250-400 m.

***Plesionika semilaevis* Spence Bate, 1888**

Diagnostic characters: Rostrum very long pointed with 7-9 dorsal teeth including 2-5 teeth on carapace posterior to the level of orbital margin while ventral margin of the rostrum is armed with 34-56 teeth.

Fishery & biology: The size of this prawn in the catches ranged from 71 to 120 mm in males and 80 to 130 mm in females. The modal lengths for males and females were at 90-95 mm and 96-100 mm respectively. Berry is deep blue in colour in the early stages and to light grey in advances stages of development.

Distribution: In Indian waters this species is known to occur along the south-west coast particularly throughout the Kerala coast abundantly noticed from Quilon and Alleppey regions from the depth of 200-450 m.

Family : Ophlophoridae

***Ophlophorus gracilirostris* Alcock, 1901**

Diagnostic characters: Carapace with dorsal carina extending to the posterior margin. Rostrum very long almost equal in length to the carapace. Branchiostegal spine quite distinct, with a well-defined keel, spine on the 3rd abdominal tergum very much longer than those on the 4th and 5th. In the male the anterior border of the first abdominal somite is bilobed with the posterior lobe more pronounced and angular.

Distribution: Arabian Sea, Bay of Bengal, Andaman Sea and Hawaiin Islands, Southwest of Cochin, off Alleppey 300-450 m

***Acanthephyra fimbriate* Alcock & Anderson, 1894**

Diagnostic Characters: The carapace is without a straight ridge or carina running on the entire length of the lateral surface i.e., from the hind margin of the orbit to the posterior edge of the carapace. Rostrum long, upcurved with 5 to 6 teeth on the dorsal side and only one tooth on the ventral side of rostrum. Dorsal carina of 3rd to 6th abdominal somites ending in pointed spines. Sometimes the posterior spine on the sixth somite may be absent. Telson generally more or less truncated at the tip and laterally it is armed with spines. Eyes are well pigmented. Incisor process of the mandible is provided with teeth throughout the entire length of its cutting edge. Pereopods are not abnormally broad and flattened. Exopods of the third maxilliped and all pereopods are neither foliaceous nor rigid.

Distribution: Southeast and Southwest coast of India

Acanthephyra sanguinea Wood-Mason, 1892

Diagnostic Characters: Rostrum longer than carapace with 7 dorsal and 5 ventral teeth, extending much beyong the tip of the antennal scale. Branchiostegal spine small, forming a small projection on frontal border of carapace and without a carina. Surface of carapace finely pitted as in all the species of the purpurea group. Dorsal carinae of 3rd to 6th abdominal somites ending in pointed spines, that of 3rd somite the longest and of 4th and 5th of equal size and smallest. Four pairs of dorsolateral spines present on the telson.

Distribution: Southeast and Southwest coast of India

INTEGRATIVE TAXONOMY- A NOVEL APPROACH TO BIOLOGICAL STUDIES

A multisource approach that takes advantage of complementarity among disciplines, i.e., fields of study, has been called combined, multidisciplinary, multidimensional, collaborative, or integrative taxonomy mainly focusing on the species level. Integrative taxonomy does not replace traditional taxonomy. Rather, it compresses the traditional but slow taxonomic routine of visiting a taxonomic problem repeatedly into one procedure by coordinating the findings of different disciplines under the procedure. By doing so, integrative taxonomy improves rigor, more confidence in taxonomic information and consequently provides taxonomic stability.

DNA barcoding, a new method for the quick identification of any species based on extracting a DNA sequence from a tiny tissue sample of any organism, is now being applied to taxa across the tree of life. As a research tool for taxonomists, DNA barcoding assists in identification by expanding the ability to diagnose species by including all life history stages of an organism. As a biodiversity discovery tool, DNA barcoding helps to flag species that are potentially new to science. As a biological tool, DNA barcoding is being used to address fundamental ecological and evolutionary questions, such as how species in plant communities are assembled. The process of DNA barcoding entails two basic steps: (1) building the DNA barcode library of known species and (2) matching the barcode sequence of the unknown sample against the barcode library for identification. Although DNA barcoding as a methodology has been in use for less than a decade, it has grown exponentially in terms of the number of sequences generated as barcodes as well as its applications. Detailed species and larval level identification forms the pre-requisite for the proper conservation and management of the declining deep water shrimp resource of the country. DNA barcoding has been successfully used for species identification and discovery of new species, utilizing 650 base pair fragment of the mitochondrial gene, cytochrome oxidase subunit I (COI). COI was effectively used for the discrimination of closely related species and detection of cryptic species as well as for the identification of fish products. Mitochondrial DNA (Mt-DNA) sequence information has been used as an accurate and automated species identification tool for carrying out studies in a wide range of animal taxa, due to the presence of a significant amount of information.

Materials and methods

2.1. Sample collection

(a) Proper disposable or easily sterilized tools. (b) Proper individual storage containers for the organisms and tissues. (c) Data collection tools to handle specimens, tissues.
(d) Photo documentation materials (digital camera with appropriate lens(es), memory cards, backup hard drives).

2.2. Storage buffers

(a) Dry ice and cooler. (b) Salt solution. (c) EtOH—95% (nondenatured). (d) Formalin or other voucher specimen preservation solution(s)

2.3. Extraction components

(a) Lysis buffer for extraction method. (b) Proper plates, tubes or storage vessels. (c) When possible, on-site portable DNA extractor.

2.4. PCR components

(a) PCR reaction ingredients and primers. (b) Positive control 16S or 18S and COI

2.5. Sequencing, data QC, and analysis.

Data analysis

Molecular sequences were checked and confirmed using ABI SeqEditor v.1.0. Protein coding gene sequences (COI and Cytb) were translated into amino acids using Transeq (EMBOSS online tool) to avoid the inclusion of pseudogenes. All the sequences were blasted to report GenBank data to verify the potential contamination and the nucleotide sequences were aligned using the Clustal W algorithm. The aligned data was edited using bioedit V.7.0.5.2, gaps of sequences treated as missing data. All the sequences were submitted to GenBank. The pairwise genetic distance was calculated using MEGA 6.0.

Morphological analysis

In case of deep sea penaeoid shrimps ancestral state reconstruction (ASR) was used to evaluate character evolutions. Fifty-two morphological characters (24 binary, 27 multistate and one non-informative) were chosen and considered for phylogenetic analyses based on the original taxonomic works of Ramadan (1938), *Crosnier (1978; 1985), Pérez-Farfante (1997) and Dall (1999). All these major characters were re-examined carefully. The data matrix was analyzed with maximum parsimony using combinations of programs: Mesquite v.3.01 (*Maddison and Maddison 2015) *and* PAUP v.4.0 (Swofford 2002). These characters were given equal weightage and unordered, the code given for each state (i.e., 0, 1, 2, 3, and 4). Branch support was assessed using 1000 bootstrap replicates without any outgroups. Results acquired from both morphological and molecular tools was combinely assessed before deriving to any conclusion of a particular species, which is nothing but integrative taxonomy.

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CHAPTER 34

Molluscan Fisheries: Present Status

Molluscs, which include bivalves, gastropods and cephalopods, belong to large and diverse phylum Mollusca, forming the second largest species rich phylum in the world after Arthropoda. Marine molluscs are important component of the marine ecosystem, contributing significantly to the biodiversity from the coastal regions to the abyssal depths of the ocean. The five major classes in Mollusca, namely Polyplacopohora, Gastropoda, Bivalvia, Cephalopoda and Scaphopoda representing about 586 families, out of which 279 families occur in Indian region which includes 3600 species of marine, 1129 terrestrial and 199 freshwater forms. (Ramakrishna & Dey, 2010).

Marine molluscs occur in a large variety of substrates such as rocky shores, coral reefs, mud flats and sandy beaches. The gastropods and chitons are found on hard substrates while bivalves usually burrow on soft substrates (sediment). However, the cephalopods, which are marine, are mostly oceanic and active predators.

BIVALVES: There are about 10000 bivalve species. The bivalves form mostly a subsistence level fishery contributing to the livelihood of coastal populations and proving nutritional security. The bivalves have two shells, left and right valve and are bilaterally symmetrical. The shell is composed of calcium carbonate. The meat is consumed mostly by the local population. The bivalves include the clams, mussels, oysters, pearl oysters and cockles.

CEPHALOPODS: Cephalopods are purely marine and about 600 living species occur in the marine realm. The cephalopods include the squids, cuttlefish and octopus. While the squids and cuttlefish have an internal skeleton known as gladius (chitinous) and cuttlebone (calcareous), the octopus do not have the internal skeleton.

GASTROPODS: Gastropoda is the largest molluscan group with about 35000 extant species. The gastropods, which possess usually a single external coiled shell, are commercially important since they form a fishery all along the Indian coast. The meat is edible, shells are highly ornamental and operculum of the gastropods have medicinal and cosmetic uses. The meat is consumed locally as well as exported, while there is a huge ornamental shell trade along both coasts.

Molluscan fisheries

Cephalopods: Cephalopods from the most important molluscan group contributing significantly to the marine fishery. They are landed as by-catch and as targeted fishery mostly in the mechanized trawlers which are operated up to 200m depth and sometimes beyond.

Exploitation: In India, cephalopods are mainly caught by bottom trawlers operating up to 200 m depth zones. Most of the cephalopod catch used to be landed as bycatch from shrimp and fish trawls, however now it is an exclusively targeted fishery during the post monsoon period (September to December) particularly cuttlefish, using off bottom high opening trawls along South west and North west coasts. Traditional gears like shore seines, hooks and lines and spearing are used along Vizhinjam coast where no trawl fishing is done. Experimental squid jigging has been attempted in India but not yet commercialized.

The cephalopod production which increased from 1500 t in 1971 to over 15000 t in 1979 has been rapidly increasing ever since, reaching a high of over 250000 t in 2017, due to the export of frozen cephalopod products to several countries. Thus, cephalopods which used to be discarded or treated as bycatch, have now become targeted fishery due to the high foreign exchange being generated.

The estimated all India cephalopods catch during 2019 was 2,17,733 tonnes, however declined drastically during 2020 at 161004 t, due to the Covid-19 pandemic resulting in loss of fishing days. Gujarat contributes maximum to the cephalopod production with an annual average of 24885 t followed by Kerala at an annual average of 23195 t during 2017-2020, followed by Maharashtra and Tamil Nadu. The average annual production of cephalopod was 92798 t (2017-2020), recording a maximum production of 251678 t in 2017. The region wise production of cephalopods was highest in the northwest with an average annual landing of 40841 t followed by south west at 33445 t (2017-2020). The south east region recorded an average annual production of 16672 t and the south west region landed 1917 t during the period. Cephalopods constitute 5-6% of the total marine fish landings of India (CMFRI annual reports). However, they are under heavy fishing pressure due to their high value as export commodity and are subjected to target fishing particularly in the post monsoon seasons along the west coast of India.

The cephalopods are landed maximum during January to March and October to December along the upper east and west coast while they are landed during July to September also in Kerala Karnataka and Tamil Nadu.

Among the cephalopods exploited from the Indian seas, three major groups are the major components in the commercial fishery, squids (Order Teuthoidea), cuttlefish (Order Sepiodea), and octopus (order Octopodidae). The squids constitute 49%, cuttlefish 47% and octopus 4% in the cephalopod landings. The list of commercially exploited neritic species of cephalopods is given below. The dominant species occurring in commercial catches are *Uroteuthis (Photololigo) duvaucelii, Sepia pharaonis, S. aculeata and Amphioctopus neglectus.*

List of commercially exploited cephalopods from Indian seas.

Resource	Common English name	Distribution
Cephalopods		
Squids		
Uroteuthis (P.) duvaucelii	Indian squid	All along Indian coast
U (P) edulis	Sword tip squid	SW coast
U (P) singhalensis	Long barrel squid	SW and SE coast
Loliolus (L) hardwickii	Little Indian squid	All along Indian coast
Cuttlefish		
Sepia pharaonis	Pharaoh cuttlefish	All along Indian coast
S aculeata	Needle cuttlefish	All along Indian coast
S elliptica	Golden cuttlefish	Veraval & Cochin
S trygonina		SW coast
S prashadi	Hooded cuttlefish	SW & SE coast
S brevimana	Short club cuttlefish	Chennai & Visakhapatnam
Sepiella inermis	Spineless cuttlefish	All along Indian coast
Octopuses		
Amphioctopus neglectus	Web foot octopus	SW & SE coast and islands
A marginatus	Veined Octopus	SW & SE coast and islands
A aegina	Marbled octopus	SW & SE coast and islands
O lobensis	Lobed octopus	SW & SE coast and islands
O vulgaris	Common octopus	SW & SE coast and islands
Cistopus indicus	Old woman octopus	SW & SE coast and islands

Management: The commercially important cephalopods have been intensely researched and stock status of important species have been assessed. Cuttlefish species such as Sepia pharaonic and S aculeata are under exploited or optimally exploited along east coast. Squid stocks along Karnataka are marginally overexploited. Trawl is the principal gear of exploitation of cephalopods and cod end mesh in these are much below the permitted or notified size and therefore considerable quantities of juveniles are caught in the trawls. Mesh size regulations are implemented by the State Fisheries Department however not very effective. Minimum Legal size of capture for three species of cephalopods has been notified by the Kerala and Tamil Nadu Governments. At present 5.3 % of *U (P) duvaucelli juveniles 8.7% of S pharaonic and 5.9% of A neglectus* is commercially exploited. The strict implementation through enforcement of MLS would lead to enormous economic gains by virtue of the export value of these species. Regulation of fleet size would also facilitate effective management of recruitment overfishing since cephalopods are targeted fishery except seasonally. The trawl ban during the monsoon period is implemented in all the maritime States for 45 to 60 which has a major regulatory effect on this important fishery.

The recommended MLS and weights of three major species are given below

Species	MLS (Mantle length) mm	Corresponding total weight (g)
U (P) duvaucelli	80	25
Sepia pharaonis	115	150
A neglectus	45	15

Utilization and marketing: Almost the total catch of Cephalopods is exported and there is very little domestic consumption. The export of cephalopods peaked during 1995 with an annual average of 24% of the total exports, however has continued at 15% from 1992 onwards without much change. The value of cephalopod exports is over ₹800 crores in 2003. Squids products followed by cuttlefish are the major commodity among which frozen, dried, whole, filleted, rings, IQF, bones and ink. Octopus products exported are meagre however in recent years there is growing demand for the in export from 1994. The major export markets are Europe, China and Japan.

Oceanic squids: In recent years, new oceanic squid resources have been identified in the Indian Ocean. The purple back flying squid *Sthenoteuthis oualensis* (lesson 1830) is distributed in the tropical and subtropical areas of the pacific and Indian Oceans. The Arabian Sea is considered one of the richest regions for these oceanic squids in the Indian Ocean. The squids are pelagic occurring at depths of 250-300. This species is considered as the master of the Arabian Sea due to its high abundance, large size, short life span, fast growth, and highest position in the ecological niche. The estimated stock of squid in the Arabian Sea id 0.9 to 1.6 million t. Purse seining and gill netting with light attraction seem to be most efficient gears for exploiting this resource.

Bivalves

The bivalves include the clams, mussels and oysters, which are distributed all along the Indian coasts. The clams and oysters are fished by the local community for domestic consumption and forms a subsistence level fishery. Bivalves are exploited by the traditional method of hand-picking, skin-diving or by operating hand-dredges. Mussels and oysters are chiselled out from the substratum. Men and women are engaged in the fishing activity during low tide; hence, daily fishing time varies with changing tides. Generally, clams and oysters are gathered by wading in shallow areas, where it is easy to operate the nets and to clean the harvest. Dredges are operated from canoe in deeper areas.

The marine clam, mussel and oyster annual production during 2009-2020 was 1,00,931 tonnes on an average from Kerala, Karnataka, Goa, Maharashtra, Andhra Pradesh and Tamil Nadu. Clams are the most important resource followed by mussels and oysters, among which *Villorita cyprinoides* contributes more than half to the bivalve fishery. *Paphia malabarica*, *Meretrix casta, M. meretrix, Marcia opima* and *Anadara spp.* are the other important species contributing to the commercial clam fisheries. The mussel fishery is comprised of two species viz., green mussel, *Perna viridis* and brown mussel, *Perna indica.* The major edible oyster species are the Indian backwater oyster *Crassostrea madrasensis* and the rock oyster *Saccostrea cucullata.* Pearl oyster fishery, which was known since ancient times in the Gulf of Mannar area is not conducted since 1962, due to paucity of oysters in the natural beds.

Clams: A number of clam species belonging to the families Arcidae, Veneridae, Cobuculidae, Tridacnidae, soleridae Mesodesmatidae, Tellinidae and Donacidae are exploited along the Indian Coast. The Arcid clams are called blood clams due to the presence of haemoglobin in the blood. A single species *Anadara granosa* is important and occurs Indian coast in soft muddy substratum and forms a significant fishery in the Kakinada Bay. The clams are essentially exploited for the meat, however, in most places the shell is in demand for the lime industry. The meat is also used in the shrimp farming sector as brood stock feed.

The venerid clams are the most exploited among the clams and three genera namely *Meretrix, Paphia* and *Marcia* are important. Along the Maharashtra Coast, *Meretrix meretrix, Marcia opima, Paphia laterisulca* are dominant species. In Goa, *M casta*, forms a fishery. In Karnataka there 14 estuaries with varying abundance of clams. *M casta* is found in all estuaries, *M meretrix* in Kalinadi and Coondapur estuaries, *Paphia malabarica* in the Mulky, Gurpur, Udayavatra and Coondapur estuaries. Marcia opima is found in Coondapur, Uppunda and Sita estuaries. Along Kerala Coast, *P malabarica* forms a fishery at Dharmadom, Koduvally, Azhikkal, Valapattinam, Karyangod and Chittari estuaries and Astamudi Lake. *Meretrix casta* forms fishery in Moorad, Korapuzha, Chaliyar, Mahe and Valapattinam estuaries along the Malabar coast. Along the east coast, *M casta* occurs in several estuaries and forms a fishery in Vellar estuary, Pulicat lake and Bhimunipatnam. *M opima*, *P malabarica* and *M meretrix* forms fishery in the Kakinada Bay. In Orissa, *Meretrix* sp occurs in the Chilka lake and Sonapur backwaters. Kerala leads in the clam production followed by Karnataka, while clam resources are smaller in the east coast.

Paphia malabarica exploited from the Ashtamudi Lake, had a flourishing fishery but has been declining over the past few years due to drastic change in climatic conditions especially due to flood over the last two years. The average annual production of the short neck clam was 8530 t during 2011 -2020. The average annual production was over 1 lakh t during 2011 to 2015 has declined to 1727 t in 2020. The spat fall has failed due to drastic change in the sediment profile of the Ashtamudi Lake due to continuous rains in the past two years.

The short neck clam fishery of Ashtamudi Lake is a regulated and managed fishery. About 500 fishers are depended on this fishery for their livelihood. Based on the recommendations of CMFRI, the Government of Kerala has enforced a ban on clam fishing during the breeding season (September to February), use of 30 mm mesh size to avoid exploitation of smaller clams, restrict the export of frozen clams grade t0 1400 nos/kg and initiate relaying of juvenile clams in suitable areas for stock enhancement. The Minimum Legal Size of fishing of *P malabarica* has been set at 20 mm.

The corbiculid black clam *Villorita cyprinoides* is a major resource of the Vembanad Lake and is also exploited in several other backwaters and estuaries (Korapuzha, Chaliyar, Moorad, Mahe, Valapattinam, Padanna and Chandragiri) of Kerala, Goa and in the Netravati, Gurpur, Udyavara, Swara and Coondapur estuaries of Karnataka.

Villorita cyprinoides exploited from the Vembanad Lake in Kerala contributed almost 90% to the total clam production in India. The average annual production of the black clam in the Vembanad Lake is 44330 t during 2005-2020. A maximum production was 75592 t was recorded in 2006; in 2018 the production was 49394t however has declined to 39243 t in 2020. The Minimum Legal Size of fishing of *V cyprinoides* has been set at 20 mm. Recently, the relaying of baby clams in new areas where clams did not exist, was highly successful with a production of over 10 t per day for the fishers.
Mussels: India has two species of mussels, the green mussel, *Perna viridis* and the brown mussel, *Perna indica.* The green mussel contributes substantially to the total mussel production and it is more widely distributed compared to the brown mussel. Green mussels are found along the intertidal coasts of Quilon, Alleppey, Kochi, Kozhikode (Calicut), Kannur and Kasargod districts of Kerala, a state on the south west coast of India. It is most abundant from Kozhikode – Kannur to Kasargod which is known as the mussel zone of India. Along the east coast of India, it ranges along Chilka Lake (Orissa), Visakhapatnam (Andhra

Pradesh), Chennai (Tamil Nadu), and Cuddalore (Pondicherry). It is also found along Mangalore, Karwar, Goa, Ratnagiri, and in the Gulf of Kutch and the Andamans and Nicobar Islands.

The green mussel fishery along the Malabar Coast is an activity independent of the other marine fishery activities of the coast. The mussel pickers are an exclusive coastal community engaged in the exploitation of this sessile resource and 1551 persons are involved in mussel picking. The green mussel fishery begins from mid-August or September onwards and lasts up to mid-June. The fishery stops during the South West monsoon (June -August). Mussel picking usually begins in the early hours from 07 00 hours and last for 4-5 hours. Picking is generally done during low tide, on bright sunny days when the water is clear. Pickers dive down to the mussel beds and use chisel or knife to scrape off the mussels from the intertidal rocks. The depth ranges from 0.5 to 10 m. The pickers stock the picked heaped in the canoe, while in Thikkodi, the pickers use "catamarans" (made by tying up 3 wooden logs) to reach the mussel beds (Figure 3: A). The fishing duration varies depending on the demand for the mussel and the availability of the particular size range.

The major mussel beds along the South west coast are distributed across three districts of Kerala and in Mahe (Union Territory of Pondicherry). The mussel beds in Kozhikode (Calicut) district are Chombala, Thikkodi, Moodadi, Kollam, Elathur, South beach and Chaliyam, constituting about 435 ha. Mussel bed off Mahe (Pondicherry) constitutes nearly 20 ha. The major mussel beds in Kannur district are along Kadalayi, Koduvally, Thalasseri and Thalayi, constituting 125 ha. In Kasargod district, the mussel beds are off Chembarica, Kottikulum, and Bekal constituting 40 ha. The total area of mussel beds along the Malabar Coast constitutes 620 ha in area. Spat settlement occurs on lateritic formations along South beach, Chaliyam, Elathur, Kollam, Moodadi and Thikkodi. Granite rocks are observed in Chembarika, Kottikulum, Bekal, Kadalayi, Koduvally, Thalasseri, Thalayi, Mahe and, Chombala. mussels in nylon bags tied around their waists. In most centers, the 2-3 pickers go out in a small canoe and return with their individual collection

The green mussel fishery of the South west Coast of India has unique features which contribute to the sustainability of the fishery. The increased demand for green mussel in recent years has led to increased effort and exploitation of the green mussels. However, the fishery is self-managed and sustained by the mussel pickers themselves by suspending fishing during monsoon season. The special topographic distribution of the mussel beds and the interactions of the climatic factors sustain the livelihood of several wild mussel harvesters in the region.

Oysters: The edible oyster *Crassostrea madrasensis* is fished to a very small extent in Kerala, Karnataka, Goa, Andhra Pradesh and Tamil Nadu. It is essentially collected for local consumption and often subsistence fishery. In Ashtamudi Lake, the oyster formed a considerable fishery, however has declined drastically over the last five years. The average annual production was 587t during 2016-2020. The oyster meat is edible and the shell is of composed of calcium carbonate and used in the lime industry.

Window pane oysters: The pearl bearing oyster *Placuna placenta* is distributed in the Gulf of Kutch (Gujarat), Kakinada Bay (Andhra Pradesh) and Nauxim Bay (Zuari estuary in Goa) and the Tuticorin Bay and Velapatti near Tuticorin (Tamil Nadu). *P placenta* is found on muddy or sandy substrata from shallow water to depths of 100 m. The Kakinada Bay in Andhra

Pradesh is a rich ground of live window pane oyster as well as dead shells. The pearls are used in the pharmaceutical preparations of medicines. The shell is large, very flat, thin and rounded and used a glass substitute and other ornamental curio items. The meat is edible.

Commonly exploited bivalve resources	Common English name	Local name
Clams and cockles		
Villorita cyprinoides	Black clam	Karutha kakka
Paphia malabarica, Paphia sp.	Short neck clam,	Manja kakka (Ma), Chippi kallu (Ka), Tisre (Ko)
Meretrix casta, Meretrix meretrix	Yellow clam	Matti (Ta)
Marcia opima	Baby clam	Njavala kakka (Ma), Vazhukku matti (Ta)
Sunetta scripta	Marine clam	Kadal kakka (Ma)
Donax sp	Surf clam	Mural,Vazhi matti (Ta)
Geloina bengalensis	Big black clam	Kandan kakka (Ma)
Anadara granosa	Cockle	Aarippan kakka (Ma)
Placuna placenta	Window pane oyster	Kapis
Mussel		
Perna viridis	Green mussel	Kallumakkai, Kadukka (Ma) Alichippalu (Te)
Perna indica	Brown mussel	Kallumakkai, Chippi (Ma)
Edible oysters		
Crassostrea madrasensis	Indian backwater oyster	Kadal muringa (Ma); Ali, Kalungu (Te) Patti (Ta)
Saccostrea cucullata	Rock oyster	Kadal muringa (Ma); Ali, Kalungu, Patti (Ta)

Ka – Kannada, Ko – Konkani, Ma- Malayalam, Mr – Marati, Ta- Tamil, Te- Telugu

Gastropods

The gastropod constitutes a large and highly diversified class within the phylum Mollusca with 1,00,000 living species, of which the estimated number of valid marine species is around 50,000 to 55,000 marine (Mollusca Base, 2021). The marine gastropod resources in India comprise a variety of species. Several species of gastropods have high economic value in international markets and play important social roles in small-scale artisanal fisheries. In India from both east and west coasts several gastropod species are being exploited from time immemorial. The gastropods form a niche in the export industry and becoming highly priced objects in Indian and foreign markets and the fishery supports a huge number of the coastal population either directly or indirectly for making the ornaments and handicrafts from gastropods shells. There is a variety of ornamental gastropods and it is used as the raw material for the shell handicraft trade. In southeast coast of India, where the most part of landings of marine gastropods are occur is considered as the hub of shell craft industry. The meat of several gastropods is consumed. The operculum of the gastropods is also in high demand for use in the pharmaceutical industry. The southwest and southeast coasts and the coral reef ecosystem in the Lakshadweep and Andaman and Nicobar Islands harbour some of the richest gastropod beds along the Indian coast. These resources are mainly exploited by either mechanised trawlers, bottom set gillnets or by diving. Very few species form a regular fishery and most of them are obtained in smaller magnitude. Among the several gastropod species that are exploited very few species are used for edible purpose. In view of the intense exploitation of several species of gastropods as raw material for the shell craft as well as pharmaceuticals, 24 species of the ornamental molluscs have been classified as endangered and are protected under the Indian Wildlife Protection Act (1972).

In India, commercial exploitation of gastropods is mainly in three States., Tamil Nadu, Andhra Pradesh and Kerala. The average annual exploitation of gastropods in India was 4909 tonnes (2012-2020). Tamil Nadu was dominant in the gastropod fishery with 58 % of the total gastropod catch followed by Kerala (25 %) and Andhra Pradesh (17 %).

Most of the commercially important gastropods are distributed in the shallow waters, lagoons and reef areas of the coastal sea. In India nearly 60 gastropod species form commercial fishery. Among the exploited gastropods, *Babylonia spirata,Turbinella pyrum, Chicoreus ramosus, Lambis lambis, Pirenella cingulata*, *Laevistrombus canarium, Telescopium Telescopium, Umbonium vestiarium*, *Neverita didyma*, *Nassaria coromandelica*, *Volegalea cochlidium, Agaronia gibbose*, *Tonna dolium and Conus spp.*were the dominant species .*Turbinellapyrum*, the sacred chank, has formed an inextricable bond with humanity out of all the shells. It has played a key role in the observance of traditional customs o fthe Indians, especially Hindus, as a divine symbol. It occupies the top status and they are exploited from both the east and west coasts of India. Exploitation of *T. pyrum* by skin diving method is most popular in south east coast of Tamil Nadu.

List of commercially exploited gastropods from Indian waters

Resource	Common English name
Gastropods	
Turritellidae	
Turritella attenuata	Turret/Screw shell
Turritella duplicata	Duplicate turret
Terebridae	Auger shell
Duplicaria duplicata	Duplicate auger
Harpidae	Harp shell
Harpa major	Major harp
Olividae	Olive shell
Agaronia gibbosa	Gibbous olive
(*Oliva gibbosa*)	
Ancilla acuminata	Pointed ancilla
Ficidae	Fig shell
Ficus ficus	Common fig shell
Naticidae	Moon shell
Tanea lineata	Lined moon shell
(*Natica lineata*)	
Natica vitellus	Calf moon shell
Polinices mammilla	Pear-shaped moon
Polinices fibrosa	
Architectonicidae	Sundial shell
Architectonica perspectiva	Perspective sundial
Architectonica purpurata	Purpurata sundial
Rostellariidae	Tibia shell

Tibia curta	Curta tibia
Cassidae	Helmet/Bonnet shell
Phalium glaucum	Grey bonnet
Semicassis bisulcata	Japanese bonnet
Cassis cornuta	Horned helmet
Tonnidae	Tun shell
Tonna dolium	Spotted tun
Muricidae	Rock shell
Rapana rapiformis	Turnip shell
(*Rapana bulbosa*)	
Murex trapa	Rare spined murex
Muricidae	
Chicoreus virgineus	Virgin murex
(*Murex virgineus*)	
Haustellum haustellum	Snipe's bill murex
(*Murex haustellum*)	
Vokesimurex malabaricus	Malabar murex
(*Murex malabaricus*)	
Purpura bufo	Toad purpura
(*Thais bufo*)	
Strombidae	Conch shell
Mirabilistrombus listeri	Lister's conch
(*Strombus listeri*)	
Dolomena plicata sibbaldi	Pigeon conch
(*S.plicatus sibbaldi*)	
Volutidae	Volutes shell
Harpulina lapponica loroisi	Lorois's volute
Babyloniidae	Babylon shell
Babylonia spirata	Spiral babylon
Babylonia zeylanica	Indian babylon
Melongenidae	Crown conch
Hemifusus cochlidium	Spiral melongena
Fasciolariidae	Spindle shell
Fusinus colus	Distaff spindle
Fusinus forceps	Forceps spindle
Turbinellidae	chank shell
Turbinella pyrum	Sacred chank
(Xancus pyrum)	
Bursidae	Frog shell
Bufonaria echinata	Spiny frog shell
(*Bursa spinosa*)	
Bufonaria crumena	Frilled frog shell
(Bursa crumena)	
Tutufa bufo	Red-mouth frog shell
Ranellidae	Triton shell
Cymatium(lotoria) perryi	Perry's triton
(*C.(Lotoria) lotorium*)	

Gyrineum natator	Tuberculate gyre triton
Turridae	Turrid shell
Lophiotoma indica	Indian turrid
Cypraeidae	Cowry shell
Mauritia arabica	Arabian cowry
(*Cypraea arabica*)	
Erronea errones	Wandering cowrie
(*Cypraea errones*)	
Nassariidae	Nassa shell/Dog whelk
Nassarius conoidalis	Cone-shaped nassa
Nassarius olivaceus	Olive nassa
Nassarius stolatus	
Conidae	Cone shell
Conus betulinus	Betuline cone
Conus textile	Textile cone
Conus milneedwardsi	Glory of India cone
Conus inscriptus	Engraved cone
Conus figulinus	
Personidae	Common distorsio
Distorsio perdistorta	Hunchback distorsio
Buccinidae	Whelk shell
Cantharus tranquebaricus	Tranquebar goblet
Ovulidae	False cowries
Volva volva	Shuttlecock volva
Cancellariidae	Nutmeg shell
Trigonostoma scalariformis	Scalariform nutmeg
Calyptraeidae	Slipper shell
Desmaulus extinctorium	Conical slipper shell
Trochidae	Top shell
Clanculus spp.	
Gibbula spp.	

Gastropod species composition

In Tami Nadu, the average annual gastropod catch was 2848 tonnes (2012-2020). Along Tamil Nadu coast gastropods are mainly exploited from six districts in which, Ramanathapuram contributes 54 % of the total catch followed by Tuticorin (14 %), Nagapattinam (9 %), Cuddalore(7 %), Kannyakumari (7 %) Chennai(6 %) and Tirunelveli (3 %). Trawl net is the major contributing gear (53 %) followed by Skin diving (38 %), gill net (6 %) and other gears (3 %). In the Tuticorin and Ramanathapuram, gastropods formed a targeted fishery traditionally by skin diving, whereas in gillnet and trawl net, these resources are landed as by catch. The targeted gastropods from skin diving is *T. Pyrum, C. ramosus* and *L. lambis* . In the trawl net, Babylonia, Strombids, Olivids, Naticids, Nassarids, Bursa, Conus and Muricids are the most important group. In Tirunelveli, chank net (gill net) is the major gear for gastropod exploitation and *T. Pyrum* was the dominant species. In this region, gastropods are mainly exploited for its shell and plays an important role in the commercial shell craft industry in Southern coast of India. From Thoothukudi District, the meat of *C.ramosus* exported to Thailand. Apart from the shell and meat, the dried operculum of gastropods is in immense demand in the international market. The operculum of gastropods has good market value ranging from Rs. 1,000 to 14,000 depends on the species and operculum powder is an important ingredient in fragrance making. In addition, from the Thoothukudi region the under sized and infested gastropod has been transported to Northern part of Tamil Nadu where the minced and powdered shell is used as an ingredient for the poultry feed. In Chennai, the ornamental gastropods are mainly landed as by-catch along with other resources in the trawl landing. The fishery was compromised of about 30 species of gastropods. *Babylonia sp.* is the targeted fishery along the coast and it contributes about 68.24% to the total gastropod landings. There is a high export demand on Babylonia in the foreign counties like China, Hongkong, Thailand. The other species which are regularly landed in by catch were *Ficus spp*., *Bursa spp.*, *Turittella spp.*, *Tona dolium, Nassarius dollium , Conus spp., Phalium spp., Rapana rapiformes.* Major landing of gastropods was contributed by multiday trawl net (58%).

In Kerala, Shakthikulangara and Neendakara are the major landing centres of the Kollam district and ranked top gastropod landing centres along the western coast of India. An estimated annual gastropod landing of Kerala is 1225 tonnes (2012-2020). In Kollam, gastropods occur as a by-catch of shrimp trawlers and the exploited gastropods are mainly used for meat and ornamental shells. Although a large number of gastropod exporting firms exist in this area, due to lacking of hell craft industries exploited ornamental shells are traded to shell craft industries located in Tamil Nadu, Pondicherry, and Goa. Few years before in Kollam a large number of species are being exploited and traded and they include *Babylonia, Turbinella, Harpulina ,Bufonaria, Rapana, Turritella, Conus, Natica, Tibia, Oliva, Nassarius, Ficus* and*Phallium.* In order to prevent juvenile fishery, in recent years, the strict vigilance from Coastal Police and State Fisheries Department has been carried out at the major landing centre of Kerala including Kollam. Owing to this, trash landings at the landing centres have been reduced because only the trash landings will bring the ornamental gastropods at the landing centres. Gastropods catch was mainly contributed by Babylonia species because of its targeted fishery every year during April – June. The entire gastropod catch was contributed by two main gears, 90 % by Single day trawl net (MTN) and 10 % by multi-day trawl net (MDTN). *Babylonia spirata* and *B. zeylanica* were the dominant species in the catch forming 99.8%. of the total gastropod catch. *Babylonia spirata* and *B. zeylanica* were the dominant species in the catch forming 99 %. Babylonia spp were obtained as by catch during shrimp trawling throughout the year. Whelk trawl net is specially designed notably it has heavy rigging which help this net to plough deep into the sediment and thereby catching these whelks. Observations on the landings of shells indicated that 54 species of gastropods belonging to 27 families; 9 species of bivalves belonging to 5 families and one species of scaphopod were landed as by-catch of trawlers.
In Andhra Pradesh, the gastropods are mainly exploited from Kakinada, Kancheru and Visakhapatnam regions. The targeted centres for gastropod fishery are Kakinada and Kancheruand and in most landing centers the gastropods are mainly came under by-catch discard categories. The average annual landing of gastropods from Andhra Pradesh is 837 tonnes. The main species contribute to the fishery are *Cerethidia sp., Bursa sp., Babylonia spp., Telescopium sp., Umbonium sp., Murex sp., Hemifusus sp., Harpa sp. Conus sp. Oliva sp. Tonna sp. etc.* The annual landings of Gastropods at Kakinada is 524.23 t and catch/effort was 509.52 kg/unit (2017-2019**)**. About 43% is contributed by the *Cerethidia sp.* and rest mainly by *Murex sp., Telescopium sp*. and *Umbonium sp.*etc. In Kancheru, average annual gastropod landing was 0.75 tonnes with the catch/effort of 3.53 kg/unit respectively. *Babylonia zeylanica, Harpa major, Murex Sp., Bursa Spp.* contributes more to the landing

The landings is mainly in the by-catch form from gillnets; mostly from the "crab nets" –the bottom set gill nets used in August to December season. In Visakhapatnam the gastropod catch is mainly from trawl by-catch. The total gastropods landings during the year 2017-2019 were about 17.42 tonnes with an average annual landing of about 5.81 tonnes with the catch/effort of 5.65 kg/unit respectively. Nearly 32% of the catch was contributed by the *Bursa* species, 22% by *Ficus sp.* and rest 46% by other species like *Polinices sp., Tonna spp*., *Conus sp.* etc. The Shells were collected by ladies for domestic consumption mainly the *Ficus sp. and Melo sp.*The marketing of these shells is mainly depending on the nearby states like Tamil Nadu, Orissa, Maharashtra and Telengana; besides the small scale exporters of Kakinada, Yanam, Guntur and other regions of the Andhra Pradesh.

The molluscan fishery of India can be further developed and production can be increased on a sustainable level with better focused management and regulations. Bivalve and gastropod fishery are not adequately monitored and reported moreover, it is restricted to domestic consumption only and lack of awareness regarding the nutritive values of these high protein nutritive resources. Also, conservation and stock enhancement strategies are to be implemented for the endangered species. Exploitation of cephalopods can be enhanced up to the potential yield estimates only and hence fishery management and gear and fleet size restrictions need to be strictly enforced. Potential for exploitation of Oceanic cephalopods exists and has to be tapped.

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CHAPTER 35

Importance of Taxonomy and Identification in Shell Trade

The gastropods constitute a large and highly diversified class within the phylum Mollusca with 1,00,000 living species, of which the estimated number of valid marine species are around 50,000 to 55,000 (Mollusca Base, 2021). Gastropods encompass 80 % of living molluscs species. Gastropods are considered as the oldest known fossils with their shells being evolved in rocks 540 million years ago. Many gastropods possess a shell that protects the soft body of the animal. In most species, the coiled shell opens on the right-hand side (dextral). Rarely, right-hand coiled species will produce left-hand coiled (sinistral) shells and vice versa. Many species bear an operculum that assists to protect the animal in addition to the shell. About 5070 species have been reported from India belonging to 290 families and 784 genera which are recorded from Gulf of Mannar (428 species), Lakshadweep (424 spp.), Gulf of Kutch (350 spp.), Orissa coast (337 spp), West Bengal coast (425 spp.) and Andaman & Nicobar Islands (1434 spp). Nearly 3,370 species of molluscs are recorded from marine habitat (Venkataraman and Wafar, 2005). Among these, gastropods are the most diverse, followed by bivalves, cephalopods, polyplacophores and scaphopods. About 1900 marine species of gastropods are known to date.

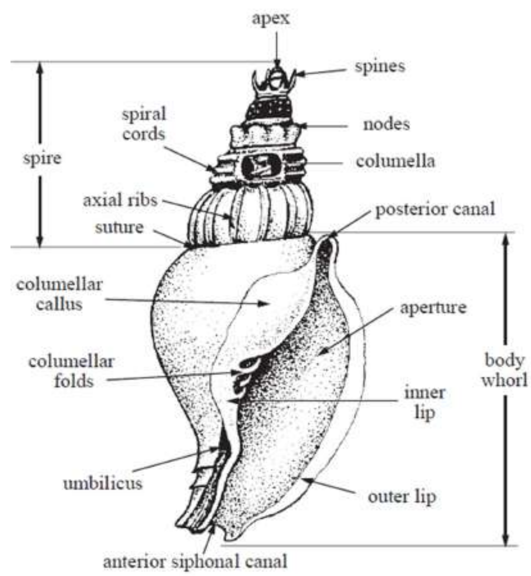
The marine gastropod resources in India comprise a variety of species and the resources are exploited regularly for various purposes. They are mainly exploited regularly for ornamental purposes and food. Very few species forms a regular fishery and most of them are obtained in smaller magnitude making them unnoticed. Even though these resources are smaller in magnitude compared to other fisheries, they play an important role as raw materials for the multi-million dollar 'SHELLCRAFT INDUSTRIES' world over. In southeast coast of India, where the most part of landings of marine gastropods are landed and considered a hub of shell craft industry. Gastropods are characterised by having single shell and an operculum and an active foot. Wide range in size and the shell has been modified enormously in many groups.

Major identifying features of Gastropods

- Structure of the radula (rhipidoglossan, docoglossan, taenioglossan, ptenoglossan, stenoglossan and toxoglossan)
- Structure of the operculum (Chitinous, calcareous, multispiral, paucispiral, ungulate, ovate).
- Character of the aperture

- Character of the columella (curvature, sculpture)
- Presence and character of umbilicus.

Morphometrics of a typical marine gastropod



<u>**Glossary of technical terms used in identification of gastropods**</u>

Anterior canal - expansion looking like a groove or a tube
Aperture - opening in gastropod shells.
Apex - extremity of a gastropod shell opposite to the anterior region.
Body whorl - most anterior whorl of the gastropod shell, last and largest whorl.
Callus - thickening of the shell, usually secreted on the parietal region of the columella.
Columella - column or pillar located on the centre of a gastropod shell.
Cord - element of gastropod shell sculpture, usually spirally oriented, thicker than line.
Cordlet - narrow cord, thicker than line.
Crenulations - notches, or wrinkles that are small and delicate.
Denticles - features of sculpture elements looking like small teeth-like projections.
Fold / Plication - ridge spiralling on columella.
Granulated - surface covered with minute grains, pustules, or beads.
Growth lines - lines on shell surface indicative of alternating periods of growth and rest;
Incised lines - features of shell sculpture represented by cuts or narrow grooves on the shell surface.
Indentation - cut or notch on shell edge or parietal region.
Knob - large nodule, rounded projection.
Lamella - thin plate or blade-like projection.

Lip - edges of the outer surface of the aperture in the gastropod shell.
Nacreous - characteristic of being iridiscent, like mother-of-pearl.
Nodules - projections that are rounded as tubercules.
Notch - cut or depression on any margin, canal, or on the gastropod aperture.
Opalescent - characteristic of being whitish, but with nacreous luster.
Operculum - plate which closes the aperture of gastropod shells
Outer lip - edge of the external part of the aperture away from the shell axis.
Parietal - region of the internal part of the aperture
Periostracum - layer of the outside part of the shell. It is horny and sometimes hair-like.
Peristome - aperture rim or periphery.
Plication - same as fold.
Protoconch - larval shell remaining on the apex of well-preserved gastropod shells.
Radial - structures that are directed away from the apex toward the shell margin, in limpets.
Ribs - strucutural elements forming a well-defined, narrow ridge in gastropod shells.
Serrated - resembling tiny saw teeth.
Septum - partition found in the internal side of gastropod shells; characteristic of slipper-shells.
Shoulder - angled region of the whorls of gastropod shells.
Siphonal canal - projection of the anterior region shell in tubular form protecting the anterior siphon.
Spire - series of successive whorls in a gastropod shell, with exception of the last one.
Striation - fine, repeated lines or furrows on shell surface.
Suture - line or region of junction between two adjacent whorls in the gastropod shell.
Umbilicus - cavity at base of gastropod shells.
Varix - axial sculptural element that is more prominent than a costa, and usually more widely spaced;
Ventral - region of the animal opposed to the dorsal region; region of the foot in gastropods.
Whorl - a complete turn or coil of the gastropod shell.

Commercially important gastropod families

The class Gastropods consists of as many as 39 families (FAO,1998), represented by numerous species. In order to have a broader understanding on the taxonomy of this group the following most commercially valued families numbering 26 have been considered citing the important representative key species. A mention is also made for better understanding on the key contrasting species under the same family which otherwise look different.

Bouchet and Rocroi (2005) use six main clades: Patellogastropoda, Vetigastropoda, Cocculiniformia, Neritimorpha, Caenogastropoda and Heterobranchia,which are generally recognized by researchers.

Patellogastropoda: This is a major group of marine gastropods that contains true limpets, traditionally called Docoglossa.
Vetigastropoda: This includes top shells, abalone, keyhole and slip limpets and several other families.
Cocculiniformia: This group includes white limpets that attach to organic matter in the deep ocean.
Neritimorpha: Includes some sea snails and deep water limpets.

Caenogastropoda: This group is highly diverse and has colonized almost all marine, freshwater, and terrestrial environments. This clade (large group) consist of about 60 % of extant gastropods and contains a large number of ecologically and commercially important marine families such as Muricidae, Volutidae , Mitridae, Buccinidae, Terebridae ,Conidae , Littorinidae, Cypraeidae, Cerithiidae , Calyptraeidae, Tonnidae , Cassidae , Ranellidae , Strombidae and Naticidae .

Heterobranchia: This group includes pulmonates (comprises more than 20,000 species) and opisthobranchs includes sea hares, sea slugs and bubble shells. This group includes the gastropod groups positioned by Thiele's taxonomic scheme into the 'Opisthobranchia' and 'Pulmonata', as well as some 'prosobranch' groups.

Major gastropod species in shell trade

Haliotidae: Shell ear-shaped, depressed and loosely coiled. Spire eccentric. A spiral row of holes on body whorl. Operculum absent.

***Haliotis varia* Linnaeus, 1758 : Ear shell**

Moderately large, thick and broadly ovate shell. Outer surface coarse looking with flat spires. The aperture is large and the inner surface smooth and lustrous. Body whorl with 4-5 perforations near the margin. Olive green with white mottling/ dull greyish brown with green tinge.	

Trochidae: Shell conical to globose, often with a flattened base. Aperture without a siphonal canal, nacreous within. Operculum corneous, nearly circular

***Trochus radiatus* Gmelin, 1791 : Radiate Topshell**

Moderate sized top shaped shells. Moderate to well-developed spires. Surface sculptured by spiral rows of tubercles, upper rows of tubercles are larger and pearly inner. Columella is smooth and not denticulated. Ground colour white to pale, uninterrupted axial reddish streak. Aperture white in colour.	

***Umbonium vestiarium* (Linnaeus, 1758) : Button shell**

Small solid rounded shells (up to 2 cm). Smooth, highly polished surface. Spire is depressed. Body whorl broad and more or less flattened. Aperture is flattened and 'D' shaped. Colour pattern polymorphic and highly variable in exterior.	

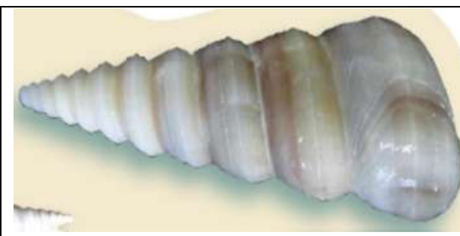
Turbinidae: Shell varies greatly in shape and size from orbicular, rounded, top shaped, elongately ovoid or even conical. Body whorl is always enlarged and moderately inflated. Pearly within. Thick calcareous operculum.

Turbo bruneus (Roding, 1798): Brown dwarf turbon

More or less top shaped shell with well- developed spire and rounded whorls, lower surface is rounded or inflated and never flattened. Three to four whorls on the flat inner surface, outer one is rounded, smooth and sculptured. Largest ridge in the middle ends at the margin of outer lip as a distinct tooth. Umblicus narrow and deep with a keel around. Inner lip shiny. Dark greenish brown, irregular yellow blotches. Thick calcareous operculam, with nearly central nucleus.	

Turritellidae: shell elongate, sharply conical, with numerous whorls and a small aperture.Whorls sculptured with spiral ribs or keels. Siphonal canal absent. Operculum corneous, rounded.

***Turritella duplicata* (Linnaeus 1758): Duplicate turret**

Shell is large and thick without an umbilicus, often very tall and slender with more or less numerous whorls and usually with spiral sculpture. Aperture is small, rounded or angular and margin unbroken by canals, outer lip distinctly sinuate. Two sharp ridges in the middle of each whorl. This sharp angle tends to disappear in larger specimens but is retained in the top five or six whorls.	

Architechtonidae: Shell wider than long, with a large, rather flat base. Umbilicus broadly open, within which can be seen the inverted larval shell. A nodular spiral rib bordering the umbilicus. Aperture without a siphonal canal. Operculum corneous, with a tubercle internally.

Architechtonica perspectiva (Linnaeus, 1758): Perspective sundial

The shell is moderately large and thick with a broad, flattened base and expressly conical spire and resembles a winding staircase. There is a distinct spiral rib near the lower edge of each whorl. The ground colour is pale brown; the raised band at the bottom of each whorl is spotted alternatively with white and dark brown. Immediately below the suture there is a white spiral band bounded above and below by dark brown spiral bands.	

Potamididae: Shell high-conical, with many spire whorls. Sculpture generally coarse. Aperture relatively small, with a short siphonal canal. Outer lip often flaring. Operculum rounded, corneous, with many spiral coils.

Pirenella cingulata (Gmelin, 1791): Girdled horn shell

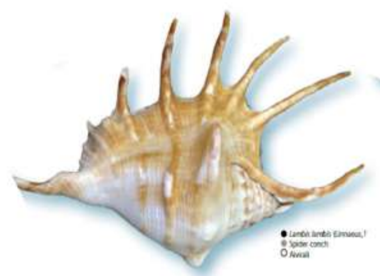
Small, moderately elongate, soild shell with flat sided whorls and deep suture. The surface of each whorl bears four distinct spiral ridges. The tubercles on the ridges are so arranged as to form regular transpiral rows. The anterior canal is represented by a deep notch. Dark brown coloured shell with two or three white lines per whorl.	

Strombidae: shell thick and solid, with a relatively large body whorl. Aperture with a well-marked siphonal canal. A distinct notch along the anterior margin of the outer lip. Operculum corneous, claw-like

Laevistrombus canarium (Linnaeus, 1758) : Dog conch

Large, thick and heavy shell. Spire very small compared with globus, pear shaped body whorls. Thick wide incurved lip extending length of body whorl. Body whorl much broader than the height of the shell. Columellar callus well developed. White or cream with fine wavy network of brown lines. Aperture white.	

Lambis lambis (Linnaeus, 1758): Spider conch

Shell very large with thick callus zone. Outer lip bears 7 fingers like channelled processes. Anterior canal long and pointed. Shell covered with horny periostracum. Shoulder angular and strongly nodulated near suture. Chestnut or cream yellow with brown markings. Callus and inner part smooth white or cream in colour.	

Naticidae: shell globular to ovate-conical. Outer surface smooth or with reduced sculpture. Aperture large, semicircular. Siphonal canal absent. Umbilicus open or closed, sometimes with an internal rib. Operculum corneous or calcified.

Neverita didyma (Roding, 1798): Bladder moon shell

Shell quite large, globular in shape and decidedly wider than long. Spire short, poorly protruding, with slightly convex whorls and shallow sutures. Outer surface of shell smooth apart from fine lines of growth. Umbilical callus with a deep median groove. Operculum corneous. Colour bluish grey to light brown or fawn. Whitish on base and umbilicus, and sometimes with faint spiral banding. Operculum yellowish brown.	

Cpyraeidae: Shell ovate or oblong, Spire concealed under body whorl. Surface highly polished, smooth .Aperture long and narrow channelled at both ends. Both lips with teeth. No operculum.

Cypraea tigris **(Linnaeus, 1758): Tiger cowry**

Shell, glossy, solid, heavy and inflated. Dorsum elevated and doom shaped. Dorsal surface profusely ornamented with large rounded blackish brown spots of various size on white base. Both the lips are dentate and curved inside, giving the aperture a slit like appearance. Base flat or slightly concave. Dorsal side inflated with an unbranched, linear mantle groove.	

Monetaria annulus **(Linnaeus, 1758) :Ring cowry**

Ovate,humped shell with coarse teeth. Dorsum creamy bluish with clear golden yellow ring where dorsum meets marginal calluses. Margins base and teeth mushroom.	

Cassidae:Shell thick and solid, with a large body whorl and rathersmall, conical spire. Sculpture variable, axial varices sometimes present. Aperture elongate, with a short siphonal canal, recurved dorsally. Outer lip thickened. Inner lip with a shield-like callus. Operculum quite small, corneous.

Phalium glaucum **(Linnaeus, 1758) :Grey bonnet**

Shell moderately large, ovate to globular with short pointed spires. Spiral rows of blunt or sharp tubercles on spire. Outer lip thickened with short teeth along inner edge and three or four sharp spines projecting basally from outer edge. Broad columella shield flared and crossed by numerous strong and irregular ridges. Dark grey with orange or brownish blotches on varices. Aperture dark brown pinkish on outer lip.	

Ficidae: Shell thin, pear-shaped, drawn out anteriorly into a long, tapered and gracefully curved siphonal canal. Operculum absent

***Ficus ficus* (Linnaeus, 1758) : Common Fig shell**

Thin shell somewhat pear-shaped with a long narrow aperture. Large body whorl with tiny spire. Spiral ribs and longitudinal striations less distinct and give a reticulated outer surface. Shell surface finely serrated. The inside is orange and there is no operculum. Shell brownish in colour with narrow interrupted lines of dark brown and a few broader whitish lines interrupted with larger patches of dark brown.	

Bursidae: Shell ovate, often slightly dorso ventrally compressed, with 2 strong axial varices per whorl. Periostracum obsolete. Aperture with a short siphonal canal and a distinct posterior canal. Operculum corneous.

***Bufonaria crumena* (Lamarck, 1816): Purse frog shell**

Shell moderate sized; broad, ovate; apex pointed; sculpture composed of nodulose spiral threads; Body whorl with rows of short sharp nodes; remaining whorls with single spiral row of tubercles. Two fin-like varices on both sides; varices with sharp nodes at regular intervals. columella denticulate at the base; Siphonal canal short and twisted; colour light brown; with dark brown spots close to the nodes; aperture and lips white with slightly orange tinged.	

Tonnidae: Shell thin, globose, with a short spire very inflated body whorl. Sculpture only spiral. Siphonal canal short. Operculum absent.

***Tonna dolium* (Linnaeus, 1758) : Spotted tun**

Shell is thin, ovate-globose and ventricose. The spire is generally short, of six whorls, slightly flattened. The body whorl is large and very convex. All the whorls are encircled by wide and distant ribs, slightly convex, ornamented with alternate white/red spots, often also orange, numbering ten upon the body whorl. Very large aperture chestnut colored. The outer lip is thin, notched, canaliculated within, and its edge is white and undulated.	

Muricidae: shell variably shaped, generally with a raised spire and strong sculpture with axial varices,spines, tubercles or blade-like processes. Periostracum absent. Aperture with a well-marked siphonal canal. Operculum corneous.

***Chicoreus ramosus* (Linnaeus, 1758) : Branched Murex**

Shell large, thick and heavy. Spire short; body whorl slightly inflated; sculptured with thick foliaceous spines on varices. Aperture whitish with light rose pink colour along the aperture margin. Outer lip crenulate and with a prominent tooth-like process anteriorly, siphonal canal moderately long and broad	

***Chicoreus virgineus* (Roding, 1798): Virgin murex**

Shell moderately large in size. Spire acute; body whorl large and inflated. Varices prominent on each whorl. Sculpture composed of four rounded varices ornamented with 6 to 7 strong spiral cords alternating with a few minor cords. Aperture large; ovate; anal sulcus not deep; outer lip thick, coarsely denticulate with a conspicuous tooth on the lower part. Colour pale brown with a slight pinkish band on middle of body whorl. Aperture white, margin of aperture pinkish white	

***Rapana rapiformis* (Born, 1778) : Turnip shell**

Large, thick and heavy shell. Shape globose. Spires low and grooved. Surface finely striated with weakly developed or blunt spines. Siphonal canal very short. Colour chestnut.	

Buccinidae: shell with a fairly high spire and large body whorl. Outer surface smooth or with sculpture, without axial varices. Siphonal canal rather short. Operculum corneous.

***Nassaria coramandelica* (E.A. Smith, 1894) : Indian phos**

Shell small, fusiform; spire high; Body whorl half the length of total height; Sculpture formed of narrow axial ribs and thin spiral ribs inter crossing to form nodules at junctions. Surface nodulose, interspaces seen between strong spiral cords with fine spiral thread. Aperture narrow with lirations within, outer lip thick and margined by a varix. Colour half white or dull brown with white aperture.	

Babyloniidae: Shell with a fairly high spire and large body whorl. Outer surface smooth or with sculpture, without axial varices. Siphonal canal rather short. Operculum corneous

***Babylonia spirata* (Linnaeus, 1758) : Spiral Babylon**

Body whorl inflated, spire high and elongate, sutures deep and channelled. Shoulders prominent; whorls inflated; columella smooth and heavily calloused; umbilicus broad, deep, and heavily calloused. Aperture large, ovate, outer lip sharp and strongly flexed at the top, interior of aperture smooth and thickened; Colour white with prominent light brown blotches, oblique streaks and spots; aperture ,outer lip and columellar callus white, fasciole orange brown, tip of apex and aperture tinged blackish;.	

***Babylonia zeylanica* (Bruguiere) : Indian Babylon**

Shell fusiform, less solid and with less inflated whorls, body whorl narrower than in *Babylonia spirata*, sutures not canaliculated. Spire high ending in dark purple apex. Aperture dark, outer lip sharp and smooth, but not flexed at top, columella smooth with heavy broad callus posteriorly but narrow anteriorly. Surface smooth, colour white with large brown blotches.	

Melongenidae: shell pear-shaped to fusiform, nodular to spiny on the shoulder. Aperture anteriorly narrowing into an open siphonal canal. Columella smooth. Operculum corneous.

Volegalea cochlidium **(Linnaeus,1758) : Spiral melongina**

Whorls strongly and angularly shouldered. Shoulder bears strong tubercules which are fewer and more widely separated. Spiral ridges prominent, except on body whorl. Sutures sunk in deep, narrow grooves. Aperture elongated and rectangular, anterior canal wider. Colour dark reddish brown. Columella pale yellow brown. Periostracum brown.	

Olividae: shell elongate-ovate, with a short spire, a large body whorl and channeled sutures. Surface smooth, highly polished. Aperture elongate, with a short siphonal canal. Inner lip calloused, with oblique grooves anteriorly. Operculum absent.

Agaronia gibbosa **(Born I von, 1778): Gibbosus olive**

Shell moderately large, stout, thick upto 60mm in height , fusiformly ovoid, surface smooth and highly polished; spire rather short, but acuminate, apex pointed, lower part of body whorl is generally sharply demarcated from the upper by an oblique spiral line. Anterior canal in the form of a semilunar notch. Colour pale yellowish brown with a prominent yellow band at the base, mottled with black spots,sometimes whitish with zig zag transspiral brownish bands, spire and columella yellowish white, aperture bluish white	

Turbinellidae: Shell thick and heavy, biconical to fusiform, often nodulose to spinose on shoulder. Periostracum conspicuous. Siphonal canal present. Inner lip with strong folds. Operculum corneous.

***Turbinella pyrum* (Linnaeus, 1767): Sacred chank**

Shell large, thick and heavy with large anterior canal. Three or four prominent columellar plicae present. Spires well elevated. Whorls with feebly developed shoulders. It is usually pure white under a heavy brown periostracum, but it can also be a pale apricot color. It can sometimes be dotted with dark brown.	

Harpidae: Shell ovate, with an inflated body whorl and a small conical spire. Surface glossy, with strong axial ribs. Inner lip covered by a smooth, large callus. Columella without folds. Siphonal canal short and wide. Operculum absent.

***Harpa major* (Roding , 1798) : Large/Major harp**

Shell medium to large in size; broad, oval; solid; body whorl inflated; with a heavily calloused spire, not much elevated. Aperture large and widely ovate; outer lip arcuate. Body whorl ornamented with twelve axial ribs ending in spines on subsutural ramp; interspaces provided with fine axial striae ; colour pinkish, space between ribs coloured white; columellar region dark chestnut brown in colour The columella, or the lower portion of the inside coil, has dark brown coloring.	

Volutidae: shell variable in shape, often glossy and brightly coloured. Aperture long, with a short siphonal canal. Inner lip with strong folds, weaker posteriorly. Operculum horny, often absent.

***Melo melo* (Lightfoot, 1786): Bailer shell**

The notoriously large shell of Melo melo has a bulbous or nearly oval outline, with a smooth outer surface presenting distinguishable growth lines. The outside of shell colour is commonly pale orange, sometimes presenting irregular banding of brown spots, while the interior is glossy cream, becoming light yellow near its margin. The columella has three or four long and easily distinguishable columellar folds. It has a wide aperture, nearly as long as the shell itself, yet this species is known to have no operculum.	

Turridae: shell generally fusiform, with a high spire. Siphonal canal well marked. A characteristic notch along the posterior part of the outer lip reflected in the growth lines. Operculum corneous.

***Unedogemmula indica* (Roding, 1798) :Indian turrid**

The fusiform shell is somewhat less ridged and striated and has a long siphonal canal. The shoulder angle is very slight, the central ridge forming a carina. The other revolving ridges are smaller and closer than other species in this genus. The whole surface is covered with close, raised revolving lines, of which two or three below the carina are more prominent. The color of the shell is whitish with minutely numerously brown-spots and with usually a row of larger spots below the suture.	

Conidae: shell cone-shaped, with a low spire and a well-developed body whorl tapering towards the narrow anterior end. Aperture very long, with a short siphonal canal. Operculum corneous, quite small.

Conus (Dendroconus) betulinus **(Linnaeus, 1758) : Betulline cone**

Large, thick and heavy and elegant cone. Spire almost flat and slightly elevated at the last few whorls. Body whorl slightly globular. Basal portion slightly threaed. Trans-spiral plates or growth lines can be seen. The color of the shell is yellow or orange-brown, with revolving series of spots, and short lines of chocolate upon narrow white bands. The spire is radiated with chocolate.	

Conus geographus**(Linnaeus,1758) : Geography cone**

The ground color of the shell is pink or violaceous white, occasionally reddish. It has a mottled appearance, clouded and coarsely reticulated with chestnut or chocolate, usually forming two very irregular bands. This intricately brown-and-white pattern is highly prized by shell collectors. Wide, violaceous white or pink aperture and numerous shoulder ridges or spines. The shell is covered with thread-like revolving striae, usually nearly obsolete except at the base. The flattened spire is striated and coronated**.**	

Conus virgo **(Linnaeus, 1758) : Virgin cone**

Moderately large to large pale yellowish brown tinged with violet at the base 1, solid to heavy. Last whorl conical; outline slightly convex at adapical fourth, straight below. Shoulder angulate. Spire low, outline slightly concave to slightly convex. Last whorl with weak to obsolete spiral ribs near base; widely spaced fine ribs and wrinkled threads between may extend to centre or beyond.	

Operculam – Gate way of Marine gastropod snails

The most gastropods are born with hard, horny or shelly plates attached to the upper surface of the foot that close the shells when the soft parts of the animals are retracted. These plates are known as operculum. It is often round, or more or less oval in shape. The operculum serves as a sort of trapdoor-like devices to close the aperture of the shell when the animal is retracted.

Operculum are of four types.

- Multispiral or polygyrous with numerous turns and a central nucleus
- Paucispiral or oligogyrous with few turns

- Concentric
- Calcareous operculum

Turns/pattern on the dorsal surface of both multispiral and paucispiral opercula are spiral *i.e.* a shape of continuous, curving lines or arcs which is in a continuous and gradually widening around a nucleus and nucleus of these opercula can be formed either internally or marginally or terminally.Pattern/turns on the dorsal surface of concentric opercula are concentric i.e. a shape made up of circles or rings shares the common centre wherein the larger often completely surrounding the smaller ones forming a concentric pattern. Calcareous operculum is strongly calcified externally, its inner layer corneus, usually showing spiral coiling with a subterminal or central nucleus. Rotation of opercula varies in dextral and sinistral gastropods for the outside spiral pattern – clockwise in dextral and counter clockwise in sinistral forms.

Multispiral

Paucispiral

Concentric

Calcareous

Scheduled marine gastropods

The large number of marine gastropods has been placed in the endangered list which is a major cause of concern (Table 1). An endangered gastropods are the species that is in danger of becoming extinct. In most cases species that are listed as endangered will become extinct in the very near future unless some positive action is taken. The collection, possession and trading of these scheduled molluscs or their products (live or dead) are prosecuted and will attract a punishment of severe imprisonment upto 7 years along with heavy fine under section 50, 51 of wildlife (Protection) Act 1972.

Table 1: List of scheduled marine gastropods from India

Family	**Species**
Conidae	*Conus milneedwardsi* Jousseaume,1894
Cassidae	*Cassis cornuta* (Linnaeus, 1758)
	Cypraecassis rufa (Linnaeus, 1758)
Charoniidae	*Charonia tritonis* (Linnaeus, 1758)
Tudiclidae	*Tudicla spirillus* (Linnaeus, 1767)
Cypraeidae	*Staphylaea limacina* (Lamarck, 1810) (= *Cypraea limacina*)
	Leporicypraea mappa (Linnaeus, 1758) (= *Cypraea mappa*)
	Talparia talpa (Linnaeus, 1758) (= *Cypraea talpa*)
Fasciolariidae	*Pleuroploca trapezium* (Linnaeus, 1758) (= *Fasciolaria trapezium*)
Volutidae	*Harpulina arausiaca* (Lightfoot, 1786)
Strombidae	*Dolomena plicata sibbaldi* (G.B. Sowerby II, 1842) (= *Strombus plicatus sibbaldi*)
	Ophioglossolambis digitata (Perry, 1811) (= *Lambis crocea*)
	Lambis millepeda (Linnaeus, 1758)
	Lambis scorpius (Linnaeus, 1758)
	Lambis truncata ([Lightfoot],1786)
	Harpago chiragra (Linnaeus, 1758) (= *Lambis chiragra*)
	Harpago arthriticus (Roding 1798) (= *Lambis chiragra arthritica*)
Tegulidae	*Rochia nilotica* (Linnaeus,1767) (= *Trochus niloticus*)
Turbinidae	*Turbo marmoratus* Linnaeus, 1758

Uses of Operculum

The operculum of certain gastropods is in immense demand from various part of the world. The dried operculum is used as an important raw material by Chinese and Japanese incense makers. There is a huge international market for operculum trade with the price ranging from US $ 10 to US $ 185/kg. Operculum is traditionally treated with vinegar, alcohol and water to remove any fishy smell. The cleaned opercula are then ground to a powder and used as a scent fixative which is similar to the technique used in perfumes with certain plant resins. In some countries the operculum is rubbed with an alkali solution prepared from the plant bitter vetch to remove impurities and it is then soaked in fermented berry juice of the Caper shrub or strong white wine, in order to enhance its fragrance. India is one of the major exporter countries of dried high quality operculum. The operculum of certain species of Turbinidae is sometimes used as a very inexpensive organic "gemstone" in rings, bracelets, amulets etc.

These opercula are commonly known as "cats eye". Some of the major gastropod operculum exported are *Turbinella pyrum, Chicoreus ramosus, Lambis lambis, Laevistrombus canarium, Rapana rapiformis, Murex virgineus, Hemifusus cochlidium, Babylonia spirata* and *Babylonia zeylanica*. These operculum are exported to different countries the world over especially the eastern countries.

Turbinella pyrum	*Chicoreus ramosus*	*Chicoreus virgineus*
		

Babylonia spirata	*Lambis lambis*	*Rapana rapiformis*
		

CHAPTER 36

Taxonomy of Bivalves

1. Introduction

Bivalves - General Remarks

Most bivalves are marine and there are no terrestrial forms. Bivalve is the second most dominant class in the phylum Mollusca. Bivalves are characterized by a laterally compressed body with an external shell of two halves that is hinged dorsally. The bivalve hinge has sets of interlocking teeth that prevent valves from sliding along each other. The valves are united dorsally by elastic, a partially calcified or chitinous external or internal ligament and are held together by one or two adductor muscles. The head is rudimentary and have lost the buccal or radular apparatus. The mantle lobes are either connected or free ventrally. They are mostly ciliary feeders, with sieving and sorting mechanisms on labial palps and leaf-like ctenidium. The mantle cavity includes a pair of ctenidia suspended laterally. The mouth and anus are located at opposite ends of the body and the gut is typically convoluted. The foot is compressed and adopted for burrowing, except in sedentary forms where it is rudimentary.

Main Features of Bivalves

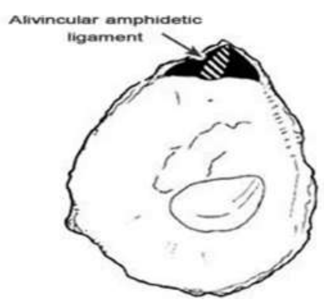
Muscle scars	Ligament	Dentition	Lunule	Pallial line	beak
Homomyar Heteromyar Monomyar	Internal External amphidetical Prosodetic opisthodetic	Cardinalia lateralia	escutcheon	Sinupalliate integripalliate	Orthogyrate prosogyrate opisthogyrate

Orientation of Shell

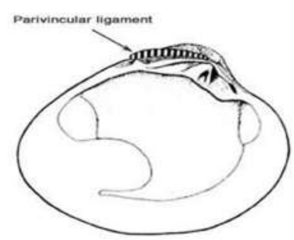
- Ligament typically posterior
- posterior adductor muscle scar stronger developed
- pallial sinus posterior / shell gaps posterior
- posterior part of shell typically better developed
- umbo (beak) typically points anterior (prosogyre)
- byssal notch anterior
- Oysters: left valve bigger/cemented

Ligament

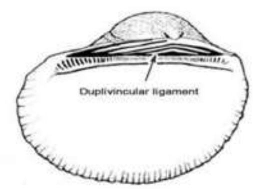
The ligament may lie symmetrically between the beaks "amphidetic" or more often behind the beaks "opisthodetic" and very occasionally in front of the beaks "prosodetic. Examples of Parivincular ligament are Veneridae



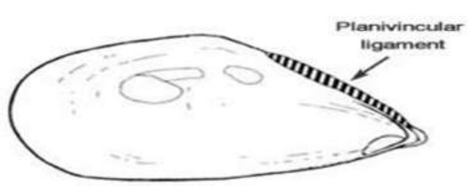
Examples of Alivincular amphidetic are *Limopsis* & *Ostrea* &Tellinidae



Examples of Parivincular ligament are Veneridae &Tellinidae



Examples of Duplivincular ligament are Arcidae and Glycymeridae &Tellinidae

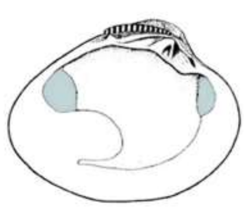


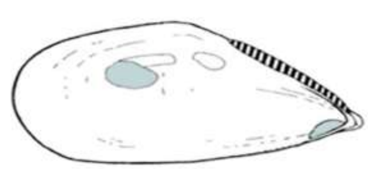
Examples of Planivincular ligament are Mytiloidea

Beak

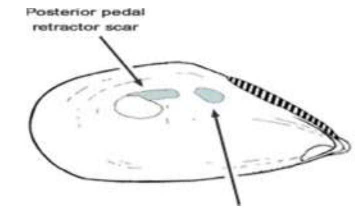
The beaks may face each other across the dorsal margin, i.e. **orthogyrate** but more commonly they point in the anterior, **prosogyrate** or posterior **opisthogyrate** directions. In a few bivalves, they may actually be **coiled.**

Muscle Scar





Dimyarian & Homomyarian **Heteromyarian**

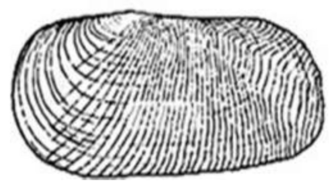


Monomyarian **Posterior Pedal Retractor Scar**

Sculptures

Radial

Co-marginal" or "Concentric

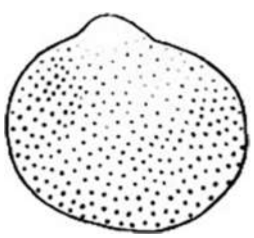


"Oblique" or "acentric

Scissulate

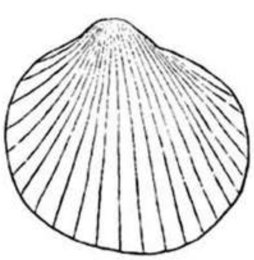
Divergent

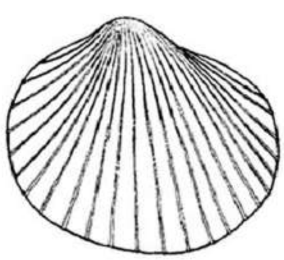
Divaricate



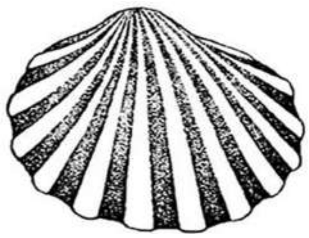
Non linear - granular or pustulose/pitted

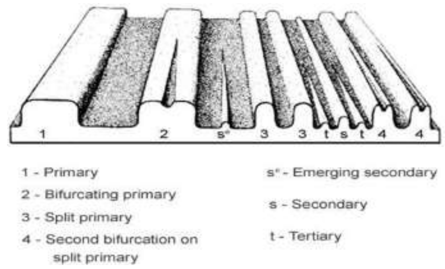
Radial Patterns





Lines **Threads** **Riblets**

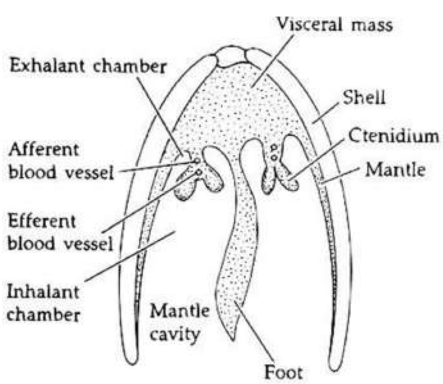




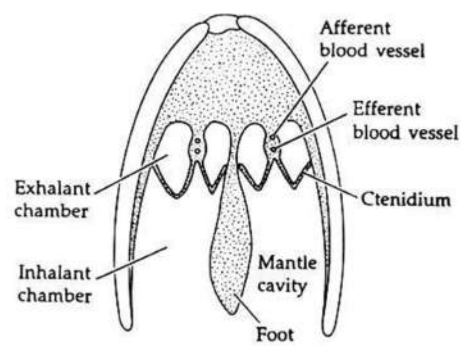
Ribs **Secondary Ribbin**

Basic for systematics are the gill type and the hinge dentition

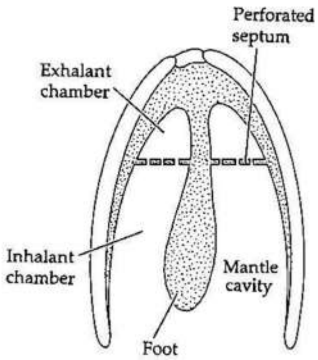
GILL TYPE	DESCRIPTION
Protobranch (deposit feeders, most primitive)	This gill structure tends to occur in primitive groups, demibranchs are comparatively small and consist of a series of ciliated leaf-like discs e.g. *Nucula* species
Filibranch (suspension feeders)	Demibranchs are considerably longer and consist of extended parallel structures - the filaments—rather than parallel discs. This gill structure consists of individual filaments forming 'W'-shaped structures that come together to form lamellar sheets. *Mytilus edulis*
Eulamellibranch (suspension feeders)	The filament structure also appears on the surface of the demibranch in these gills; however, their demibranchs are much more complex organs, because the filaments are connected by various tissue junctions. These form 'W'-shaped gills with cross-partitions joining the filaments to create water-filled cavities in between them. *Corbicula* sp.
Septibranch (carnivores, most derived)	These gills are only found in Poromyacea a super-family of the rock borer. They run transversely across the mantle cavity, enclosing the inner chamber, with only a small connection to the outer cavity.



Protobranch Gill



Eulamellibranch Gill

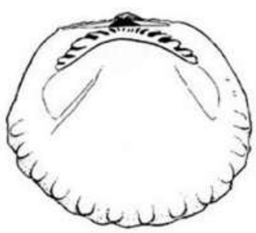


Septibranch Gill

Transverse Illustrated Section of Bivalves Showing Different Types of Gills

Dentition: Various Types and Subtypes

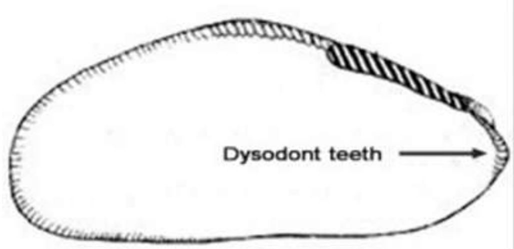
Taxodont: many small similar teeth & sockets all along hinge plate (e.g., *Glycimeris sp. and Arca sp.*)



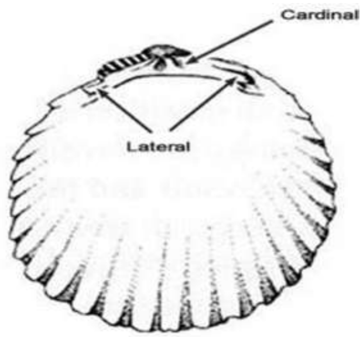
Glycimeris sp

Arca sp

Dysodont: small simple teeth near the edge of the valve. It's no teeth just crenulation (eg.*Mytilus)*



Heterodont: few teeth varying in size and shape, distinguished as cardinal teeth, beneath the umbo, and lateral teeth which lie obliquely along the hinge plate (e.g., most recent bivalves) Corbiculidae



Isodont: teeth very large and located on either side of a central ligament pit. *i.e*. two grooves two teeth correspond (e.g., *Spondylus*).

Desmodont: teeth very reduced or absent (e.g., *Mya)* with a large internal process (the chondrophore) carrying the ligament.

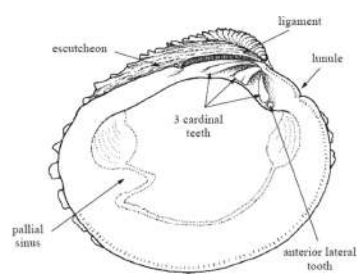
Schizodont: two or three thick teeth with prominent grooves *i.e.* teeth have crenulations ("teeth with teeth") (e.g., *Trigonia*).

Pachydont: large, heavy and massive teeth (e.g., rudists)

Guide to Families/Species of Commercially Important Species

The following guide can be used for identification of marine or brackish water bivalve families regularly exploited from Indian waters.
VENERIDAE – Venus Clams

Shell usually solid, umbones anterior to midline, lunule and escutcheon usually present, sculpture usually concentric, sometimes lacking. Ligament external. Hinge with 3 or rarely 2 cardinal teeth in each valve. Adductor muscles (and their scars) usually equivalent in size.



Commercially important species under this family are

- *Paphia malabarica* (Dillwyn, 1817)/ *Protapes gallus* (Gmelin, 1791)
- *Meretrix meretrix* (Linnaeus, 1758)
- *Meretrix casta* (Gmelin, 1791)
- *Marcia opima* (Gmelin, 1791)
- *Gafrarium tumidum* (Roding, 1798)/ *Gafrarium pectinatum* (Linnaeus, 1758)
- *Sunetta scripta* (Linnaeus, 1758)

***Paphia malabarica* (Dillwyn, 1817)**

FAO names: En – Short neck Clam

Description

Shell is slightly inflated, triangularly ovate and surface is concentrically grooved. The anterior and posterior margins are narrowly rounded. Hinge area is short with narrowly diverging teeth. Pallial sinus is 'U' shaped and very deep. Lunule is relatively short. Shell length is only one and one third times longer than height. The outer shell valves are yellowish brown in colour indistinctly rayed with greyish brown bands or blotched with brownish angular markings.

***Meretrix casta* (Gmelin, 1791)**

FAO names: En – Backwater Hard Clam

Description

Shell is thick, moderately large with a brown horny periostracum. Shell is also smooth and triangularly ovate with devoid of any sculpture. Outer surface of the valves is very fainted rayed with greyish radial lines or pale yellowish brown tinted with dark grey posteriorly.

***Meretrix meretrix* (Linnaeus, 1758)**

FAO names: En – Asiatic Hard shell

Description

Shell varies from *M. casta* in having less elongated lateral tooth, more ovate shell and larger size. Periostracum is thin and of grey or straw colour. Postero-dorsal margin of the outer shell is greyish blue or bluish brown band.

***Marcia opima* (Gmelin, 1791)**

FAO names: En – Fertile Venus

Description

Shell is thick, inflated, smooth, and triangularly ovate. Pallial line is deeply sinuate. Tip of the pallial sinus is bluntly angular. Lunule is distinct, flattened, and rather broad. Area behind the umbones is clear, flattened and deeply elongated reaching almost upto the hind margin of the shell. Outer surface of shell is pale yellowish brown or straw

coloured variously blotched and rayed with purplish grey markings. The inner surface of the valve is white.

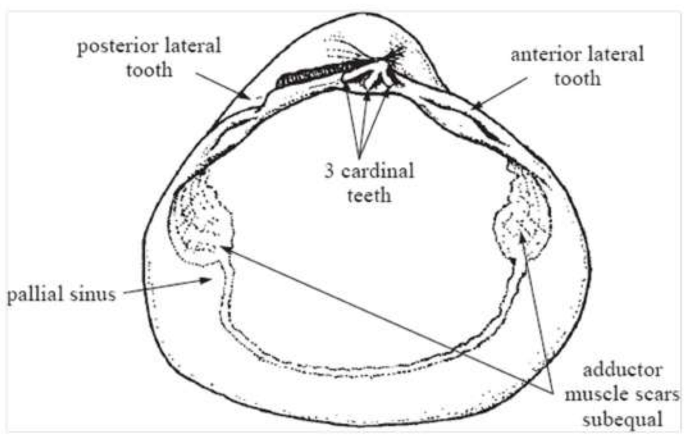
***Sunetta scripta* (Linnaeus, 1758)**
FAO names: En – Broad Hinged Venus
Frequent synonyms: *Donax Scriptus* **(Linnaeus, 1758)**
Description:

Rounded-trigonal, compressed shell with well produced anterior end and steeply sloping slightly arched anterior slope. Strong, smooth concentric ridges with narrow, deep grooves between. Inner margins stained with pale purple. Creamy, with small, purplish brown blotches which are often arranged in a zig zag pattern. Inside white stained with pale purple.

***Gafrarium tumidum* (Roding, 1798)**
FAO names: En – Tumid Venus
Description

Shell is thick, strongly inflated and sculptured with thick, nodular radial ribs which tend to bifurcate towards the ventral margin. The interstitial spaces between some of the main ribs, there are secondary rows of nodules. The pallial line is full and well developed. The outer surface is white with irregular dark spots posteriorly and near the umbo.

CORBICULIDAE/CYRENIDAE – Marsh clams
Shell oval to triangular. No lunule or scutcheon. Hinge with 3 cardinal teeth in either valve. Pallial sinus short to absent.



Commercially important species occurring in India are

- *Geloina bengalensis* (Lamarck 1818)
- *Geloina expansa* (Mousson, 1849) /*Geloina erosa* (Lightfoot, 1786)
- *Villorita cyprinoides* (Gray, 1825)
  Geloina bengalensis (Lamarck 1818) **FAO names:** En- Bengali Geloina

Red List Category & Criteria: Least Concern
Frequent synonym(s):

- *Cyrena bengalensis*
- *Polymesoda (Geloina) bengalensis*
- *Polymesoda (Geloina) galatheae*

Distribution: The species is common in the Indo-Pacific region; recorded from coastal areas in the Bay of Bengal (Bangladesh, India (West Bengal (Gangetic Delta), Orissa (Mahanadi estuary), Andra Pradesh and the Nicobar Islands

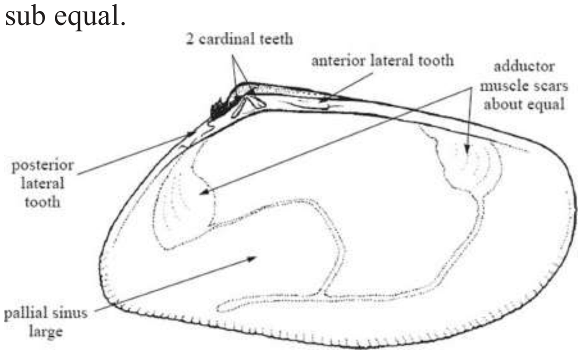
Description

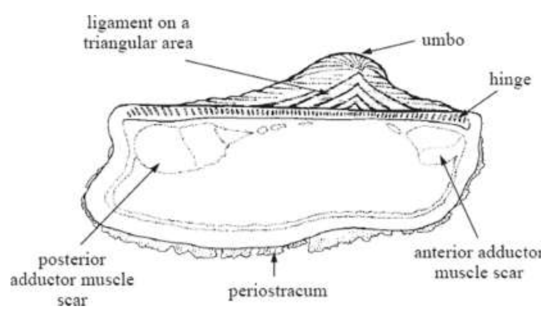
The shells are ovato-subcircular, inequilateral, strong and heavy, with concentric striations; umbones directed anteriorly; hinge area very thick; teeth well-developed.

Villorita cyprinoides **(Gray, 1825)**
FAO names: En- Black Clam
Red List Category & Criteria:
Least Concern

Description
Shell is thick, ovately triangular with strong concentric ridges. Hinge border is very short and thick, always with three oblique cardinal teeth; the anterior in the right valve and posterior in the left valve are less developed. Ridges are more strongly developed in the anterior half. Umbones are prominent and well elevated. Pallial sinus is small. Lunule is narrow and ligament is large. Shell is dark olive brown to blackish brown in colour.

DONACIDAE – Donax Clams
Shell wedge-shaped, usually with an angled (keel-like) posterior surface. Ligament external. Hinge with 2 cardinal teeth on each valve. Adductor muscle scars sub equal.





- *Donax cuneatus* (Linnaeus, 1758)
- *D. scortum* (Linnaeus, 1758)
- *Donax cuneatus* (Linnaeus, 1758)

FAO names: En- Cuneate Donax
Description
Shell is trigonal, inequilateral. Shell possesses a curved keel extending from the umbo to the postero-ventral corner; there are sharp concentric and fine radiating ones which are

conspicuous in the anterior and posterior regions only. The anterior end is broad and rounded while the posterior end is narrow and rounded. Pallial sinus is deep. The outer surface of shell is white covered with pale violet especially towards umbo and the posterior region is darker. The inner surface is of deep violet colour

D. scortum (Linnaeus, 1758)
FAO names: En- Leather Donax /Asian Wedge Clam
Frequent synonym(s): *Venus scortum* (Linnaeus, 1758)

Description

Shell ovate with fine concentric striae; keel between the umbo and the posterior margin absent; colour pattern variable; outer shell pale bluish grey or greyish blue with greyish concentric bands and brown rays or patches; ventral margin with slight indentation at posterior end; pallial sinus moderately deep; two primary teeth; ligament external, short and inserted at the posterior impression.

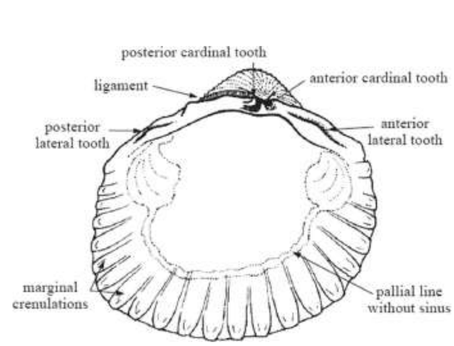
ARCIDAE - Ark Shells
Shells very thick, heavy, box-like. Hinge with a large number of teeth perpendicular to main shell axis, usually of equal size and perpendicular to main shell axis. Usually with thick, dark periostracum.

Commercially important species under this family are

- ✓ *Anadara granosa* (Linnaeus, 1758) /*Tegillarca granosa* (Linnaeus, 1758)
- ✓ *Anadara rhombea* (Born, 1778)/*Tegillarca rhombea* (Born, 1778)
- ✓ *Anadara granosa (Linnaeus, 1758)*

Frequent synonyms: *Arca granosa* Linnaeus, 1758

CARDIIDAE- Cockles
Shell round, large, inflated, usually with strong radial sculpture that yields crenulated shell margins; scales or spines sometimes present along radial sculpture elements. Foot long and strong



Commercially important species under this family are

- *Tridacna maxima* (Roding, 1798)
- *T. crocea* (Lamarck, 1819)
- *T. squamosa* (Lamarck, 1819)

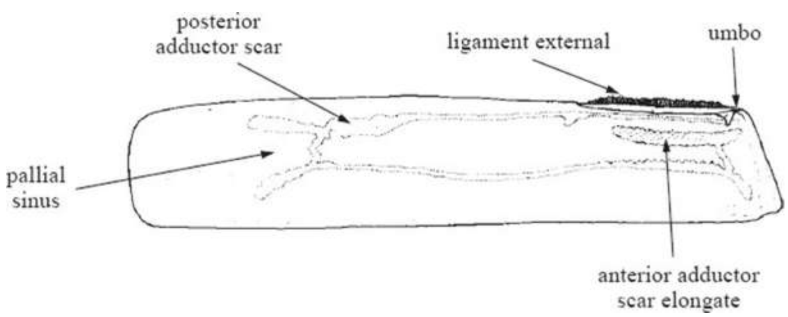
Tridacna maxima **(Roding, 1798)**
FAO names: En – Elongate Gaint Clam
Frequent synonyms:

Description

Shell is strongly inequilateral. The shell is similar to that of *T. crocea* except that the 6-12 broad radial ribs have better developed concentric scales. Large byssal gape with distinct plicae is at edges. Ventral border of the valve often deeply scalloped. Shell is greyish white, sometimes tinged with yellow or pinkish orange.

SOLENIDAE – Knife and Razor Clams

Shell narrowly elongate, very inequilateral; umbones near the anterodorsal end of valves; pallial sinus relatively shallow; siphons generally quite short, fused at their base.



Solen kempi **Preston, 1915**
FAO names- Kemp's Razor shell

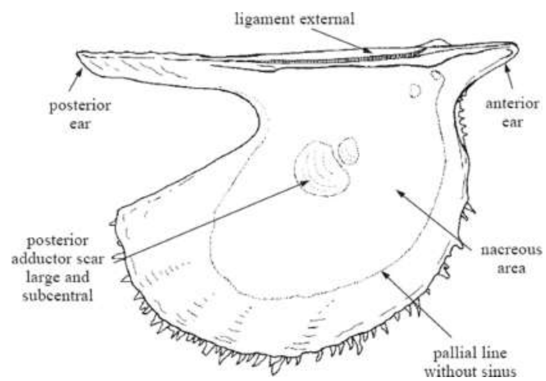
Description

Shell is small, about six times as long as high. Anterior region is obliquely truncate while posterior region rounded. Cardinal tooth is in right valve with a shallow groove all over its breadth. Dorsal margin of soft body is somewhat concave in the anterior region and convex in the posterior region. Siphon is long and segmented. Foot is long flattened and about half the length of body. Periostracum is yellowish brown and glossy.

PTERIIDAE – Pearl Oysters

Shell compressed, usually gaping, with concentric, often scaly, sculpture; hinge lacking teeth, straight, projecting at both ends as wing-like expansions; posterior expansion usually longer; ligament external, sunken; anterior muscle scar very reduced or absent, posterior muscle scar large, central; pallial sinus absent.

FAO names: En – Akoya Pearl Oyster



PTERIIDAE – Pearl Oysters
Shell compressed, usually gaping, with concentric, often scaly, sculpture; hinge lacking teeth, straight, projecting at both ends as wing-like expansions; posterior expansion usually longer; ligament external, sunken; anterior muscle scar very reduced or absent, posterior muscle scar large, central; pallial sinus absent.

Commercially important species under this family are

- *Pinctada fucata* (Gould, 1850)/*P. imbricata* (Roding, 1798)
- *Pinctada margaritifera* (Linnaeus, 1758)
  Pinctada fucata (Gould, 1850)

Pinctada fucata (Gould, 1850)

FAO names: En – Akoya Pearl Oyster

Description

The hinge is nearly as wide as the width of the shell, left valve is deeper than the right, byssal notch slit-like, left valve greatly convex, posterior ear well developed with fairly developed sinus, anterior margin of shell just far in advance in front of anterior ear. Hinge teeth are present in both valves, one each at the anterior and posterior ends of the ligament. The anterior ear is larger than in the other species. The posterior ear is fairly well developed. The outer surface of the shell valves with 6 - 8 radial bands of reddish brown on a pale yellow background. The nacreous layer is thick and has a bright golden, pink or ivory colour with metallic lustre. The non-nacreous margin on the inner surface of valves has reddish or brownish patches.

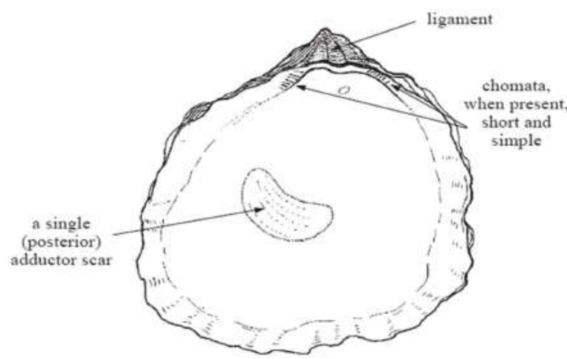
Pinctada margaritifera **(Linnaeus, 1758)**
FAO names: En – Black-lip Pearl Oyster

Description

The hinge is nearly as wide as the width of the shell, left valve is deeper than the right, byssal notch slit-like, left valve greatly convex, posterior ear well developed with fairly developed sinus, anterior margin of shell just far in advance in front of anterior ear. Hinge teeth are present in both valves, one each at the anterior and posterior ends of the ligament. The anterior ear is larger than in the other species. The posterior ear is fairly well developed. The outer surface of the shell valves with 6 - 8 radial bands of reddish brown on a pale yellow background. The nacreous layer is thick and has a bright golden, pink or ivory colour with metallic lustre. The non-nacreous margin on the inner surface of valves has reddish or brownish patches.

OSTREIDAE – Oysters

Shell irregularly shaped, attached (cemented) to hard substrate by the left valve. Ligament external, in shallow depression. Only posterior adductor muscle scar present.



Commercially important species under this family are

- *Crassostrea madrasensis* (Preston, 1916)/*C. bilineata* (Roding, 1798)/ *Magallana bilineata* (Roding, 1798)
- *Saccostrea cucullata* (Born, 1778)
- *C. gryphoides* (Schlotheim, 1813)
- *C. rivularis* (Gould, 1861)/ *Magallana rivularis* (Gould,1861)

Crassostrea madrasensis **(Preston, 1916)**
FAO names: En – Indian Backwater Oyster

Description

Shell valves are irregular in shape usually straight/elongate. Shell valves are covered by numerous foliaceous laminae. Left valve is deep while right one slightly concave. Hinge is narrow and elongated. Adductor muscle scar is kidney-shaped and sub central; dark purple in colour. Inner surface of valve is white, glossy and smooth with purplish black colouration on the inner margin.

***Saccostrea cucullata* (Born, 1778)**
FAO names: En – Hooded Oyster

Description
Shell more or less trigonal, sometimes oblong, extremely hard and pearshaped. The margins of the valves have well developed angular folds sculptured with laminae. Small tubercles present along the inner margin of the right valve and there are corresponding pits in the left valve.
Adductor muscle scar is kidney shaped.

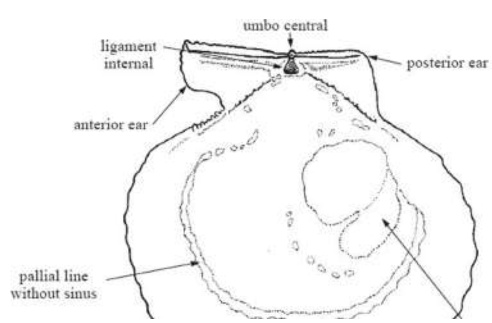
Placunidae

Placuna placenta (Linnaeus, 1758)
Frequent synonym(s):
- *Ephippium transparens* Roding, 1798
- *Placenta communis* Megerle von Muhlfeld, 1811
- *Placuna placentis* (Linnaeus, 1758)
- *Anomita placenta* Linnaeus, 1758
- *Placuna ovalis* Blainville, 1826
- *Placuna orbicularis* Philipsson in Retzius, 1758
- *Placenta auriculata* Morch, 1853

FAO names- Windowpane Oyster
Description
Placuna placenta is a highly asymmetrical bivalve with a characteristically thin, translucent shell. The almost-flat concave shells can grow to over 150 mm in diameter, a V-shaped ligament. Male and female oysters are distinguished by the color of the gonads. It lives mostly on mangrove coasts, preferring a muddy substrate. Lacking a byssus, *P. placenta* does not anchor itself to its substrate, but lies free at the mercy of the currents.

PECTINIDAE- Scallops

Shell oval to circular, umbones centrally located, hinge typically with wing-like expansions. In some genera (e.g., *Euvola*) top valve is flattish and bottom valve deeply convex. Ligament internal. Hinge without teeth. Single adductor muscle, pallial sinus absent.



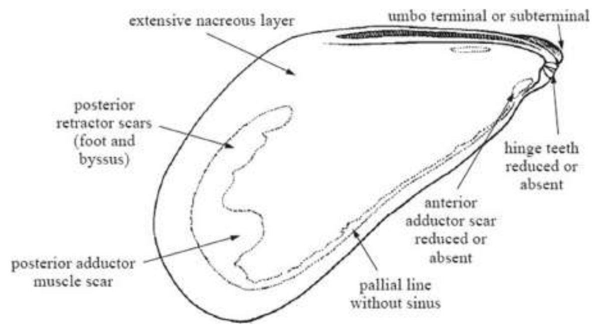
Commercially important species under this family are

- *Volachlamys tranquebaria* (1791)
- *Mimachlamys* sp

Volachlamys tranquebaria (1791)

MYTILIDAE – Sea Mussels

Shell elongate, with umbones near or at anterior end. Ligament in anterior margin. Hinge without teeth or with tiny denticles. Internal surface nacreous. Adductor muscle scars differing in size, the anterior small or absent.



Commercially important species under this family are

- *Perna viridis* (Linnaeus, 1758)
- *Perna indica* (Linnaeus, 1758)

Perna viridis (Linnaeus, 1758)

FAO names: En - Asian Green Mussels

Description

The outer shell surfaces and mantle margin are respectively green and yellowish green in colour. Shell is large, elongate sub-trigonal. Anterior end of the shell is pointed with the beak turned down. Ventral shell margin is slightly concave. Middle dorsal margin is angularly convex while posterior margin is broadly rounded. Two small hinge teeth on the left valve and one on the right valve, foot is tongue shaped with byssal threads.

***Perna indica* (Linnaeus, 1758)**
FAO names: En - Brown Mussels

Description

The outer surfaces of the shell valve and mantle margin are respectively dark brown and brown in colour. Anterior end of the shell is pointed and straight. Ventral shell margin is more or less straight. Middle dorsal margin has a distinct angle/lump while posterior margin is broadly rounded. One large hinge teeth on the left valve and

a corresponding depression on the right valve, foot is tongue shaped with byssal threads.

*Disclaimer: The views expressed by the authors are theirs and not necessarily those of the Institute

CHAPTER 37

Taxonomy of Cephalopods

Introduction

Cephalopods are ecologically and commercially important invertebrates with a wealth of extant marine taxa spanning from neritic continental shelf to the abyssal plains. The class Cephalopoda includes two, distantly related, extant subclasses, the primitive Nautiloidea, represented by the externally shelled nautiluses; and Coleoidea, which includes the ten-armed squids & cuttlefishes and the eight-armed octopuses.

The commercial importance of this exclusive marine mollusc has risen in the last six decades remarkably across a highly diverse set of cephalopod taxa. The positive trend in cephalopod abundance has been attributed to a range of coastal and oceanic environmental changes, together with the potential release of cephalopods from predation and competition pressures (Doubleday et al., 2016). The fishery mainly targets the coastal species of squid, cuttlefish and octopus besides the oceanic squids when encountered within the operational range of commercial fleets while undertaking migration (Rodhouse et al., 2014).

Classification

The systematics and classification of the Recent Cephalopoda are under considerable discussion (Jereb and Roper, 2016). The higher classification above the family level is still not resolved, but species-level taxa can be placed in well-defined families. Early in their evolution, cephalopods emerged in the fossil record in Cambrian, later, the extant lineages which arose in the late Silurian, diverged into the two sub-classes, Nautiloidea, with external shell and Coleoidea, without external shell (internalized shell), in the mid-Palaeozoic. The living cephalopods (~ 800), notable for their many arms and soft bodies, are at present not the most successful of the molluscan groups, while, there is fossil evidence to suggest that they were once a much more important group (17,000). The ancient cephalopods were mostly known from their shells as they are well preserved as fossils. In cephalopods, the taxonomic efforts can be quite challenging in comparison to finfish due to the lack of fixed meristic characters.

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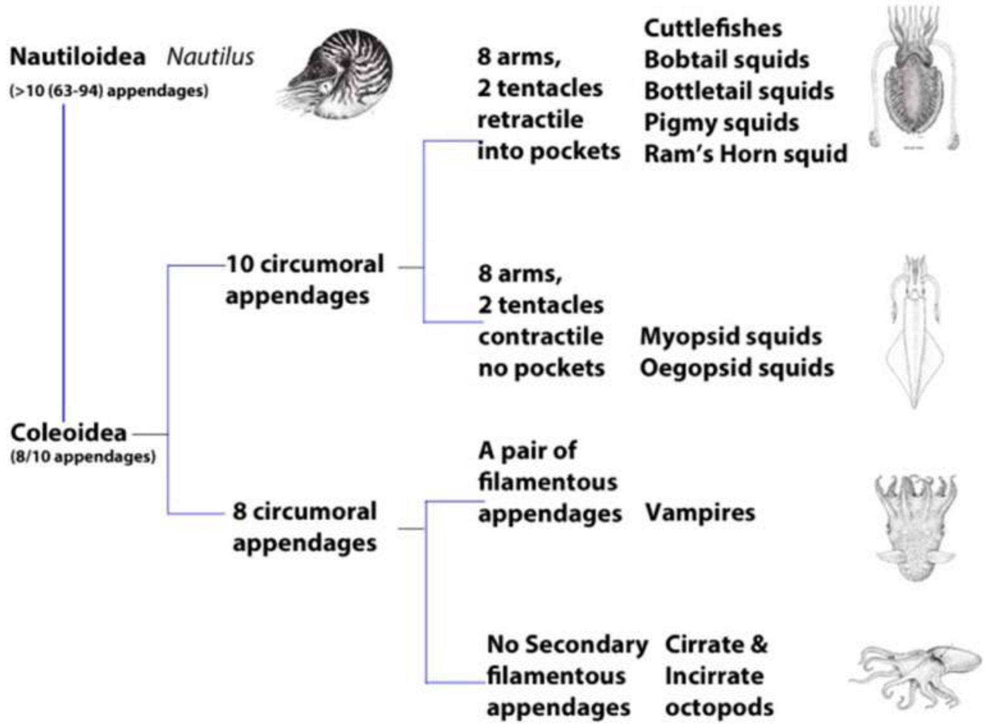

Cephalopod classification (Modified from **Jereb and Roper, 2005**)

I) Sub-class Nautiloidea

Nautiluses are unique from other extant cephalopods by having a distinctive, ornate, coiled shell. They are considered as living fossils since they retained the external chambered shell and simple "pinhole camera" eyes (without a lens) similar to their Palaeozoic ancestors. The nautilus shell has chambers that are interconnected and the animal lives in the outermost chamber with its body attached to the sides of the chamber by the adductor muscles. Nautilus regulate its buoyancy through the control of fluid and gas in the chambers. Nautiluses have two pairs of gills and up to 47 pairs of circumoral arm-like appendages, also called 'tentacles', arranged in 2 rings around the mouth and 2 pairs lateral to the eyes. Above the tentacles is a large fleshy wedge, called the 'hood'. This is used as a trapdoor to seal the shell closed if the animal is attacked. They are known to occur in the tropical Indo-Pacific region, where they live close to the bottom, primarily over reef slopes, from near the surface to about 500-750 m depth. Their optimal range seems to be from 150 to 300 m. Although their taxonomy is poorly resolved, the family Nautilidae is currently considered to include seven species in two genera, *Nautilus* and *Allonautilus*. The Umbilicus is small, or moderate, about 5-16% of shell diameter in *Nautilus* and the whorl cross-section is oval, compared to a larger Umbilicus (20% of shell diameter) and quadrate cross-section in *Allonautilus*.

The systematic position of important species under the Class Cephalopoda in Indian Seas

Sub-class	Super order	Order	Family	Species
Nautiloidea		Nautilida	Nautilidae	*Nautilus pompilius*
Coleoidea	Decapodiformes	Spirulida Ram's horn squid	Spirulidae	*Spirula spirula*
		Sepiida Cuttlefishes	Sepiidae	*Sepia pharaonis* *Sepia elliptica* *Sepia trygonina* *Sepia omani* *Sepia prashadi* *Sepia vecchioni* *Sepia aculeata* *Sepia brevimana* *Sepia prabahari* *Sepia arabica* *Sepia ramani* *Sepiella inermis*
		Sepiolida Bob-tailed squids and bottletailed squids	Sepiolidae	*Euprymna spp.*
		Myopsida Neritic squids	Loliginidae	*Uroteuthis (Photololigo) duvaucelii* *Uroteuthis (Photololigo) edulis* *Uroteuthis (Photololigo) singhalensis* *Loliolus (Nipponololigo) uyii* *Loliolus (Loliolus) hardwickei* *Sepioteuthis lessoniana*
		Idiosepiida Pygmy squids	Idiosepidae	
		Oegopsida Oceanic squids	Thysanoteuthidae	*Thysanoteuthis rhombus*
			Ommastrephidae	*Sthenoteuthis oualaniensis*
			Enoploteuthidae	*Abralia (Heterabralia) andamanica*
				Abraliopsis (Micrabralia) lineata
		Bathyteuthida Squids	Bathyteuthidae	*Bathyteuthis bacidifera*
	Octopodiformes	Vampyromorphida	Vampyroteuthidae	*Vampyroteuthis infernalis*
		Octopoda	Octopodidae	*Amphioctopus neglectus* *Amphioctopus marginatus* *Amphioctopus aegina* *Amphioctopus rex* *Cistopus indicus* *Cistopus platinoidus* *Octopus cyanea* *Octopus vulgaris*

Nautilus pompilius

The umbilicus is small, visible as shiny silver and black patch, closed; callus usually present (with rare exceptions). No inner coils are visible. Shell colour patterns variable: irregular brown to reddish-brown stripes radiates from the umbilicus to venter in the usual colouration, but this striping can be reduced to various degrees, leaving the umbilicus and even much of the flanks white. The chambered nautilus, *Nautilus pompilius*, is a highly vulnerable species because of its life history characteristics, including low reproductive rates, slow growth, and late maturity. Chambered nautiluses are primarily targeted for their shells, which are sold commercially and traded internationally for use in art, furniture, jewellery, and other items. *Nautilus pompilius* is listed under the Schedule I Part IV-B of the Wildlife Protection Act, 1972.

II) Sub-class Coleoidea
Eight or ten circumoral appendages; suckers (and/or hooks) present; no external shell.

Superorder Decapodiformes
Decapodiformes comprises about 500 recent species in between five and seven orders depending on taxonomic opinion (Allcock, 2015). The relationships among orders of Decapodiformes are not well understood, and molecular systematics has failed to provide much resolution, although there is some evidence for a sister-taxon relationship between Spirulida and Sepiida

- **Family Spirulidae**: The ram's horn squid have an internal calcified coiled, chambered shell. It is represented by a single extant species, *Spirula spirula*. A spirally coiled internal shell comprising of over 30 chambers is located in the posterior end of adults. Fins narrow, ovate, attached dorsolaterally on the posterior end of the mantle (almost perpendicular to the longitudinal axis of the body). Arms increase in length dorsally to ventrally, with arms I short, arms IV longest. All arms except the fourth pair are united by broad webs. All arms except the fourth pair united by broad webs; arm suckers tetraserial, or in 6 rows. Hectocotylus present, both ventral arms modified: right hectocotylized arm grooved, concave, with spoon-like expansion, pointed tip and 2 finger-like outgrowths; left hectocotylized arm round in cross-section with 2 spoon-like and one finger-like outgrowth with soft papillae at the distal tip. Tentacular club straight, slender; not expanded, the same width as stalk; with 12 to 16 suckers in transverse rows; all suckers of similar small size

- **Family Sepiidae (**for a detailed description see Reid et al. 2005): Cuttlefishes have an internal calcified cuttlebone. There are three genera in the family Sepiidae namely *Metasepia, Sepiella* and *Sepia*.

1) ***Metasepia***: Cuttlebone is diamond-shaped in outline and much shorter than the mantle, located in the anterior 1/2 to 2/3 of the mantle; dorsal anterior edge of mantle without tongue-like projection.

2) ***Sepiella***: A gland and gland pore located on the ventral side of the posterior end of the mantle; mantle-locking apparatus with triangular projection; cuttlebone inner cone with very short limbs; outer cone a wide, spatulate, chitinized border around the posterior end of cuttlebone.

- ***Sepiella inermis***: Posterior gland and gland pore pigmented reddish. Club with 12 to 24 suckers in transverse rows. Cuttlebone outline oval, broad; cuttlebone width 33 to 43% cuttlebone length; strongly convex in lateral view; granulose dorsally; dorsal median rib distinct. Spine absent. Striated zone and last loculus convex; sulcus extend the entire length of cuttlebone. Inner cone limbs are uniform width, narrow, inner cone U-shape posteriorly, thickened, raised in the centre as a rounded knob; outer cone chitinous, spatulate, expanded. The dorsal mantle has more than 7 reddish patches adjacent to the base of fins.

3) ***Sepia***: Mantle-locking apparatus semicircular, without triangular projection. Cuttlebone inner cone with relatively long limbs; outer cone usually calcareous, not spatulate posteriorly.

Sepia pharaonis: Tentacular club sucker-bearing surface flattened, with 8 suckers in transverse rows; suckers differ markedly in size: 5 or 6 median suckers enlarged (3 or 4 of these are greatly enlarged). Cuttlebone outline oblong; bone bluntly rounded anteriorly; acuminate, acute, posteriorly; dorsal surface creamy white; dorsal surface evenly convex; texture smooth; dorsal median rib distinct, rib broadens anteriorly; lateral ribs indistinct. Chitin borders lateral and anterior margins of cuttlebone. The spine is short, pointed, curves dorsally, keel absent. Striated zone concave; last loculus flat; sulcus deep, wide, extends the entire length of cuttlebone; sulcus flanked by rounded ribs. Anterior striae are inverted U-shape; limbs of the inner cone extend anteriorly to the end of the striated zone. Inner cone limbs are narrow anteriorly, broad posteriorly with distinctive thick bulbous swelling; outer cone calcified; narrow anteriorly, broadens posteriorly. Dorsal mantle with series of elongate papillae along each side, adjacent to the base of each fin, or covered with numerous small papillae.

Sepia elliptica: Tentacular club sucker-bearing surface flattened, with 10–12-minute suckers in transverse rows; suckers all similar size. Cuttlebone outline oval; bone very angular, V-shape anteriorly; bluntly rounded posteriorly; dorsal surface creamy white; dorsal surface evenly convex; texture smooth; dorsal median rib indistinct, broadens anteriorly; lateral ribs indistinct. Spine is short, pointed, curves dorsally, keel(s) absent. Striated zone concave; last loculus convex; sulcus deep, wide. Anterior striae are inverted U-shape. Inner cone limbs are narrow anteriorly, broaden posteriorly; outer margin of inner cone raised into flat posterior ledge; ledge whitish (sometimes with a thin rim of chitin on outer margin); ledge not thickened; outer cone calcified.

Sepia prabahari Mantle broad, ovate and broadest at the anterior end. Dorsal mantle, head and arms zebra stripe pattern occurs, which is more prominent in males. Arms I and IV elongate, robust, whip-like in males and females arms approximately subequal in length. Tentacular club short with 6 suckers in transverse rows; all suckers are minute without any enlarged suckers. Cuttlebone elliptical in shape; broader in females than males; rugose dorsally, with indistinct median and lateral ribs. Spine curved dorsally, without keels. Anterior striae are inverted V-shape. Inner cone limbs are narrow anteriorly, broaden posteriorly, then are raised into a thick, round ledge.

- **Family Sepiolidae**: The members of the family have rounded posterior mantle with internal gladius present, rudimentary, chitinous, or absent. Fins wide; rounded, semicircular, or kidney-shaped, with pronounced anterior lobes, or 'earlets'; attached about midway along mantle; fin attachment short, fin length exceeds attachment length. Large eyes covered by corneal membranes.

***Euprymna* sp.:** Dorsal mantle fused to head by the cutaneous occipital band; anterior edge of ventral mantle not forming a ventral shield. Arm suckers usually tetra serial; left dorsal arm hectocotylized; distal suckers on male hectocotylized arm greatly modified, with closely packed fleshy papillae formed from enlarged and elongate swollen sucker pedicels; male third arms not bent inward.

- **Family Loliginidae (**Jereb et al.,2010): Internal shell straight, chitinous; tentacles contractile, mantle edge near mantle cartilages with small projections. Eye covered by a transparent membrane. Four longitudinal rows (series) of suckers on manus of tentacular clubs; fins united at the posterior end of the mantle; medial posterior border of fins concave.

Uroteuthis (Photololigo) duvaucelii: Fins gently rhombic, broad, approximately 50% of mantle length (up to 60% of mantle length). Tentacles long; tentacular clubs expanded, large, up to 45 to 50% of mantle length; large median manal suckers, (<2 times diameter of marginal suckers), with 14 to 22 short, sharp teeth, subequal in size, regularly spaced around the entire margin. Arm suckers with 5 to 9 broad, large, square teeth on the distal margin in females and up to 18 teeth around the entire ring in males. Mantle moderately long, slender, cylindrical for about half its length; it tapers gently into a blunt tip. Anterior margin with a small rounded lobe in the dorsal midline.

Uroteuthis (Photololigo) edulis: Fins rhombic, attain 70% of mantle length in adults, anterior margin slightly convex, posterior margin gently concave, lateral angles rounded; fins slightly longer than wide in adults, width 60% of mantle length (usually slightly larger in females). Mantle moderately stout, elongate, slender in mature males. Arm sucker rings with up to 12 (more often 6 to 8) long, slender, square-cut (bluntly-pointed) teeth on the distal margin; the proximal margin smooth or only irregularly denticulate with inconspicuous teeth.

Sepioteuthis lessoniana: Mantle long, robust, width about 40% of length. Fins very large, broadly oval in outline, fin length over 90% up to nearly 100% of mantle length, their width up to 75% of mantle length; the greatest width occurs posterior to the midpoint of the fins. Tentacular clubs long expanded.

- **Family Thysanoteuthidae**: Funnel free from mantle; funnel-mantle locking apparatus present. Funnel-locking cartilage with a longitudinal groove from which a shorter groove branches medially, ┤ shaped; fins more than 80% of mantle length.

Thysanoteuthis rhombus is monotypic, so the characters detailed at the family level are diagnostic.

- **Family Ommastrephidae**: Funnel-locking cartilage with a longitudinal groove crossed by a transverse groove at its posterior end, ┴ shaped; fins less than 60% of mantle length

Sthenoteuthis oualaniensis: Based on size differences of mature squid, as well as dorsal photophore and gladius morphology, 5 forms of undetermined status are distinguishable.

- **Family Enoploteuthidae**: Funnel-mantle locking apparatus straight. Hooks are present on all arms. Photophore present on mantle, funnel, head, eyeballs, and arms. Nuchal folds are present.

  Abralia andamanica: Five photophores (two large terminal opaque organs and three intermediate silvery organs) on the ventral side of the eyeball. The arm formula was 4<2<3<1. The mantle apex (tail) is long.

  Abraliopsis lineata: The mantle is weakly muscular, short conico-cylindrical, terminating in a blunt-ended short tail. The ventral surface of the mantle, funnel, head and arms III and IV are ornamented with photophores. Three longitudinal photophore rows are present on the arms IV. The ventral side of the eyeball has five photophores.

- **Family Bathyteuthidae**: Photophores absent on eyes; buccal membrane with 7 lappets or less. Buccal membrane connectives attach to the dorsal sides of IV arms. The surface of mantle and head without photophores. Minute suckers are present on the oral surface of the buccal membrane.

  Bathyteuthis bacidifera: The animal is dark brown in colour. Protective membranes on arms reduced or absent; trabeculae free, elongate, finger-like; arm suckers numerous; sucker rings with 18 to 34 protuberances; gills long, broad.

Superorder Octopodiformes (for a detailed description see Reid et al., 2005)

Octopodiformes comprises ~300 species in two orders. The relationships among Octopodiformes are better understood among cephalopods. The vampire squid is placed in a separate order (Vampyromorphida), and all other octopods are placed in the order Octopoda. Within Octopoda there are two major forms, the deep-sea cirrate octopods and the incirrate octopods.

Incirrate octopods: The incirrate octopods contain the greatest number of species including the familiar, muscular, bottom-dwelling (benthic) octopuses that are popular as fisheries targets (family Octopodidae). They are found in intertidal habitats to the deep-sea floor. This group also includes seven less familiar families of pelagic octopods of the open ocean, such as the argonauts and the Glass octopus (*Vitreledonella richardi*). Mature animals range in size from pygmy octopuses at under one gram to the Giant Pacific octopus (*Enteroctopus dofleini*) (Jereb and Roper, 2016). They are united by 8 arms with 1 to 2 rows of sessile suckers and the absence of fins or cirri. Females of all members of this order brood their young, tending and remaining with the eggs until hatching.

- **Family Octopodidae:** Eyes lateral, round to oblong, not telescopic; body and arms muscular or semi-gelatinous; funnel free from the ventral mantle. Body and arms muscular, transparent only in smallest juveniles. Distinct locking apparatus joining inner edge of the lateral mantle to funnel base absent. Male octopuses possess a modified third arm, typically the third right arm. This arm, the hectocotylus, typically has a spoon-like tip ligula and a curved gutter or groove along its length.

Amphioctopus neglectus: It is one of the major commercial species in the Indian Seas, usually caught in large quantities by bottom trawls. Moderate-sized species with oval mantle and relatively slender arms. Numerous small, rounded white spots are distributed on the dorsal mantle. A narrow, small, slightly U-shaped transverse bar is present between eyes. False-eye spots (ocelli) are present, containing a simple blue/ purple iridescent ring. Lateral or ventral arms longest (typically 4=3>2>1).

Amphioctopus marginatus: Moderate sized, arms 2 to 3 times mantle length, two rows of suckers on each arm. Slightly enlarged suckers present in mature males, 4 to 5 on arms 2 and 3, starting around the 7^{th} proximal sucker. False-eye spots (ocelli) absent. The typical pattern of orange-brown to the purple background with dark purple-brown reticulations, defining distinct patches in irregular longitudinal rows. Suckers white to pink, contrasting against dark brown to the black border along the leading edge of arms 1 to 3. Narrow transverse "head bar" visible in live animals. The white triangle below each eye. Dark vein-like reticulations are distinctive on lateral arm crown in the same position as false eyespots in ocellate species. Transverse pair of white spots present on the dorsal mantle, slightly anterior to midpoint of the mantle. The diamond shape of four longitudinal skin ridges on the dorsal mantle

Cistopus indicus: Moderate-sized species. Arms long, length around 6 times mantle length. Dorsal arms longest (1>2>3>4). Water pouches present in the oral surface of webs close to mouth; pores located adjacent to the level of 3rd to 4^{th} proximal sucker. Two rows of suckers on each arm. The right third arm of males hectocotylized, length around 75% of the opposite arm. Ligula tiny and blunt, 0.5 to 0.7% of arm length. Calamus absent. Hectocotylized arm with 116 to 123 suckers.

Octopus cyanea: Large, robust, muscular species. Mantle round to oblong with a few large tubercles. Arms robust and long, 4 to 6 times mantle length, arms IV slightly longer. Lateral arms longest (typically 4=3=2>1). Deepest web on lateral arms and shallow webs between the dorsal arms. Interbrachial web pouches are absent. Arms with two rows of suckers. Large size animal has 450 to 500 suckers on each normal arm. Ocellus present as dark oval patches within a dark narrow outer ring; located at the base of arms III and IV. Ocellus without an iridescent ring. Arm tips with 3 to 7 longitudinal rows of small white spots, often pronounced against the dark base colour. Mantle mottled, reticulate, arms with purple-brown blotches. Four large primary papillae in diamond arrangement on the dorsal mantle.

Conclusion:

The morphological traits in cephalopods are not well-delineated as their body forms differ so widely; most of them lack a shell; possess few hard structures; and often gets distorted in size, colour and shape on preservation, thus hindering their identification. In some species, hectocotylus morphology (which varies to a great extent across genera and species), is recognised for species-level classification. This may limit identification of female cephalopods, without the support of other identification tools in such groups.

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CHAPTER 38

Cephalopod Aging Using Hard Parts

1. Introduction

Cephalopods are exclusively marine mollusc (~800 species) characterised by a bilateral body, prominent head and set of arms. They play a key role in many marine ecosystems, both as predators and prey (Boyle & Rodhouse, 2005) and represent one of the most valuable commercial marine resources (Arkhipkin et al., 2015) contributing global catches of 3.6 million tonnes in 2018 (FAO, 2020). Cephalopods were fished from the Indian Seas as by-catch in shrimp trawls and currently contribute as one of the most important exploited marine fishery resources (CMFRI 2020) from India. During 1959, the annual catch of cephalopods that was 349 tonnes (Silas et al., 1982) increased drastically to 1.61 lakh tonnes in 2020. They are important resource in the Indian export trade, contributing to 15-20% annually.

Stock assessment challenges of cephalopods from Indian waters

The "live fast, die young" life history strategies of cephalopods present particular challenges for the stock assessment and management of squids. Most fishery models were developed for finfish that usually live much longer than cephalopods. They have a voracious appetite and grow fast, reaching commercial sizes in the first few months, which generally takes years in finfishes (Arkhipkin, 2020). Traditional modelling of stock assessment is generally unsuitable for cephalopods which are typically short-lived, with one or two generations present in the fishery at a given time. The poor stock-recruitment relationship strongly influenced by environmental factors (Arkhipkin, 2020), semelparity; continuous spawning contributing to microcohorts within (by hatching dates) each generation; the simultaneous presence of animals of different sizes and ages, having different growth trajectories; wide interannual fluctuations in abundance and mixed species nature of the tropical marine fisheries pose challenges in stock assessment. Meiyappan et al. (2000) pointed to several gaps that exist in the knowledge of cephalopods especially its life history and they argued for detailed studies from Indian waters.

The age composition and growth rate of fishery stocks are among the most important parameters for studying population biology, stock structure, life span and eventually for monitoring and managing the stocks appropriately. Reliable age and growth estimates are crucial parameters for better understanding of the population dynamics and for conducting a stock assessment, for which information on longevity, mortality rate, recruitment pattern, and age structure must be integrated (Andrade et al., 2019). The age and growth studies in squids were first studied by the Petersen method (Verrill, 1881). This analysis required a substantial sample size over a short time. The length-frequency analysis gives a slow growth rate and high longevity (Jackson et al., 1997). However, recent studies based on culture and age estimation using hard parts demonstrated squids have a short lifespan and fast growth rate (Arkhipkin, 2004; Jackson, 2004). Moreover, many studies provide further evidence that length-frequency analysis is inappropriate for squids (Jackson et al., 1997).

Recent studies confirm length-frequency analysis over-estimate the lifespan and underestimate the growth rate of squids (Jackson et al., 1997). The evidence from statolith ageing (Jackson, 2004) and laboratory experiments (Forsythe et al., 2001) unequivocally supports short lifespans and non-asymptotic growth rather than long-lived asymptotic growth models.

2. Methods for age and growth studies

Age estimation gives details of the individual as well as the age structure of the entire population. Cephalopod growth is estimated by using indirect and direct methods
Different methods that are used for estimating the age of squid populations can be grouped into three categories.

2.1. Direct growth studies

The direct method for understanding cephalopod growth is by examining growth of known-age individuals or of laboratory-maintained field-caught individuals. Absence of a proper larval stage, the very rapid growth rates, the short lifespan and high nutritious value make cephalopods a highly promising species for aquaculture as food production (Nabhitabhata, 1995) and it also help us to understand age and growth rate of cephalopods. Shevtsova (1977) identified the cephalopods as a potential object for rearing under a controlled environment. The culture experiments of bigfin reef squid *Sepioteuthis lessoniana*, pharaoh cuttlefish *Sepia pharaonis* and *Sepiella inermis* has been conducted from the Indian waters (Sivalingam et al., 1993, 1999; Anil et al., 2005).

2.2. Tagging and recapture

To date, very little work has been reported for assessing squid growth using tagging and recapture. Direct methods of tag-recapture and laboratory are generally unrealistic because of low recapture rate and high mortality (Krstulovic-Sifner, 2008). The first tagging and marking experiments of cephalopods were conducted on pelagic species starting in 1927 with Soeda (1950), who studied the patterns for the establishment of migration models of *Todarodes pacificus*. Different kind of tags (Chemical, mechanical and electronic) were used for cephalopods. Despite extensive tagging efforts and intense commercial fisheries recapture rate of the squids have generally been lower.

The northern shortfin squid *Illex illecebrosus* tagged in offshore waters of Newfoundland did not yield any successful recapture. Many squid species such as Argentine shortfin squid *I. argentines*, European flying squid *Todarodes sagittatus*, neon flying squid *Ommastrephes bartramii*, Japanese flying squid *Todarodes pacificus* and jumbo squid *Dosidicus gigas* have been studied for age and growth by tagging and recapture method.

2.3. Indirect method for growth studies in squids

The length-frequency analysis method constructs a growth curve by connecting the modes or mean length values for successive time intervals. Verrill (1881) first demonstrated the growth of cephalopods by using this method over 130 years ago.

Analysis of length-frequency data has been the main method used to obtain estimates of the squid growth rate and longevities (Pauly,1985). The length-frequency analysis produces an asymptotic growth curve and a long lifespan (Mohamed, 1996). However, numerous studies have reported its errors and inadequacies (Alford & Jackson, 1993) since it underestimate growth in squids (Jackson et al., 2000).

2.4. Age and growth studies of squid by using hard structure

Almost all the hard parts such as statoliths, gladius, beaks and crystalline lens of squids have increments, except chitinous rings of arms and tentacles (Arkhipkin et al., 2018).

2.4.1. Gladius

The gladius is the internal shells of squid (suborders Oegopsida and Myopsida) and bobtail squid (order Sepiolida). Typically, it consists of inner, intermediate, and outer shell layers, but there are variations with respect to the number of layers in some families. These layers grow periodically and the increments or the striae are used in age estimation. Gladius processing for age estimation can be divided into four stages: extraction, preservation, sample preparation and reading. The intermediate layer is the most promising gladius layer for ageing studies.

2.4.2. Stylets

Statolith and shell analyses of octopus species are unsuitable for ageing. The increment analysis in the hard rod-like vestigial shells or the stylets are used for ageing octopus. However, stylet increment analysis is not suitable for all octopus species because of variation in stylet structure and increment readability

2.4.3. Beaks

The beaks are basically composed of a chitin–protein complex. Growth process takes place from the posterior border of the beak, where the most recent chitinized and hydrated material is deposited. Growth increments in cephalopod beaks were reported for the first time in the 1960s for the squid *Onykia ingens* using the inner surface of lateral walls. Beak increments have been used for age estimation in squid species in which daily deposition was confirmed by comparing with statolith-determined ages. Beak microstructure increment analysis is affected by processes such as feeding that wear down the beak, resulting in inaccurate estimates.

2.4.4. Sepion

Most attempts to age cuttlefish have concentrated on the cuttlebone. This structure functions as a dorsal backbone providing both support and buoyancy control. It consists of a thin, hard, calcified, dorsal shield and a ventral porous phragmocene comprised of numerous narrow chambers, delineated by chitinous septa. The cuttlefish controls its buoyancy by moving gas or liquid into or out of the chambers as required. As the cuttlefish grows, further septa are laid down at the anterior end. Early studies concluded that the periodicity of chamber formation was daily, however, recent studies found it was related to growth rate rather than chronological age. The growth rate of cephalopods is strongly influenced by temperature and food availability and thus subject to seasonal fluctuations. The width of individual chambers also varies with growth rate.

2.4.5. Crystalline lens

Few attempts have been made for tentative ageing of cephalopods with unreadable statoliths, like in octopus, from their crystalline eye lenses. They grow continuously throughout life by the addition of concentric layers of fiber cells to their outer surface.

The stained histological sections of lenses are observed for growth rings after decalcification and dehydration.

2.4.6. Statolith ageing

Statoliths are currently the most frequently used hard part for estimating the age and growth of squids (Jackson, 2004). They are paired calcified structures located inside the cephalopod's equilibrium organ called statocyst. When polished, their exposed microstructure reveals a series of concentric increments which have been frequently shown to be deposited at approximately a 24 h cycle (Jackson, 2004). During the last three decades, statoliths have been used for estimating age and growth of squids from all over the world (Arkhipkin, 2004; Sajikumar et al., 2020).

2.4.6.1. Statolith analysis

The sequences of statolith extraction and process for age estimation are shown in Fig.1.

2.4.6.2. Extraction of statolith

Statoliths are located just posterior and ventral to the eyes and were extracted by the following procedure: The squid is placed with the ventral side up for the removal of the funnel apparatus. In large squid, this is possible only after making the necessary incision on the mantle before removing the funnel. A transverse cut through the ventral portion of head cartilage is done by a surgical blade to exposes the statocyst. The statoliths are located at the anterior wall of statocyst. In squids the two statoliths are generally visible, appearing as white opaque objects lying side by side under a thin layer of transparent tissue and cartilage. The pair of visible statoliths were gently removed using a fine needle (Fig.2).

2.4.6.3. Statolith cleaning and storing

After extraction, statoliths were cleaned of organic debris using a fine brush and stored in vials (centrifuge tubes) with 70% alcohol.

2.4.6.4. Microscopic slide preparation

The coded clear glass ground edges slides (26×76 mm size) are used to fix the statoliths.

Procedure for statolith extraction and process

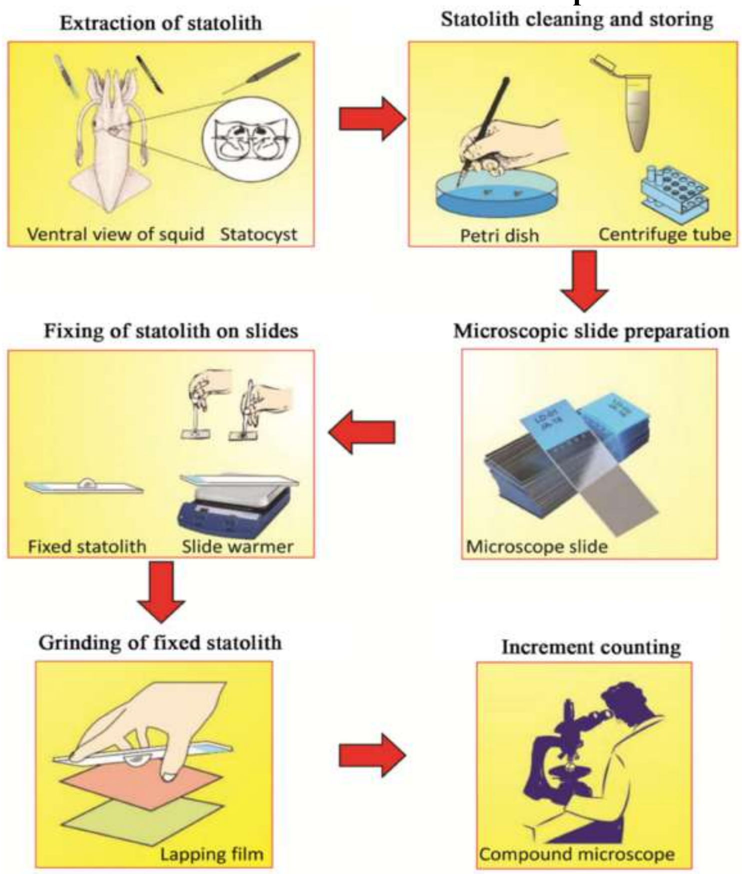

Fig. 1 Illustration of procedure for statolith extraction and process

Fig. 2 Extraction of statolith from statocyst of squids

2.4.6.5. Statolith measurements and terminology

Statoliths are paired structures and are attached to the cartilage cavity called statocyst. The statolith size is usually less than 2 mm. The statolith consists of four parts, including dorsal dome, lateral dome, rostrum and wing. The first three parts are usually hard but the fourth part (wing) a fin-like extension is weak due to the presence of loosely packed crystals (Fig.3). The dorsal dome may be large or small, that clearly separated from the lateral dome (Fig.3). The surface of the dome is generally rough. The lateral dome is dorso-ventrally elongated. The rostrum is roughly cigar-shaped and the end may be pointed, rounded or broad (Fig.3). The attachment area or wing usually has a dorsal and ventral indentation separated by a spur.

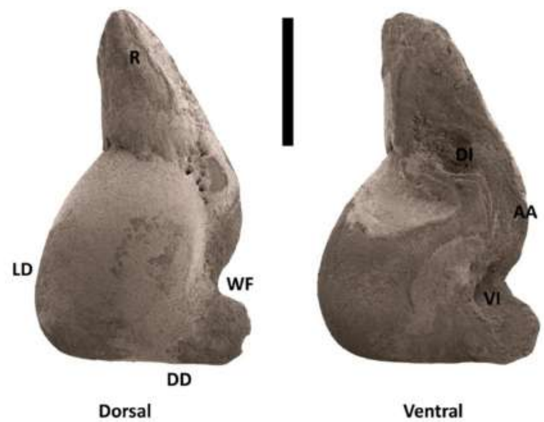

Fig. 3. Dorsal and ventral view of statolith of *Uroteuthis duvaucelii* (250 mm DML♂) DD= Dorsal dome, LD= Lateral dome, R=Rostrum, WF=Wing fissure, AA=Attachment area, DI=Dorsal indentation and VI= Ventral indentation (Scale bar=500µm).

The total statolith length (TSL) is measured from the edge of the dorsal dome to tip of the rostrum under the light microscope (Nikon Eclipse 85). The total statolith length (TSL) is measured to the nearest 0.01 mm.

2.4.6.6. Fixing of statolith on slides

The single statolith from one individual is generally enough for the estimation of age. Lipinski (1981) showed that both statoliths gave similar counts of increments. The dried statolith is mounted on a microscopic slide using thermoplastic cement (Crystalbond™). The thermoplastic cement Crystalbond™ is completely translucent, does not fluoresce under UV irradiation, and highly viscous. Statoliths can be easily turned-over and mounted using this cement as it melts at a low temperature (40 °C) and hardens relatively rapidly after removal from heat (Arkhipkin and Shcherbich, 2012.).

A small amount of thermoplastic cement is placed on the microscopic slides and warmed on a hotplate until it melts. After melting, the statoliths is placed over the cement. Both right and left statoliths can be placed on a single slide.

2.4.6.7. Grinding or polishing of fixed statoliths

Grinding is done for each statolith individually using waterproof sandpaper. Statoliths mounted on the slide are initially polished with coarse sandpaper (600 grit) followed by a fine paper (800-1200 grit) for 6-8 times.

2.4.6.8. Increment observation

Growth increments were examined under a compound microscope (Nikon, Eclipse-80i and Zeiss, Axiostar) under different magnification of 20×10, 40×10 and 60×10 X depending upon the size and visibility of statolith. When viewed under transmitted light, a growth increment is defined as the interface between an inner light and outer dark band (Fig.4). Each increments in statolith of squids comprised of two components, *i.e.,* one translucent layer and another opaque layer. The opaque layer is counted as a "ring" as described in Natsukari et al. (1993). Increments are counted from the first check (hatching ring) to the edge of the dorsal dome, where increments are generally most clearly visible (Villanueva, 1992; Dawe, 1985). However, it is sometimes necessary to extrapolate from adjacent areas to resolve increment counts in unclear areas. Growth increments are assumed to be daily, based on the validation studies in squids (Jackson, 2004; Arkhipkin, 2004).

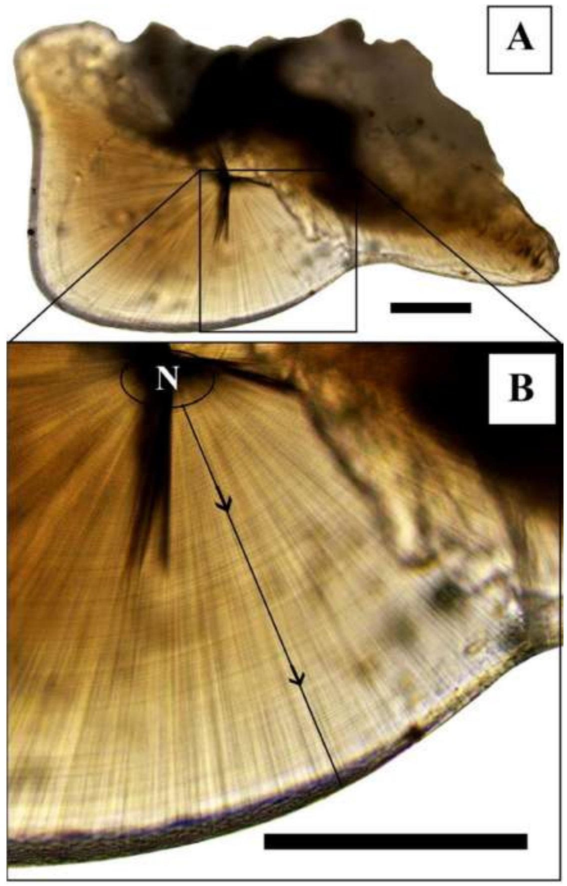

Fig.5. (A) Light micrograph of the ground statolith of *Uroteuthis duvaucelii* adult (male of 220 mm DML). (B) Magnified view of the area outlined by the rectangle showing growth increments. Scale bar= 200 um

A sequence of growth increments is counted more than once for minimizing the error. If the difference between first and second count is < 10%, the mean count is accepted. Counting is repeated when the difference is > 10%. However, if the final, difference is >10%, then the statolith is not used for increment analysis.

3. Summary

Determination of both age and growth are critical to understand the life history of harvested species and to model the dynamics of their populations, both of which are essential for assessment and management purposes. Successful age estimates have been achieved for many squid species by counting validated concentric daily increments found in statoliths. Recent years have seen the emergence of extensive studies of myopsid squid growth of the family Loliginidae. This has greatly advanced our understanding of their life histories. Growth data have accumulated from both statolith-based field studies and culture work. Validation studies on loliginids continue to support that statolith increments are laid down daily.

Ageing cuttlefish from statoliths has been less successful. In cuttlefish, the growth increments have proven difficult to distinguish due to the irregular and concentric deposition of the aragonite crystals, which result in a strong radial appearance, and the lower percentage of organic matter, which results in weak dark rings. Statoliths of octopods contain randomly arranged statoconia, without any visible increments. This technique has failed to provide results for octopus due to the lack of growth rings and the morphology of octopus statoliths not possessing the same landmarks as those of squid and cuttlefish, which minimizes increment visualization. Stylets, however, do have concentric rings and have been validated for age estimation using *Octopus pallidus* of known age reared in captivity. At present there is no generally applicable method of age and growth determination for all cephalopods and several techniques are in their infancy necessitating continued research in finer refinements and validation.

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CHAPTER 39

Taxonomy of Marine Mammals

INTRODUCTION

Marine mammals are warm-blooded aquatic vertebrates belonging to the class Mammalia, breathe air through lungs, locomotion by fins & flippers and produce milk to nurse their young ones. They are classified into four different taxonomic groups: **cetaceans** (whales, dolphins, and porpoises), **sirenians** (manatees and dugong), **pinnipeds** (sea lions, walrus, and seals) and **fissipeds** (sea otters and polar bear). They have undergone major adaptations which permit them to live in water with extreme temperature, depth, pressure, and darkness. The adaptations are the loss of hind limbs (cetaceans and sirenians), use of limbs for propulsion through water (pinnipeds), and the general streamlining of the body for hydrodynamic efficiency. Structural modifications to the sea otters and the polar bear are less apparent in body form and they continue to closely resemble their terrestrial counterparts. While cetaceans and sirenians spend their entire lives in the water, other marine mammals come ashore for various reasons, at particular times in their lives[1].

Marine mammals are often referred as "ocean sentinels" and ecosystem indicators of productivity and biodiversity. They are considered as keystone species in the marine ecosystem where their population collapse has a cascade effect in the food web which can eventually affect the human communities. Due to wide distribution, large body size, and predatory nature, marine mammals exert a major influence on marine food webs and on the structure and function of marine ecosystems. These organisms are known to inhabit tropical, subtropical, temperate, and polar oceans and seas as well as estuaries and contiguous seas of the world's large rivers. Marine mammals have a crucial role in determining the behaviour and life history traits of prey species and predators, as well as nutrient storage and recycling, and habitat modification in benthic environments[2]. With the push on the blue economy in India, there is an urgent need to assess and monitor marine mammal populations and characterise their habitats to better understand their biology, behaviour, and potential impacts from anthropogenic activities and environmental change.

In recent times marine mammals face a wide range of threats including incidental killing of their coastal populations as a result of entanglement in fishing gear, collisions with powered vessels, and entrapment in water regulation devices, pollution, ocean acidification, stresses due to infectious diseases and harmful algal blooms, disturbances due to seismic activities and ocean warming[4]. Conservation and sustainable management of this highly valuable resource is important for maintaining and restoring the distribution, abundance and diversity of marine

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mammals and thus for healthy ocean. Taxonomy is the basic tool in conservation of living resources. Units of conservation is determined by population structure and ultimately by species designation.

Identification of marine mammals includes several methods like morphology based classical taxonomy, acoustics detection by comparing the sound frequencies and modern tools such as molecular identification of marine mammals by application of DNA barcoding (COI, 16S rRNA), mass spectrometry (collagen peptide mass fingerprinting) and eDNA (droplet digital PCR). Next-Gen Sequencing (NGS) has been applied frequently on present cetacean populations recovering full mitogenomes, genomic single nucleotide polymorphisms (SNPs), or even complete nuclear genomes to develop more nuanced models of their evolutionary systematics and population histories. Some of the current areas of molecular research on cetaceans globally are, DNA barcoding[5], eDNA analysis[6], whole genome sequencing[7], mitogenomics[8] and molecular identification of market samples[9]. Even though molecular approaches are successful in identifying marine animals, they are expensive and due to difficulty in getting fresh tissue samples, researchers commonly use morphology-based visual identification.

Marine mammal specimens can be identified by using morphological characters, such as ratio of the outer margin of the flipper to the total body length, coloration pattern, teeth count, shape of body, shape of head, extent of throat grooves, shape of flipper, position and shape of dorsal fin, shape of caudal fluke, body colour, position of blow holes etc. and in visual surveys, blow pattern is a key feature of species identity. Photographs of dorsal fins and flukes help in identification of individual cetaceans and this technique, known as photo-identification, is useful for studying the school size, structure and species composition. A repeated photo-session from the same geographical location for a protracted period of time will help in monitoring resident and migrant populations as well as the reproductive success. Identification of the species at sea is somewhat different from that of a dead animal on land. Even under ideal conditions, an observer often gets little more than a brief view of a splash, blow, dorsal fin, head, flipper, or back, often from a great distance[1].

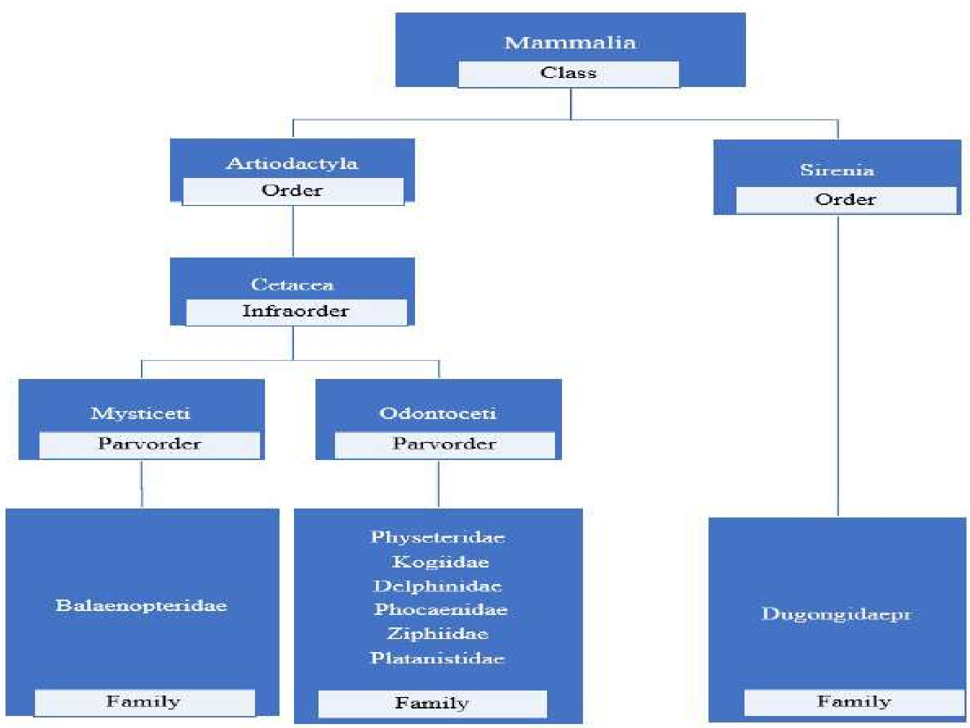
Marine mammals comprise of 21 families (8 are monotypic) and 135 recognized species in the world belonging to four taxonomic groups i.e., cetaceans (whales, dolphins and porpoises), sirenians (manatees and dugongs), pinnipeds (seals, sea lions and walruses), and marine fissipeds (polar bears and sea otters) [10]. IUCN has listed 25% of these species as threatened (IUCN, 2009), and many species are expected to become extinct if proper management and conservation measures are not taken[11].

MARINE MAMMAL DIVERSITY OF THE WORLD[10]

Order	Infraorder	Parvorder	Family	No. of Species
Carnivora (38)	Arctoidea (3)	Ursida	Ursidae	1
		Mustelida	Mustelidae	2
	Pinnipedia (35)		Otariidae	15
			Odobenidae	1
			Phocidae	19
Artiodactyla (92)	Cetacea (92)	Mysticeti (15)	Balaenidae	4
			Neobalaenidae	1
			Eschrichtiidae	1
			Balaenopteridae	9
		Odontoceti (77)	Physeteridae	1
			Kogiidae	2
			Ziphiidae	23
			Platanistidae	2
			Iniidae	1
			Lipotidae	1
			Pontoporiidae	1
			Monodontidae	2
			Delphinidae	37
			Phocoenidae	7
Sirenia (5)			Trichechidae	3
			Dugongidae	2
Total				**135**

CLASSIFICATION OF MARINE MAMMALS OF INDIA

In the Indian seas, the marine mammals are represented by cetaceans and sirenians, and they together contribute 28 species[12, 4], comprises almost 25 percentage of the world's marine mammals, and almost 8% of all mammalian fauna recorded in India[13]. The sirenian group in India is represented by a single species, *Dugong dugon*. The Wildlife (Protection) Act 1972 of India listed all the marine mammal species under Schedule I.



ORDER: ARTIODACTYLA
INFRAORDER: CETACEA[14]

- All cetaceans share a similar streamlined body structure
- Nostril(s) on the top of the head make up the blow hole, with one in odontoceti and two in mysticeti
- Propulsion by up and down movement of tail ends with a flattened paddle like cartilaginous fluke
- Telescoping in skull- restructuring process that pushed the nasal passages posteriorly in the cetacean skull[15]
- Body is enfolded in well-developed blubber layer
- Newly derived boneless structures in the form of tail flukes and a dorsal fin or ridge

PARVORDER: MYSTICETI (BALEEN WHALES) [16]

- This group having the largest animal on the planet. Antarctic blue whale, weighing up to 181 tonnes (approximately 33 elephants) and reaching up to 98 feet in length
- Paired nostrils or blowholes are longitudinal slits situated at the top of the cranium causing a V-shaped blow
- Wing like flipper movement helps in the propulsion of the body
- Presence of baleen (keratinaceous baleen plates (or "whalebone")) instead of teeth in their mouths to sieve planktonic creatures from the water
- Indian baleen whales are represented by the family Balaenopteridae

KEY CHARACTERISTICS FOR WHALE IDENTIFICATION

- Shape of head
- Shape and location of dorsal fin
- Body color and pattern
- Baleen plates colour
- Number of ventral (throat) grooves
- Flipper length and shape
- Girth to length ratio
- Head length to body length ratio

FAMILY: BALAENOPTERIDAE

- Members of this family also known as rorquals, contains the gigantic animals ever to live
- In India Balaenopteridae comprises 6 species belonging to 2 genera: Balaenoptera and Megaptera
- Except the humpback whale other members shares a streamlined body with a series of long pleats from the snout tip to as far back as the navel on the ventral surface
- Lunge feeding is an extreme, fast and active feeding method, their morphology allows them to accelerates to a high velocity and then open their jaws wide and distend their throats to take in huge mouthful of water during feeding
- The baleen plates are of moderate length and fringe fineness. Density and fringe diameter- vary among species, and along with plate number and width to length ratio, are diagnostic characters
- Dorsal fins situated behind the midpoint of the back at 2/3$^{rd\ to}$ 3/4th of total length.
- Pleated throat grooves distinguish balaenopterids from other whales.

BALAENOPTERA MUSCULUS (LINNAEUS, 1758) - Blue whale

- Dorsal fin very small (about 1% of body length) and positioned at 3⁄4 of total length
- 260 to 400 black baleen plates with black bristles per side (all 3 sides of each plate roughly equal in length)
- Bluish or light grey body colour with grey patches on dorsal surface
- 60-80 ventral grooves extending near to navel
- Maximum body length: 33 m.
- Most adults measuring 23 to 27 m and newborn measuring about 7-8 m
- IUCN status: Endangered

BALAENOPTERA PHYSALUS (LINNAEUS, 1758) - Fin whale

- Head V-shaped from above, and pointed at the tip
- A ridge on the upper side of mouth and another prominent ridge between dorsal fin and fluke
- 260 to 480 grey baleen plates with white streaks on the side
- Head coloration asymmetrical (left side grey, much of right side white); back dark, with light streaks; belly white
- Tall and falcate dorsal fin positioned farther forward on caudal peduncle
- 50-100 ventral grooves extending up to naval
- Adults reach a maximum size of 27 m in southern hemisphere and 24 m in the northern hemisphere
- IUCN status: Vulnerable

BALAENOPTERA BOREALIS LESSON, 1828- Sei whale[17]

- The rostrum is pointed, snout slightly down and turned at tip
- The pectoral fins are relatively short, only 9%–10% of body length, and pointed at the tips
- Ventral pleats 32 to 60, longest ending past flippers, but well short of navel
- 300 to 380 pairs of black baleen plates with many whitish bristles, less than 80 cm long
- Flippers are all dark
- A single median ridge
- Maximum body length 19.5 m
- IUCN status: Endangered

BALAENOPTERA EDENI ANDERSON, 1878- Bryde's whale

- Pointed head with three prominent ridges on dorsal side of rostrum
- 40 to 70 ventral pleats extending to umbilicus
- 250 to 370 slate-grey baleen plates per side; with white to light grey fringes
- Head coloration symmetrical
- Tall and well falcate dorsal fin
- Dorsal profile is dark gray and light ventrally
- Tip of the lower jaw is dark
- Maximum body length 14 m
- IUCN status: Least Concern

BALAENOPTERA ACUTOROSTRATA LACEPEDE, 1804- Common Minke whale

- Sharply pointed and V-shaped head with prominent ridge on upper rostrum
- Tall and falcate dorsal fin; located at two third of body
- Dark grey with shades on lateral side of body
- 50-70 throat grooves extending just past the flippers
- 231 to 360 cream coloured baleen plates with coarse bristles per side, less than 21 cm long, mostly white or yellowish white (sometimes with dark margin along outer edge); often conspicuous white bands on upper surface of flippers
- Head sharply pointed from above; maximum body length 9 m
- IUCN status: Least Concern

MEGAPTERA NOVAEANGLIAE (BROWSKI, 1781) - Humpback whale

- Robust and stocky body
- Top of head covered with knobs, 1 prominent cluster of knobs at tip of the lower jaw
- Prominent tubercles near the lips and chin
- Elongated flippers one-fourth to one- third of body length, with knobs on leading edge
- Small dorsal fin usually at top on an obvious hump
- Black and dark grey in colour
- 14-35 ventral grooves extending beyond navel
- 270 to 400 black to olive brown baleen plates with grey bristles per side, less than 80 cm long
- Flukes with irregular trailing edge

- Maximum body length 16m
- IUCN status: Least Concern

PARVORDER: ODONTOCETI (TOOTHED WHALES) [18]

- Represented by 6 families (India)
- These are small to medium sized cetaceans except sperm whales (male of which can grow at least 18 m)
- Presence of teeth throughout life
- Single blow hole
- An asymmetrical skull with
    - Concave profile
    - Sternum with 3 or more parts
    - Complex system of nasal sacs
    - Fatty organ in the forehead area called the melon
- Capable of echolocation to
    - Navigate
    - Find food
    - Avoid predators

FAMILY: PHYSETERIDAE (SPERM WHALES) [19]

- The sperm whales are the largest toothed cetacean
- There is a low dorsal hump, followed by a series of crenulations
- Has a large head with a squarish profile, narrow underslung lower jaw, and functional teeth only in the lower jaw (these fit into socket in the upper jaw)
- Caudal flukes are triangular and very thick
- Blowhole located at the left front of the head
- Head is divided into sections called the “junk” and the spermaceti organ or “case”
- The spermaceti: is large oil filled reservoir
- Capable of very deep and long dives

PHYSETER MACROCEPHALUS (LINNAEUS, 1758) - Sperm whale

- Head squarish and large, 20 to 30 % of body length
- Narrow lower jaw
- Short and broad flippers
- Small, thick and round dorsal hump followed by a series of crenulations along the midline
- 18-26 pairs of teeth in only lower jaw, fitting into sockets in upper jaw
- Body black to charcoal grey, with white lips and inside of mouth
- 2-10 short throat grooves present

- S- Shaped blowhole at left side of front of head
- Maximum size: 18 m
- IUCN status: Vulnerable

FAMILY: KOGIIDAE[20]

- Blunt squarish heads not more than 15% of the body length with very short rostrum
- Blowhole is not located at the front of the head
- Dorsal fin is larger than the sperm whale
- 8 to 16 long thin and sharply pointed homodont teeth in each side of lower jaw, fitting into upper jaw sockets
- Similar to that of sperm whales, Kogiidae also possess spermaceti in their head
- Body size less than 4 m

KOGIA BREVICEPS (BLANINVILLE, 1838) - Pygmy sperm whale

- Tiny underslung lower jaw
- Small and sqaurish head
- A hump on dorsal side between blowhole and dorsal fin
- Well curved dorsal fin and set behind the midpoint of the body
- Flipper set near to head
- Throat creases generally absent; dorsal fin short (< 5% of body length)
- Distance from tip of snout to blowhole greater than 10.3% of total length
- 12 to 16 (rarely 10 to 11) sharp fang-like teeth in each half of lower jaw
- Maximum body length:3.5 m
- IUCN status: Least Concern

KOGIA SIMA OWEN, 1866- Dwarf sperm whale

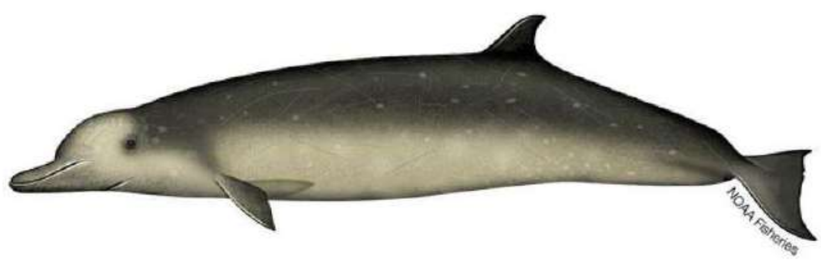
- Tiny underslung lower jaw
- Triangular or squarish head

- No hump on dorsal side between blowhole and dorsal fin
- Tall and slightly falcate dorsal fin
- A pair of short throat grooves
- Small flipper with blunt tip positioned near head
- Sharp fang-like 7-12 pairs of teeth present on lower jaw
- Distance from tip of snout to blowhole greater than 10.2% of the total length
- Maximum body length 2.7 m
- IUCN status: Least Concern

FAMILY: ZIPHIIDAE

- Beaked whales are medium size cetaceans (4 to 13 m long)
- Have a pronounced beak in general
- Relatively small dorsal fin set far back on the body
- Small flippers that fit into depressions on the sides
- A pair of converging grooves under the throat, and the notch is absent in the tail fluke.
- Not more than 1 or 2 pairs of exposed teeth in the lower jaw of males only
- The blubber of these whales is predominantly composed of wax ester, a unique characteristic of this family[21]

INDOPACETUS PACIFICUS -Longman's beaked whale



- Large and robust body
- Bulging foreheads and moderate tube beaks
- Beak with single pair of oval teeth at tip of the lower jaw
- Large and falcate dorsal fin located behind the midpoint of body
- Broad flukes with straight trailing edges
- Small and blunt flipper
- A pair of V shaped grooves on the throat
- Umber brown to bluish colour
- Maximum size :6m
- IUCN status: Least Concern

ZIPHIUS CAVIROSTRIS CUVIER, 1823 - Cuvier's beaked whale

- Slender and relatively robust body than other beaked whales
- Relative to body size head is short and poorly distinct beak
- Forehead smoothly sloping, slightly concave in front of blowhole
- Light rusty brown with lighter area around the head
- Mouth line gently upwards
- Small and rounded flipper
- Single paired V-shaped throat grooves
- Small falcate dorsal fin set near to hind end of the body
- A single pair of teeth directed forward and upward at tip of lower jaw (exposed only in adult males)
- Maximum body length 6 m
- IUCN status: Least Concern

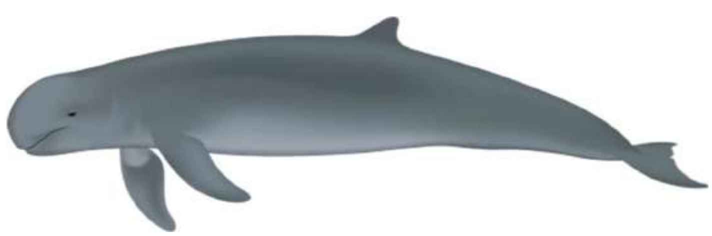
KEY CHARACTERISTICS FOR IDENTIFICATION OF DOLPHINS

- Shape and location of dorsal fin
- Shape of flipper
- Shape of head
- Colour and pattern of body
- Teeth count

FAMILY: DELPHINIDAE[22]

- Many small to medium sized odontecetes of various forms have been lumped together in this group, and so the family has been referred to as "taxonomic trash basket" range in size from the 1 to 10 m
- Most delphinids share the following characteristics
  - ➢ Marine habitat
  - ➢ A noticeable beak
  - ➢ Conical teeth
  - ➢ A large falcate dorsal fin set near the middle of the back.

ORCAELLA BREVIROSTRIS (GRAY, 1866) - Irrawaddy dolphin



- Moderately robust body
- Blunt, bulbous head with no beak and straight mouthline
- Dorsal groove between neck to falcate dorsal fin
- Dorsal fin set just behind the midpoint of the body
- Indistinct neck crease
- U-shaped blow hole open towards front
- Gray colour on dorsal and lateral side with white belly
- 8 to 19 pairs present in the upper jaw and 11-18 in lower jaw
- Maximum size 2.4 m
- IUCN status: Endangered

ORCINUS ORCA (LINNAEUS, 1758) - Killer whale

- Robust and spindle shaped body
- Very tall and straight erect or triangular dorsal fin in male and slightly shorter falcate dorsal fin with pointed or round tip in female
- White oval shape patches behind eyes; a light gray saddle patch behind dorsal fin
- Large and oval shaped flipper with blunt tips
- Peculiar black and white coloration, with post ocular patches, white lower jaw, white ventrolateral field and light grey saddle patch behind dorsal fin
- 10 to 14 pairs of large oval teeth in each tooth in each jaw
- Maximum body length 8 m
- IUCN status: Data Deficient

PSEUDORCA CRASSIDENS (OWEN, 1846) - False killer whale

- Long and slender and cigar shaped body
- Rounded and overhanging melon with no discernible beak
- Dorsal fin moderately height with rounded tip
- Flipper slightly curved with distinct hump on leading edge located near midpoint of back
- Body predominantly dark grey or black
- 7 to 12 pairs of large teeth in each half of both jaws
- Maximum body length 6 m
- IUCN status: Near Threatened

PEPONOCEPHALA ELECTRA (GRAY, 1846) - Melon headed whale

- Moderately robust body
- Head triangular and sharply pointed bulbous
- Extremely short, indistinct beak may be present in younger animals
- Faint cape that dips low below tall and falcate dorsal fin
- Lip of lower jaw white
- Body is coloured charcoal gray to black with a white urogenital patch
- 20-25 pairs of teeth per side of each jaw
- Flippers are sickle shaped with sharply pointed tips
- Maximum body length 2.75 m
- IUCN status: Least Concern

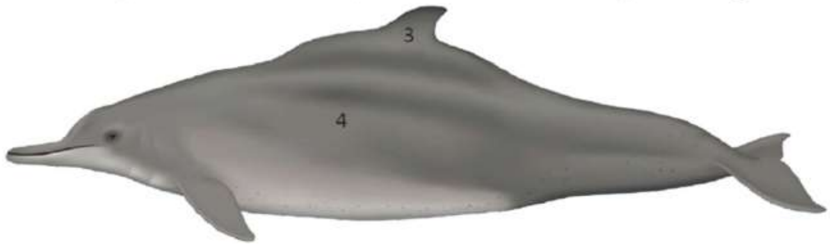
FERESA ATTENUATA -Pygmy killer whale[23]

- Short and rounded head
- Body colour is dark gray to black on the cape and has a sharp change to lighter gray on the sides
- White patches on belly and lips of jaw white
- Rounded tipped dorsal fin
- Higher teeth count, they have approximately 48 teeth, with 22 on the upper jaw and 26 on the lower jaw
- IUCN status: Least Concern

SOUSA CHINENSIS (OSBECK, 1765) - Indo- Pacific humpback dolphin

- Robust body grey with bluish, cream, or pink tinge and light belly
- Long and well-defined beak, but no distinct crease
- Dorsal fin is small and wide based placed on a mid-dorsal hump
- Dorsal ridge is absent
- Light coloured calves become grey or brown when they are adults
- 31- 39 pairs of teeth in upper jaw and 29-38 pairs in lower jaw
- Maximum size to 2.5 m
- IUCN status: Vulnerable

SOUSA PLUMBEA (G. CUVIER, 1829) – Indian Ocean humpback dolphin



- Robust body
- Long well-defined beak
- Small dorsal fin sits on a dorsal hump
- Colour: brown/grey, sometimes with white/pink on dorsal fin
- Teeth: upper jaw 33-39 in each tooth row, 31-37 lower jaw
- Maximum size to 2.8 m
  IUCN status: Endangered

STENO BREDANENSIS (LESSON, 1828) - Rough toothed dolphin

- Robust body, dark grey to black above and white below, with many scratches and spots
- Long and conical head
- No distinct crease between melon and long beak
- Dark grey cape below slightly falcate dorsal fin
- Belly, lips and lower are white in colour with spots
- Flippers very large and set farther back
- 19 to 28 slightly wrinkled teeth in each half of both jaws
- Maximum body length: 2.5 m
- IUCN status: Least Concern

GRAMPUS GRISEUS (CUVIER, 1812) - Risso’s dolphin

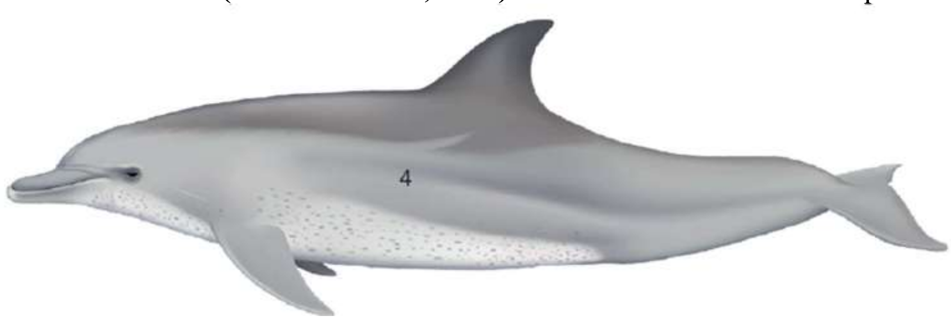
- Robust body

- No beak and blunt head and vertical crease on front of melon
- Very tall, slender and dark falcate dorsal fin pointed at tip
- Mouthline slopes upwards
- 2 to 7 pairs of teeth at front of lower jaw only (1 to 2 pairs in upper jaw), but teeth may be absent or extensively worn
- Body grey to white, covered with scratches and splotches in adults and young ones relatively unmarked
- Flippers long, pointed and sickle shaped
- Maximum body length 3.8 m
- IUCN status: Least Concern

GLOBICEPHALA MACRORHYNCHUS GRAY,1846 -Short-finned pilot whale

- Bulbous and round head with up sloping mouth lines with short or no prominent beak
- Long and sickle shaped flipper
- 7 to 9 pairs of short sharply pointed teeth present
- Round and broad base dorsal fin situated near to fore end of the body
- Black in colour and white cape below dorsal fin
- Adult grow up to 5 m
- IUCN status: Least Concern

TURSIOPS ADUNCUS (EHRENBERG, 1833) – Indo-Pacific bottlenose dolphin



- Moderately robust body
- Short beak set of by distinct crease
- Tall, slightly falcate and broader dorsal fin

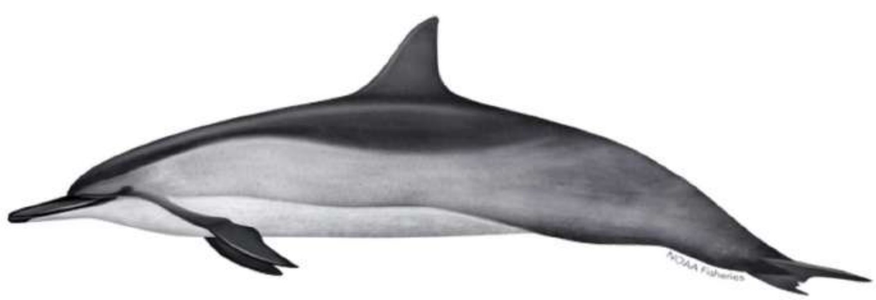
- Gray body with white belly. Prominent black spots or flecks on bellies
- 20 to 26 teeth in each half of upper jaw, 18 to 24 in lower jaw
- Body length to 2.7 m
- IUCN status: Near Threatened

STENELLA ATTENUATA (GRAY, 1846) - Pantropical spotted dolphin

- Fairly slender body
- Long slender beak with white tip separated from melon by a distinct crease
- Slender and strongly curved flipper. Dark stripe from gape to flipper
- Narrowly curved falcate dorsal fin with pointed tip
- Body spotted heavily

- Dark grey band between eye to apex of melon
- Adults with light to extensive spotting and grey bellies (spotting sometimes absent)
- 34 to 48 teeth in each jaw
- Maximum size 2.1 m
- IUCN status: Least Concern

STENELLA LONGIROSTRIS (GRAY, 1828) - Spinner dolphin



- Slender body
- Long and slender beak with black tip
- Erect and triangle or slightly falcate dorsal fin located in mid of the body
- Dark grey cape and followed by light grey sides and white belly
- Dark strip present between eye and origin of flipper
- 40 to 62 very fine sharply pointed teeth per tooth row.

- Maximum size 1.8 m
- IUCN status: Least Concern

STENELLA COERULEOALBA (MEYAN, 1833) - Striped dolphin

- Moderate snout and black in colour
- Moderate beak length, distinct crease between melon and beak
- Prominent dark stripes from eye to anus and eye to flipper
- Colour pattern black to dark grey on back, white on belly
- Light grey spinal blaze extending to below dorsal fin (not always present)

- Shallow palatal grooves often present
- 40 to 50 pairs of slender and pointed teeth present in each jaw
- Maximum size 2.4 m
- IUCN status: Least Concern

DELPHINUS CAPENSIS (GRAY, 1828) – Long-beaked common dolphin

- Elongated rostrum, deep crease present between beak and melon.
- A distinctive V shape present below the tall and slightly falcate dorsal fin
- Stripe extent from chin to origin of flipper
- Flipper is recurved and pointed at tips
- Back dark and belly white
- Tan to buff thoracic patch and light grey streaked tail stock from an hourglass pattern that crosses below dorsal fin

- 47 to 67 sharp and pointed teeth in each jaw; palate with two deep longitudinal grooves
- Maximum size 2.4 m
- IUCN status: Data Deficient

FAMILY: PLATANISTIDAE[24]

- Includes the extant susu and the bhulan of the Ganges and Indus rivers, respectively
- Long forceps like beak, with front teeth that extend outside the closed mouth
- Blowhole is a longitudinal slit
- Instead of a true dorsal fin a short dorsal ridge is present

PLATANISTA GANGETICA (ROXBURGH, 1801) - Ganges River dolphin[24]

- National aquatic animal
- Body tan, chocolate brown or light blue with lighter or pinkish belly
- Slit like single blowhole
- Long beak with sharp and pointed teeth protruding outside closed mouth at front half
- 26 to 39 teeth in each row
- It has a rectangular, ridge like dorsal fin
- Reach maximum size up to 2.5 m
- IUCN status: Endangered

FAMILY: PHOCOENIDAE[18]

- They are small cetaceans generally coastal in distribution with no prominent beak
- Streamlined body and two limbs that are modified into flippers
- Spade-shaped teeth distinguished from the conical teeth of dolphins
- Short triangular shaped or no dorsal fin
- Exhibit sexual dimorphism in which females are larger than males

NEOPHOCAENA PHOCAENOIDES (CUVIER, 1829) - Finless porpoise

- Round forehead rises steeply from the snout tip, devoid of beak
- True dorsal fin is absent, but there is a narrow dorsal ridge covered in thick skin bearing several lines of tiny tubercles
- Tiny bumps on dorsal side behind forehead
- Body colour is grey or black, with lighter belly
- 15 to 22 teeth present in each jaw
- Flipper with large rounded tips
- Fluke with concave trailing edge
- Maximum size of 1.7 m
- IUCN status: Vulnerable

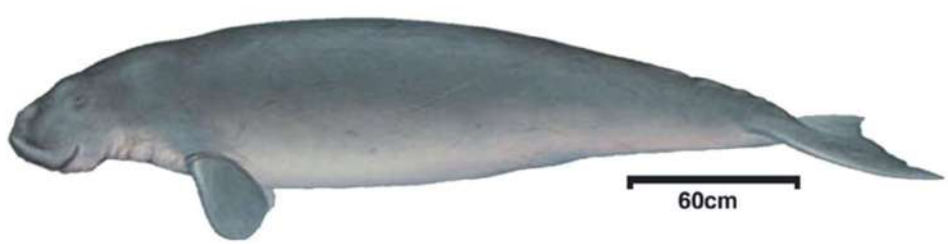
ORDER: SIRENIA[25]

- These are herbivorous group of marine mammals
- Robust fusiform body with tough and thick skin bearing short hair
- They have heavy bones that act as ballast to counteract the buoyancy of their blubber
- 2 nostrils present on top or at the front of a thick muzzle
- External ear pinnae and hind limbs are absent
- Forelimbs modified as flippers
- Horizontally flattened tail; and dense and swollen bones

FAMILY: DUGONGIDAE

- There is only one extant species in the family
- Flattened tail is broadened into flukes similar to cetaceans
- Rostrum is deflected downwards, presence of erupted tusks in males
- Absence of nails on the flippers

DUGONG DUGON (MULLER, 1776) - Sea cow or dugong



- The sole sirenian species found in the Indo- pacific
- Streamlined body shape like cetaceans
- Valve like nostrils on top of snout
- Incisors present in the form of tusks
- Head with muzzle deflected downward ends in a “rostral disk” with short and dense bristles
- Dorsal fin is absent
- Smooth skin sprinkled with short hairs

- Paddle shaped flippers containing no nails, Tail spilt into flukes, with a median notch; tail stock laterally compressed into peduncle
- Maximum size- 3.3m
- IUCN status: Vulnerable

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CHAPTER 40

Classification of Algae with Special Reference to Seaweed

Algae are photosynthetic organisms that occur in most habitats, ranging from marine, brackish water, freshwater to desert sands and from hot boiling springs to snow and in polar ice. They vary from small, single-celled to complex multicellular forms, The microscopic algae are called as phytoplankton whereas large benthic algae are called as macro algae. Some of the algae like giant kelps of the eastern Pacific that grow to more than 60 meters in length and form dense marine forests. Algae are found in the fossil record dating back to approximately 3 billion years in the Precambrian.

Taxonomy of algae is being modified from 1935 till date. Earlier classification was based on five important characteristics 1.type of pigments 2. nature of reserve food material, 3. type of cell wall material 4. Type, number and attachment of flagella and 5. cell structure. Fritsch (1935) divided the algae into 11 classes based on pigmentation, types of flagella, assimilatory products, thallus structure and methods of reproduction which was very well explained in his book entitled "Structure and reproduction of Algae".

1.Chlorophyceae
2. Xanthophyceae
3.Chrysophyceae
4.Bacillariophyceae
5.cryptophyceae
6.Dinophyceae
7.Chloromonadineae
8.Euglenineae
9.Phaeophyceae
10.Rhodophyceae
11. Myxophyceae.

G.M. Smith (1950) classified algae into seven divisions. These divisions based on colour, storage food and cell wall composition. He included certain algae of uncertain position into Chloromonadales & Cryptophyceae.

1.Chlorophyta: Chlorophyceae & Charophyceae
2.Chrysophyta: Chrysophyceae, Xanthophyceae & Bacillariophyceae
3. Pyrophyta: Dinophyceae & Desmophyceae
4. Euglenophyta
5. Phaeophyta
6. Rhodophyta
7. Cyanophyta

Further Round (1973) has classified algae in two groups like Prokaryota & Eukaryota keeping Cyanophyta under Prokaryota and all other like Chlorophyta Euglenophyta Charophyta Parsinophyta Xanthophyta Haptophyta Dinophyta Bacillariophyta Chrysophyta Phaeophyta Rodhophyta Cryptophyta under Eukaryota.

Papenfuss (1946) included the suffix 'phyco' to the divisions of algae and named chlorophyta as Chlorophycophyta. The name green alga is given because of the presence of dominant pigments like Chlorophylls a and b over the carotenoids and xanthophylls.

Bold and Wynne (1978, 1985) recognized ten divisions of algae retaining the nomenclature given by Papenfuss (1946), except for blue green algae. They considered Cyanophyceae as a division and called it Cyanochloronta whereas Papenfuss had included it in phylum Schizophyta as a class.

1. Cyanophyta (Blue Green Algae)
2. Prochlorophyta (Single genus: Prochloron)
3. Chlorophyta (Green algae)
4. Charophyta (Stone worts)
5. Euglenophyta
6. Phaeophyta (Brown algae)
7. Chrysophyta (Golden and yellow green algae)
8. Pyrrhophyta (Dinoflagellates)
9. Cryptophyta
10. Rhodophyta (Red algae)

Robert Edward Lee's Classification (1989) divided the algae based on evolution and formed 4 evolutionary groups of algae which are further divided into 15 divisions.

1. Prokaryotic algae (Cyanophyta)
2. Eukaryotic algae with chloroplast surrounded by the two membranes
    - Glaucophyta,
    - Rhodophyta
    - Chlorophyta
3. Eukaryotic algae with chloroplast surrounded one membrane of chloroplast endoplasmic reticulum
    - Euglenophyta
    - Dinophyta
4. Algae which have two membranes of chloroplast endoplasmic reticulum
    - Cryptophyta
    - Heterokontophyta

Graham and Wilcox (2008) again classified algae based on the photosynthetic pigments, storage food and cell wall. He divided alga into 9 division such as

Phylum	Pigment constituents	Storage food	Cell wall
Cyanobacteria	Chl a, phycocyanin, allophycocyanin, phycoerythrin, β carotene and Xanthophyll	Cyanophycean starch, granules and glocogen	Peptidoglycan
Glaucophyta	Chl*a*, phycocyanin, allophycocyanin, β carotene and Xanthophyll	Starch	Cellulosic
Euglenophyta	Chl *a*,b β carotene, other carotenoid and Xanthophyll	paramylon	Proteinaceous pellicle beneath plasma membrane
Cryptophyta	Chl *a*,c, phycocyanin, phycoerythrin, α & β carotene and Xanthophylls	Starch	Proteinaceous periplast beneath plasma membrane
Haptophyta	Chl *a*,c, β carotene and Xanthophylls	Chrysolaminaran	Mostly calcified
Dinophyta	Chl *a*,c, β carotene and Xanthophylls	Starch	Cellulosic plate in vesicles beneath plasma membrane
Ochrophyta	Chl *a*, α & β carotene and Xanthophylls	Chrysolaminaran & lipid	Some naked, some with silica organic scales, cellulose, some having alginate
Rhodophyta	Chl*a*, phycocyanin, allophycocyanin, α & β carotene and Xanthophyll	Floridean starch	Cellulose, sulphated polysaccharides, some are calcified
Chlorophyta	Chl *a*,b, α & β carotene, other carotenoids and Xanthophyll	Starch	Cellulose, some are naked some are calcified

Cavalier-Smith, 2007 explained seaweed are not having a single taxonomic entity. Molecular phylogeny show they belong to three kingdom like Plantae (Which include Chlorophyta and Rhodophyta), the kingdom Chromista (includes Phaeophyta, dinoflagellates and diatoms) and the kingdom Bacteria (includes cyanophyta or blue green algae). Diatoms are the largest group of algae perhaps more than 25000 species described till date. Around 7000 species of red algae, 2000 species of brown, 1800 species of green and 1500 species of blue green are recorded so far.

Seaweeds are classified into three major groups based on their pigmentation like brown algae (Phaeophyceae), green algae (Chlorophyta), and red algae (Rhodophyta).

	Chlorophyta	Phaeophyta	Rhodophyta
Habitat	Marine, Freshwater & Terrestrial	Marine	Mostly marine & few freshwater
Pigments	Chl a & b , carotenoid	Chl a & c, Xanthophyll, Fucoxanthin & carotenoid	Chl a & d , carotenoid, Phycobiloprotein
Cell wall	cellulose	Cellulose	cellulose
Stored food	starch	Alginic acid, Laminarin, Mannitol	Agar, carrageenan
Species	*Ulva, Enteromorpha, Caulerpa*	*Sargassum, Turbinaria,Padina*	*Gracilaria, Gelidiellla,Hypnea, Kappaphycus*

Seaweeds are nothing but marine macroalgae found from the intertidal area to deep Ocean. Seaweeds are not grouped with the true plants because they lack a specialized vascular system like xylem, phloem, roots, stems, leaves, and enclosed reproductive structures like flowers and cones. They are simple thallus and the whole plant are responsible to do all the activities like photosynthesis, reproduction, fluid transport and respiration. Like true plants, seaweeds are photosynthetic, they convert solar energy to chemical energy and produce carbohydrate with the help of pigment systems present in each cell of the thallus. Within their cells seaweeds have the green pigment chlorophyll, which absorbs the sunlight they need for photosynthesis. Chlorophyll is also responsible for the green colouration of many seaweeds. In addition to chlorophyll some seaweeds contain other light absorbing pigments. These pigments can be red, blue, brown, or golden, and are responsible for the beautiful colouration of red and brown algae. In Chlorophyll Chl a is responsible for light reaction in the photosystem where as other chlorophyll pigments like chl b, c, d are accessories pigments which channel the solar energy photon to chla. Similarly other pigments like xanthophyll, phycobiloprotein also present in seaweed and these pigments provides beautiful colors for seaweed. Despite of the undeserved negative connotation associated with such a name, seaweeds play a fundamental role marine ecosystems, where they have a multitude of beneficial effects.

Brown algae: *Sargassum, Padina, Stoechospermum, Turbinaria, Fucus, Laminaria* etc . It is a large group of algae consisting of 240 genera and over 1,800 species out of which 32 genera and 93 species are reported from India. About 99.7% members are marine and a few grow in freshwater. They range from simple microscopic heterotrichous filament (Ectocarpus) to largest alga like *Macrocystis pyrifera*, which attains a length of 60-90 meters. The brown colour of the algae due to the dominance of xanthophyll pigments like fucoxanthin which masks the other pigment like chl a & c (there is no chl b in phaeophyta), β carotene and other xanthophylls. There is no unicellular or colonial form in brown algae, They are branched, filamentous. Most of the plant are having a hold fast. Some of the higher brown algae are having stipe and lamina and is the only alga having tissue differentiation into conducting tissues but there is no true xylem or phloem found as in higher plants. In general they are larger in size and mostly found in temperate waters. Worldwide biomass harvested (from wild and farmed) comes from relatively few number of species from Laminariales and Fucales.

Turbinaria

Sargassum

Fritsch (1935, 45) classified the Class. Phaeophyceae into nine orders. This was also followed by Mishra (1966).

1. Ectocarpales e.g., Ectocarpus, Haiothrix.
2. Tilopteridales e.g., Ptilopteris.
3. Cutleriales e.g., Cutlria.
4. Sporochnales e,g. Sporochnus.
5. Desmarestiales e.g., Desmarestia.
6. Laminariales e.g., Laminaria.
7. Sphacelariales e.g., Sphacelaria.
8. Dictyotales e.g., Dictyota.
9. Fucales e.g., Sargassum.

Padina

The green algae represent a very diverse group distributed not only in the sea, but also in freshwater and terrestrial habitats. In recent years, based on DNA sequence data green algae do not form a homogeneous and coherent entity.

Ulva

Enteromorpha

They are part of a larger group called Viridiplantae, in which the land plants are also included (Lewis & McCourt, 2004). However, all marine green algae are classified in a common class, called Ulvophyceae. The Ulvophyceae are a very diverse group and include about 920 species, which are distributed in all seas of the world. In the green seaweeds, the body of the alga shows a great range of variation in morphology but usually its morphology . It may be very thin filamentous as found in *Cladophora* and *Chaetomorpha* or in the form of sheets in *Ulva* or siphonaceous like *Caulerpa.* Species of this genus consist of a creeping stolon (that grows attached to the rocky bottom), from which numerous erect frond of variable shape arise. Siphonalean green algae are classified in two orders, Bryopsidales and Dasycladales, and are among the most ecologically successful seaweeds. The body of these algae is formed by one single giant cell, which contains numerous nuclei. There are few green algae which are calcareous like *Halimeda.*

Caulerpa

The red algae are one of the most ancient groups of eukaryotic algae. Fossil record of 1.2 billion years old was found for Bangiomorpha sps. Red algae lacks flagella in any stage of their life history as found in other algae. They have a complex life history, which usually involves the alternation of three generations like gametophyte, carposporophyte and tetrasporophyte. Saunders & Hommersand (2004) and Yoon et al(2006) emphasized based on the molecular data produced in the last two decades which revolutionise the classification of red algae belonging to a single phylum (Rhodophyta) which subdivided in two subphyla (Cyanidiophytina and Rhodophytina), seven classes (Cyanidiophyceae, Bangiophyceae, Compsopogonophyceae, Florideophyceae, Porphyridiophyceae, Rhodellophyceae and Stylonematophyceae)and 33 orders. The red algae show wide morphological variation from the simplest single cells *Porphyridium* to thin filaments in *Bangia*. The habit of expanded blades is found in many generasuch as *Delesseria Polyneura, Porphyra* and *Halymenia.* There are certain coralline algae attached to rocky substratum where the cell wall accumulate calcium carbonate. A typical example is represented by species of the order Corallinales, in which the cell walls accumulate calcium carbonate in the form of aragonite such as *Lithophyllum*, *Lithothamnion* and *Phymatolithon*, look like pink or red calcified crusts. Many branched species of red algae are found in the intertidal rocky shore. They are *Chondrus, Geledium, Gracilaria, Hypnea, Laurencia* & *Kappaphycus.*

Acanthophora

Kappaphycus

Hypnea

Most of the red algae are having sulphated polysaccharides like agar-agar & carrageenan and for this purpose they are farmed on large scale in tropical regions.

CHAPTER 41

GIS in Marine Ecosystem Mapping

In the universe, every phenomenon that occurs has a spatial dimension. An analysis of these phenomena without a spatial dimension is incomplete. Spatial information should form an integral part of the studies leading to the management of living natural resources. The inherent data linkages become more clear when spatial dimension is added. In the past, integration of spatial data to analytical process was not that easy as the required expertise and skill were possessed by very few and software options necessary for the analysis was limited and costly. In the last decade, there has been an explosion in the spatial data realm in terms of software tools, data collection procedure and analysis, human expertise available for handling spatial data and how spatial information is used in the day to day life. Spatial information has been extensively used in almost all the fields of study, be it natural sciences, social sciences, archaeology, surveying, marketing and particularly in fish resource mapping elsewhere in the world. It shows the importance of geographic information system (GIS) in the present world. The strength of GIS is its ability to integrate data from different sources and carryout spatial analysis to arrive at meaningful conclusions which otherwise would not be possible.

GIS is mainly concerned with location of the features as well as properties/attributes of those features. It helps us gather, analyse and visualize spatial data for different purposes. A GIS quantifies the locations of features by recording their coordinates which are the numbers that describe the position of these features on Earth. The uniqueness of GIS is its ability to do spatial analysis. GIS helps us analyse the spatial relationships and interactions. Sometimes, GIS proves to be the only way to solve spatially-related problems and it is one of the most important tools that aid in decision making process. GIS basically helps to answer three questions; How much of what is where? What is the shape and extent of it? Has it changed over time?

Globally, on an average, GIS tools save billions of dollars annually in the delivery of goods and services through proper route planning. GIS regularly help in the day-to-day management of many natural and man-made resources, including sewer, water, power, and transportation networks. GIS help us identify and address environmental problems by providing crucial information on where problems occur and who are affected by them. It also helps us identify the source, location and extent of adverse environmental impacts. GIS enable us to devise practical plans for monitoring, managing, and mitigating environmental damage. Human impacts on the environment, conflicts in resource use, concerns about pollution, and precautions to protect public health have spurred a strong societal push for the adoption of GIS.

GIS is composed of hardware, software, data, humans and a set of organizational protocols. The selection and purchase of hardware and software is often the easiest and quickest step in the development of a GIS. Data collection and organization, personnel development and the establishment of protocols for GIS use are often more difficult and time consuming endeavours. A fast computer, large data storage capacities and a high quality, large display form the hardware foundation of most GIS. GIS software provides the tools to manage, analyse, and effectively display and disseminate spatial information. GIS as a technology is based on geographic information science and is supported by the disciplines like geography, surveying, engineering, space science, computer science, cartography, statistics etc.

In GIS, we handle the spatial and attribute data sets. Spatial data describes the absolute and relative location of geographic features while the attribute data describes characteristics of the spatial features. These characteristics can be quantitative and/or qualitative in nature. Attribute data is also referred to as tabular data. Vector and raster are two different ways of representing spatial data. Raster data is made up of pixels (or cells), and each pixel has an associated value. A digital photograph is a simple example of a raster dataset where each pixel value corresponds to a particular colour. In GIS, the pixel values may represent elevation above/below sea level, or chemical concentrations, or rainfall etc. The key point is that all of this data is represented as a grid of (usually square) cells. Vector data consists of points, lines, and polygons. The individual points are stored as pairs of (x, y) co-ordinates. The points may be joined in a particular order to create lines, or joined into closed rings to create polygons, but all vector data fundamentally consists of lists of co-ordinates that define vertices, together with rules to determine whether and how those vertices are joined.

As with many other systems, GIS basically works on the principle of '*GIGO'* that is *garbage in garbage out*. Hence the quality of data that you feed into GIS is very important and it determines the quality of the end products. But, when used wisely, GIS can help us live healthier, wealthier, and safer lives.

The following paragraphs throw some light on how GIS could be used to analyse how the climate change has affected the SST over Barents Sea and to calculate Oceanic Niño Index (ONI).

Hands on:

Monitoring of SST over Barents Sea

The northern Barents Sea to the north of Scandinavia and east of the remote archipelago of Svalbard is known as the Arctic warming hotspot. This region has warmed extremely rapidly; by 2.7 degrees Fahrenheit just since the year 2000. Using timeseries SST data, we would analyse how the SST varied during the period 1891 to 1900 and 2000 to 2018 taking the climatic mean monthly SST for the period 1981-2010 as the base value. We could also see how the mean Arctic Ocean SST has changed over the said periods.

Task 1: Monitoring the changes in SST over Barents Sea.

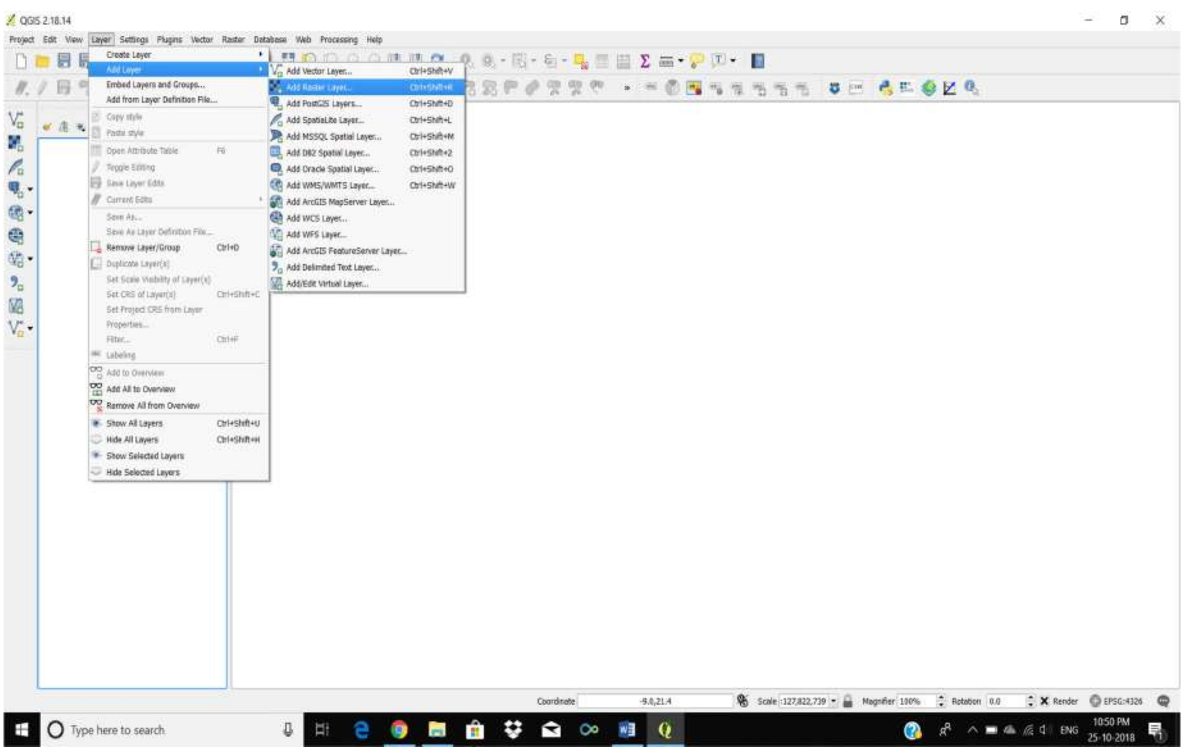
Software Required: QGIS 2.18.14 and Microsoft Excel

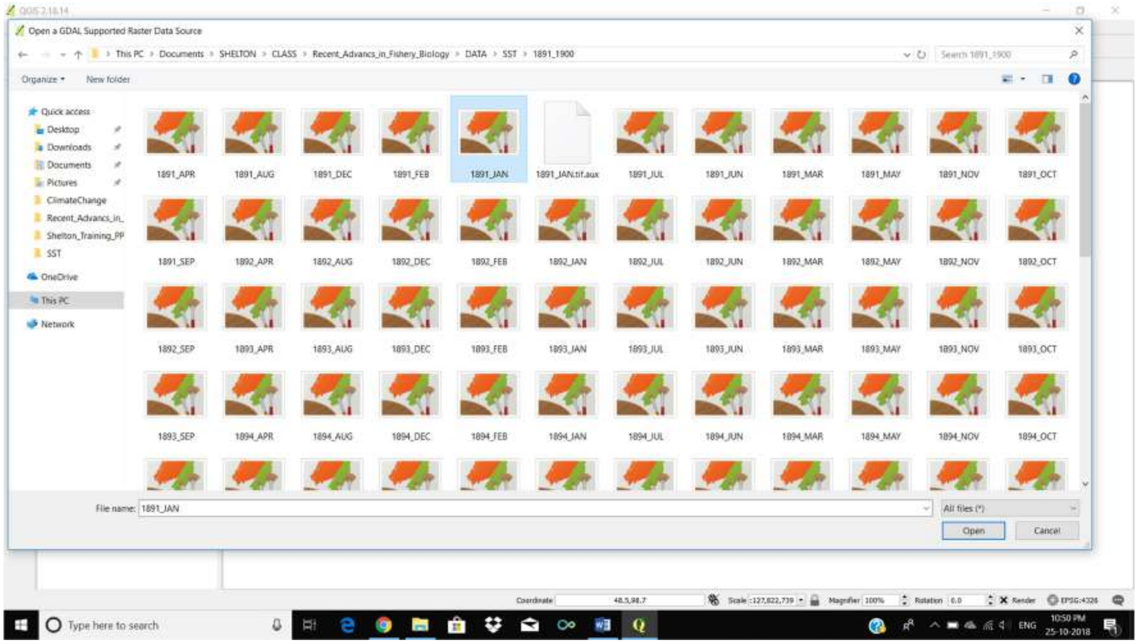
Data sets required:

Climatic (1981-2010) monthly mean SST (1_JAN.tif, 2_FEB.tif, 3_MAR.tif, 4_APR.tif, ……….. 12_DEC.tif)
Actual monthly mean SST: Set 1 (1891_JAN.tif, 1891_FEB.tif, 1891_MAR.tif, ………… 1900_DEC.tif)
Actual monthly mean SST: Set 2 (2000_JAN.tif, 2000_FEB.tif, 2000_MAR.tif, ………… 2018_SEP.tif)

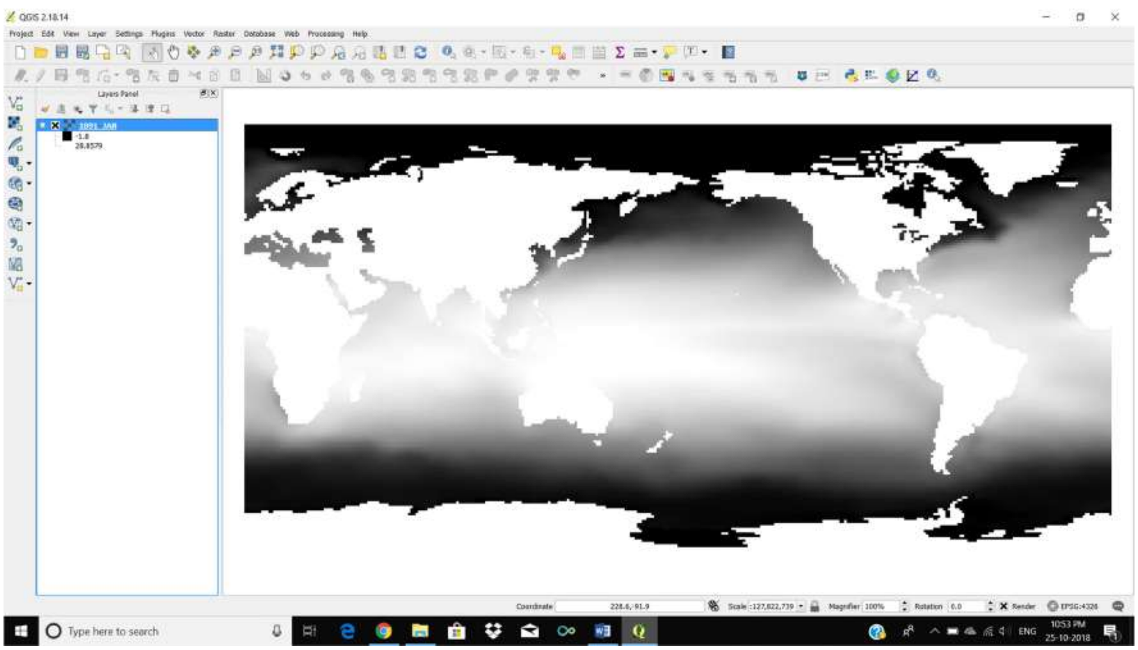
Shape file for Barents Sea: BarentsSea.shp

Loading SST data into QGIS:
Open QGIS -> Go to Layer menu -> Add raster layer -> Browse to the folder location -> Select the file -> 1891_JAN.tif and load the file into the map view.

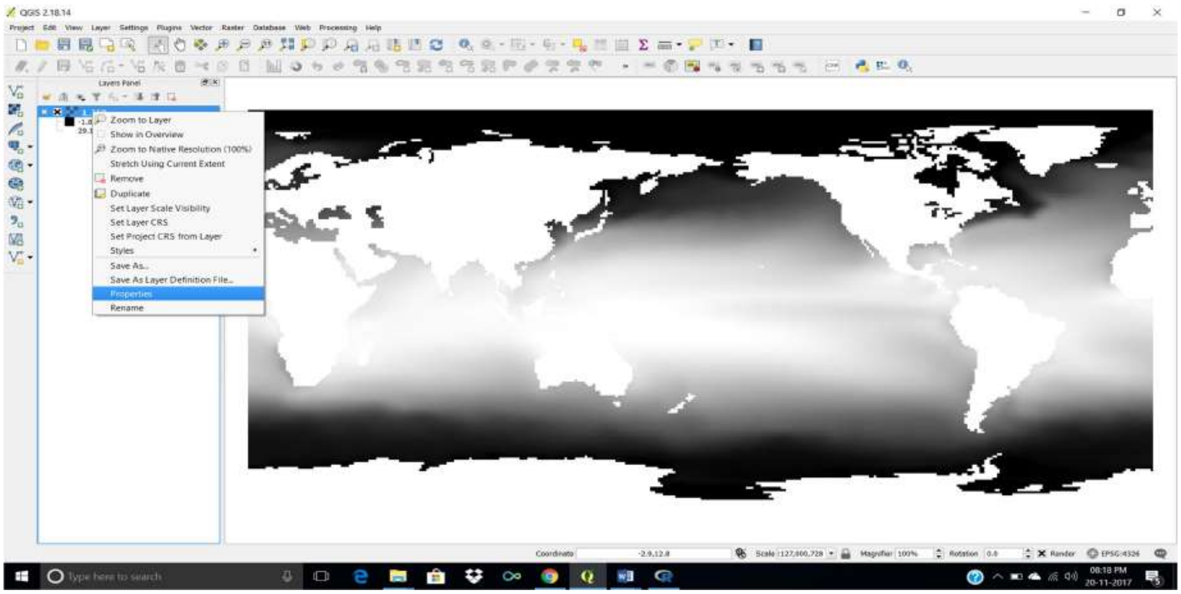




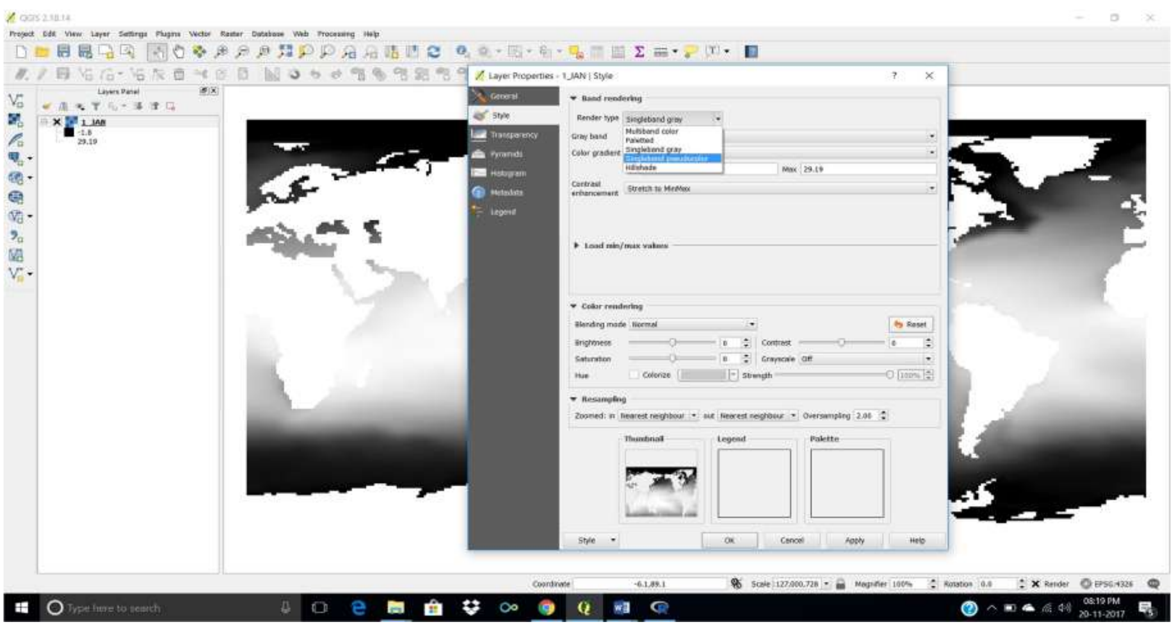
Now you get the SST data for 1891 January loaded on to the Map view as shown below



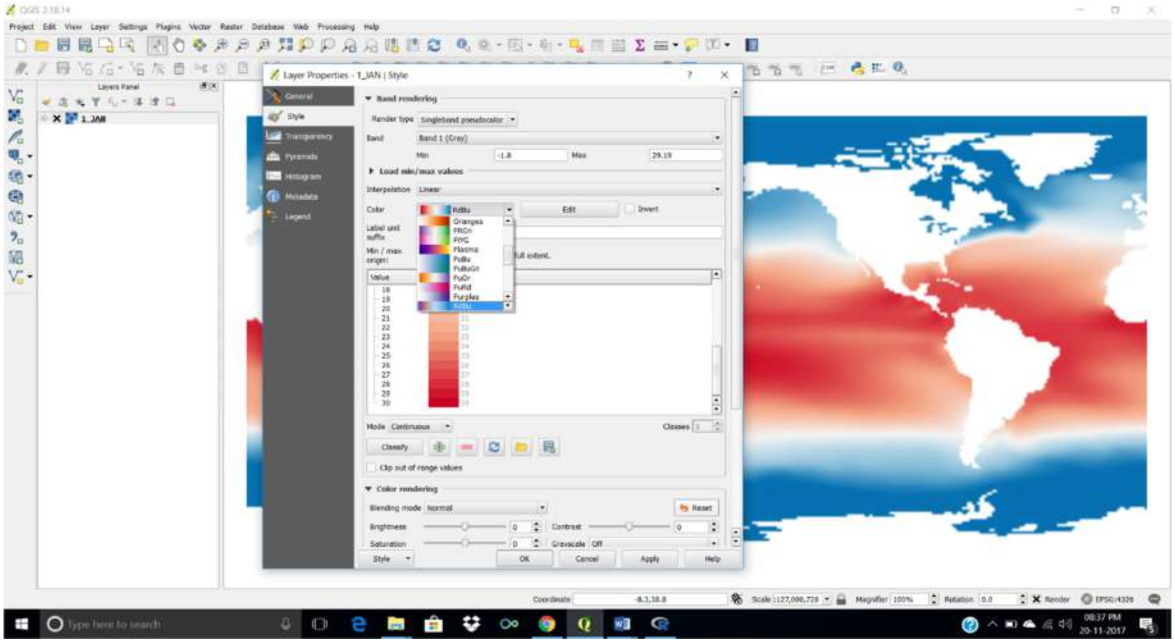
Now, to get a clear visual effect of the temperature variation, change the grey scale of the map to pseudo colour rendering. For that, right click the file name on the Layers panel (left side of the main view panel) and select the properties.



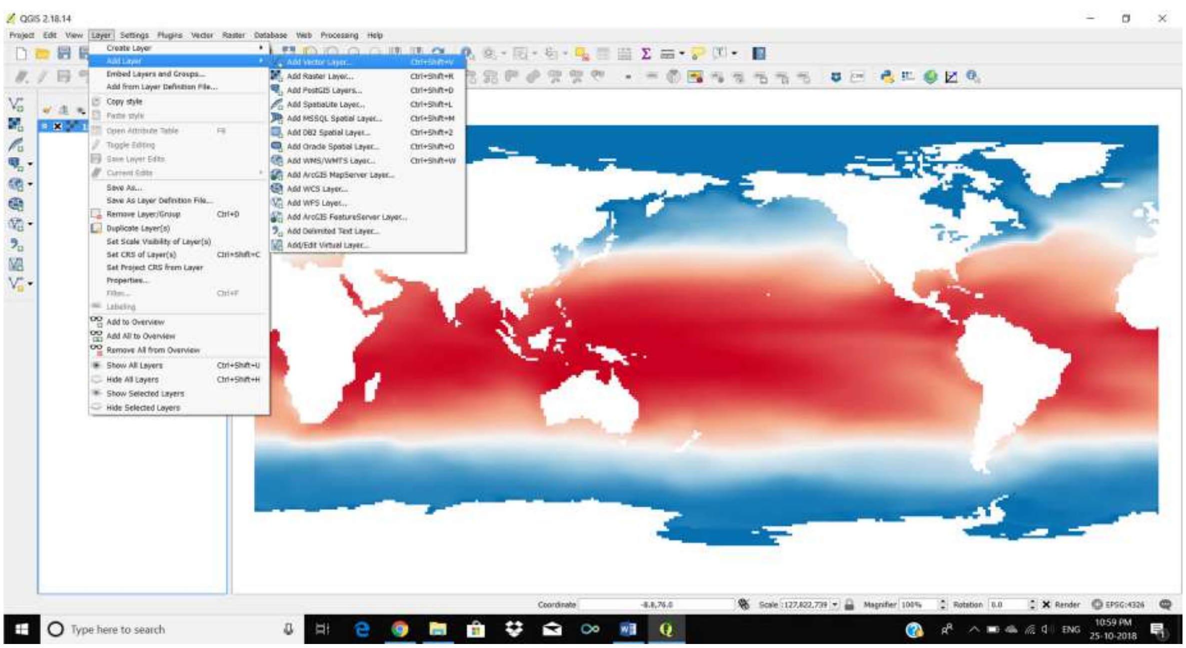
From the Layer Properties pane, go to style tab and change the band render type to ‘Single band pseudo colour’.



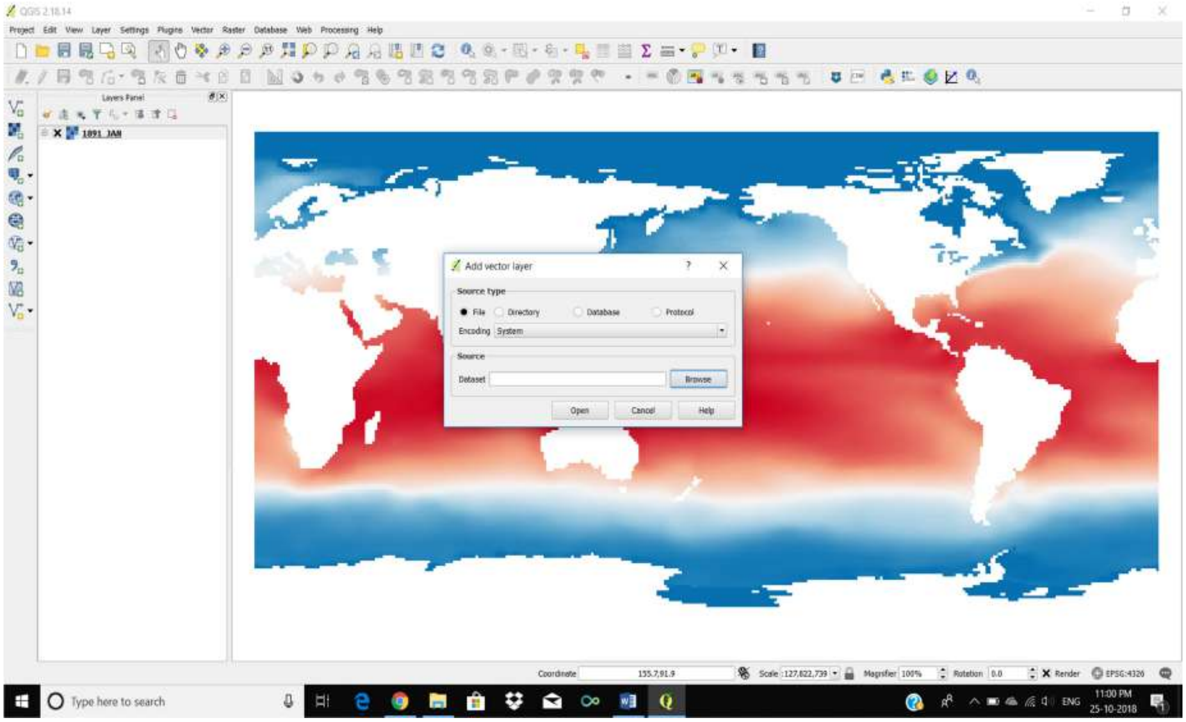
Then choose a ‘Colour’ band. Change the ‘Mode’ to ‘Equal interval’, set ‘Classes’ to ‘30’ and press the ‘Classify’ button. The display will change to pseudo colour gradient as per the SST variations.



As explained above, add all the SST layers for the period 1891 to 1900 (total 120 layers). Now, load the Barents Sea shape file into QGIS. For that Go to Layers menu -> Add Layers -> Add Vector Layer.



Navigate to the required folder and open the file BarentsSea.shp


QGIS 2.18.14
Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Help
Layers Panel
1891_JAN
Add vector layer
Source type
File
Directory
Database
Protocol
Encoding
System
Source
Dataset
Browse
Open
Cancel
Help
Coordinate
155.7,91.9
Scale
127,822,739
Magnifier
100%
Rotation
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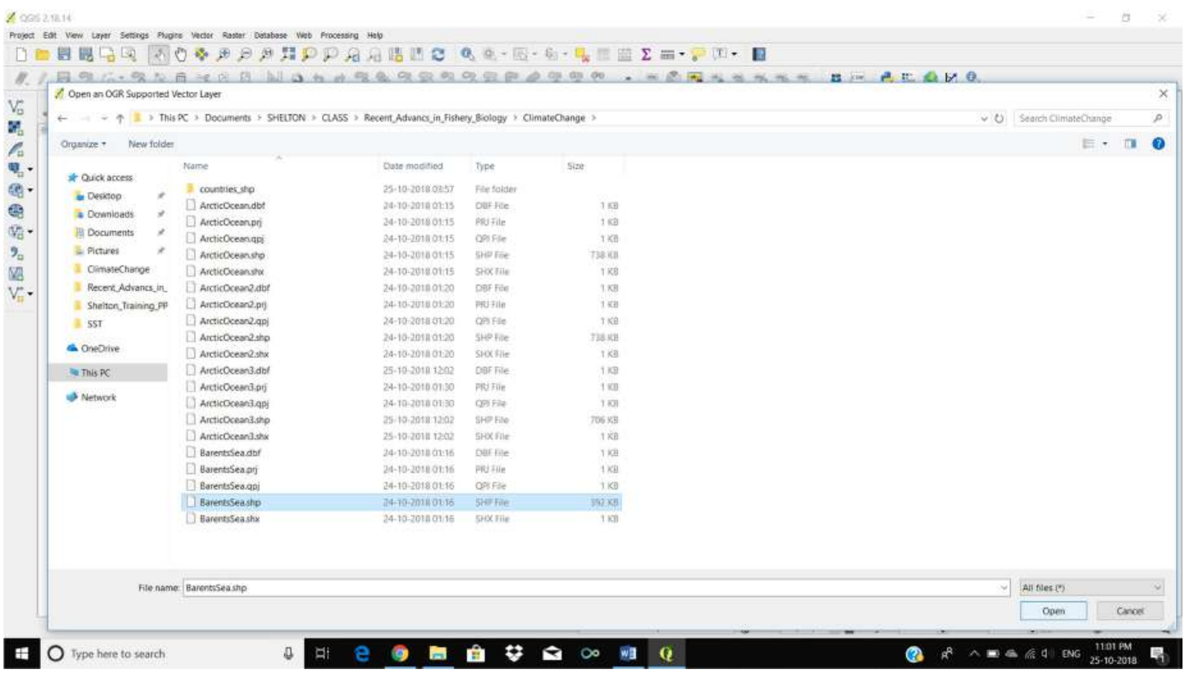
QGIS 2.18.14
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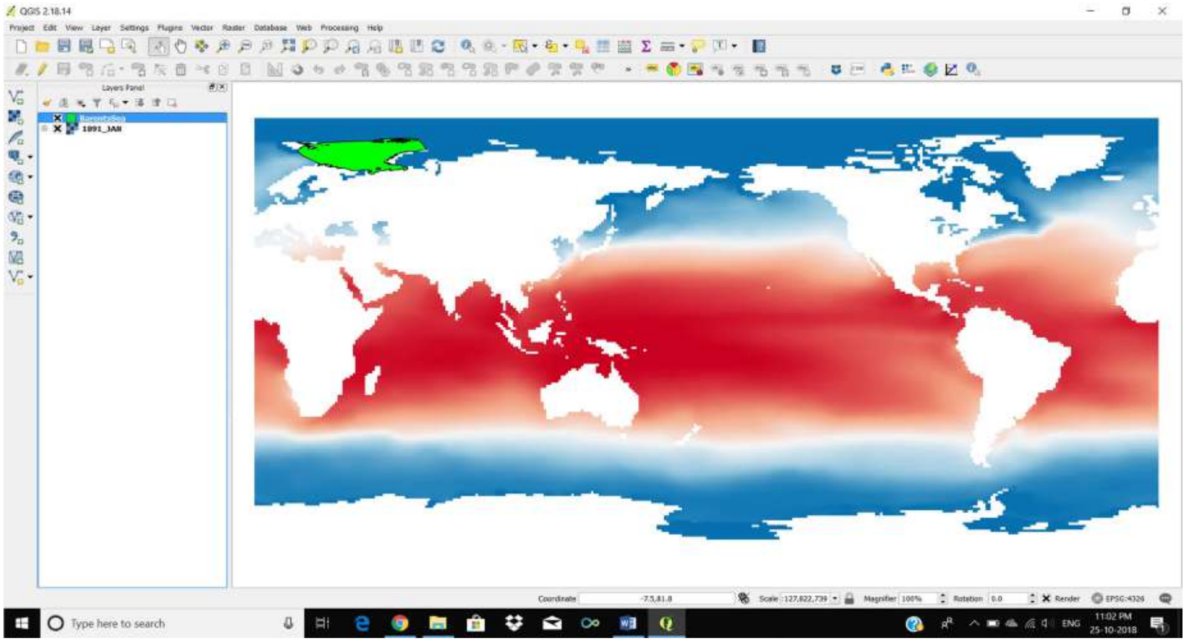
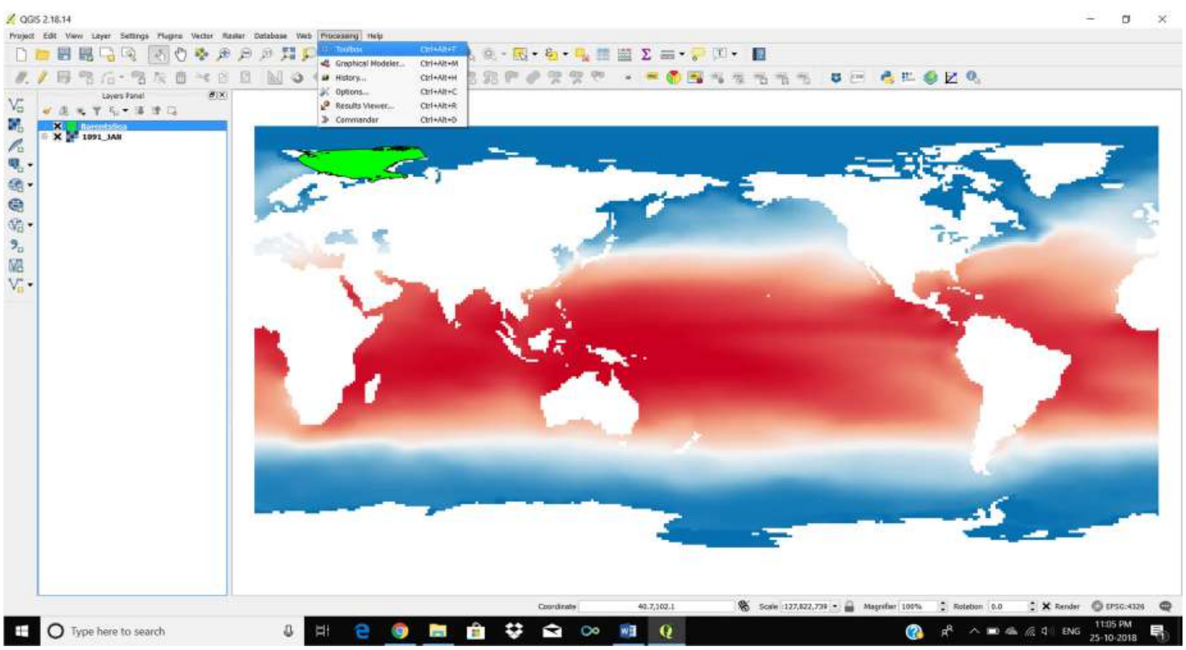
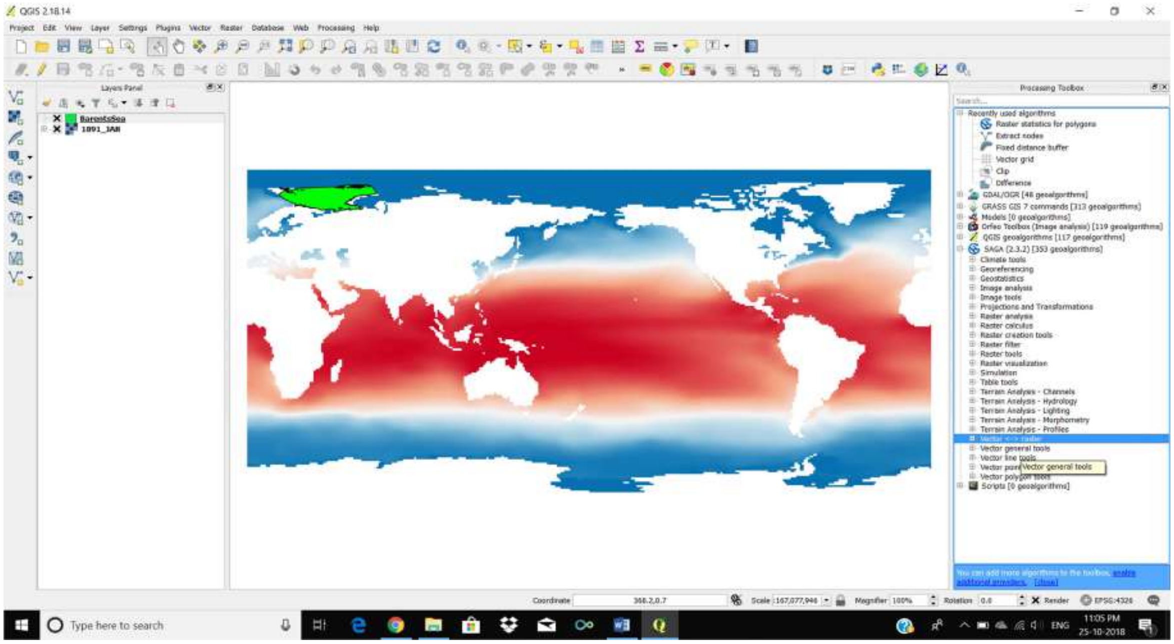
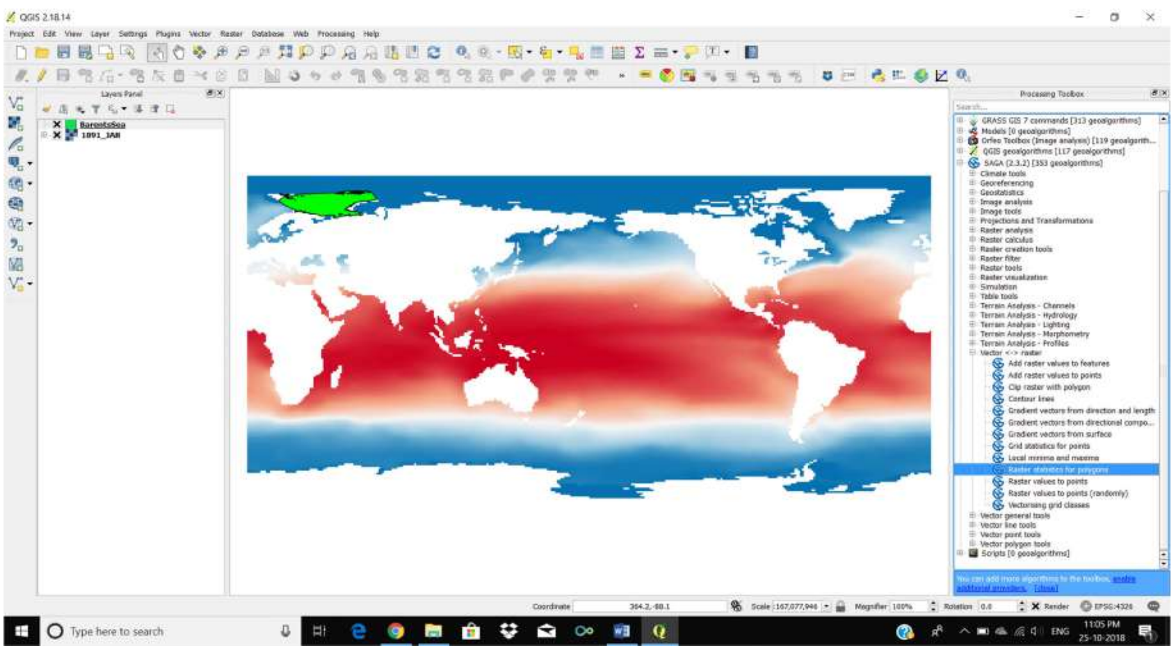


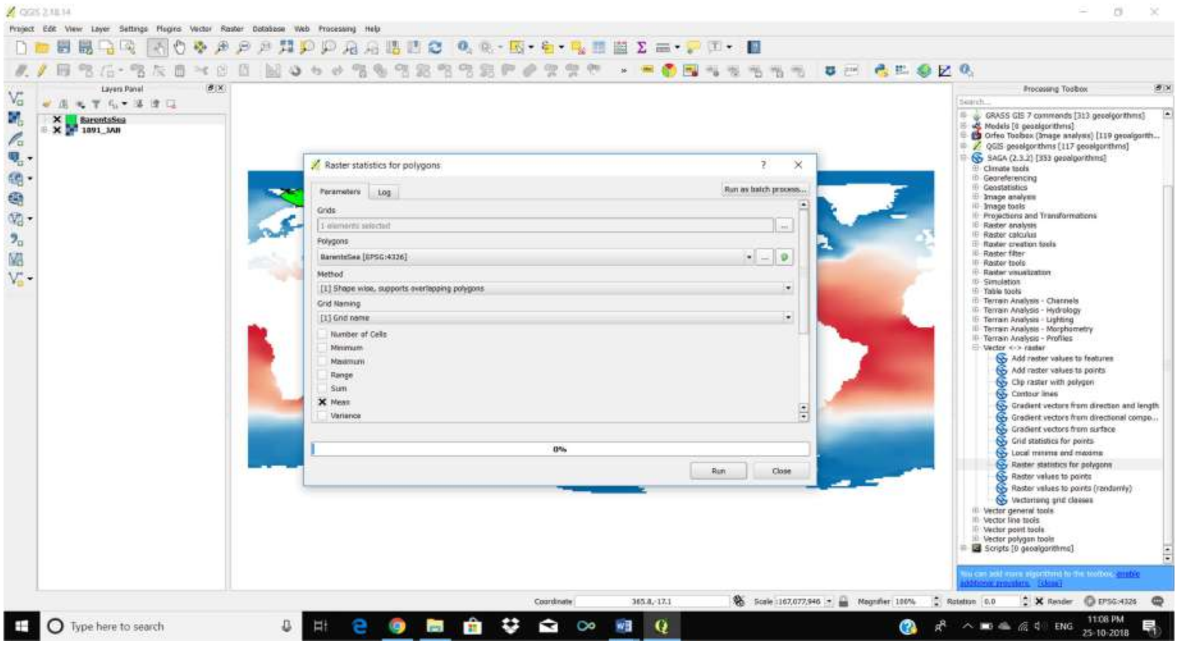
To extract the mean SST value from the 120 layers of SST, we have to use the 'SAGA' tool 'Raster Statistics for Polygons'.
Go to 'Processing' menu -> select 'Toolbox'. On right side of the Main window, tools panel will get displayed. In the tool box, under SAGA tools, go to Vector<->Raster sub group and select the tool 'Raster Statistics for Polygons'.



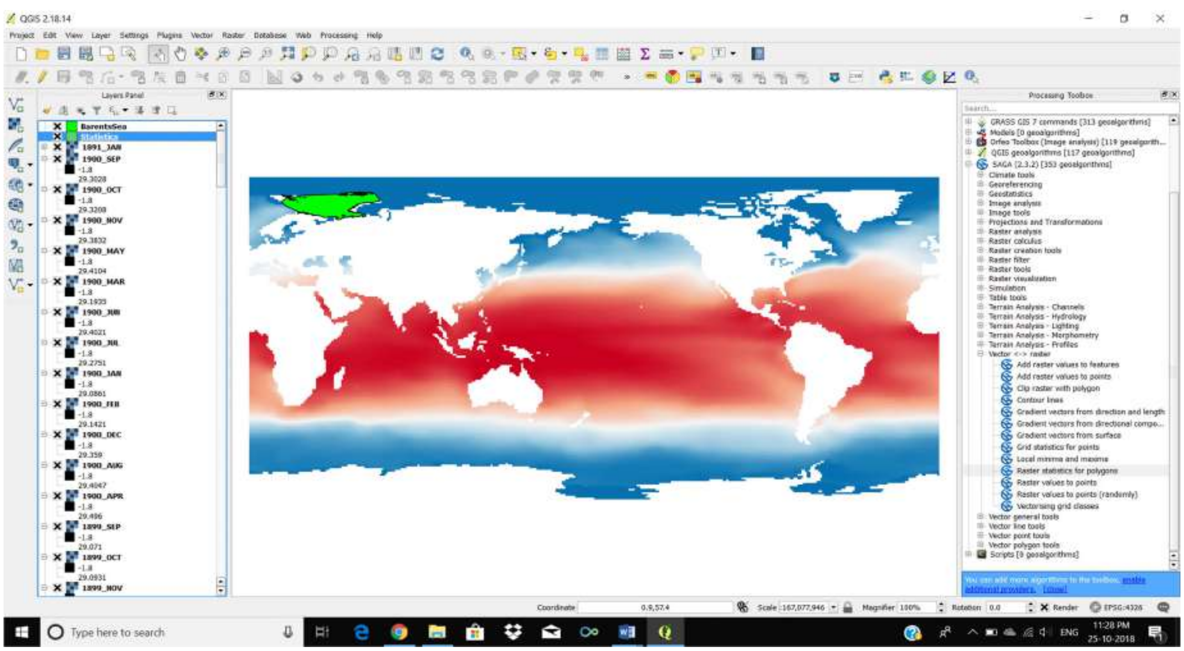




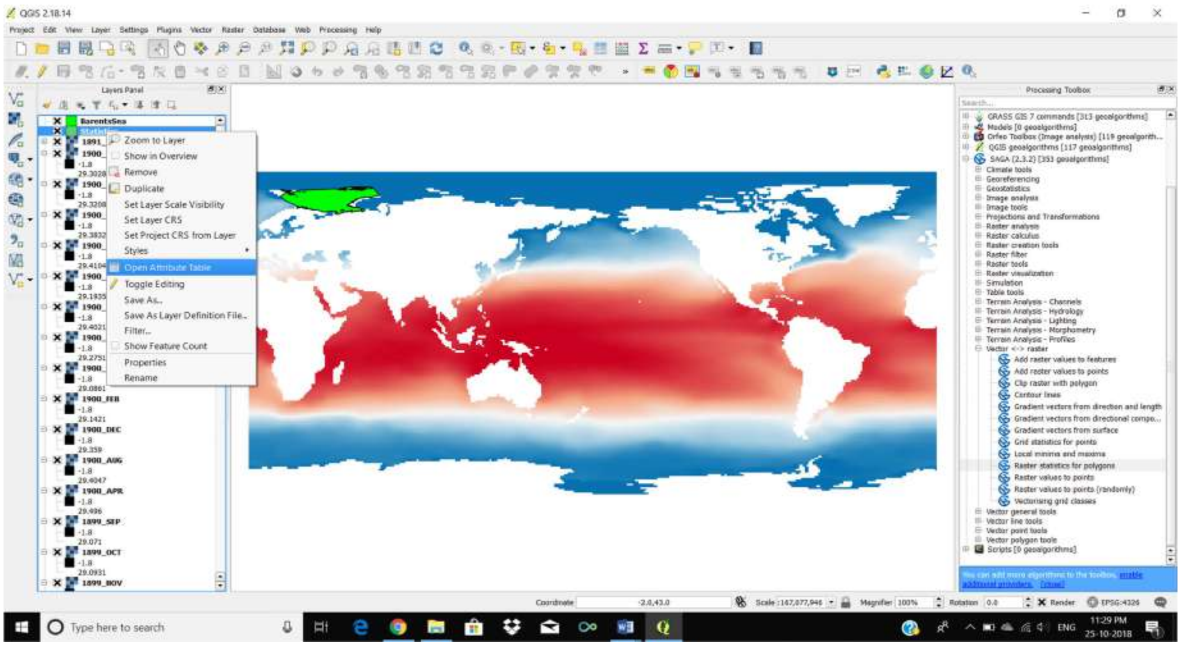
In the 'Raster Statistics for Polygons' tool panel, in the Grids option, select the SST datasets. For 'Polygons' select BarentsSea.shp', Method-> Standard, Grid Naming -> Grid Name, tick mark 'Mean' and press 'Run'.



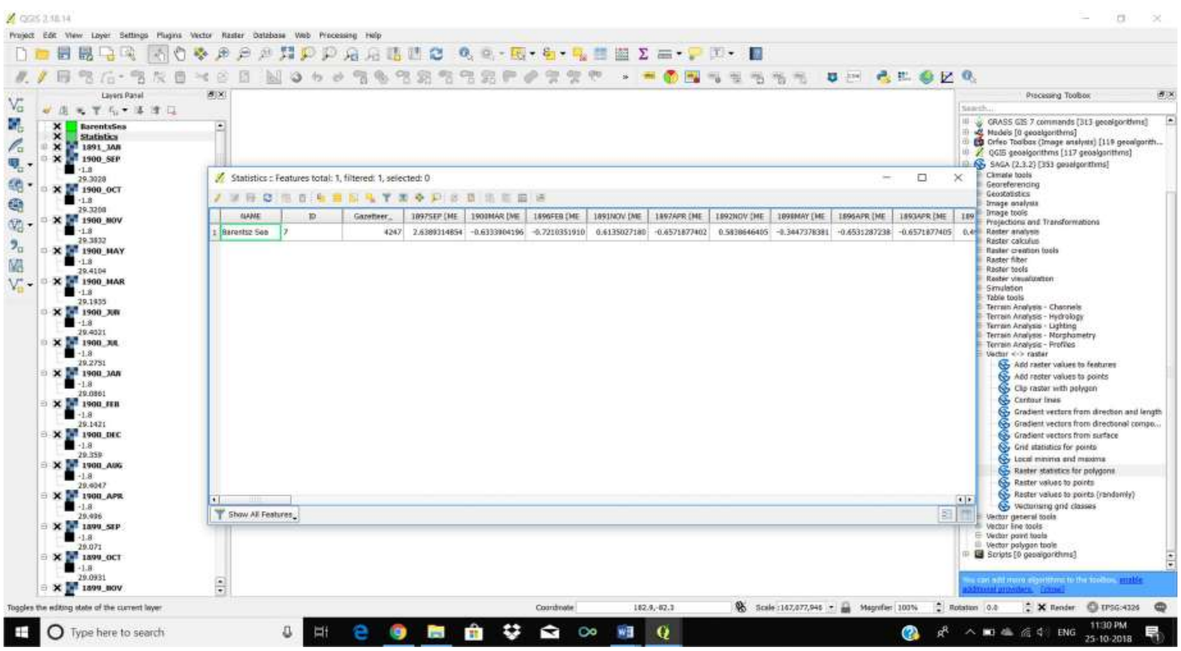
Now, you will get a ‘Statistics’ vector layer in the ‘Layers Panel’.

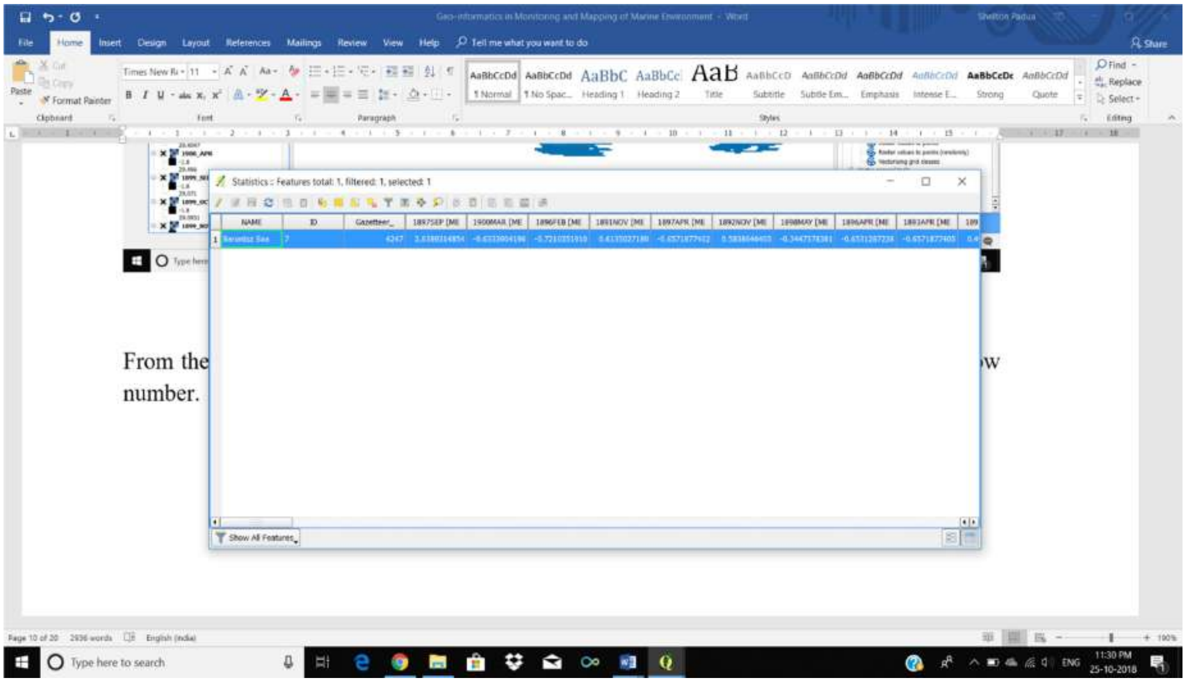


Right click on the layers panel and open the ‘Open Attribute Table’ by double clicking the Open Attribute Table icon. This will open up the attribute table.

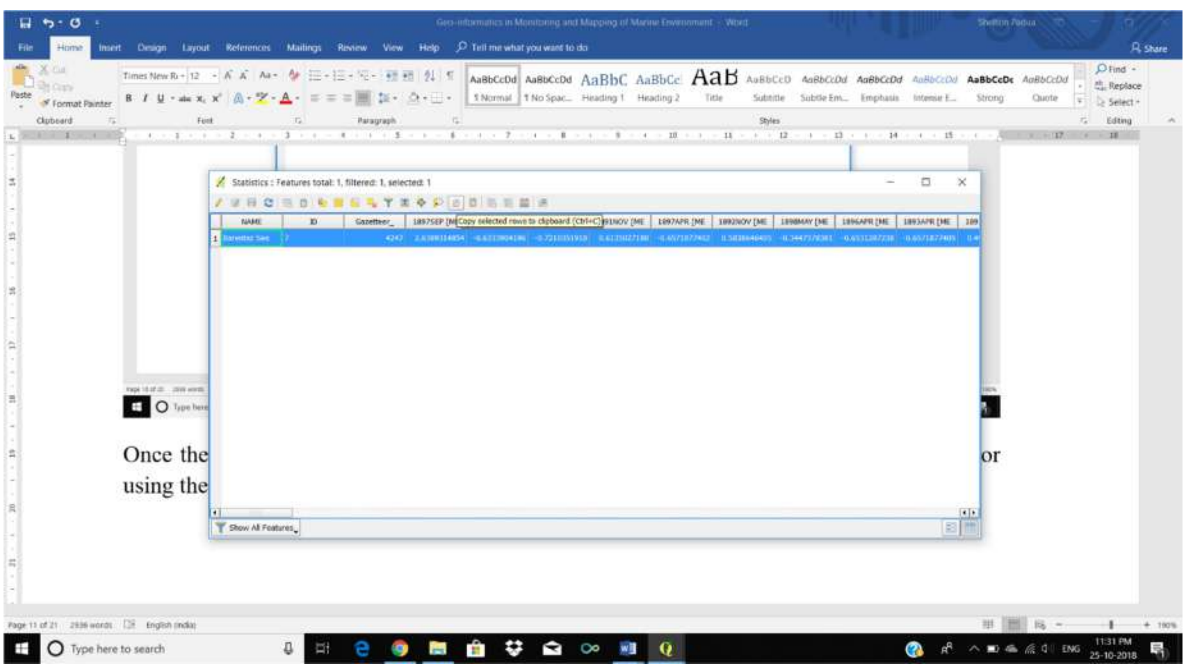


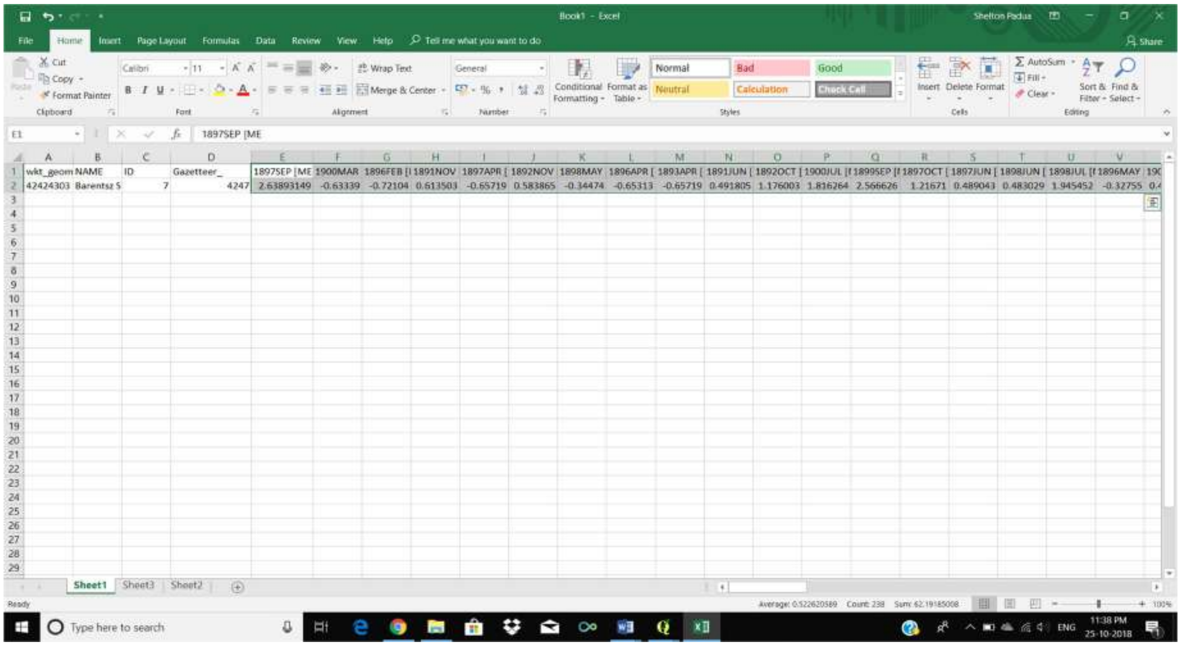
From the attribute table, select the row of attributes by 'left clicking' the corresponding row number.





Once the row is highlighted, copy the records to clipboard by clicking the ‘Copy’ button or using the keys ‘ctrl+c’. Now open a Microsoft Excel sheet and paste the copied values.





Repeat the same procedure for both climatic (1981-2010) monthly mean SST data (1_JAN to 12_DEC) and actual monthly mean SST data (2000_JAN to 2018_SEP).
Do the line plot in Excel and for SST in Barents Sea region for the periods 1891-1900, 2000 to 2018 and compare with climatic monthly mean SST and report the results.

Task 2: Monitoring the changes in SST over Arctic Ocean.

Software Required: QGIS 2.18.14 and Microsoft Excel

Data sets required:
Climatic (1981-2010) monthly mean SST (1_JAN.tif, 2_FEB.tif, 3_MAR.tif, 4_APR.tif, ……….. 12_DEC.tif)
Actual monthly mean SST: Set 1 (1891_JAN.tif, 1891_FEB.tif, 1891_MAR.tif, …………. 1900_DEC.tif)
Actual monthly mean SST: Set 2 (2000_JAN.tif, 2000_FEB.tif, 2000_MAR.tif, …………. 2018_SEP.tif)

Shape file for Arctic Ocean: ArcticOcean.shp
As explained in task 1, load different SST layers in to QGIS and extract the mean value of SST over Arctic Ocean using the shape file provided, for the study period.
Load these extracted values in to Excel and compare with the climatic mean monthly SST of the Arctic Ocean region and report the results.

Mapping the Progress of El Nino/La Nina using ONI

El Niño and La Niña are the two phases of the El Niño-Southern Oscillation (ENSO) cycle. The ENSO cycle describes the fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific. La Niña is referred to as the cold phase of ENSO and El Niño as the warm phase of ENSO. These deviations from normal sea surface temperatures can have large-scale impacts not only on ocean processes, but also on global weather and climate. El Niño and La Niña episodes typically last nine to 12 months, but some prolonged events may last for years. The frequency of El Niño and La Niña episodes can be quite irregular, but El Niño and La Niña events occur on average every two to seven years. Typically, El Niño occurs more frequently than La Niña.

El Niño

El Niño means The Little Boy, or Christ Child in Spanish. El Niño was originally recognized by fishermen off the coast of South America in the 1600s, with the appearance of unusually warm water in the Pacific Ocean around December. The term El Niño refers to the large-scale ocean-atmosphere climate interaction linked to a periodic warming in sea surface temperatures across the central and east-central Equatorial Pacific. Typical El Niño effects are likely to develop over North America during the upcoming winter season. Those include warmer-than-average temperatures over western and central Canada, and over the western and northern United States. Wetter-than-average conditions are likely over portions of the U.S. Gulf Coast and Florida, while drier-than-average conditions can be expected in the Ohio Valley and the Pacific Northwest. The presence of El Niño can significantly influence weather patterns, ocean conditions, and marine fisheries across large portions of the globe for an extended period of time.

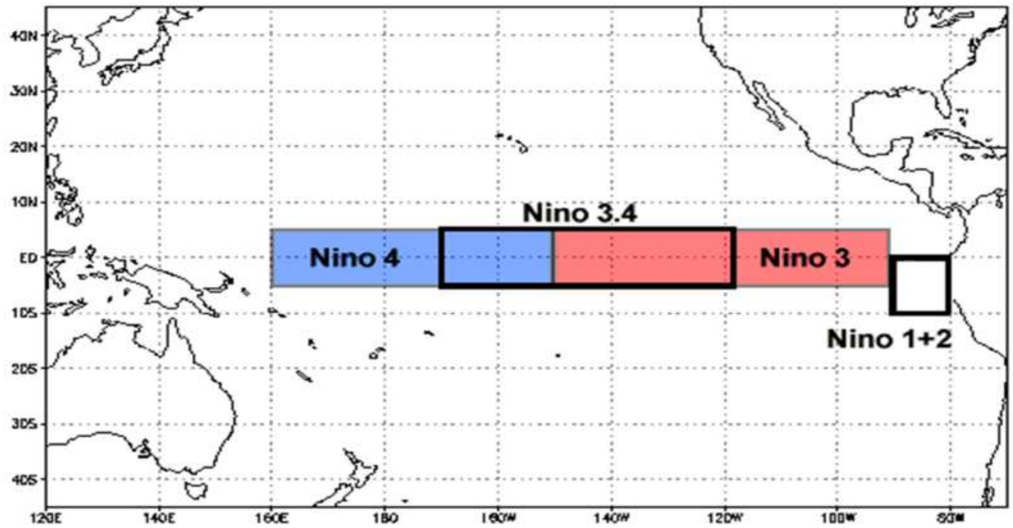
La Niña

La Niña means The Little Girl in Spanish. La Niña is also sometimes called El Viejo, anti-El Niño, or simply "a cold event." La Niña episodes represent periods of below-average sea surface temperatures across the east-central Equatorial Pacific. Global climate La Niña impacts tend to be opposite those of El Niño impacts. In the tropics, ocean temperature variations in La Niña also tend to be opposite those of El Niño.

ENSO events are thought to have been occurring for thousands of years. Modern day research and reanalysis techniques have find that at least 26 El Niño events since 1900 with the 1982-83, 1997–98 and 2015–16 events among the strongest on record.

Different countries have different criteria to determine what constitutes an El Niño / La Niña event, which is tailored to their specific interests. For example, the Australian Bureau of Meteorology looks at the trade winds, Southern Oscillation Index (SOI), weather models and sea surface temperatures in the Nino 3 and 3.4 regions, before declaring an El Niño. However, the Japan Meteorological Agency declares that an El Niño event has started when the average five-month sea surface temperature deviation for the NINO 3 region, is over 0.5 °C (0.90 °F) warmer for 6 consecutive months or longer. The Peruvian government declares that an El Nino is under way, if the sea surface temperatures in the Nino 1 and 2 regions, equal or exceed +0.4 °C for at least 3 months.

The Oceanic Niño Index (ONI) is the standard used by NOAA for identifying El Niño (warm) and La Niña (cool) events in the tropical Pacific. It is the running 3-month mean SST anomaly for the Niño 3.4 region (i.e., 5^oN-5^oS, 120^o-170^oW). The events are defined as 5 consecutive overlapping 3-month periods at or above the $+0.5^oC$ anomaly for warm (El Niño) events and at or below the -0.5 ^{o}C anomaly for cold (La Niña) events. The threshold is further categorized as Weak (with a 0.5 to 0.9 SST anomaly), Moderate (1.0 to 1.4), Strong (1.5 to 1.9) and Very Strong (≥ 2.0) events.



Spatial Extent of Nino regions

It has been found that necessary condition for the development and persistence of deep convection (enhanced cloudiness and precipitation) in the Tropics develops when the local SST is 28°C or greater. Once the pattern of deep convection has been altered due to anomalous SSTs, the tropical and subtropical atmospheric circulation adjusts to the new pattern of tropical heating, resulting in anomalous patterns of precipitation and temperature that extend well beyond the region of the equatorial Pacific. An SST anomaly of +0.5°C in the Niño 3.4 region is sufficient to reach this threshold from late March to mid-June. During the remainder of the year a larger SST anomaly, up to +1.5°C in November-December-January, is required in order to reach the threshold to support persistent deep convection in that region.

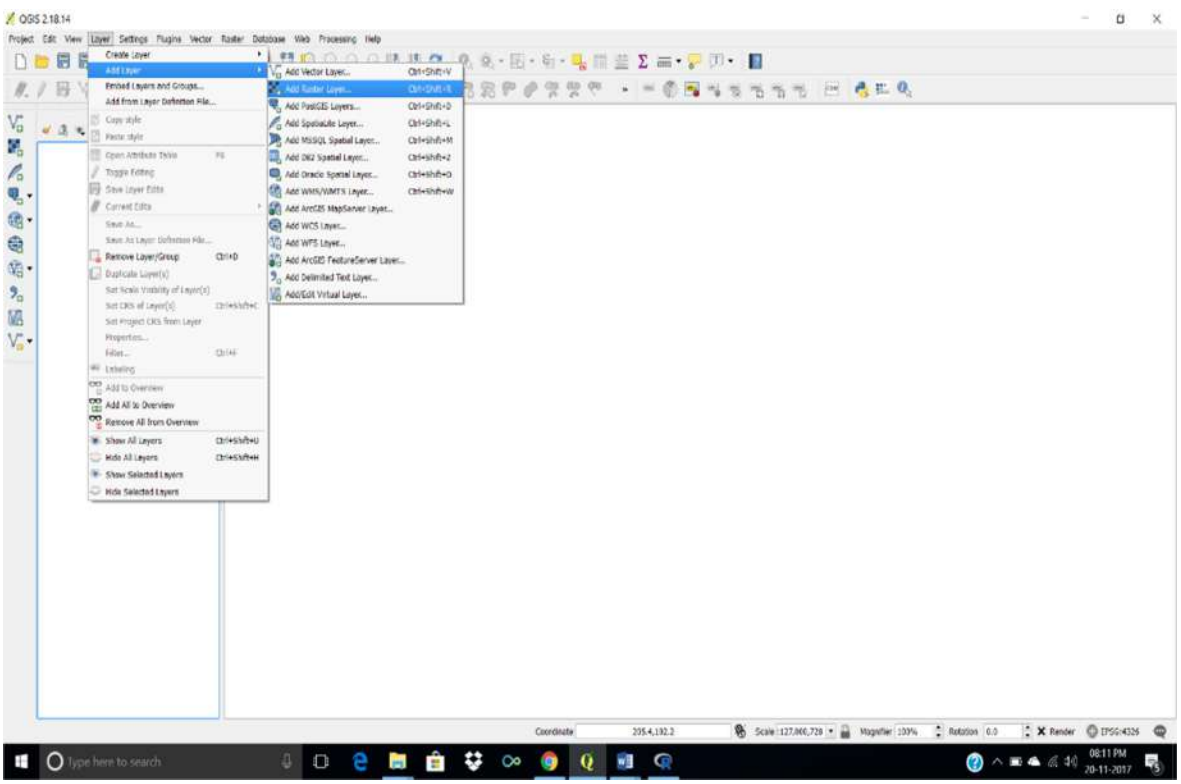
Task 3: Categorize the years into El Nino/La Nina or normal year based on ONI.

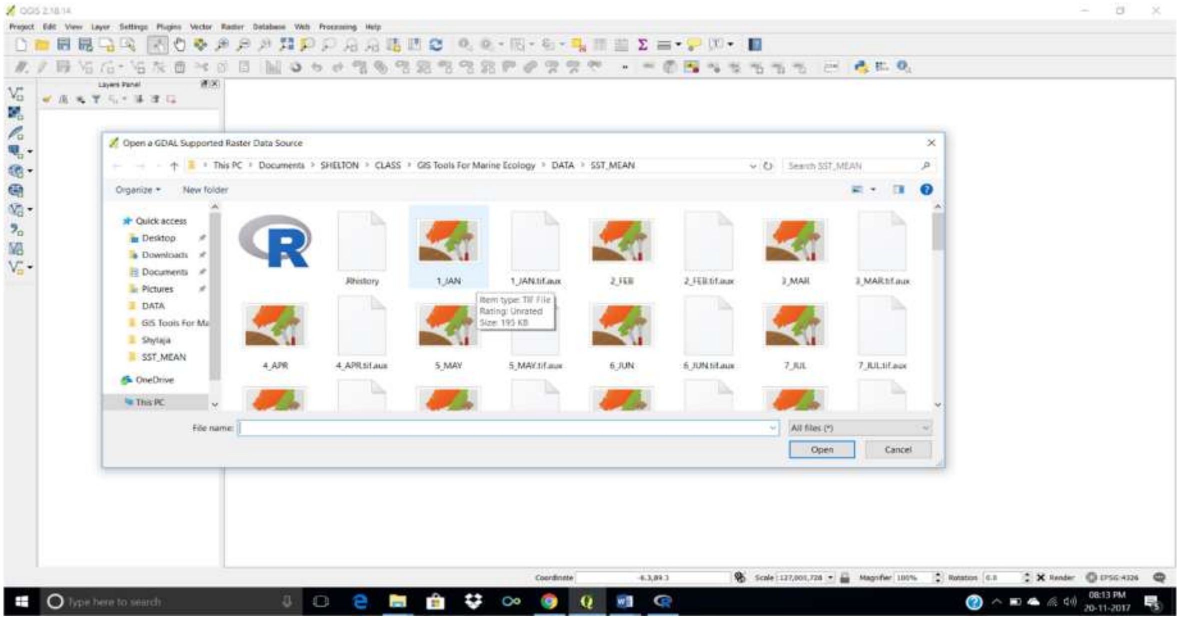
Software Required: QGIS 2.18.14 and Microsoft Excel

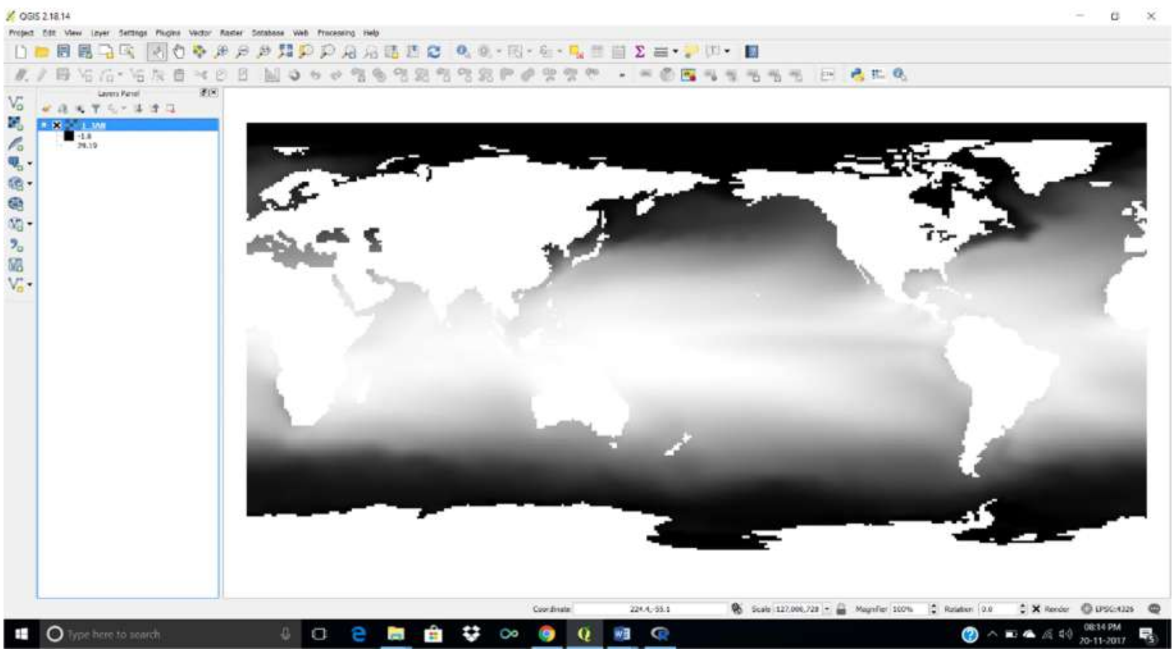
Data sets required:
Climatic (1981-2010) monthly mean SST (1_JAN.tif, 2_FEB.tif, 3_MAR.tif, 4_APR.tif, ……….. 12_DEC.tif)
Actual monthly mean SST (2015_JUN.tif, 2015_JUL.tif, 2015_AUG.tif, …………. 2017_OCT.tif)

Shape file for Nino 3.4 region: NiNo_3.4_Poly.shp

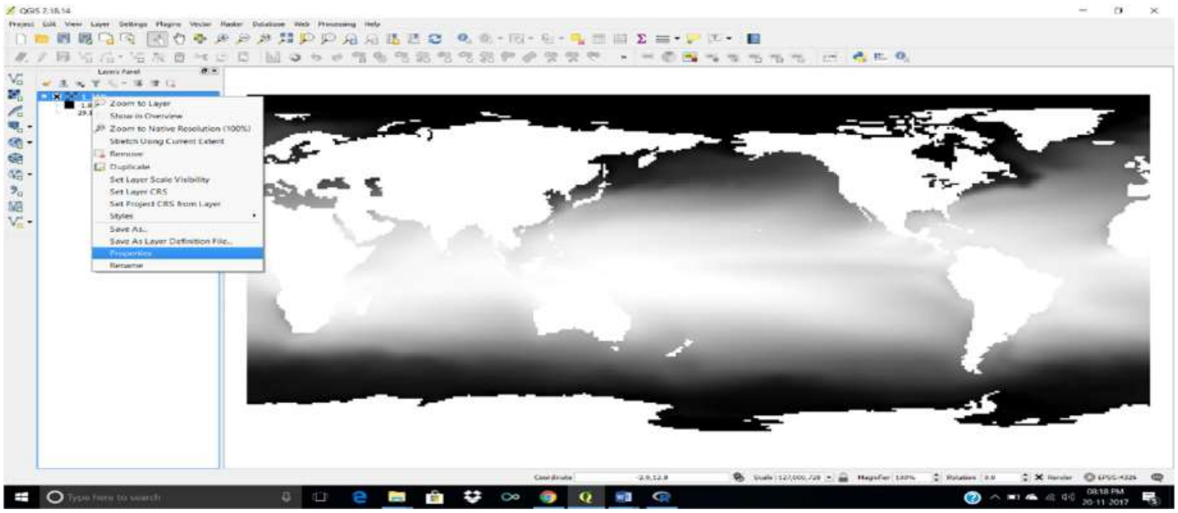
Loading SST data into QGIS:
Open QGIS -> Go to Layer menu -> Add raster layer -> Browse to the folder location -> Select the file -> 1_JAN.tif and load the file into the map view.



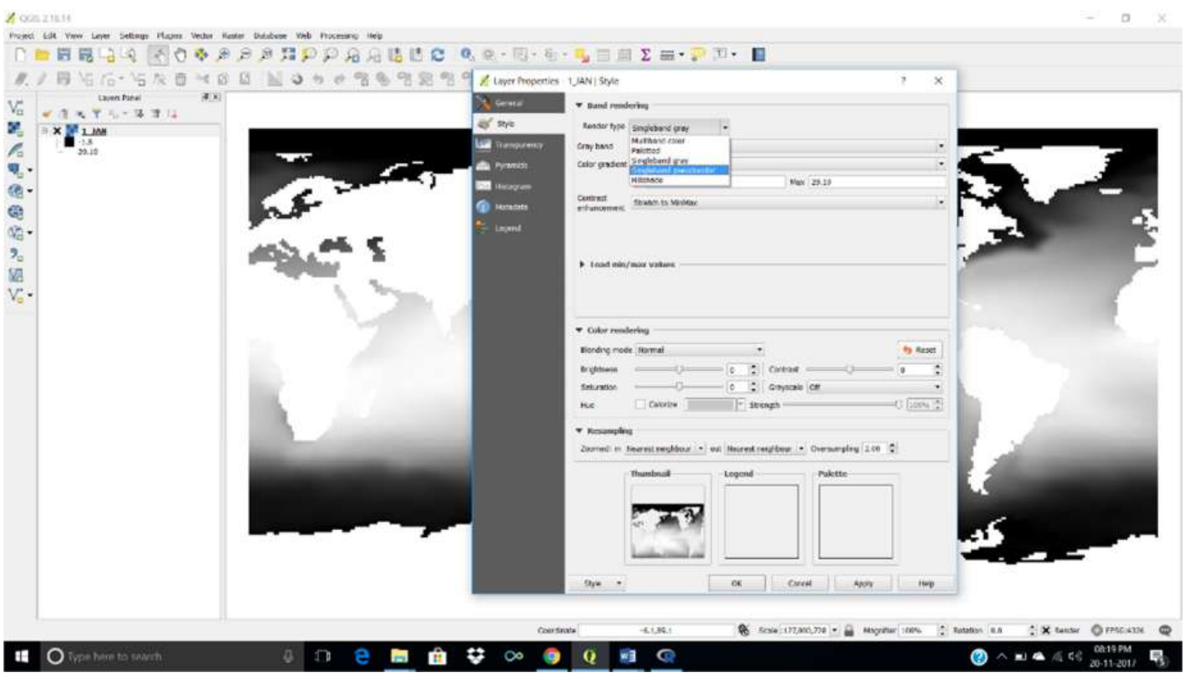




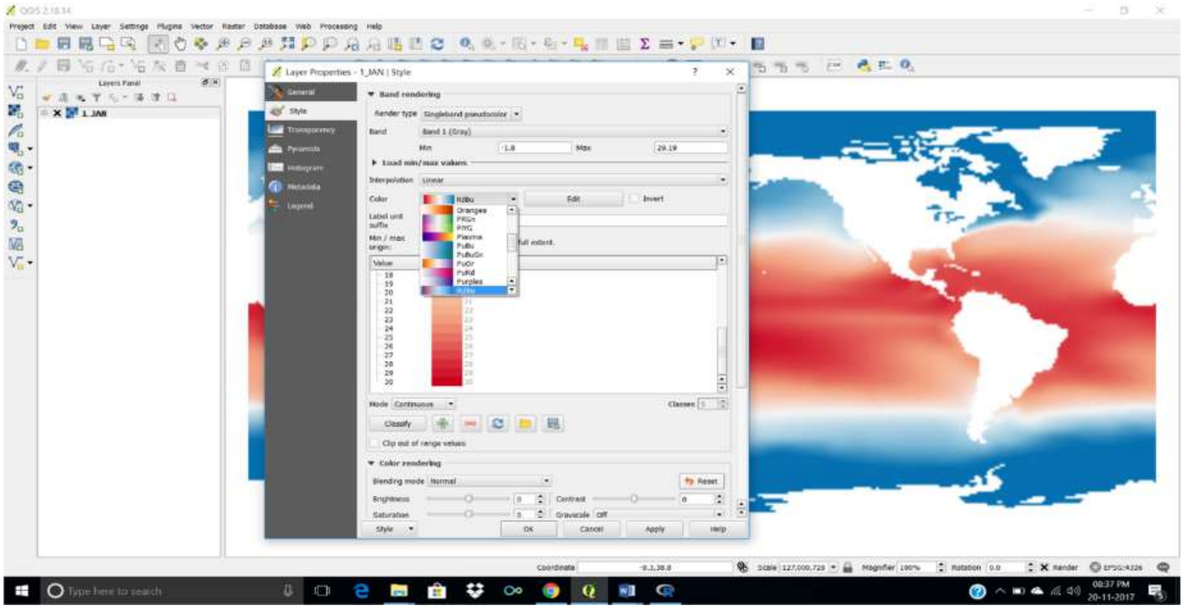
Now, to get a clear visual effect of the temperature variation, change the grey scale of the map to pseudo colour rendering. For that, right click the file name on the Layers panel (left side of the main view panel) and select the properties.



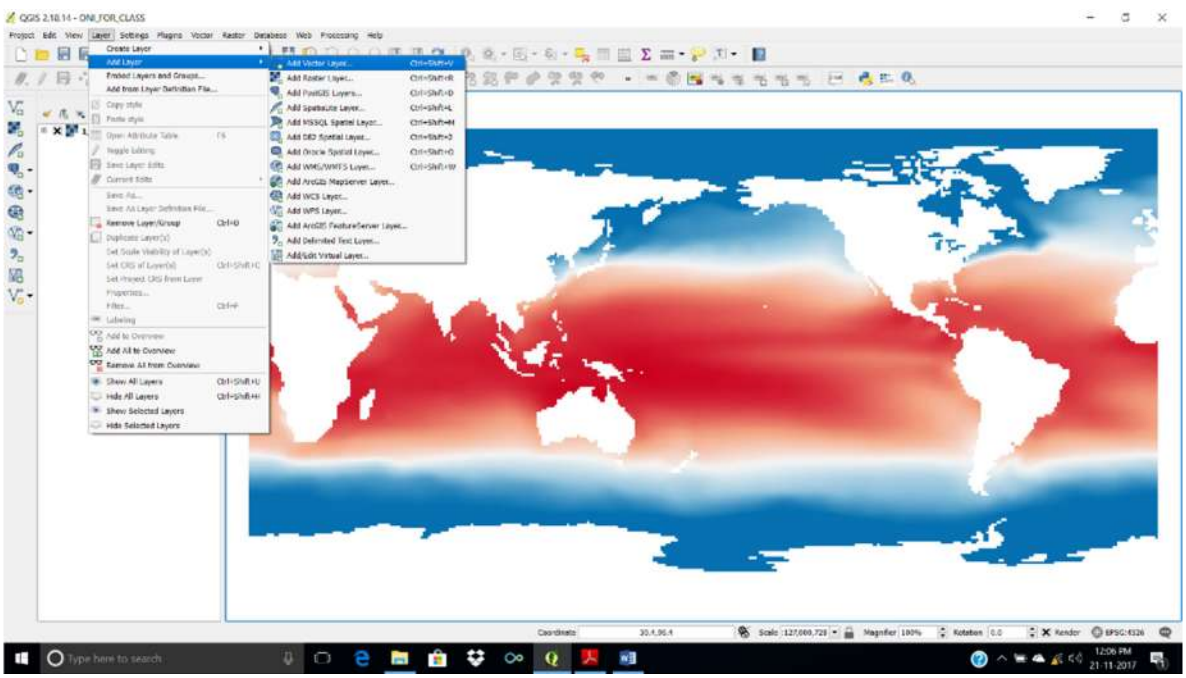
From the Layer Properties pane, go to style tab and change the band render type to ‘Single band pseudo colour’.



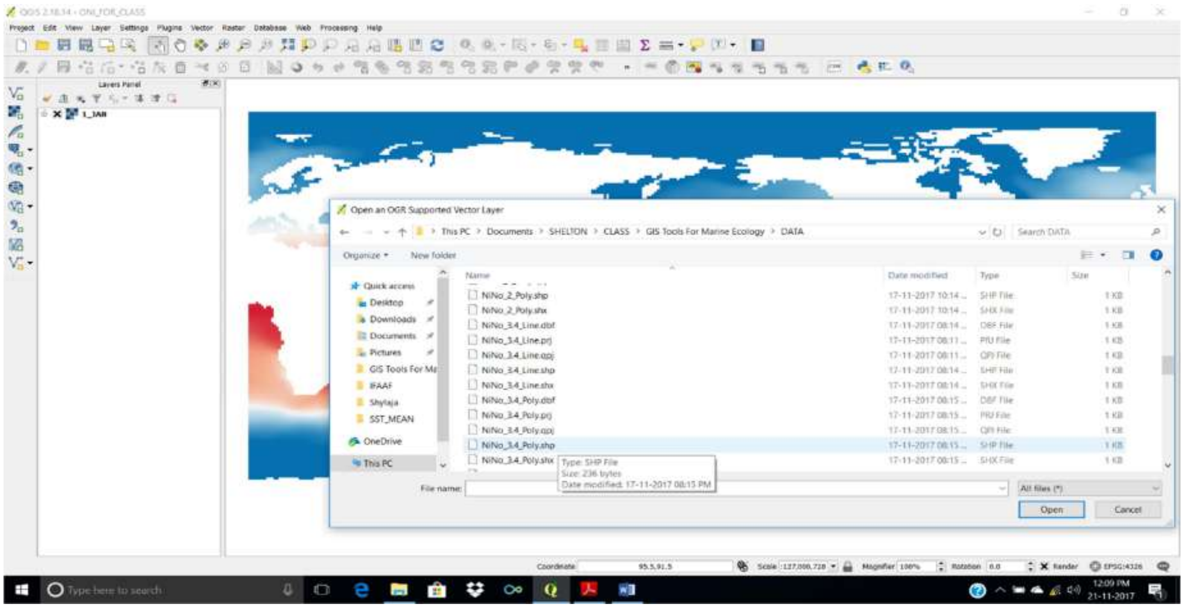
choose a ‘Colour’ band. Change the ‘Mode’ to ‘Equal interval’, set ‘Classes’ to ‘30’ and press the ‘Classify’ button. The display will change to pseudo colour gradient as per the SST variations. Likewise, load all the SST layers.



Now, we have to load the shape file for Nino 3.4 region. Go to Layers menu -> Add Layers -> Add Vector Layer.

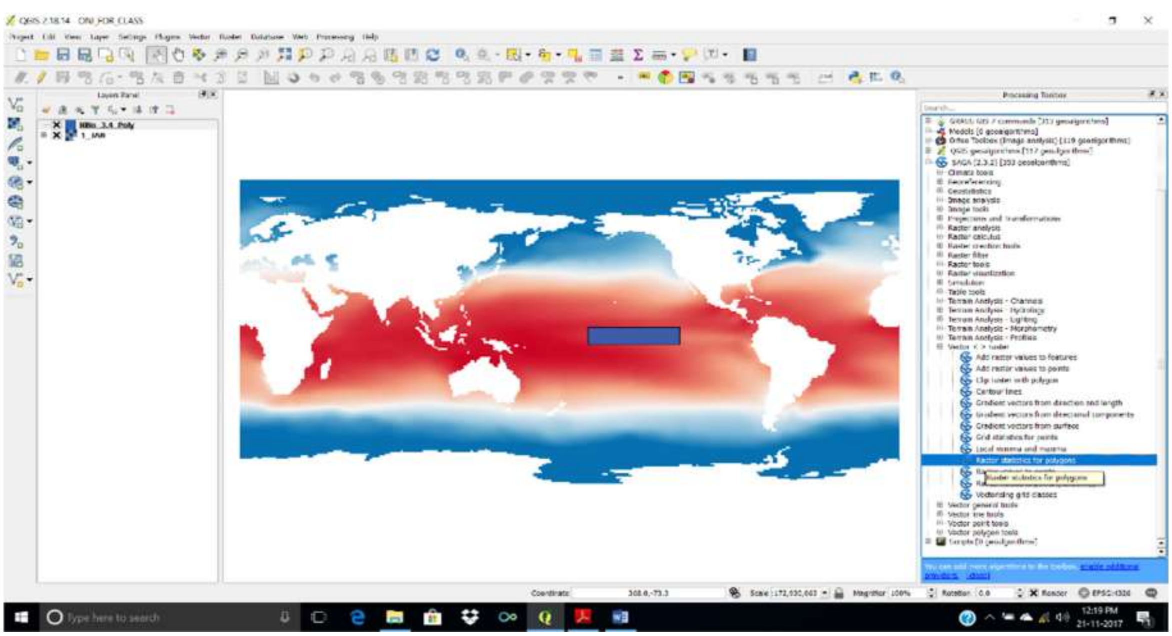


Browse to the file ‘NiNo_3.4_Poly.shp’ and open it.

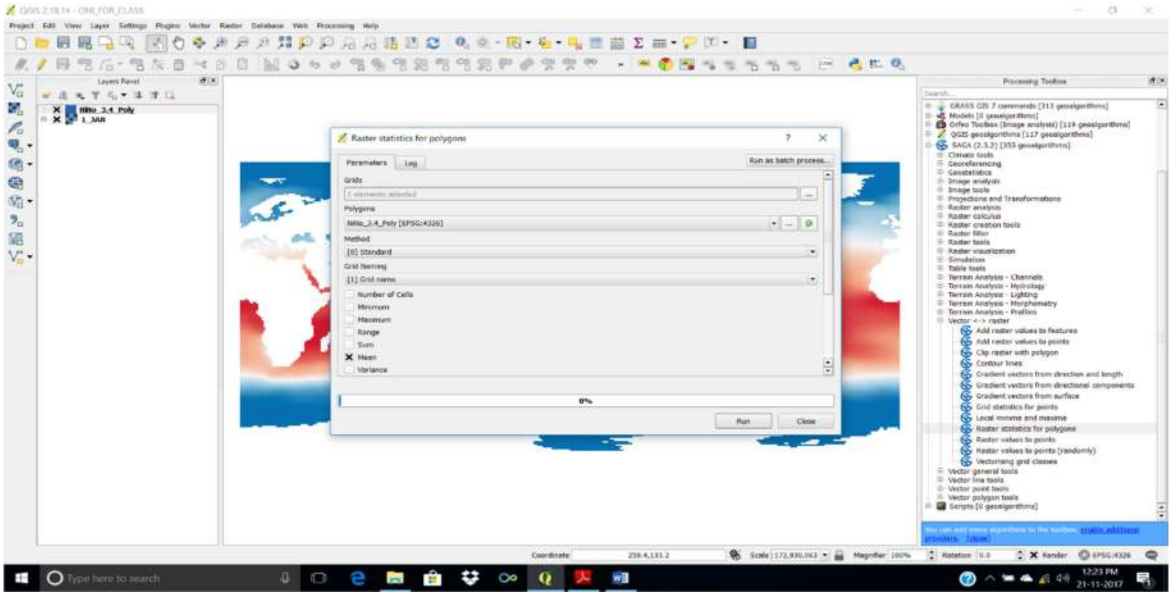


Now, we have to extract the mean value of SST from the Nino 3.4 region. For that we have to use the ‘SAGA’ tool ‘Raster Statistics for Polygons’.

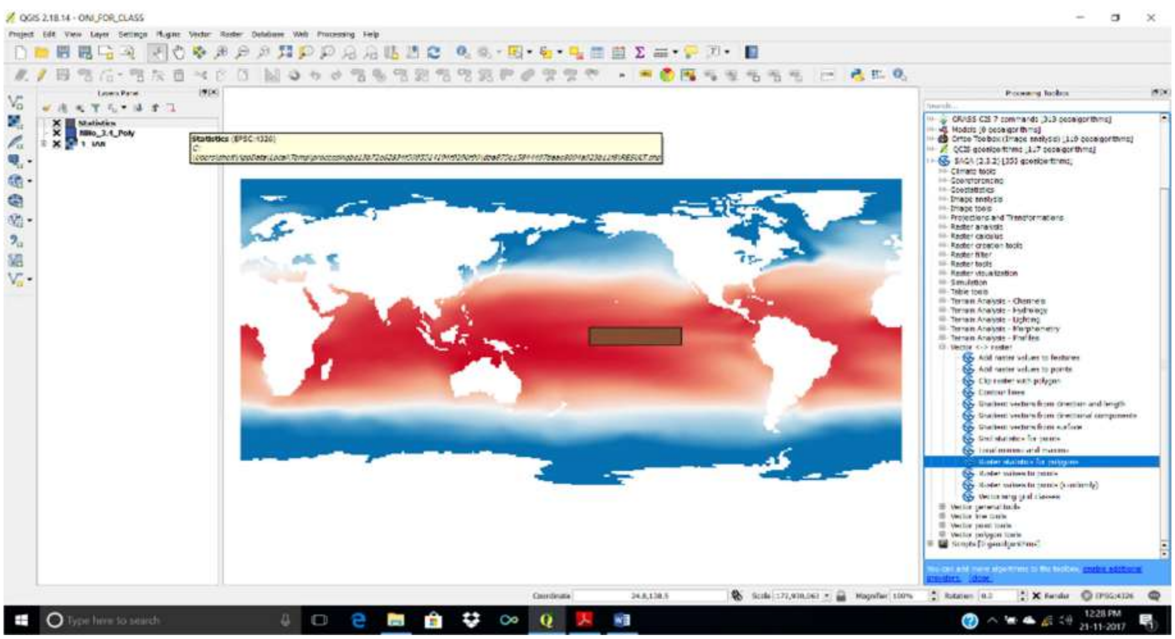
Go to ‘Processing’ menu -> select ‘Toolbox’. On right side of the Main window, tools panel will get displayed. In the tool box, under SAGA tools, go to Vector<->Raster sub group and select the tool ‘Raster Statistics for Polygons’.



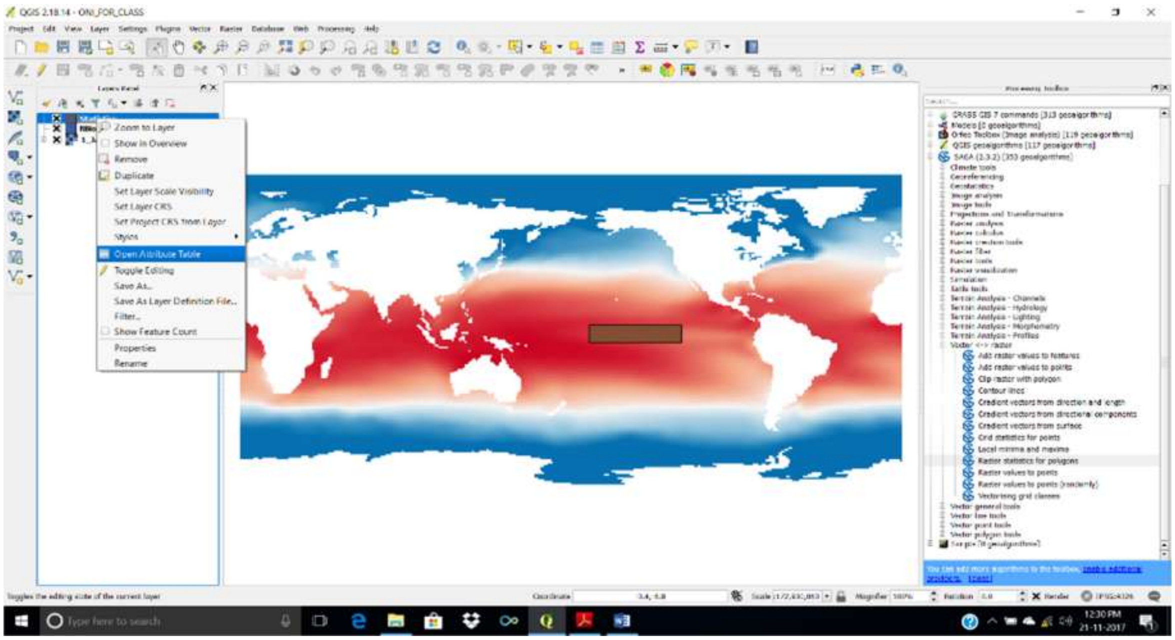
In the ‘Raster Statistics for Polygons’ tool panel, in the Grids option, select the SST datasets. For ‘Polygons’ select NiNo_3.4_Poly.shp’, Method-> Standard, Grid Naming -> Grid Name, tick mark ‘Mean’ and press ‘Run’.



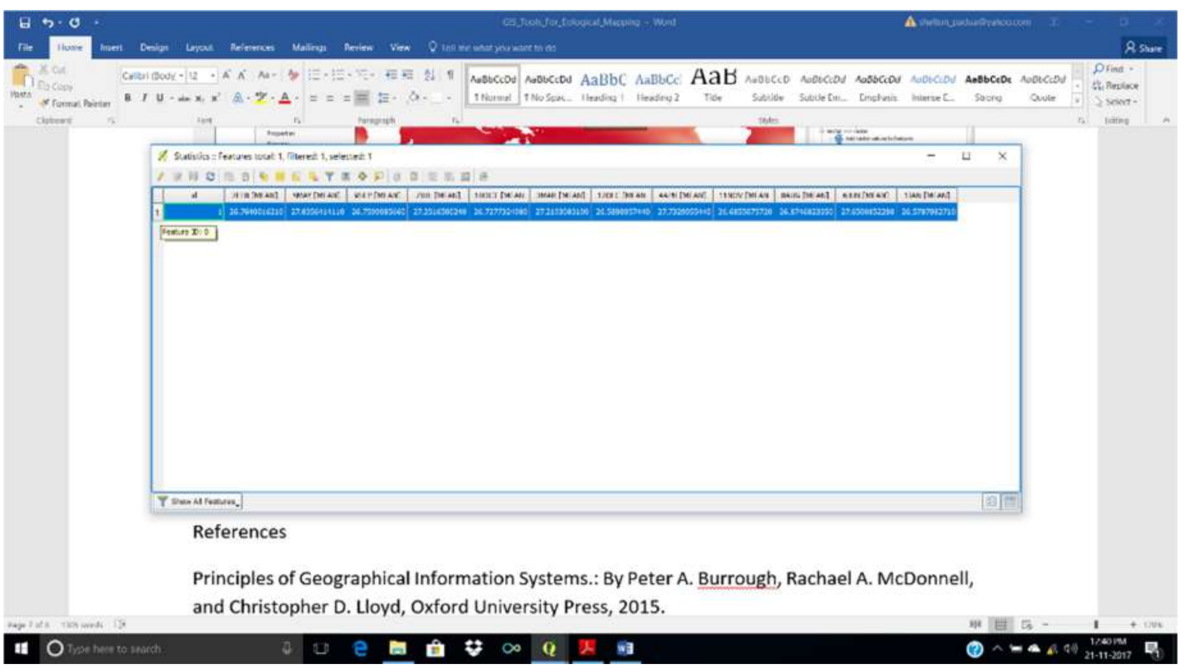
Now, you will get a ‘Statistics’ vector layer in the ‘Layers Panel’.



Right click on the layers panel and open the ‘Open Attribute Table’ button. This will open up the attribute table.

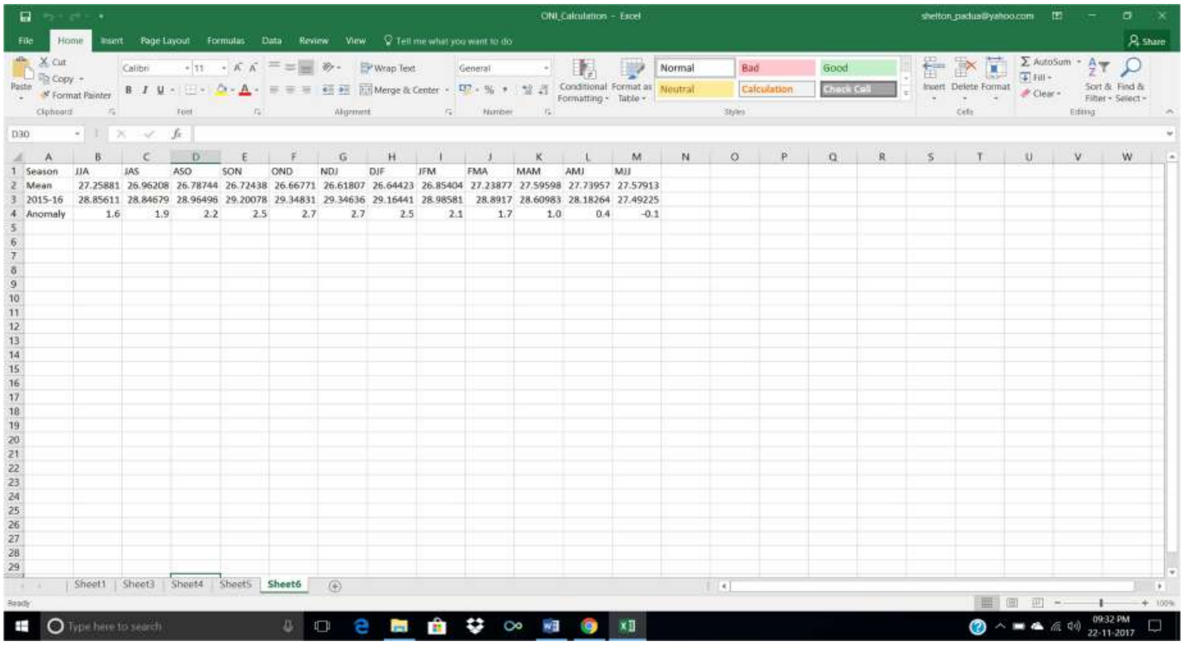


From the attribute table, select the row of attributes by ‘left clicking’ the corresponding row number.



Once the row is highlighted, copy the records to clipboard by clicking the ‘Copy’ button or using the keys ‘ctrl+c’. Now open a Microsoft Excel sheet and paste the copied values. Do the procedure for both climatic monthly mean SST data (1_JAN to 12_DEC) and actual monthly mean SST data (2015_JUN to 2017_OCT).

Calculate the three months running mean from 2015_JUN to 2017_OCT and three months climatic running means. Now, find the SST anomaly (difference between these two sets of running means).



Season	JJA	JAS	ASO	SON	OND	NDJ	DJF	JFM	FMA	MAM	AMJ	MJJ
Mean	27.25881	26.96208	26.78744	26.72438	26.66771	26.61807	26.64423	26.85404	27.23877	27.59598	27.73957	27.57913
2015-16	28.85611	28.84679	28.96496	29.20078	29.34831	29.34636	29.16441	28.98581	28.8917	28.60983	28.18264	27.49225
Anomaly	1.6	1.9	2.2	2.5	2.7	2.7	2.5	2.1	1.7	1.0	0.4	-0.1

Now, see if the SST anomaly qualifies for El Nino/La Nina or normal year as per the criteria and report accordingly.

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CHAPTER 42

Statistical Methods in Ecological Data Analysis

Introduction

Although analytical methods in statistics have all along been generic and evolutionary in the first half of past century, the developments happening in the field of computational statistics in the past couple of decades are more need based and custom tuned. A lot of effort is being put in by researchers in bundling methods, theory and procedures in classical statistical literature on their common applicability to a targeted exploration. It is common place to collate various univariate, multivariate, parametric, non-parametric, frequentist and non-frequentist methods, which have applications in different domains like ecology, clinical trials, bioinformatics etc. and tag them as per the domain subject matter. Thus the generic and specific procedures which are of relevance in exploratory and confirmatory analyses in the field of ecological studies of communities have been grouped under a common pivot. During the course of this discussion a couple of such statistical methods used in community structure studies would be dwelled upon.

On the ecological datasets

The typical community structure dataset would have either or both the tags, viz. temporal and spatial. The data could have been collated over multiple sampling spots in a region and also over a period of time. This makes these data to be looked upon from the time series as well as space- series points of view. And another ubiquitous feature of such datasets are their being multivariate. Communities, comprising many species at various levels of abundance, are always recorded as n-tuples at each sampling session and hence are multivariate at core. Although there are possibilities of isolating responses and causes from the bunch and possible univariate procedures could be applied upon, thereafter.

Multivariate tools

Analysis of ecological data involves almost the entire gamut of multivariate data analytical tools. The pivot based (could be labelled region or cluster) comparison of the community abundance has its roots in Hotelling's T square(d) thereafter raising to the multiple comparisons using MANOVA using Wilk's Lambda, Pillai's trace etc. Needless to add, a set of single response multiple regression analysis and univariate ANOVA get subsumed in the multivariate projection and analysis. The common thread in most of these analyses is the

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polarization of near independent components which have a telling impact on the response variables or the system tracking as a whole.

Another important area in multivariate analysis is the clustering and discrimination domain. The basic thrust in this sector is about measuring the closeness or remoteness of the multiple streaks of expressions of communities, which then gets utilized in grouping or clustering the similarly placed or paced dynamics or also for contrasting the most orthogonal or independent of bunches of variables which could sufficiently project the overall variability in the system. In a way these types of procedures aim at reducing the dimensionality of the bouquet of variables in such a way that inferences and depictions of scenario can be made with two or three dimensional projections. The community datasets often indicate similarity in pattern amongst their subsets, which when zoomed in would yield more interesting bio-climatic cause- effect mechanisms. Tools like Principal Component Analysis (PCA), ordinations by Principal Coordinate Analysis (PCoA) and Redundancy Analysis fall broadly under this conceptualization. Of this the RDA can be viewed as the multivariate extrapolation of univariate multiple regression analysis and it yields the proportion of variance of a set of variables that could be explained by a set of causative factors. PCoA has its action rooting on the distances (preferably Euclidean) between the multi-dimensional points and routing a starting point with its nearest neighbor in as much less a dimension possible so that the resultant scatter of these points clearly shows clusters based on which further PCA type recasting can be done. This is otherwise referred to as Multi Dimensional Scaling (MDS), the metric variant of it. Also in the context of abundance of communities datasets, the dissimilarities (distances) between the observations can be estimated more nonparametrically (with less leanings on the traditional orthodox assumptions on the values thrown out by the study variables, aka distribution) by using a "Stress" reducing monotonic transformation which simultaneously takes care of point-point contrast as well as distances between the realized observations.

The major bottleneck or invisible opportunity with ecological datasets is that they are predominantly counts based with a large possibility of null entries. Also at times the community sampling boils down to presence or absence type of information. Hence under these circumstances parametric exploration and testing on orthodox moulds would be highly inefficient and error prone. Hence a whole lot of quasi parametric or non-parametric tools have been conceptualized by resonating or tweaking the existing parametric options. One such set of tools is available in the Plymouth Routine In Multivariate Ecological Research (PRIMER). The following routines enshrined in the software are quite useful in numerically testing and robustly inferring and graphically assimilating large sets of community sample sets.

(i)CLUSTER (grouping) (ii) MDS (Ordination) (iii) PCA (recast visualisation) (iv) ANOSIM (hypothesis testing) (v) SIMPER (sample discrimination) (vi) BEST (trend correlations) (vii) BIOENV (paired group comparison) and (viii) PERMANOVA (permutational multivariate analysis of variance) among others. PRIMER also has extensive routines for estimating various beta, alpha and gamma diversity measuring indices. All these routines are built on a near total non-parametric platform thereby warding off the presumption and assumption blues.

A classic routine worth focusing on is ANOSIM. Smartly worded to sound akin ANOVA this routine has a refreshingly different set of approach rooted deeply on all generated by the data alone. Under this procedure the samples are treated as arrays whose rows are samples and columns are the component resources like planktons etc. Based on the intensity of the resources available in each location, a rank based similarity matrix is generated equivalent to the sample dimension. This index popularly known as Bray- Curtis similarity is then subjected to the inter and intra factor comparison yielding a functional known as R statistic. The value falling between 0 to 1 practically with lower limit indicating perfect similarity in divergence within factor groups and between them and the upper limit indicating near perfect similarity between pairs within groups as compared to those between them, thereby indicating significant inter group heterogeneity. The measure of the R value's robustness is also arrived at by estimating the R estimate on prior number of large recombinations of the sample data and noting down the values of R falling above the one realized from the original sample. Thus the non-parametric conceptualization right from estimating the group similarity to studying its distributional aspect is complete in this approach.

Modeling options with Ecological data sets

To start with even the simple multiple regression itself is a model in the strict statistical sense which depicts the role and measure of causal factor upon explaining the variability of the response variables. These regression models fall under the category of linear models with normality assumptions. However with the responses being binary at times and highly skewed and noisy counts on the other end of the spectrum, the classical assumptions of normality which validates the tests of significance are most inapplicable in these datasets. Hence the more liberated and broader versions of the linear model called Generalised Additive Models (GAM) are the most aptly poised set of paradigms to fit into such situations. With a wide range of link functions, smooth functions and a range of distributions including non Gaussian like Poisson etc. GAMs can practically link any type of causative variable with any type of response sets which can be foreseen in ecological studies. With many measures for their rates of success based on Information criterion, the best of such group of models can always be zeroed in on.

The developments made in the time series modeling area including the methods to split the time spanned datasets into components of trend, cyclicity etc. have come in handy while dealing with the biotic and temporal factors and their influence on the community structures. The direction oriented process based decomposition of time series like Asymmetric Eigenvector Mapping and the direction free mapping like Morgan/s Eigenvector Mapping have given a specific thrust towards modeling the data with a view to focus on temporal and spatial angles.

Tools like Local contributions to beta diversity (LCBD) help in arriving at comparative measures of ecological uniqueness of samples which would go a long way in studying and inferring about the community structures.

To conclude, it can be safely assumed that the rate of development of computational statistics has lead a sort of newer opportunities and horizons in locating and studying the hitherto unknown camouflaged patterns and undercurrents existing in community structure datasets. With the rate of innovation higher on the computational front the treading of hitherto unheralded territory is becoming all the more in vogue thing for researchers.

Referred literature

(i) Legendre P, Gauthier O. 2014 Statistical methods for temporal and space–time analysis of community composition data. Proc. R. Soc. B

(ii) **Clarke**, KR, Warwick RM (2001). Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition. **PRIMER**-E

(iii) Other classical statistical text books

Annexure:

Certain computational tools that can be put to use in Ecological data analysis

In R language

(1) Vegan- A contributed package totally dedicated to the procedures and methods discussed by Clarke and Warwick (2001), whose software version is Primer-E. This contains most of the common tools like dissimilarity measures, Anosim, BioEnv etc.

(2) **CatDyn: Fishery Stock Assessment by Generalised Depletion Models**

As a recourse to viewing the stock dynamics through catch rather than the population, which is of course used as an index for the latter, routines have been developed to assess, model and predict stock health using Generalised Depletion models. The entire gamut of parametrisation, modelling and forecasting has been made handy by the R library CatDyn. As per the introduction given by the author(s) of CatDyn, the library is capable of the following:

Based on fishery Catch Dynamics instead of fish Population Dynamics (hence CatDyn) and using high-frequency or medium-frequency catch in biomass or numbers, fishing nominal effort, and mean fish body weight by time step, from one or two fishing fleets, estimate stock abundance, natural mortality rate, and fishing operational parameters. It includes methods for data organization, plotting standard exploratory and analytical plots, predictions, for 77 types of models of increasing complexity, and 56 likelihood models for the data.

The concept of depletion modelling is set into motion using the following parametrization.
The process equations in the Catch Dynamics Models in this package are of the form

$$C_t = ke^{-\frac{M}{2}}E_t^a N_t^b$$

$$N_t = N_0 e^{-Mt} - e^{\frac{M}{2}} \sum_{i<t} C_{t-1} e^{-M(t-i-1)} + \sum_j P_j e^{-M(t-j)}$$

where *C* is catch in numbers, *t*, *i* are time step indicators, *j* is perturbation index (j=1,2,...,100), *k* is a scaling constant, *E* is nominal fishing effort, an observed predictor of catch, *a* is a parameter of effort synergy or saturability, *N* is abundance, a latent predictor of catch, b is a parameter of hyperstability or hyperdepletion, and M is natural mortality rate per time step. The second summand of the expanded latent predictor is a discount applied to the earlier catches in order to avoid an M-biased estimate of initial abundance. Perturbations to depletion represent fish migrations into the fishing grounds or expansions of the fishing grounds by the fleet(s) resulting in point pulses of abundance. In transit models (limited to one fleet) there are also emigration events happening at specific time steps for each perturbation. In 2 fleet cases the fleets contribute complementary information about stock abundance, and thus operate additively; any interaction between the fleets is latent and affects the estimated values of fleet dependent parameters, such as k, a, and b.

The observation model can take any of the following forms: a Poisson counts process or a negative binomial counts process for catch recorded in numbers, an additive random normal term added to the continuous catch (in weight) predicted by the process (normal and adjusted profile normal), a multiplicative exponential term acting on the process-predicted catch such as the logarithm of this multiplier distributes normally (lognormal and adjusted profile lognormal), and Gamma (shape and scale parameterization).

The library CatDyn takes care of almost all the parameterisation issues and dishes out the type of output which would magnify the status of fisheries as seen from the macro dynamic level in such a way to aid the policy makers.

(3) **mefa-** Yet another package in R which specializes in data analysis using ecological information. This apart from dealing with community structure information, progresses to the extent of generating analysis based report in popular formats like LaTeX and html etc.

Other sources

(1) XLSTAT- is an MS Excel friendly data analysis package which performs canonical correspondence analysis in tandem with Excel spreadsheet and finds EC50 values etc. and omics data analysis.

(2) FLORA- is another software scripted for Windows environment, which handles the multivariate routines as applied to community structure data
Summarizing, it can be recorded that the tools mostly applied for dealing with eco- biological data sets based on communities of flora and fauna stem from multivariate analysis tools and the software variants focus mostly on the customized output and report generation.

CHAPTER 43

Application of Primer Package in Studying Taxonomic Diversity Indices of Fishes and their Conservation and Management

INTRODUCTION

Biological Diversity (Biodiversity) is the central tenet of nature and one of its key defining features (Anon., 2002). As biodiversity forms the basis of survival of all the species (including Man) and ecosystems, it is considered as the central theme of ecology. After the Rio's Earth Summit, it has become the main theme not only for ecologists, but also for the entire biological community, environmentalists, planners and administrators. Many countries including India are signatories to the Convention on Biological Diversity (CBD) and as such these nations have the task of protecting all the species of microbes, plants and animals. Among the various biological resources, fishes constitute an important resource as a rich source of protein and have many other desirable nutritional qualities. Besides providing top notch protein, fishes support the livelihood of innumerable people besides supporting the economy of all the maritime countries. Hence these countries must assess the biodiversity and evolve suitable management strategies for conserving the resources which are often described as the 'Living Heritage of Man'. This article elaborates the usefulness of PRIMER (Plymouth Routines in Multivariate Ecological Research) package in evaluating fish diversity indices besides its use in conservation and management of fishery resources.

WHICH MEASURE IS GOOD FOR BIODIVERSITY ASSESSMENT?

Various measures are available for assessing diversity, richness, evenness and dominance. Species richness has been suggested as a good measure (iconic measure) of assessing diversity. Richness means strait forward count of number of species. No doubt it is relatively a simple measure, used successfully in many studies and is one of the components of diversity. However, it does not measure the variety (diversity). That way diversity measures are often more informative than species counts alone. Investigators often want to find a means of quantifying Darwin's proportional numbers and kinds in a single statistic. Diversity is traditionally taken to be a function of both richness and evenness. In other words, it is a combination of both richness and abundance. Less even communities are less diverse than those having higher evenness. There are swathe of measures which make use of both richness

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and evenness in the calculation of diversity and it is difficult to evaluate which method is appropriate under what circumstances. Selection of a diversity measure based on whether it fulfills certain functions or criteria is more scientific. Diversity measures are selected in relation to four criteria namely: 1. Ability to discriminate between sites, 2. Dependence on sample size, 3. What component of diversity is measured and 4. Whether the index is widely used and understood (Magurran, 1988). The best way suggested is to evaluate the performance of various indices on a range of data and to select the best one. This article does exactly this (ability to discriminate etc.) and suggests a more realistic measure die assessing diversity.

CONVENTIONAL METHODS

Diversity indices are synonymous with ecological quality. Under the conventional methods, two categories of diversity measures are there namely parametric and non-parametric. The parametric and non-parametric indices discussed in this article include the following:

Parametric methods

Log series (a) index:
It is used to calculate diversity for a normally distributed population. This method is very widely used because of its good discriminating ability. This index is less affected by the abundances of the commonest species.

Q statistic:
It is an innovative approach to diversity measurement. It takes in to consideration the distribution of species only and does not entail fitting a model like the above index. It measures inter-quartile slope of the cumulative species abundance curve and provides an indication of the diversity of the community.

Non-parametric indices:

Shannon-Wiener Index:
It is a benchmark measure of biological diversity and denoted as H'. It is a widely used measure of diversity index for comparing diversity between various habitats (Clark and Warwick, 2001). Shannon and Wiener independently derived the function which has become known as Shannon index of diversity. It is often wrongly called as Shannon and Weaver index because the original formula was published in a book by them (Shannon and Weaver, 1949). It is derived from information theory – on the rationale that diversity or information in a natural system can be measured in a similar way to the information contained in a code or a message. This indeed assumes that individuals are randomly sampled from an infinitely large population. The index also assumes that all the species are represented in the sample. The value of Shannon diversity is usually found to fall between 1.5 and 3.5 and only rarely it surpasses 4.5. It has been reported that under log normal distribution, 105 species will be needed to produce a value of Shannon diversity more than 5. It is used extensively in pollution research.

Expected H' (EH'):
It is being used as an alternative to H'. It is equivalent to the number of equally common species required to produce the value of H' of the sample.

Maximum Shannon diversity (Hmax):
The observed diversity (H') is always compared with maximum Shannon diversity (Hmax) which could possibly occur in a situation where all species are equally abundant.

Brillouin Index (HB):
This index is used instead of Shannon index when diversity of non-random samples or collections is being estimated. For instance, fishes collected using the light produce biased samples since all the fishes are not attracted by light. Brillouin index is used here to calculate the diversity of fishes collected by gears which use light for fishing. It is denoted as HB.

McIntosh's Measure of Diversity:
Mcintosh proposed that a community could be envisaged as a point in an S dimensional hyper volume and that the Euclidian distance of the assemblage from the origin could be used as a measure of diversity. This index is denoted as U. The demerit of this index is that it is influenced by evenness.

The performance of the above indices was evaluated against the following recent methods.

Recently introduced indices:
Warwick and Clarke (1995) based only on the topology ('elastic shape') of a phylogenetic tree introduced the following measures incorporating the taxonomic relatedness of species in their calculation:

Taxonomic Diversity (Δ):
Delta (Δ) is the symbol of taxonomic diversity as it is empirically related to the Shannon's species diversity H' but has an added component of taxonomic separation. It is defined simply as the average (weighted) path length between every pair of individuals.

Taxonomic distinctness (Δ*):
It is defined as Δ divided by the value it takes when the hierarchical tree has the simplest possible structure, that of all species belonging to the same genus.

Average taxonomic distinctness (Δ+):
It is the average taxonomic distance apart of all its pairs of species.

Total taxonomic distinctness (sDelta+):
It is the average taxonomic distance from species i to every other species, summed over all species.

Phylogenetic diversity (sPhi+):
It is simply a cumulative branch length of the full tree.

Average phylogenetic diversity index (Phi+):
It is the total tree length divided by the total number of species.

Unlike most other diversity measures, these indices do not involve systematic bias of low sample size. This is considered to be a desirable property for any index. These indices are also demonstrated as the most robust and sensitive indices of community perturbation (Hall and Greenstreet, 1998).

Calculation of diversity indices for hypothetical set of data

Consider two hypothetical habitats namely two islands, each with only 2 species of fishes in equal abundance: 2 species belonging to the same genus in one case, and 2 species belonging to two different genera in the other. As the number of species and abundance are equal, both the islands will have the same diversity as per the conventional indices. However, intuition tells us that two species belonging to two different genera represents more biodiversity than does the first case (Purvis and Hector, 2000). Conventional indices cannot discriminate the diversity of the above islands. This is quite apparent with the following example also: This example involves 2 samples collected from unit areas in 2 mangrove forests (forests 1 and 2). In each forest, 12 species of fishes were recorded (Table 1). In the first forest, all the 12 species were represented by 30 fishes each and the total was 360 fishes (no community consists of species of equal abundance and thus it is a hypothetical/artificial data designed to explain a point). In forest 2 also, 12 species of fishes were recorded and the total number of fishes was again 360. However, in this forest, one species of fish (C) was found dominant (represented by 300 fishes) and other species represented by few fishes (10) species by 5 fishes and the remaining one species by 7 fishes). From the results, it is clear that the diversity is on the higher side in mangrove forest 1 and less in mangrove forest 2. Shannon index is able to differentiate the diversity in two mangrove forests in the absence of taxonomic information. In this example log 2 was used for calculating the Shannon index. There is a problem in the usage of this index as three log bases (log 2, natural logarithm and log 10) are used for calculating this index. Table 2 presents the results of Shannon-Wiener diversity calculated using the 3 log bases. Let us assume that Scientist A is calculating the Shannon diversity of forest 2 using log 2 and reports the results as 1.223. However, he is forgetting to indicate the log base he used (perusal of literature showed results of Shannon index without log base in most instances). Later let us again assume that scientist B is calculating the Shannon diversity for forest 1 and uses log 10 which is easy to obtain. He arrives at the result of 1.079. Now he is trying to compare his result with the earlier result of scientist A. As 1.079(log10) is lower than 1.223(log2), scientist B concludes that forest 1 is less diverse than forest 2. How misleading it is (Shannon diversity for forest 1 calculated using log 2 is 3.585- larger than 1.223 of forest 2). As scientist A has not mentioned the log base he used, this mistake is creeping in.

Brillion index always produces a lower value than Shannon as it describes a known collection about which no uncertainty is there (Table 3). Shannon by contrast calculates the diversity of sampled/ unsampled portion of community. The above example explains this fact well.

Table 1. No. of fishes belonging to various species sampled in two mangrove forests (1 and 2)

Species	Mangrove island 1	Mangrove island 2
A	30	5
B	30	5
C	30	300
D	30	5
E	30	5
F	30	5
G	30	5

H	30	5
I	30	5
J	30	5
K	30	5
L	30	7
Total no. fish species	**12**	**12**
Total no. fishes	**360**	**360**
Shannon diversity	**3.585**	**1.223**
Brillouin diversity	**3.474**	**1.145**

Table 2. Shannon-Wiener diversity values calculated using different log bases for fishes in two mangrove forests

Log base	Mangrove forest 1	Mangrove forest 2
H' (ln)	**2.485**	**0.847**
H' (log 2)	**3.585**	**1.223**
H' (log 10)	**1.079**	**0.368**

Shortcomings of the conventional methods

Magurran (2004) listed the demerits of the conventional indices. Log series (α) index may not give accurate results when the population studied is not following the log series distribution model. The widely used Shannon Wiener diversity index is called a dubious method with no direct biological interpretation. However, it is regarded as a notoriously popular method. It is influenced very much by the sample size and is weighted slightly towards species richness. It is often used for historical reasons to compare data collected presently with earlier. In the calculation of this index various log bases are used. It is of course essential to be consistent in the choice of log base when comparing diversity between samples. As many investigators have not indicated the log base they used in the past and continue to do so, effective comparison with the earlier results is often difficult.

All these indices are heavily influenced by the sample size. As a result, indices with similar effort can only be compared. Moreover quantitative data is required for the calculation of these indices. With qualitative data (historical data in most instances are qualitative only (+ or -), indices cannot be calculated and compared with the present quantitative data. Moreover these indices do not reveal the higher level diversity (genus level and above) and show only the species level diversity. Lastly these indices do not have the statistical framework for testing departure from the normal distribution. In this background, no conventional measure appears to be appropriate for assessing diversity.

What is the way out for correctly measuring diversity?

To overcome the demerits elaborated above, the newly introduced diversity Indices were used. The efficiency of the newly introduced indices vis-à-vis conventional indices has been tested presently for a set of data (again hypothetical) given in Table 3. The diversity values calculated are given in Table 4. In both the stations, 12 species of fishes were recorded and the total number of fishes collected was 360 each (as before). In station 1, the 12 species belonged to 12 genera, 12 families, 12 orders and 2 classes. In station 2, the 12 species belonged to 4 genera, 4 families, 3 orders and 1 class. That way the taxonomic breadth in station 1 was more. The conventional indices calculated for the above data such as Fisher a, H' (log2), Max.H', EH',HB', N1, Q statistics and Macintosh did not differentiate diversity in the two stations and showed one and the same values. However, the values representing new indices such as taxonomic diversity (Δ), taxonomic distinctness (Δ*), average taxonomic distinctness (Δ +), total taxonomic distinctness (sDelta+), total phylogenetic diversity (sPhi+) and average phylogenetic diversity (Phi.+) were higher in station 1 and lower in station 2 reflecting well the taxonomic breadth (Figs.1 and 2). The efficiency of the newly introduced diversity indices became clear from the above (hypothetical) data. How these indices will behave under field conditions? It was checked with the help of works carried out on diversity using these indices. Ajmalkhan et al. (2004) compared the diversity of brachyuran crabs in two mangroves (natural and artificial) using the conventional and the new indices (Table 5). The Shannon diversity, Margalef and Simpson reflected the trend noticed in the number of species. However the taxonomic distinctness index and average taxonomic index did not. Clarke and Warwick (2001) mentioned that they are size independent and are attributed to reflect the taxonomic breadth of the biota. For stations I-IV, where the number of species was in the range of 16-30species (number of genera12-18 and number families 4-5), the taxonomic distinctness and average taxonomic distinctness were in the ranges of 86.51-87.85 and 87.20- 89.33 respectively. However, in stations V-VII, where the number species was only in the range of 5-8 (number of genera-4-6 and family only 2), the above indices were in the ranges of 81.32- 83.07 and 80.95-84.13 respectively. But the total taxonomic distinctness (1400-2616.09 in stations I-IV and 416.67-588.89 in stations V-VII) and total phylogenetic diversity (1100-1733 in stations I-IV and 368-500 in stations V-VII) clearly brought out the wide variations in the crabs diversity between the two mangroves. However, Warwick and Clarke (1995) pointed out that phylogenetic diversity is unsuitable for biodiversity assessment as it is a total rather than has an average property and as new species is added to the list, it always increases (has dependence on sampling effort). But the other one Total taxonomic distinctness is having the average property. Therefore it can be used for biodiversity assessment as it is independent of sample size and truly reflects the taxonomic breadth of the samples.

Table 3. Abundance of fishes recorded in two stations

Name of species	**Station 1**	**Station 2**
Raja radiata	30	30
Raja naevus	0	30
Raja undulata	0	30
Raja clavata	0	30
Raja microocellata	0	30
Raja brachyura	0	30
Raja montagui	0	30
Torpedo marmorata	0	30
Torpedo nobiliana	0	30
Scyliorhinus canicula	0	30
Scyliorhinus stellaris	0	30

Mustelus mustelus	0	30
Anguilla anguilla	30	0
Gadus morhua	30	0
Lophius piscatorius	30	0
Gasterosteus aculeatus	30	0
Hippocampus ramulosus	30	0
Capros aper	30	0
Gobius niger	30	0
Diplecogaster bimaculata	30	0
Solea solea	30	0
Taurulus bubalis	30	0
Mola mola	30	0

Raja (2010) studied the diversity of macrobenthos at various depths (30, 50, 75, 100, 150 and 200 m) in the continental shelf off Singarayakonda in Andhra Coast. He recorded 48 species at 30m depth and 26 species at 50m depth. The Shannon diversity values recorded were 5.38 and 4.58 at the above depths respectively (Table 7). However, the taxonomic distinctness value was higher at 50m depth (87.11) where comparatively less number of species, genus, family and order were reported (Table 8) and lower at 30m depth (81.77) where higher number of species was recorded. Do these indices also fail? Warwick and Clark (1995) who introduced these indices pointed out that these indices vouch for the taxonomic breadth of diversity in areas sampled. Somerfield et al. (2008) pointed out that these indices are weakly related to species richness. However, only the total taxonomic distinctness (4000 & 2520) and the phylogenetic diversity indices showed wide variations in the above depths (30 & 50m). As phylogenetic diversity is having the demerit of being total and linked to species richness, the total taxonomic distinctness which is having the average property appears to be the suitable measure for biodiversity assessment.

Table 4. Diversity of fishes in stations 1 and 2

Diversity measure	S1	S2
S	**12**	**12**
N	**360**	**360**
d	**1.87**	**1.87**
J'	**1**	**1**
Fisher a	**2.39**	**2.39**
H'(log2)	**3.59**	**3.59**
Max.H'	**3.59**	**3.59**
E H'	**1.6**	**1.6**
HB'	**2.41**	**2.41**
N1	**12**	**12**
Q stat.	**0**	**0**
Macintosh	**0.75**	**0.75**
Delta(Δ)	76.6	53.76
Delta(Δ*)	83.33	58.48
Delta (Δ+)	83.33	58.49
sDelta+	1000	701.82
sPhi+	1000	480
Phi.+	83.33	40

For assessing the diversity, conventional index as Shannon and Wiener is still used extensively besides others. However, it is very much influenced by the sample size. Moreover, it measures only the species level diversity. The diversity indices introduced by Warwick and Clarke (1995) are attributed to have no such demerits and have taxonomic relatedness. The suitability of these indices vis-à-vis conventional indices with their ability to discriminate situations was tested using both hypothetical data and with field data collected. Among all the indices, the total taxonomic distinctness is found to have the ability to discriminate between situations. It shows clearly the taxonomic breadth and in addition allows species inter-relatedness. Therefore it is suggested that for biodiversity assessment, this index may be used in future. As taxonomic information is an input, the use of this index in biodiversity monitoring will generate interest in taxonomy which is slowly waning.

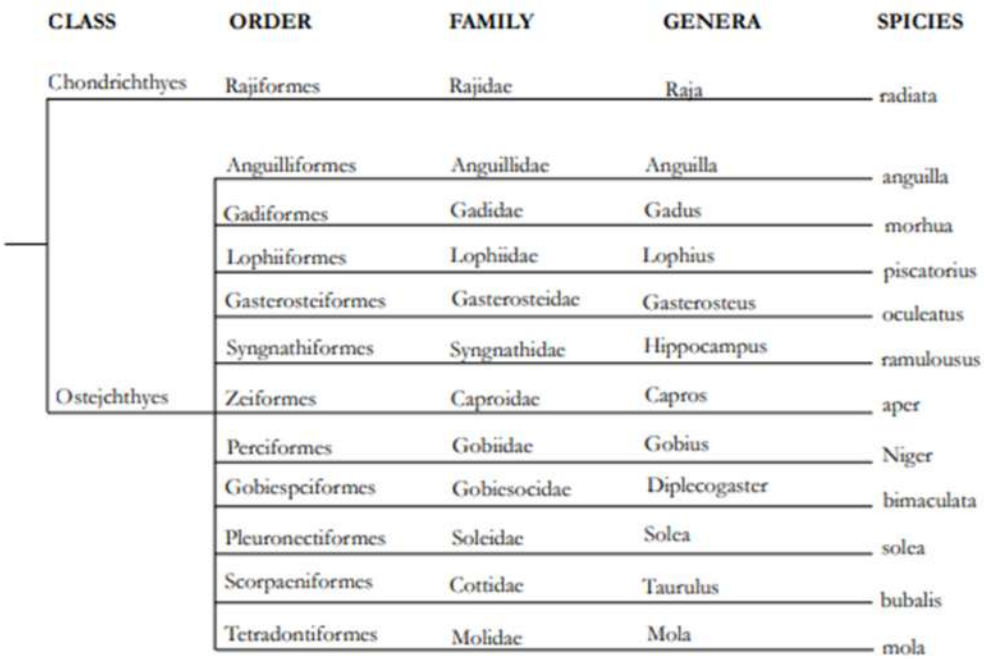

Fig.1. Taxonomic tree for station 1

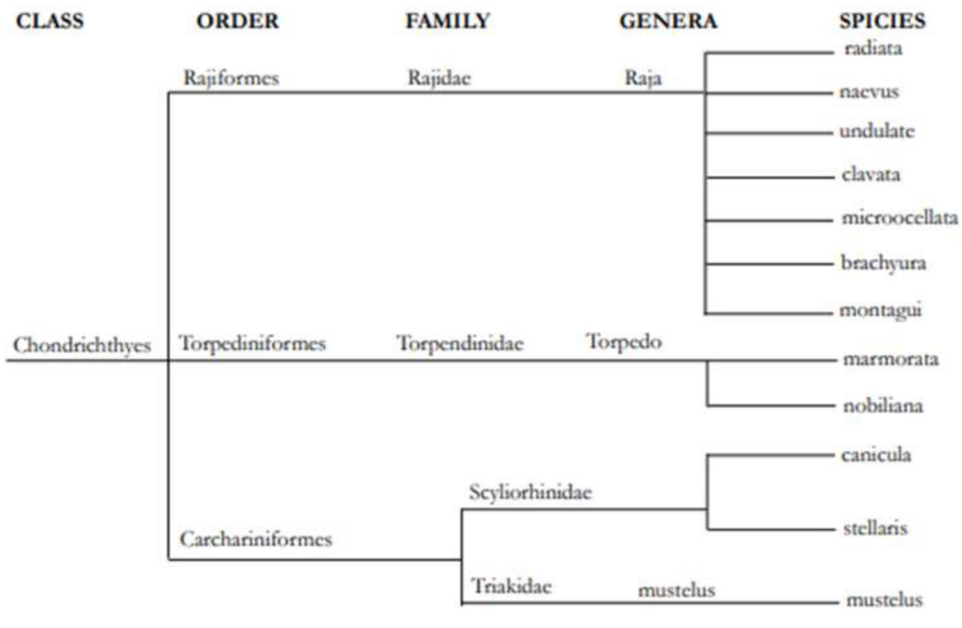

Fig.2. Taxonomic tree for station 2

Table 5 . Diversity of brachyuran crabs in Pitchavaram (stations I-IV) and Vellar (stations V-VII) mangroves (Ajmalkhan et al., 2004).

Stations	S	N	d	J'	H'(log2)	Lambda'	1-Lambda'	Delta	Delta*	Delta+	sDelta+	Phi+	sPhi+
I	16	71	4.44	0.95	3.81	0.05	0.95	82.61	86.99	87.50	1400.00	68.75	1100
II	30	82	7.79	0.96	4.69	0.02	0.98	84.95	87.06	87.20	2616.09	57.78	1733
III	21	65	5.83	0.95	4.16	0.04	0.96	83.33	86.51	86.83	1823.33	61.90	1300
IV	26	78	6.75	0.97	4.56	0.02	0.98	85.81	87.85	89.33	2322.67	60.26	1568
V	7	27	2.41	0.93	2.62	0.11	0.89	72.12	81.32	84.13	588.89	71.43	500
VI	8	40	2.56	0.92	2.77	0.11	0.89	72.42	81.37	80.95	647.62	62.50	500
VII	5	33	1.61	0.95	2.20	0.16	0.84	69.67	83.07	83.33	416.67	73.33	368

Table 6. Diversity of macrobenthos in continental shelf off Singarayakonda (Raja, 2010)

Depth	S	N	d	J'	H'(log2)	1-Lambda'	Delta	Delta*	Delta+	sDelta+	Lambda+	sPhi+
30m	48	289	8.29	0.88	4.91	0.96	78.56	81.77	83.33	4000	432.86	2520
50m	26	108	5.34	0.90	4.23	0.94	81.73	87.11	86.52	2250	402.99	1520
75m	19	99	3.92	0.88	3.73	0.92	77.14	84.02	82.11	1560	416.62	1220
100m	18	125	3.52	0.76	3.18	0.84	64.10	76.68	85.36	1536	397.42	1120
150m	21	179	3.86	0.93	4.09	0.94	74.22	79.14	86.00	1806	457.33	1140
200m	12	58	2.71	0.85	3.06	0.86	66.12	76.59	86.06	1033	411.75	800

Usefulness of PRIMER package in the identification of fishes

The tool Canonical Analysis of Principal Coordinates available in the add-on package of PRIMER namely PERMANOVA+ (Anderson et al., 2008) is helpful in the identification of fish species. Suppose a model has been developed based on morphometric characteristics of clearly identified fish specimens of few species, when unknown specimens belonging to the above species are obtained, the above tool enables correct identification. Of course, the example available in the manual refers to four morphometric variables of three species of flowers whose petal length (PL), petal width (PW), sepal length (SL) and sepal width (SW) were measured in terms of cms. There were 150 samples in total, with 50 flowers belonging to each of 3 species: *Iris versicolor* (C), *Iris virginica* (V) and *Iris setosa* (S). Interest lies in using the morphometric variables to discriminate or predict the species to which individual flowers belong. The canonical ordination plot of the discriminant analysis obtained for the above data is shown in Fig.3. The first squared canonical correlation is very large (0.97) and indeed the first canonical axis does quite a good job of separating the three iris species from one another (Fig. 3). The second canonical axis is also helpful in separating species *I.versicolor* from *I.virginica*.

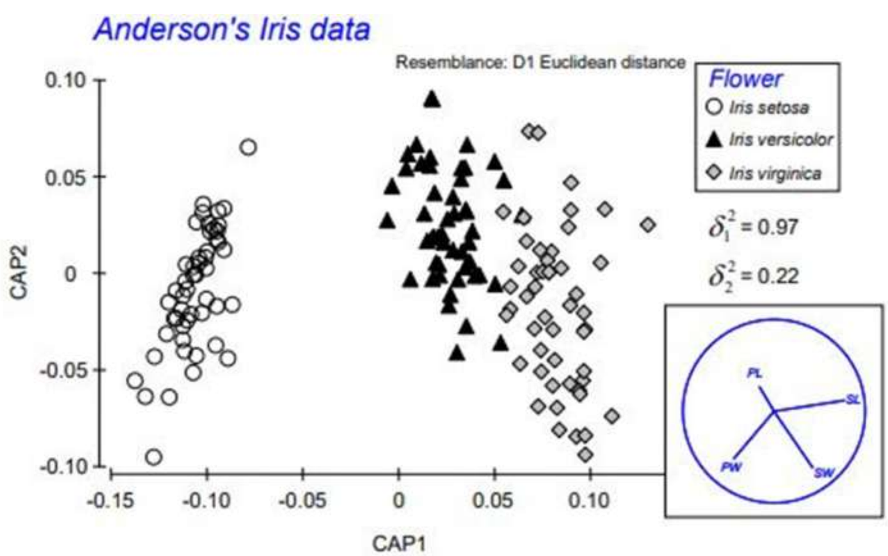

Fig.3. Canonical ordination for the discriminant analysis of Anderson's Iris data.

For example, suppose we have three new flowers which we suspect belong to one of the three species of irises analysed by CAP as indicated above. Suppose the values of the four morphometric variables for each of these new flowers are shown in Table 7.

Table 7. Morphometric variables of the new flowers

Species	PL	PW	SL	SW
New 1	6.3	2.8	5.4	1.9
New 2	4.8	3.5	1.4	0.2
New 3	6.6	3.0	5.7	2.1

The morphometric values given in the above table were fed into the CAP model developed above and the results are shown in Fig.4.

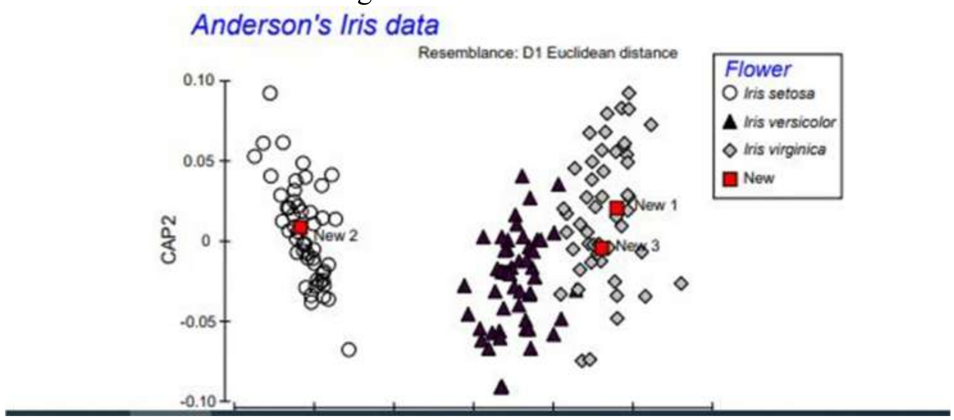

Fig. 4. CAP plot of iris data, showing the positions of three new flowers

The results clearly showed that the three sets of morphometric data belonged to two species namely *I.setosa* (New 2) and *I.virginica* (New 1 and 3).This tool can be used effectively for identifying unknown fish species.

Use of PRIMER package in the management of fisheries

To understand the usefulness of this package, in the management of fisheries, let us make use of the temperate reef fish assemblages at the Poor Knights Islands, New Zealand. Divers have counted the abundances of fish belonging to 62 species in each of nine 25 m × 5 m transects at each site. Data from the transects were pooled at the site level and a number of sites around the Poor Knights Islands were sampled at each of three different times: September 1998 ($n1 = 15$), March 1999 ($n2 = 21$) and September 1999 ($n3 = 20$). These times of sampling spanned the point in time when the Poor Knights Islands were classified as a no-take marine reserve (October 1998). Interest lies in distinguishing among the fish assemblages observed at these three different times of sampling, especially regarding any transitions between the first time of sampling (before the reserve was established) and the other two times (after). To characterize these three groups of samples, to visualize the differences among them and to assess just how distinct these groups are from one another in the multivariate space, a CAP analysis was done (Fig. 5). The constrained CAP analysis showed that the three groups of samples (fish assemblages at three different times) are indeed distinguishable from one another. For this sample, 2 axes are quite sufficient to distinguish the three groups. The sizes of each of these first two canonical correlations are reasonably large: $\delta 1 = 0.78$ and $\delta 2 = 0.69$. These canonical correlations indicate the strength of the association between the multivariate data cloud and the hypothesis of group differences. For these data, the first canonical axis separates the fish assemblages sampled in September 1998 (on the right) from those sampled in March of 1999 (on the left), while the second canonical axis separates fish assemblages sampled in September 1999 (lower) from the other two groups (upper).

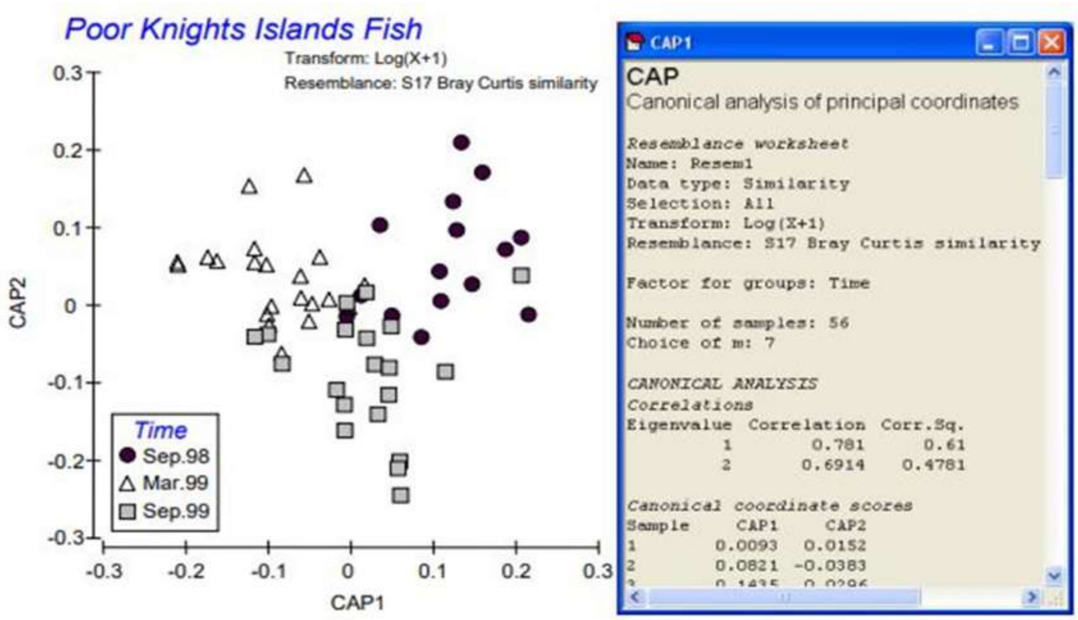

Fig.5. CAP analysis of fish data from the Poor Knights Islands

From the vector plot drawn on the CAP plot (Fig. 6), we can see that some species apparently increased in abundance after the establishment of the marine reserve, such as the snapper *Pagrus auratus* ('PAGRUS') and the kingfish *Seriola lalandi* ('SERIOLA'), which are both targeted by recreational and commercial fishing, and the stingrays *Dasyatis thetidis* and *D. brevicaudata* ('DTHET', 'DBREV'). Vectors for these species point toward the upper left of the CAP plot 6 indicating that these species were more abundant, on average, in the March 1999 samples. Some species, however, were more abundant before the reserve was established, including leatherjackets *Parika scaber* ('PARIKA') and the (herbivorous) butterfish *Odax pullus* ('ODAX'). These results lead to new ecological hypotheses that might be investigated by targeted future observational studies or experiments.

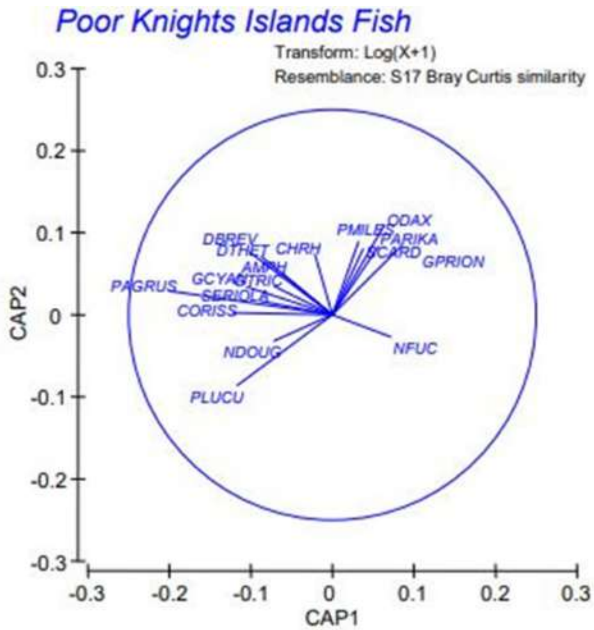

Fig.6. Vector overlay of Spearman rank correlations of individual fish species with the CAP axes

Conclusion

In addition to the above applications, PRIMER package is also helpful in studying the assemblage of fishes.

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CHAPTER 44

Diversity Analysis using R

A diversity index is a numerical measure that quantifies the number of distinct types (such as species) in a dataset (a community) while also accounting for evolutionary relationships among the individuals distributed throughout those types, such as richness, divergence, and evenness. These indicators are numerical representations of biodiversity in a variety of ways (richness, evenness, and dominance). The amount of distinct species present in a community is referred to as species diversity (a dataset).

The effective number of species is the number of equally abundant species required to achieve the same mean proportional species abundance as seen in the dataset under consideration (where all species may not be equally abundant). Using diversity analysis, questions like "how many species are in a sample?" and "how similar are these two samples?" are investigated. The number of species recorded within a region is referred to as alpha diversity, while beta diversity is defined as the number of species not common to the two regions being compared is referred to as beta diversity and gamma diversity is defined as the total number of species within all regions. Species richness, taxonomic or phylogenetic diversity, and/or species evenness are all examples of species diversity. The term "species richness" refers to the number of species present. The genetic link between distinct groupings of animals is taxonomic or phylogenetic diversity. Species evenness measures how evenly the species' abundances are distributed.

Several packages are available in R for calculating the diversity indices, and the vegan package is more popular.

<u>The "vegan" Package in R</u>

To install Vegan package
install.packages("vegan")

The majority of diversity approaches presume that data is in the form of individual counts. Other data types are employed in the procedures, and some claim that biomass or cover are better than counts of individuals of varying sizes.

This package uses the data set with stem counts of trees on 1 ha plots in the Barro Colorado Island.

To view the data used:
library (vegan)
data("BCI")
fix(BCI)

1. Diversity Indices

The Shannon index is calculated with:
H <- diversity(BCI)

The evenness (equitability) an be obtained using Pielou's evenness index and can be obtained using:
J <- H/log(specnumber(BCI))

The R´enyi diversities can be calculated using:
 # to select six locations randomly from the data set
k <- sample(nrow(BCI), 3)

 # R`enyi diversities
R <- renyi(BCI[k,])
plot(R)

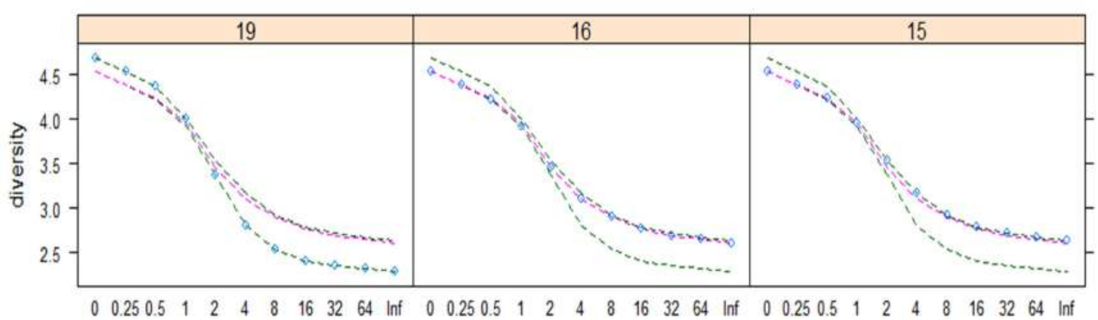


Figure 1: R´enyi diversities in 3 randomly selected plots. The dots represents the values for sites, and the lines the extremes and median in the data set.

A site is more diverse if all of its R´enyi diversities are higher than another site.

Fisher's alpha diversity index:
alpha <- fisher.alpha(BCI)

Species richness rises with sample size, and discrepancies in richness may result from sample size differences. One option is to strive to rarefy species richness while maintaining the same number of individuals to address this issue.

To express richness for the same number of individuals:

Srar <- rarefy(BCI, min(rowSums(BCI)))

Simple diversity indices consider species identity: all species are equally unique. Taxonomic and functional diversity indexes, on the other hand, assess the distinctions between species. Although taxonomic and functional diversities are utilised in distinct disciplines of science, they both follow the same logic and can be used to taxonomic or functional properties of species.

2. Taxonomic Diversity

In taxonomic diversity the primary data were taxonomic trees which were transformed to pairwise distances among species.

data(dune)
data(dune.taxon) # Taxomic trees
taxdis <- taxa2dist(dune.taxon, varstep=TRUE)
mod <- taxondive(dune, taxdis)
mod

```
> data(dune)
> data(dune.taxon)
> taxdis <- taxa2dist(dune.taxon, varstep=TRUE)
> mod <- taxondive(dune, taxdis)
> mod
         Species    Delta   Delta*  Lambda+   Delta+ S Delta+
1          5.000   22.736   29.232  900.298   43.364   216.82
2         10.000   51.046   55.988  822.191   56.232   562.32
3         10.000   41.633   46.194 1025.471   62.869   628.69
```

Figure 2: R output

3. Functional Diversity

In functional diversity the data associated with species attributes are translated to pairwise distances among species and futher grouping them.

tr <- hclust(taxdis, "aver")
mod <- treedive(dune, tr)

4. Species abundance models

Diversity indices can be thought of as variance measures for species abundance distribution. One might want to look at abundance distributions more closely. Vegan includes routines for Fisher's log-series and Preston's log-normal models and various species abundance distribution models.

#Species abundance models
k <- sample(nrow(BCI), 1)
fish <- fisherfit(BCI[k,]) # Fisher's log-series
fish

plot(fish)

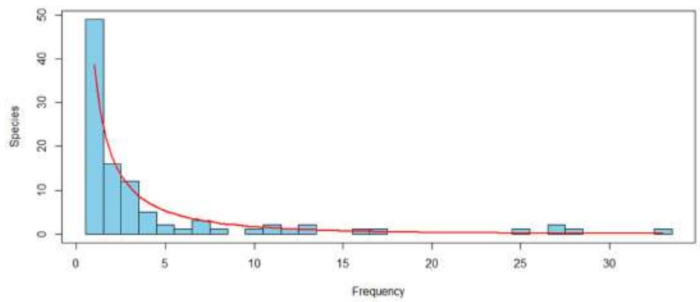


Figure 3: The result of Fisher's log-series fitted to one randomly selected site (Site number=47).

Fisher log series model
No. of species: 102
Fisher alpha: 42.56011

In Preston's log-normal model, instead of plotting species by frequency, it divides them into increasing frequency groupings. As a result, upper bins with a wide range of frequencies become more prevalent, and the result can resemble a Gaussian distribution truncated on the left in appearance.

prest<-prestondistr(BCI[k,]) # Preston's log-normal model
prest
plot (prest)

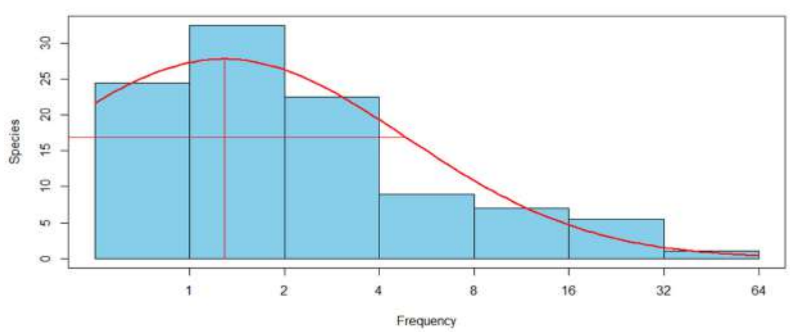


Figure 4: Preston's log-normal model fitted to one randomly selected site (47).

5. Ranked abundance distribution

rad <- radfit(BCI[k,]) # ranked abundance
rad
#plot(rad)
radlattice(rad)

RAD models, family poisson
No. of species 102, total abundance 425

	par1	par2	par3	Deviance	AIC	BIC
Null				105.2750	384.2921	384.2921
Preemption	0.045509			81.6840	362.7010	365.3260

Lognormal   0.7421   1.1905   43.1745 326.1916 331.4415
Zipf   0.1409   -0.85907   48.6464 331.6634 336.9134
Mandelbrot 2.017   -1.5363   6.7022   9.4122 294.4292 302.3042

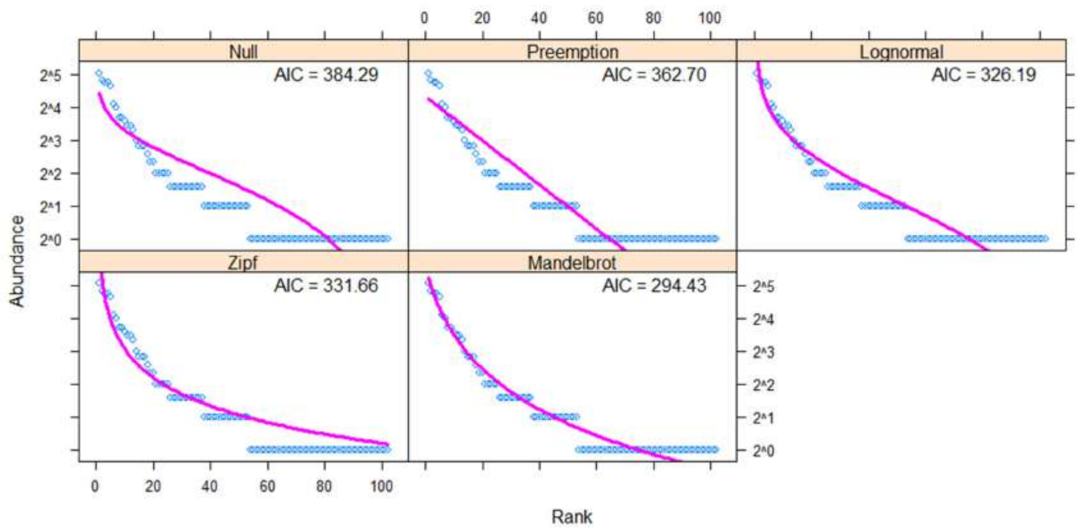


Figure 5: Ranked abundance distribution models for a random plot (no. 47). The best model has the lowest AIC.

6. Species accumulation models

Species accumulation models are similar to rarefaction in that they look at how species accumulate as the number of sites grows. There are a few other options, such as gathering sites in the order they appear and repeating the process randomly.

The recommended is Kindt's exact method

sac <- specaccum(BCI) # species accumulation model (Kindt's exact method)
plot(sac, ci.type="polygon", ci.col="green")

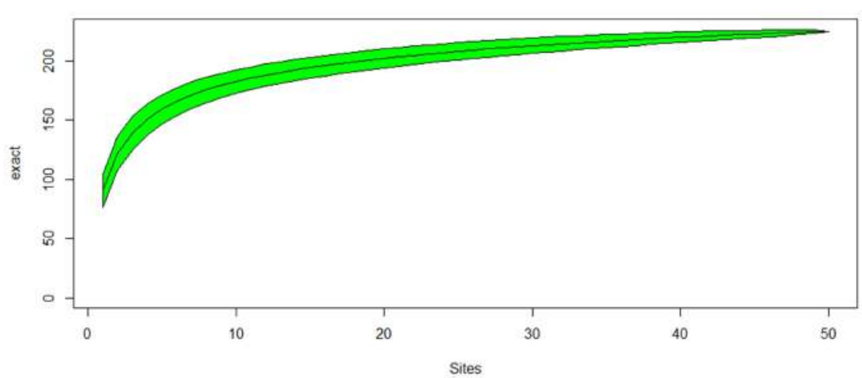


Figure 6: Species accumulation using Kindt's exact method

7. Beta diversity

The most fundamental diversity indices are alpha diversity indices. Whittaker (1960 and 1965) classified diversity into several categories. The most well-known are alpha diversity (diversity in a single location) and beta diversity (diversity over gradients). Although beta diversity should be explored in relation to gradients (Whittaker, 1960 & 1965), practically everyone thinks of it as a measure of general heterogeneity: how many more species are there in a collection of sites than in an average site.

The best-known beta diversity index is based on the ratio of total number of species in a group of sites S to average richness per site α.

#Beta diversity
ncol(BCI)/mean(specnumber(BCI)) – 1

To know the details of different beta diversities use the function:
betadiver(help=TRUE)

z <- betadiver(BCI, "z") # To get the diversity measure "z"

8. Cluster Analysis (Unsupervised learning)

Unsupervised learning is a machine learning method used to make conclusions from datasets containing unlabeled input data. Cluster analysis is the most frequent unsupervised learning method used for exploratory data analysis to uncover hidden patterns or groupings in data.

Cluster analysis is used to aggregate instances into groups when the group membership is unknown before the study. Cluster analysis is a method for classifying individuals or objects into previously unidentified groups.

8.1 Clustering Methods (Johnson and Wichern, 2006)

The clustering methods commonly used are fall into two general categories.

(i) Hierarchical and
(ii) Non hierarchical.

8.1.1 Hierarchical cluster Analysis

Either a sequence of mergers or a series of sequential divisions is used in hierarchical clustering algorithms. The agglomerative hierarchical technique begins with individual objects, there are as many clusters as there are items. The most similar objects are grouped first, and these groupings are then combined based on their commonalities. As the resemblance between subgroups declines, they eventually merge into a single cluster.

Divisive hierarchical approaches work the other way around. A single group of items is split into two subgroups, with the objects in one subgroup being separated from the ones in the other. These subgroups are then separated into distinct subgroups. The process continues until the number of subgroups equals the number of items or each object forms a group. The findings of both the agglomerative and divisive methods can be shown as a Dendrogram, a two-dimensional figure. The Dendrogram can be seen to depict the mergers or divisions that have occurred at successive levels.

Linkage methods can be used to cluster both items and variables. This isn't always the case with hierarchical agglomerative procedures. The following linking types are now discussed:

(i) Single linkage (minimum distance or nearest neighbour),
(ii) Complete linkage (maximum distance or farthest neighbour) and
(iii) Average linkage (average distances).

Other hierarchical clustering techniques, such as Ward's and Centroid methods, are also documented in the literature.

Hierarchical Cluster analysis: Agglomerative Clustering steps

The steps involved in the agglomerative hierarchical clustering algorithm for groups of N objects (items or variables) are as follows:

(i) Begin with N clusters, each of which contains a single entity and a N×N symmetric distance (or similarity) matrix $\mathbf{D} = \{d_{ik}\}$.
(ii) Look up the closest (most similar) pair of clusters in the distance matrix. Let d_{uv} be the distance between the two most comparable clusters U and V.
(iii) Combine the U and V clusters. The newly formed cluster should be labelled (UV). Remove the rows and columns pertaining to clusters U and V from the distance matrix and replace them with a row and column indicating the distances between cluster (UV) and the other clusters.
(iv) Repeat steps (ii) and (iii) N-1 times more (All objects will be in a single cluster after the algorithm terminates). Keep track of the merged clusters' identities as well as the levels (distances or similarities) at which they merged.

8.1.2 Non-Hierarchical Clustering Method

Non-hierarchical clustering approaches group things into a collection of K clusters rather than variables. The number of clusters, K, can be set ahead of time or decided during the clustering process. Because the basic data does not need to be saved and a distance matrix does not need to be calculated during the computer run. Non-hierarchical approaches can handle far larger data sets than hierarchical methods can. Non-hierarchical techniques begin with either (1) an initial grouping of items or (2) an initial set of seed points that will form the cluster's nucleus.

8.1.2.1 K means Clustering (Afifi, Clark and Marg, 2004)

The K means clustering is a popular non-hierarchical clustering method. The algorithm proceeds in the following steps for a specified number of clusters K:

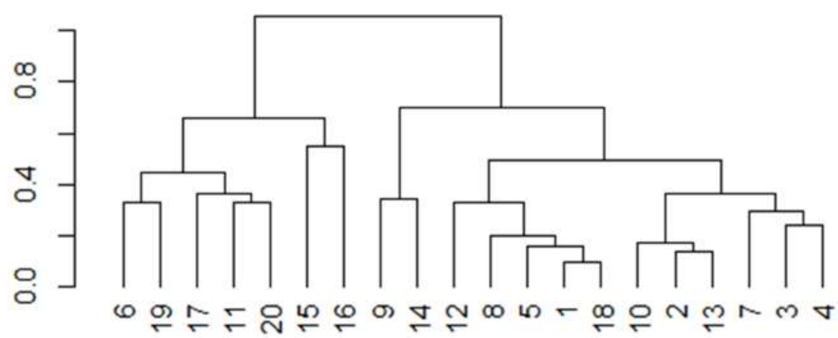
(i) First, divide the data into K clusters. The number of clusters can be set by the user or chosen by the computer according to a random approach.
(ii) Determine the K clusters' means or centroid.
(iii) Calculate the distance between each case's centroid. Leave the case in its own cluster if it is closest to the centroid; otherwise, reassign it to the cluster whose centroid is closest to it.
(iv) For each scenario, repeat step (iii).
(v) Repeat steps (ii), (iii), and (iv) until there are no more cases to assign.

8.2. Dendrogram

The relative size of the proximity coefficients at which cases are joined is shown in a dendrogram, also known as a hierarchical tree diagram or plot. The greater the distance coefficient or, the smaller the similarity coefficient, the more clustering is required, which may be undesirable. Low-distance cases are close together, with a line connecting them a short distance from the left of the Dendrogram, indicating that they have been grouped into a cluster with a low distance coefficient, indicating similarity. When the linking line is to the right of the Dendrogram, on the other hand, the linkage occurs at a high distance coefficient, showing that the cases/clusters were agglomerated despite their differences.

R code for getting a simple dendrogram:

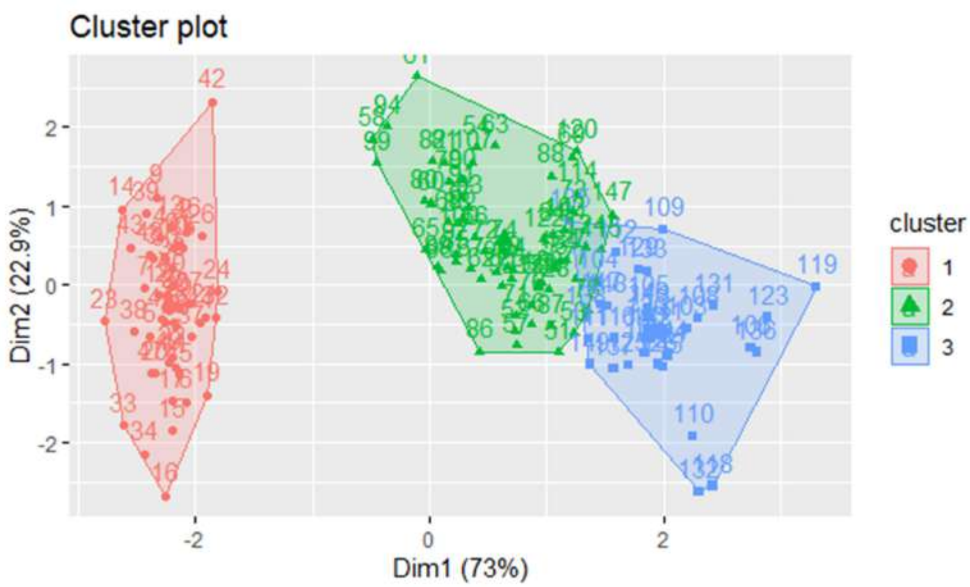
```
attach(iris)
iris1<-iris[1:20 ,-5]  # For selecting a subset data
dist <- dist(iris1, method = "euclidean")
hclust_avg <- hclust(dist, method = 'average')
hcd <- as.dendrogram(hclust_avg)
plot(hcd, main="Main")
```



8.3. PCA based clustering

The R code for the PCA based clustering:

```
library(factoextra)
attach(iris)
iris2<-iris[ ,-5]
dist <- dist(iris2, method = "euclidean")
hclust_avg <- hclust(dist, method = 'average')
sub_grp <- cutree(hclust_avg, k = 3)
fviz_cluster(list(data = iris2, cluster = sub_grp))
```



8.4. Distance Measures

Some distance measures commonly used for assessing spectral similarity/dissimilarity are as follows:

1) Euclidian Distance
2) Mahalanobis D^2
3) City-Block Distance

Some of the R functions used for computing distances between pairs of observations:

- **dist()** R base function [stats package]
- **get_dist()** function [factoextra package]

Compared to the standard dist() function, it supports correlation-based distance measures including "pearson", "kendall" and "spearman" methods.

- **daisy()** function [cluster package]: It can handle different variable types (e.g. nominal, ordinal, (a)symmetric binary). In that case, the Gower's coefficient will be automatically used as the metric. It's one of the most popular proximity measures for mixed data types. Details on the function can be obtained from the R documentation of the daisy() function (?daisy).

For example for Euclidean distance

dist.eucl <- dist(data, method = "euclidean")

Some of the methods are **"euclidean", "maximum", "manhattan", "canberra", "binary", "minkowski"**

For visualization of distances, following package can be used:

```
library(factoextra)
attach(iris)
iris1<-iris[1:20 ,-5]  # For selecting a subset data
dist <- dist(iris1, method = "euclidean")
fviz_dist(dist, gradient= list(low="green",mid= "white",high= "red"))
```

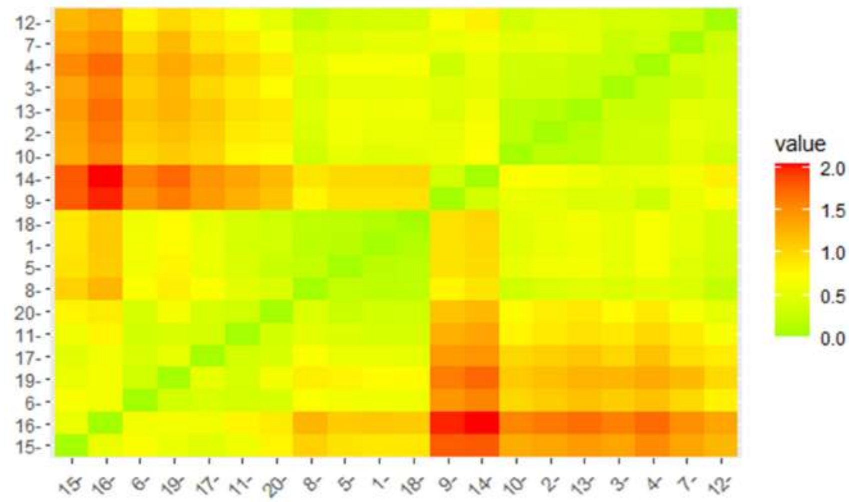


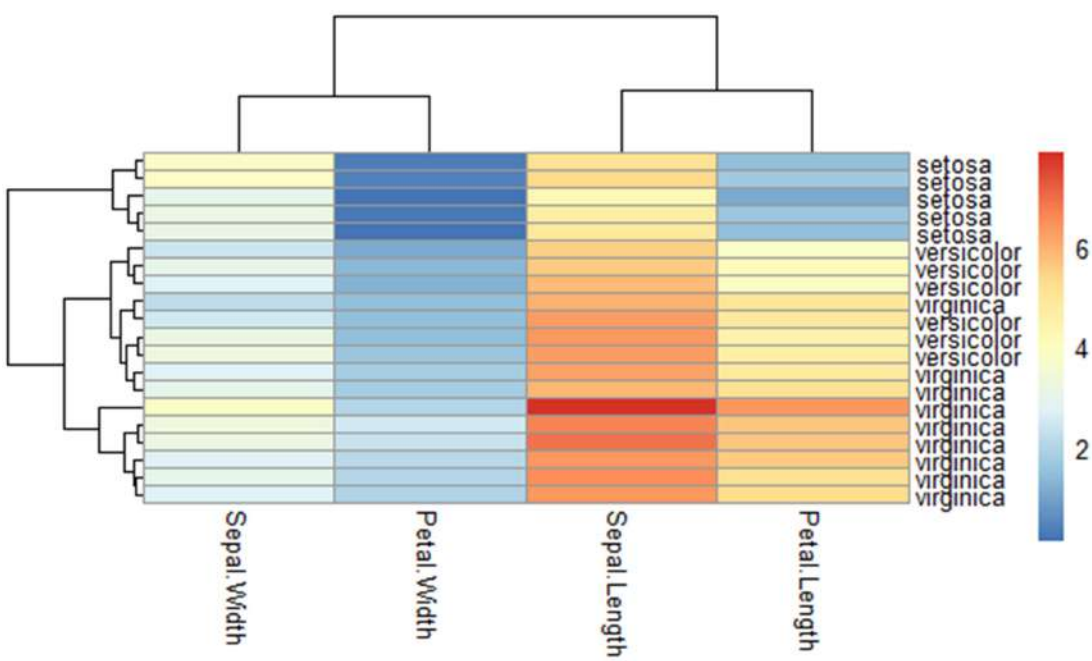
Fig. Distance plot

8.6 Heat Map

A heat map is a data visualization technique that shows the magnitude of a phenomenon as color in two dimensions. "pheatmap" function can draw clustered heatmaps.

The R code for heat map

```
library("pheatmap")
ss <- sample(1:150, 20)   # 30 rows randomly
df <- iris[ss, ]
df1<-as.matrix(df[ ,-5])
rownames(df1)<-as.matrix(df[ ,5])
pheatmap(df1)
```



9. Discriminant Function Analysis (Supervised learning)

Discriminant function analysis is a statistical technique that uses one or more continuous or binary independent variables to predict a categorical dependent variable (also known as a grouping variable) (called predictor variables). Sir Ronald Fisher created the first dichotomous discriminant analysis in 1936. Discriminant function analysis can be used to see if a group of variables is good at predicting membership in a category. Discriminant analysis is utilized when groups are known a priori (unlike in cluster analysis). A score on one or more quantitative predictor measures and a score on a group measure are required for each instance. In simple terms, discriminant function analysis is the act of grouping, classifying, or categorising things into similar groups, classes, or categories.

The assumptions of discriminant analysis are the same as those for MANOVA. The analysis Discriminant analysis is based on the same assumptions as MANOVA. Outliers can be a serious impact on the results and size of the smallest group must be larger than the number of predictor variables. The following are the main assumptions:

- Multivariate normality: For each level of the grouping variable, independent variables are normal.
- Homogeneity of variance/covariance (homoscedasticity): The Box's M statistic can be used to see if the variances of group variables are the same across levels of predictors.
- However, it has been proposed that when covariances are equal, linear discriminant analysis be used, and when covariances are not equal, quadratic discriminant analysis be employed.
- Multicollinearity: As the correlation between predictor variables increases, predictive power decreases.
- Independence: Participants are randomly selected, and a participant's score on one measure is believed to be independent of all other participants' scores on that variable.

It has been proposed that discriminant analysis is reasonably resilient to minor violations of these assumptions, and that discriminant analysis can still be reliable when utilising dichotomous variables (where multivariate normality is often violated).

The discriminant analysis creates a new variable for each function by combining one or more linear combinations of predictors. Discriminant functions are the name given to these functions. The number of functions that can be used is either Ng-1 (number of groups) or p (number of predictors), whichever is less. On that function, the first function maximises the differences across groups. The second function maximises differences on that function, but it can't be associated with the first. This process is repeated for subsequent functions, with the exception that the new function must not be connected with any of the preceding functions.

The following packages and codes are useful for running linear discriminant function analysis in R:

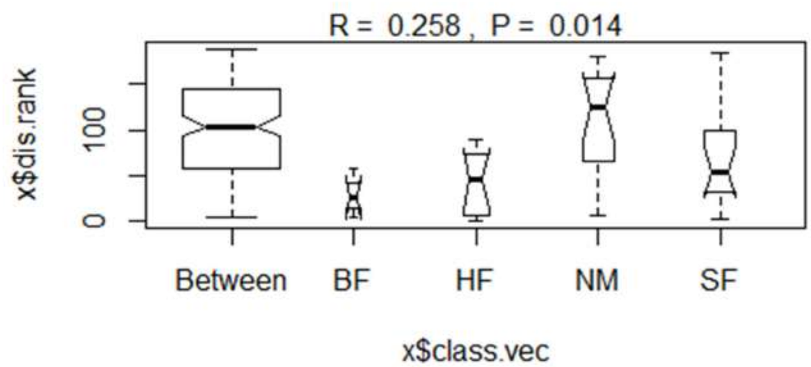
library(MASS)
library(tidyverse)
library(caret)
model <- z <- lda(Sp ~ ., Iris, prior = c(1,1,1)/3, subset = train)

Further, prediction of group membership and plotting of the membership can also be done.

10. Analysis of Similarities (ANOSIM) using anosim()

Analysis of similarities (ANOSIM) is used to test the significant difference between two or more groups of sampling units.

```
data(dune)
data(dune.env)
dune.dist <- vegdist(x, method="bray", binary=FALSE, diag=FALSE, upper=FALSE,
                na.rm = FALSE)
# method: Dissimilarity index, partial match to "manhattan", "euclidean", "canberra",
"clark", "bray", "kulczynski", "jaccard", "gower", "altGower", "morisita", "horn",
"mountford", "raup", "binomial", "chao", "cao", "mahalanobis", "chisq" or "chord".
attach(dune.env)
dune.ano <- anosim(dune.dist, Management)
summary(dune.ano)
plot(dune.ano)
```



11. Non-metric Multidimensional scaling using metaMDS()

Function metaMDS performs Nonmetric Multidimensional Scaling (NMDS). it standardizes the scaling in the result, so that the configurations are easier to interpret, and adds species scores to the site ordination. The metaMDS function does not provide actual NMDS, but it calls another function for the purpose.

```
mds <- metaMDS(dune, distance = "bray", k = 2)
plot(mds, display = c("sites", "species"))
```

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CHAPTER 45

Taxonomic Requirements in a Modelling Approach for Identifying Essential Fish

Abstract

In this lecture we are looking into the relevance of taxonomy while doing numerical modelling studies for identifying essential fish habitats. In order to develop a scientific system for developing the closed area approach, numerical models with outputs in integrated geographical information systems are used as decision supports in rightly identifying the essential fish habitats. Befitting to the fundamentals in the fisheries management concepts, numerical models are resorted for easily re-looking the fishing grounds, breeding areas and nursery areas relevant for a fish in a study domain. But while doing the simulation process, we often tend to make assumptions with respect to the biology and physiology of the fish. In this training lecture we will be looking into the taxonomic requirements which are useful in ascertaining the biological and physiological features of fish while doing a simulation experiment. Sciaenids commonly known as drums or corakers are taken as an example while simulating the larval movement of them in Gulf of Kachchh (GoK) using MIKE-21 model – a combination of hydrodynamic and particle tracking model. The model was resorted to know the amount of fish larvae retained at a particular site in the entire domain during the simulation study.

Background

It is fundamental to all fisheries management concepts that fishes have to be caught from their fishing grounds leaving a substantial number of adults to breed in their breeding grounds and further allowing the eggs and larvae to grow into juveniles or adults in their nursery grounds. We were always looking into blanket recommendations of ecologically sensitive areas such as corals, mangroves etc. to arrive at our conclusions on essential fish habitats. Off late, the researchers as well as developmental agencies are looking into the numerical simulations for identifying the essential fish habitats. For breeding grounds, we do exploratory surveys using zoo-plankton net to understand the quantity of eggs produced in a study location. The locations with the presence of more fish eggs are treated as the breeding grounds of the fishes. There are various methods to ascertain the fishing grounds as we can have established technologies such as integrated potential fishing zone advisories (IPFZ) for estimating the

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fishing grounds. The Hjort-Cushing's triangle redrawn below (Figure 1) indicates the approximate concept of fishing, breeding and nursery grounds relevant in a study.

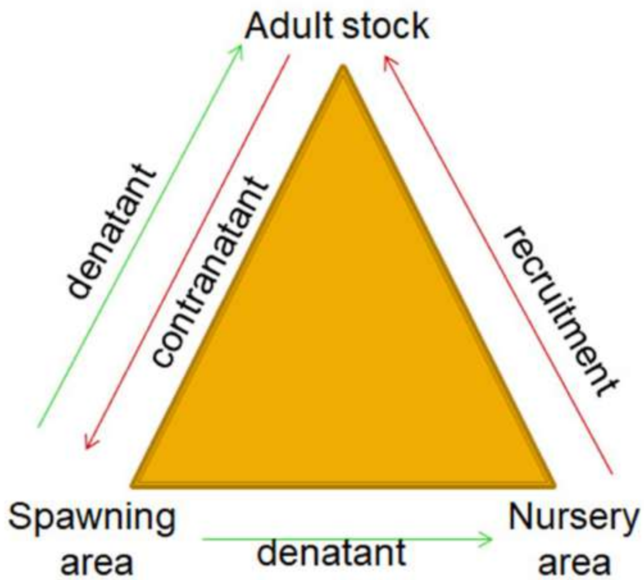

Figure 1: Hjorts-Cushing's Triangle on essential fish habitats

But as we study the delineation of nursery grounds, we understand the need for large volume of datasets in scientifically ascertaining the nursery areas. In this study we have dealt with a numerical modelling experiment where the physical forcing such as hydrodynamics and wind were superimposed on a particle tracking model to really arrive at the nursery areas of the fishes in the Gulf of Kachchh (GoK) region (George at.al., 2011). The fish eggs and larvae have to be properly defined in the particle transport model and the taxonomic relevance of this is discussed in the lecture.

How we have defined the fish eggs and larvae in the particle tracking model?

GoK region is famous for the fishery of demersal resources and the landing statistics from ICAR-CMFRI clearly indicates that the majority of fish reported from this region is belonging to the sciaenid family (CMFRI reports). Therefore, while defining the egg/ larval transport parameters in the model we have looked upon the fishes belonging to sciaenid family for setting a benchmark in the various attributes of the study. The estimates will have their best results as a model output when we give the near-real time values in defining the biology of the fish.

The various factors to be considered regarding the biology of the fish and the modelling parameters are as follows:

(i) Duration of simulation

The duration of the numerical simulation is relevant in deciding the dispersal distance of egg/ larvae which are planktonic and move at the mercy of the currents. Technically we define this time as the Planktonic Larval Duration (PLD) phase of the fish. This PLD phase vary from species to species. Therefore, it is important to know the PLD of a particular commercially important fish species and we have to develop species specific database of fishes with their corresponding PLD if we are preparing ourselves for a long-term simulation study. Similar species can have similar PLD and can be utilized for a study if proper data sets are not available. But as we go for mores assumptions, the model accuracy may go down. Based on the PLD of the sciaenid, which is similar to other tropical fish species, the larvae complete this crucial period in approximately 20 days, as for most tropical fish larvae (Wellington and Victor, 1989).

(ii) Particle size of released eggs

During the model simulation studies, we release eggs or larvae as particles. The particles have to be defined properly as eggs or larvae. Else it can lead to erroneous model outputs. For example, if we are simulating the model for sciaenid, we have to define the praticels released in the model as the egg or larvae of the sciaenid. Therefore, in our study we were in search of such an input. We came to know that Gustavo et al., 2003, based on the egg size, weight and fecundity of sciaenids, have estimated time of hatch based on the sampling point time with each egg weighing 0.02 mg. Therefore, we also estimated the same weight and defined the particles released for sciaenid in tropical waters (the most dominant group of fish found in the Gulf) and timed the release of larvae at select spawning sites.

(iii) Possibility of passive drifting

In a typical hydrodynamic regime, the larvae may be undergoing passive drifting which will necessarily be based on swimming speed of the fish which is a sciaenid in this study. The assumption of a purely pelagic phase is supported in some systems, but lab/field observations sometimes contradict the assumption that the larval component is completely passive (Leis, 2006). In a macro-tidal regime such as the GoK, weak swimmers will not contribute to dispersal trajectories because of strong currents. Tropical sciaenid fishes have a swimming speed of 0.6–1.4 cm/s (Leis et al., 2006), but the current speed is of the order of 150–200 cm/s.

(iv) Total particles released

Total particles in a modelling study indicates the total number of eggs released or the larvae that are recruited into the study domain at a particular point of time. The particles which are defines as eggs were estimated based on the fecundity of the sciaenid in this study. Particle release time is based on the spawning time of sciaenid. One particle released in the model is estimated to be equivalent to 100 eggs as fecundity of tropical fishes tend to vary from 0.1 to 1 million (Pandian, 2003). Release of 10 million eggs is achieved by assuming that a minimum of 10 fishes are spawning in a site during the active breeding phase. To visualize the movement of fish larvae, particle-tracking (numerical experiment using PA model) simulations have been carried out for the 6 spawning locations surveyed for egg abundance in the Gulf and tracked for 30 days. Final site selection for egg release in the PA model was decided based on the egg abundance and dispersal pattern observed from the particle tracking results.

(v) Nature of virtual fish eggs

The nature of the fish eggs is simulated as neutrally buoyant passive particles. In this study, we assume that fish larvae are transported with the flow without settling. Released eggs form larvae in a day in tropical conditions as their hatching time is reported to be less than a day (Pauly and Pullin, 1988). For a smooth illustration of events during larval transport, the tracer particles used in the model are termed as eggs at the spawning site, and larvae thereafter, as eggs develop into larvae in a day in sciaenid fishes. Hence, hypothetical larvae were allowed to disperse following the egg release from two major sites identified for each season. The larvae are tracked hourly in this experiment to identify their patterns of dispersal and retention. Dispersed patterns are presented as snap shots at different time steps (day 1, day 5, day 10 and day 16).

(vi) Vertical migration

Active fish larvae tend to migrate vertically. But in a well-mixed current regime such as the Gulf tends to carry forward the larvae. The difference in trajectory may result in a shift in their distribution to the order of hundreds of meters, but limitations of a 2-D depth averaged model in a 500 m grid spacing make it difficult to consider this possibility and it is assumed that the changes in distribution of larvae due to vertical migration is negligible for the study.

(vii) Predation, mortality and behaviour

The larval abundance in a region is affected by predation, mortality and behaviour. In this study, these aspects were neglected as the variation in these parameters in the study domain is not known, and it is difficult to interpolate the same in spatial scales in the numerical model.

Conclusion

The study is an indication of the various model related assumptions which we take casually while defining the biological parameters related to fish. The taxonomic identification of the species used in the study with a supplementary biological (physiological) and behvioural data set can improve the scope of the simulation studies. We have mentioned few indicative assumptions which can go wrong if the species studied is devoid of some important biological variables. It is important for fisheries biologists to record and disseminate such relevant biological data sets so that the new scientific framework using decision support systems can in a long way provide reliable results in rightly identifying the essential fish habitats.

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CHAPTER 46

A Note on Length Weight Relation in Fishes

Fishes are unique among vertebrates, especially when their growth patterns are taken into account. Baring very few exceptions, fishes show an indeterminate type of growth, implying that they show continued growth throughout the life, invariably with rate of growth declining with age (Mommsen, 2001). The growth among fishes, like other organism are affected by several factors like abundance of food, ambient physical environment, internal biological cycles (e.g. reproductive cycles), etc. Growth monitoring is a key discipline in fisheries, be it capture or culture sector. Growth can be monitored either in terms of change in length or weight. Weight-length relationship enables the inter-conversion of these two measures of growth. Establishing weight-length relationships though a routine exercise in fisheries, still the relationships are available for a limited number of species, considering the enormous α-diversity among fishes (Kulbicki et al. 2005; Froese, 2006).

Historical background of length -weight relationship

The history of weight-length relationship has its conceptual origin in 'square-cube law' of Galileo Galilei, who perhaps was the first person to pronounce that volume increase as the cube of linear measurements whereas the strength only as square. Subsequently, Herbert Spencer, in his *Principles of Biology,* reaffirmed that in similarly shaped bodies the masses, and hence weights are a function of cube of linear dimension, which later became cube law. Fulton (1904) proposed what is called as Fulton's condition factor as:

$$K = 100\frac{W}{L^3}$$

Where W = body weight in grams and L is length in cm.

He applied cube law to several fish species of North Sea and found that the law does not explicitly fit in fishes, rather most of the fishes gain more weight for length than explained by the cube law. Further, he also noticed that the variations are governed by seasons, location, and reproductive status. He thus laid the conceptual background for what is today known as 'allometric growth'.

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Subsequently, several workers like Jarvi (1920) and Weymouth (1922) have highlighted the inability of cube law to explain the weight-length relationship in fishes. Keys (1928) while working on California killifish, found cube law inefficient in explaining the weight-length relationship and established the modern relationship between weight and length in fishes as:

$$W = aL^b$$

Where W and L are weight and length and a and b are parameters.

He also gave the logarithmic equivalent of the above mentioned exponential function as:

$$Log\ W = Log\ a + b * Log\ L$$

But prior to formal publication of Keys (1928) work, Clark (1928) proposed the logarithmic form of weight-length relationship and applied the least-square regression to estimate the parameters. Clark (1928) works got a wide audience and the logarithmic function of his started being used.

Le Cren (1951) gave an exhaustive review of WLRs and condition factors and highlighted the limitation of Fulton's factor, which can be applied only when b is not significantly different from the value of 3 or the specimens were of comparable size. To address the limitation in condition factor of Fulton (1904), Le Cren (1951) proposes an index known as relative condition factor as:

$$K_{rel} = \frac{W}{aL^b}$$

Where W and L are observed weight and length and a and b are parameters of WLR.

Ricker (1958) used the term 'isometric growth' for the values of b =3, whereas Tesch (1968) introduced 'allometric growth' for values of b higher or lower than 3.

Application of weight-length relationship

- The conversion of length data in to weight and vice versa, when other measure is not available.
- To convert the growth-in-length (von Bertalanffy growth function) equation to growth-in-weight form (parameter b of LWR is required) for stock assessment.
- Calculation of biomass of the species from the available length-frequency data from commercial catches or experimental fishing.
- Conversion of length data (length) in to biomass in case of under-water surveys.
- To assess the condition of the fish in culture and capture fisheries (derivatives of WLR like condition or relative condition factor).
- Corroborate the findings of reproductive biology studies (comparison with K or K_{rel})
- Potential use of slope of regression (b) for species separation (Al-Hassan et al., 1988).

Estimation of weight-length relationship in fishes

The weight-length relationship in fishes can be estimated using least square regression method using logarithmic function, *Ln W = Ln a + b*Ln TL,* where *W* and *L* are weight and length and *a* and *b* are parameters to be estimated. There are some important things that are to be kept in mind while collecting data for estimation of weight-length relationships.

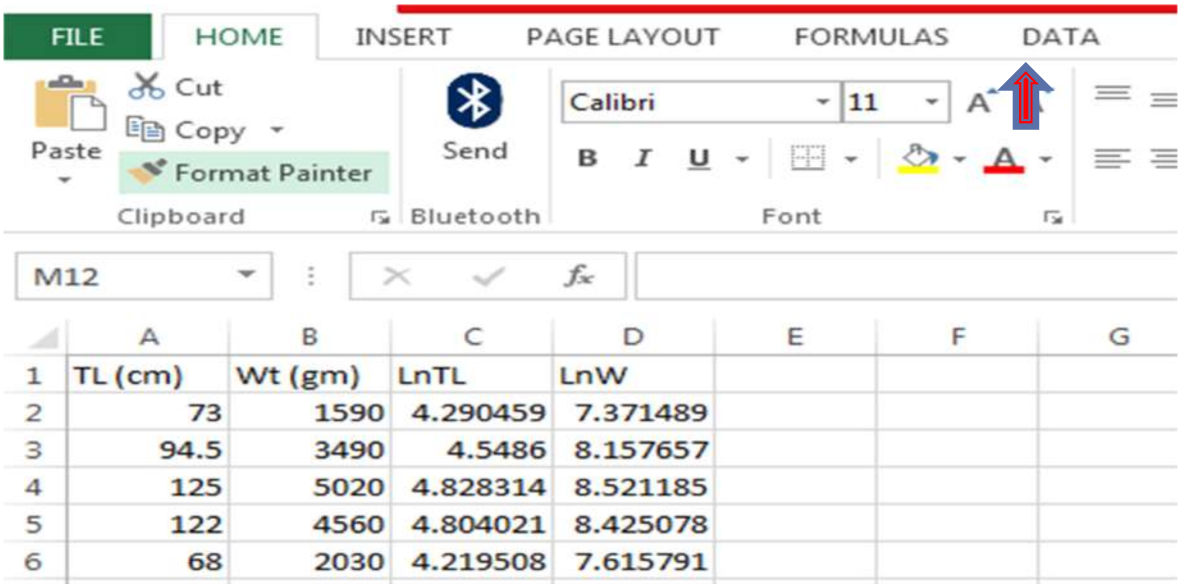
- The sample should cover different life stages of fishes. The representative samples from juveniles, sub-adults and adult phased should be covered. It is recommended to have samples from the least possible size to close of reported L_{max}. Further, it is better to have samples evenly distributed across different life-stages.
- The samples should be categorized in groups like males or females or different growth stanzas (juvenile, sub-adults, adults) based on the research question. Comparison of growth coefficient (b) across male and female are predominately practiced.
- The sufficient number of specimens must be observed to have robust and realistic estimates of the parameters. The sample size of 100, evenly distributed across different growth stanzas, should be sufficient (Froese et al., 2011).
- It is recommended to have samples collected over the entire year or all seasons of the year to capture any seasonal variations. One time sampling is mostly discouraged.

There are certain best practices in data pre-treatment and reporting (Froese et al., 2011). They are:

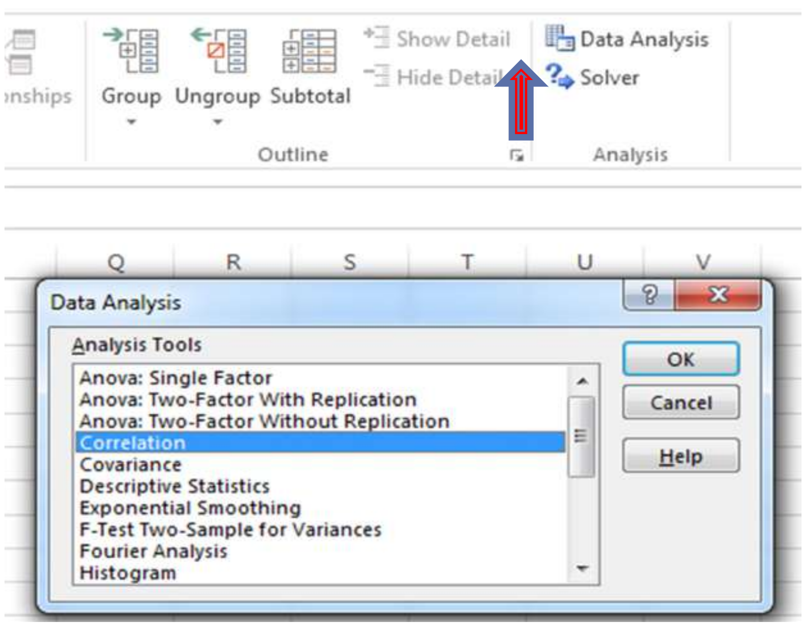
- Prior to fitting linear regression, the log-transformed variables must be plotted and outliers must be removed.
- The results of the analysis should include the minimum and maximum length and weight of the specimens in the sample.
- The presented results should include values for intercept (a) and slope (b) along with their 95% confidence limits, sample size (n) and coefficient of determination (r^2). The value of coefficient of determination (r^2) << 0.95 may be indicative of remaining outliers and data must be revisited to rectify the issue, if any.
- If the hypothesis of the work is to check its deviation from isometry (b = 3), it must be supported by a statistical test (student *t*-test).
- If the hypothesis of the work is to compare the WLR across different group (across sexes, growth stanzas, areas, etc.), both intercept and slopes should be tested for significant difference using appropriate statistical test (e.g. ANCOVA).

Demonstration of Correlation between length and weight of the fishes in MS-Excel

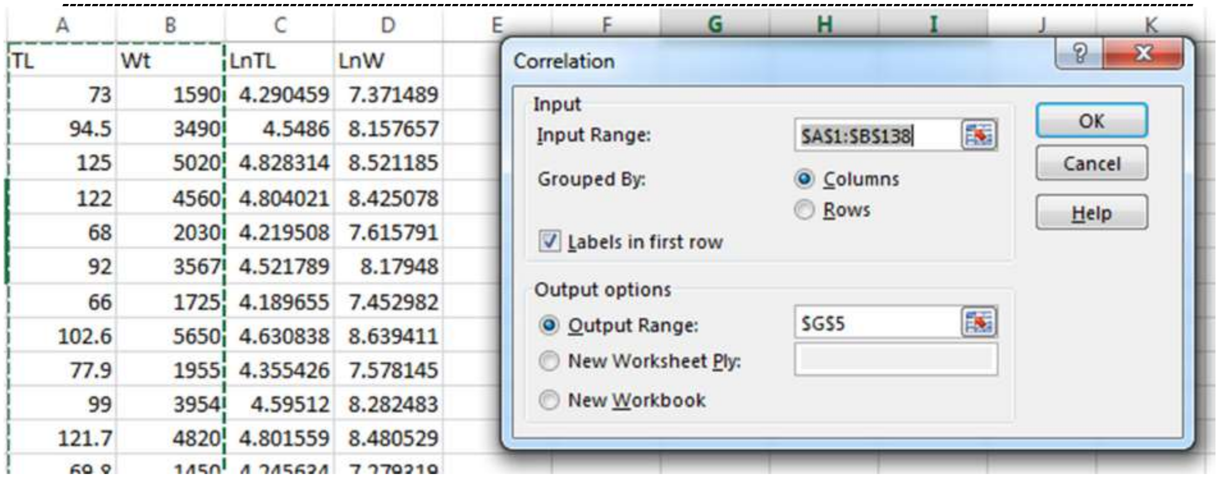
MS-Excel is most common preliminary data tabulation and analysis package familiar to most of the biologist and it can be used to basic fishery data analysis. The data for correlation and regression can be arranged in columns as shown below:



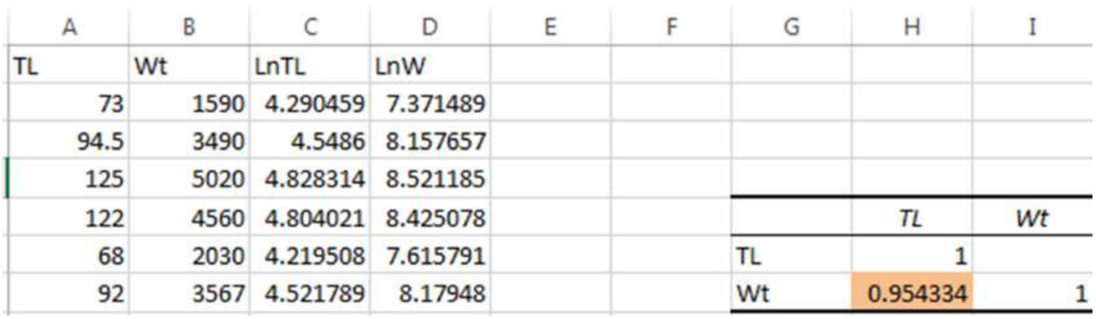
The column A and B have raw data of length (in cm) and weight (in grams) whereas column C and D have log-transformed data, here natural logarithm has been taken using function ***LN().***The linear regression can be carried out using **Data Analysis** package under **DATA** tab in main menu bar. The **Data Analysis** package may not be present under **DATA** tab as a default setting. In that case, it can be added by going to ***File – Options – Add-ins – Analysis Toolpak –OK***. Column A and Column B can be used as input columns for visualizing the correlation between length and weight variables of the fishes. The correlation coefficient (r) is generally high in related variables. Once we click on Data Analysis tab, a drop-down menu will appear as follows:



We should select **Correlation** and click **OK**. Once, we click **OK**, a new window will appear.



For **Input range**, we need to select entire data cells in Column A (TL) and Column B (Wt) We also have to check options **column** as variables are here arranged in columns and option **Labels in first row** as the column heading are presented in first row. We also have to select output range where the results of the analysis will appear. Here we have selected cell number G5 (results can also be taken to a new worksheet by selecting alternate options available in the window). After filling all the mandatory field, we click **OK** which leads us to the results as output.

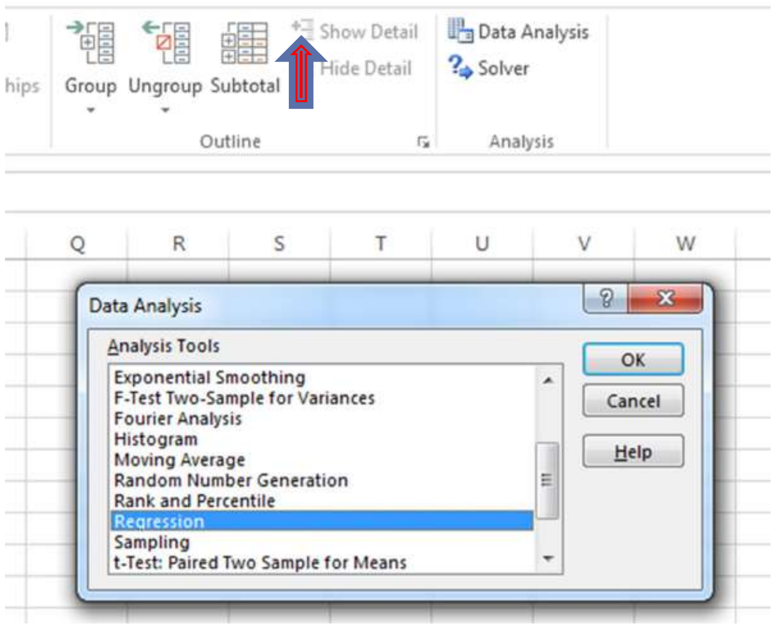


The correlation coefficient (r) between total length (TL) and weight (Wt) in the present example was found to be 0.954 (cell in light orange), which is high, indicating underlying positive (as the value is +ve) relationship between the variables which will be subsequently explored using least square regression technique.

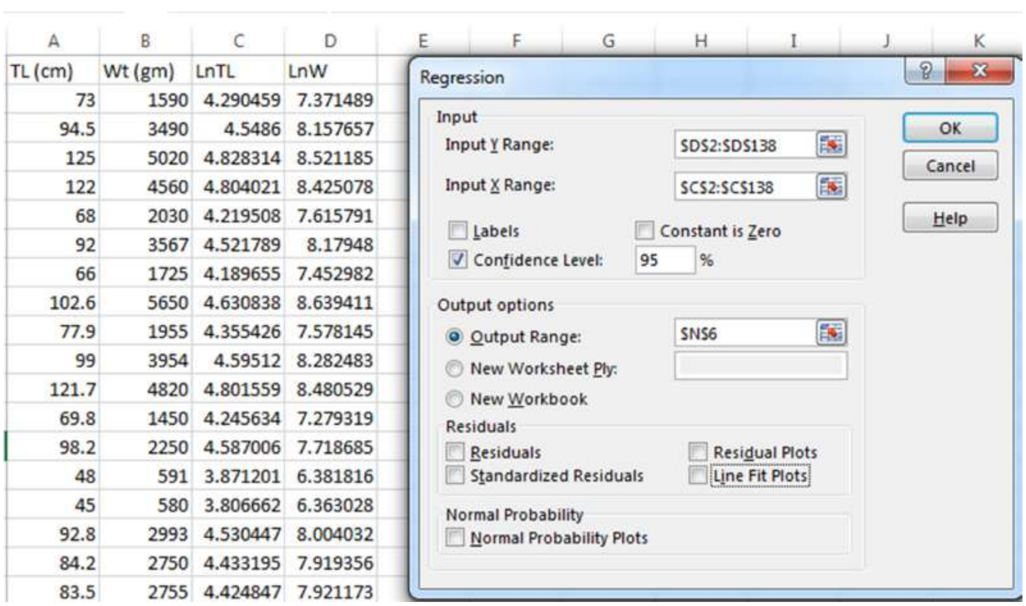
Demonstration of Linear regression for estimation of WLR in MS-Excel

Column C (x) and column (y) will be used for linear regression.

The linear regression can also be carried out using **Data Analysis** package under **DATA** tab in main menu bar. Once we click on Data Analysis tab, a drop-down menu will appear and we should select **Regression** and click **OK.**



Once we click **OK**, a new window will appear asking to select data and other informations.



For **Input Y range**, we need to provide cells having data for LnW (here column D) and for **Input X range** we select LnTL (here column C). We have also checked Confidence Level and set as 95% (default), which will give us the 95% confidence limits for slope (b) and intercept (a). We also have to select output range where the results of the analysis will appear. Here we have selected cell number N6. After filling all the mandatory field, we click **OK** which leads us to the results as output.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.961337
R Square	0.924168
Adjusted R Squ	0.923607
Standard Error	0.15877
Observations	137

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	41.47369	41.47369	1645.258	1.74891E-77
Residual	135	3.403083	0.025208		
Total	136	44.87677			

	Coefficients	*Standard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-2.94756	0.261018	-11.2925	3.11E-21	-3.46377098	-2.431344372
X Variable 1	2.420096	0.059664	40.56178	1.75E-77	2.30209783	2.538093634

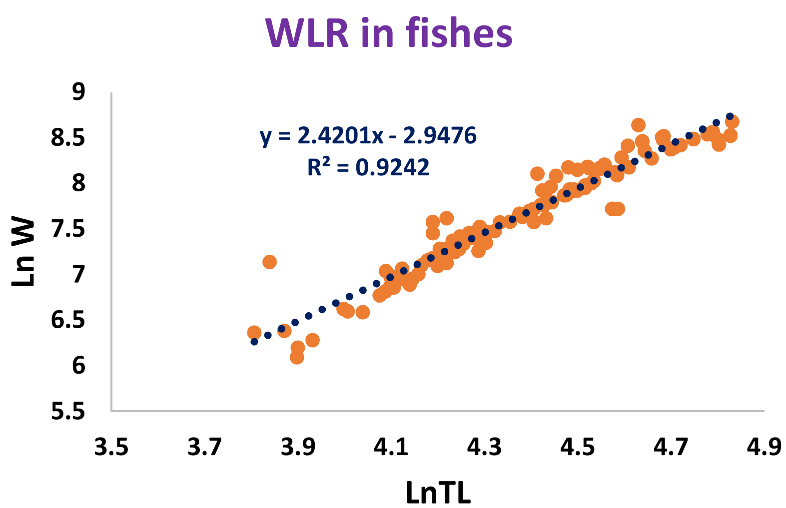
The output includes an ANOVA table and a separate table having the values of coefficients (model parameters). The cell in green represents the value of intercept (*Ln a*) while the blue cells represent the value of slope (b). The cells marked in grey are the 95% confidence limits of the corresponding coefficients and the cell in yellow gives the model fit as the coefficient of determination (r^2). The output can be written in a function form as:

$LnW = -2.947 + 2.420 * LnTL$; $r^2 = 0.924$

If we want to write the function in exponential form, first we need to convert the intercept by using an exponential function in MS-Excel (= EXP (-2.947) which gives the value of 0.052). The exponential function can be thus:

$W = 0.052 * TL^{2.42}$; $r^2 = 0.924$

The WLR relationship can also explored using graphical options in excel. The **scatterplot** options from **Charts** under **Insert** tab of main menu can be selected. The axis and other features can be customized to be presentable using **Chart tools.** Also the linear function and r^2 values cab be displayed on graph using **Add trendline option** and checking **Display equation on chart** and **Display R-squared value on chart** options appearing as pop-ups.



The value of regression slope (b) can be interpreted as:

- Isometric growth: b = 3.0
- Positive allometric or hyper-allometeric growth: b > 3.0
- Negative allometric or hypo-allometric growth: b < 3.0

In statistical terms, the deviation from the isometry (b =3) can be tested using students t-test where the null hypothesis is H_0: b =3 and the alternate hypothesis is H_1: b ≠ 3. The test statistic need to be compared with the table value for n-2 degrees of freedom, where n is the number of observations. The t-statistics can be calculated as:

$$t = \frac{|b-3|}{SE_b}$$

Where b is the slope of the regression (cell highlighted in blue) and SE is the standard error of the b (cell highlighted in orange). The calculated value of t in the example is 9.71 which is much higher than the table value of 1.97 (we must select the two-tailed value from the table). Hence, we have rejected the null hypothesis and accepted the alternate hypothesis of non-isometric (or allometric growth). As the value of slope is less than 3 in example, it is a case of negative allometric growth.

***Note:** The demonstration excel sheet (demoLWR.xlxs) having data and analysis carried out are provided for reference and practice.*

Correlation & Linear regression for estimation of WLR in R statistical package

R statistical package is a free software environment for statistical analysis and graphical presentation of data and more and more biologist are getting familiarized with the working environment of the package. The above example of linear regression can also be done using R package and incorporated for trainees who are keen towards using the package in fisheries data analysis. The same data as above in excel can be saved as CSV file for import in R. The data can be called in to R environment and saved as name **demodata** using code:

```
>demodata <- read.table(file.choose(), sep = ",", header = TRUE)
```

The above code opens a window and prompt you to select the .csv file (data file) that you have prepared earlier. Once the data in called to the R environment, one can visualize the data just by giving code

>demodata

This will print the entire data in the R console as:

```
> demodata
     TL   Wt    LnTL      LnW
1  73.0 1590 4.290459 7.371489
2  94.5 3490 4.548600 8.157657
3 125.0 5020 4.828314 8.521185
4 122.0 4560 4.804021 8.425078
```

The correaltion coefficient between total length (TL) and wieght (Wt) can be estimated using following code which will estimate the pearson corealtion coefficient (0.954) and display in R-console. Along with the value of correaltion coeffiecnt it will also provide the 95% confidence interval for the same.

> cor.test(demodata$TL, demodata$Wt)

```
	Pearson's product-moment correlation

data:  demodata$TL and demodata$Wt
t = 37.117, df = 135, p-value < 2.2e-16
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.9365133 0.9672367
sample estimates:
      cor
0.9543337
```

The linear regreesion can be carried out using following code as saved as object LWR in R environment.

>LWR <- lm(LnW ~LnTL, data = demodata)

The summarized results of the regression can be vizualized in R console using code:

>summary (LWR)

The output will be printed as:

```
Call:
lm(formula = LnW ~ LnTL, data = demodata)

Residuals:
     Min       1Q   Median       3Q      Max
-0.43475 -0.06145 -0.00609  0.05906  0.79299

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -2.94756    0.26102  -11.29   <2e-16 ***
LnTL         2.42010    0.05966   40.56   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1588 on 135 degrees of freedom
Multiple R-squared:  0.9242,    Adjusted R-squared:  0.9236
F-statistic:  1645 on 1 and 135 DF,  p-value: < 2.2e-16
```

The results and the values of intercept, slope, r^2, etc. will be interpreted in the same manner as the output given by MS-Excel.

***Note:** The demonstration data file (demoLWR.csv) has been provided for reference and practice.*

As pointed out by Kulbicki et al. (2005) and Froese (2006) that despite being considered routine work in fisheries science, there a large void in the information available for weight-length relationship of large number of fish species. Froese (2006) further emphasized that establishing LWR for fishes are increasingly considered work not worthy of publication in reputed scientific journals discouraging such work, which many time hampers the efforts to model aquatic ecosystem where conversion of length data to biomass is required. It is recommended to have more dedicated efforts towards establishing WLRs for fishes, especially those which are indigenous and have restricted distribution along Indian coast.

Importance of LWR

The length-weight relationship in fishes is influenced by a number of factors including season, habitat, gonad maturity, sex, diet, stomach fullness, health and differences in the length ranges, sampling amounts of the specimen caught (Tesch, 1968). It must be noted, however, that LWRs differ among fish species depending on the inherited body shape and the physiological factors such as maturity and spawning (Schneider et al., 2000). This relationship might change over seasons or even days (De Giosa et al., 2014). It is argued that "b" may change during different time periods illustrating the fullness of stomach, general condition of appetite and gonads stages (Zaher et al., 2015). In addition, the growth process can differ in the same species dwelling in diverse locations, influenced by numerous biotic and abiotic factors. LWR play a major role in describing the different stages when describing different taxonomic groups which change morphologically during their growth like flatfishes.

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CHAPTER 47

Conservation and Sustainable Fishery Management in Marine Fisheries – Implications on Export Trade

1) Introduction

The export markets have become more sensitive about the conservation and sustainability of the resources. The regulatory requirements from importing countries have become more stringent requiring the exporting nations to provide credible proof to satisfy the requirements of sustainability and food safety. Simultaneously the markets also have come up with various sustainable certification systems for suppliers. To continue the smooth flow of the trade, additional investments in Monitoring, Control & Surveillance and multiple sustainability certifications is required. As a result exporting nations need to upgrade the traceability mechanisms and also the export trade has to bear the additional costs toward multiple sustainability certifications. The following sections give a brief on various market access issues faced by the seafood export trade and suggests supports required from the scientific research.

2) Export Scenario

During the financial year 2020-21, India exported 11,49,510 MT of Seafood worth US$ 5.96 Billion. USA and China are the major importers of Indian seafood.

Frozen Shrimp continued to be the major export item followed by frozen fish. Frozen shrimp contributed 51.36 per cent in quantity and 74.31 per cent of the total dollar earnings.

USA remained its largest importer (2,72,041 MT), followed by China (1,01,846 MT), EU (70,133 MT), Japan (40,502 MT), South East Asia (38,389 MT), and the Middle East (29,108 MT). However, shrimp exports declined by 9.47 per cent in dollar value and 9.50 per cent in quantity. The overall shrimp export was 5,90,275 MT worth 4,426.19 million dollars. The export of Vannamei (whiteleg) shrimp decreased from 5,12,204 MT to 4,92,271 MT in 2020-21. Of the total Vannamei shrimp exports in dollar value, 56.37 per cent was exported to USA, followed by China (15.13 per cent), EU (7.83 per cent), South East Asia (5.76 per cent), Japan (4.96 per cent) and the Middle East (3.59 per cent).

Frozen fish, with a share of 16.37 per cent in quantity and 6.75 per cent in dollar earnings, retained the second position in exports basket though its shipments plummeted by 15.76 per cent in quantity and 21.67 per cent in dollar terms.

Other Items', the third largest category that largely comprised Surimi (fish paste) and Surimi analogue (imitation)products, showed a marginal growth of 0.12 per cent and 0.26 per cent by quantity and rupee value, respectively, but declined in dollar terms by 5.02 per cent.

Frozen squid and frozen cuttlefish exports declined in volume by 30.19 per cent and 16.38 per cent, respectively. However, dried items showed an increase of 1.47 per cent and 17 per cent in quantity and rupee value, respectively. Shipments of chilled items and live items, which were negatively affected due to the reduced air cargo connectivity in the pandemic situation, fell by 16.89 per cent and 39.91 per cent in volume, respectively. Capture fisheries contribution reduced from 56.03 per cent to 53.55 per cent in quantity and from 36.42 per cent to 32.01 per cent in dollar value. However, tilapia and ornamental fish performed well with 55.83 per cent and 66.55 per cent increase in quantity and an uptick of 38.07 per cent and 14.63 per cent in dollar earnings, respectively. Tuna showed 14.6 per cent increase in quantity, but its dollar earnings downed by 7.39 per cent. Crab and scampi exports reduced both in quantity and value.

The Government of India has fixed marine product export target of USD 7.81 billion for 2021-22. As per provisional estimates, during April – October 2021-22, the export achievement is US$ 5.39 billion (69% against the target of 67 %) as per DoC data. Balance Export target for 2021-22 second half is US$ 2.41 billion.

3) Market access issues faced by seafood export from India

A. Turtle Excluded Devices (TED) –USA

Section 609 of US Public law 101-162 mandates that our shrimp trawlers should be fitted with Turtle Excluded Devices (TED) during the fishing. Nations can be certified under this section, only if the trawl net is fitted with TED & the provision is effectively implemented with strict enforcement. Presently US banned export of wild caught shrimp from India due to non- implementation of TED and India has lost the US market for wild caught shrimp export which is worth around Rs. 2500 crores per annum.

B. USA Marine Mammal Protection Act (MMPA)

US have enacted the MMPA during 1972. US has brought the MMPA regulation in 2017 and requested all exporting nations to adhere to the MMPA regulations. NOAA – NMFS, USA has observed that the overall risk of the marine mammal by-catch in Indian fishery, as 'High'. India has to develop an appropriate regulatory program comparable in effectiveness to the US programs.

MPEDA has taken the initiative and entrusted CMFRI to conduct the Marine Mammal stock assessment study. Accordingly CMFRI and FSI have conducted Visual Survey in both offshore & onshore and for by-catch estimate CMFRI and NETFISH – MPEDA has conducted the survey. Based on the study report, India has submitted Comparability Finding Application (CFA) of US NOAA successfully on 25.11.2021 in order to fulfil the conditions of US-MMPA. The end of exemption period will be 31 December 2022. Non-compliance of MMPA will affect the export of sea caught materials to US worth Rs. 3000 crores per annum from 1 January 2023.

C. USA Seafood Import Monitoring Programme (SIMP)

The US authorities established a risk based Traceability programme from 1st January 2018 under which exporters have to furnish the traceability records of the seafood exported from India to the Importers On Record (IOR) in US. Currently, 17 species are listed under the SIMP, of which 9 species are exported from India (including Shrimp, Tuna etc). US SIMP covers the traceability of the materials exported to USA both aquaculture and sea caught. The shrimp farm enrolment programme of MPEDA provides the traceability details required by SIMP for farmed shrimp.

D. Illegal Unreported And Unregulated(IUU) Fishing- EU Regulation 1005/2008

EC Regulation No. 1005/2008 dated 29th September 2008 insist to prevent, deter and eliminate Illegal Unreported and Unregulated (IUU), fishing. To comply with the EU regulation, Catch Certificate is a mandatory export document for the export of all wild caught fishery products to European Union. Ministry of Commerce and Industries, Government of India has notified MPEDA as the nodal agency to validate catch certificates from 2010.

MPEDA developed an online catch certificate system for the validation of catch certificates to exporters. In the catch certificate system, 100 No of Harbour data collectors (HDC) are engaged for collection and entering of fishing vessel landing details in real time basis from major fishing harbour/landing centre in all maritime states of India. Catch certificates to exporters are issued from an exclusive portal called C-catch portal **(https://c-cert.mpeda.gov.in)**.

E. Detection of WSSV, IMNV & IHHNV in shrimp consignments exported from India

Biosecurity issues acts as a trade barrier in seafood trade. Detection of WSSV in shrimps exported to countries like Australia, Saudi Arabia, Kuwait and Canada will result in the rejection of export consignments. Detection of IMNV in farmed shrimp has resulted in suspension of farmed shrimp exports to Thailand by Thai authorities.

Recently China has came up with the detection of White spot syndrome viruses (WSSV) and Infectious Hypodermal Hematopoietic Necrosis Virus (IHHNV) in the frozen shrimp consignments which are exported to China. China suspended exports from 18 exporters.
By addressing the bio-security issues, India can capture 50% market in these countries which is USD 4.6 billion.

F. Shrimp trade and issues related to Antibiotic residue

(I) **European Union**

***(i) Increased sampling frequency for inspection of Indian farmed shrimps*:**
EU has increased sampling frequency from 10% to 50% for farmed shrimp to test antibiotic residues since October 2016. The higher rate of sampling of 50% is a trade barrier for export of aquaculture shrimps from India and is still continuing.

(ii) Addition of new fishery establishments which are handling Aquaculture products:
Based on our requests in various bilateral meetings including the 13th SPS - TBT Joint Working Group held in July 2020, 57 new units and 5 de-listed units have been permitted to export sea caught items since November 2020.

More than 15 seafood processing units qualified for approval and recommended by the Export Inspection Council of India (EIC) for aquaculture products / Fish meal, are awaiting listing by the EU to export fish & Fishery products to the member countries. These units have invested heavily in setting up units that meet the EU norms and the EU market is being denied to them.

(II) Japan
(i) Compulsory inspection of Indian farmed Shrimps:

Farmed shrimp exports to Japan are subjected to 100% inspection by Japanese health authorities for Nitrofuran metabolite, AOZ (antibiotic residue).
There has been no detection of AOZ in Black Tiger shrimp since 2013. In early March 2020, an inspection team from Ministry of Health Labour and Welfare, Japan visited Black Tiger shrimp farms, hatcheries and processing sites in India. Subsequently, Japanese Government has decided to lift the Inspection Order for Black Tiger among Indian cultured shrimp and its processed products. In continuation Japan health authorities has withdrawn import inspection of farmed Indian black tiger shrimp for banned antibiotics since December 2020. However, the 100% inspection continues for vannamei shrimp imports as there is continued detection of Nitrofuran metabolites (AOZ) in the consignments

G. Lack of sustainable certification programme for sea caught materials
Certification of fishery to promote sustainable practices in the areas of capture and culture fisheries will support the increased access to international market. As a first step, Fishery Improvement Programme (FIP) such as reduction in juvenile fish catch by use of square mesh cod end in trawl fishery, TEDs etc need to be implemented in all major fisheries in the country. Certification of fishery can be used as an extension of the normal monitoring, conservation and enforcement activities for reducing illegal, unreported and unregulated (IUU) fishing. Certification also ensures the hygienic handling of fishes, job security and betterment of fisher's livelihood in the future.

Fishery in India is complex and it involves multi-species fishing, therefore selection of a single species in a fishery for certification is challenging. The factors such as high cost of certification, requirement for improved record keeping and management are discouraging factors for certification from small scale fishers/farmers in the country.

H. Actions required from Research Institutions on the trade issues

1) Sustainable Fishery Certification and IUU

a) A model sustainable certification programme suitable for Indian marine capture fishery may be developed and demonstrated.
b) Innovations in recording, monitoring and reporting the catch on board using latest technological solutions
c) Research to develop indigenous two-way communication equipment with latest technologies for the Vessel monitoring system (VMS) and ISAT Phone for safety of fishermen as well as meeting the traceability requirements.
d) Juvenile fishing- CMFRI has already come up with Minimum Legal Size (MLS) for certain States such as Kerala, Tamil Nadu and Karnataka. The study should be conducted in remaining maritime states to recommend the MLS for different species.

2) Marine Mammal and Turtle conservation

a) Bring out a status paper on trawl, gillnet, long line and purse seine fishery of India and impact of these fishing methods on the marine mammal and turtle population in Indian EEZ with recommendations to concerned state Fisheries departments and DoF, Govt. of India for overcoming the impact.
b) Organise a marine mammal stock assessment programme in collaboration with all the institutions concerned
c) Carry out the gear wise mitigation studies to prevent the by-catch especially of Turtles and Marine Mammals.

3) Antibiotic Residues & Biosecurity issues in farmed shrimp

a) Bring a status paper on antibiotic residue and bio security issues in shrimp production and its impact on seafood export from India and concrete recommendations in compliance with OIE, codex, or importing countries requirements in these areas.
b) As shrimp is a major item for commercial aquaculture and export earnings, research need to be concentrated on production and processing sector of shrimp to address the A & B issues, suitable technological interventions for production of disease free crop viz. real time crop monitoring through ICT technologies, artifical intelligence etc may be focused.
c) Models for disease free area/ Zone/ region for shrimp production in the country also need to be demonstrated by the scientific community to the farmers to emulate the same in different areas for production of quality shrimp in compliance with OIE guidelines.

CHAPTER 48

Taxonomy of family Hemiramphidae

Introduction

The fisheries sector has been recognized as a powerful income and employment generator, as it stimulates growth of number of subsidiary industries and as a source of high quality and nutritious food. occupies an important place in the socio-economic development of the country. India is very rich in marine natural resources, with a coastline of about 8129 km and 2.02 million sq. km of exclusive economic zone (EEZ).The potential of fish from the coastal waters of India is exploited to the maximum and hence; there is need for finding an alternate resource to increase production. Exploitation of Beloniformes resources is identified as one of the thrust area for increasing fish production and export of Indian marine products.

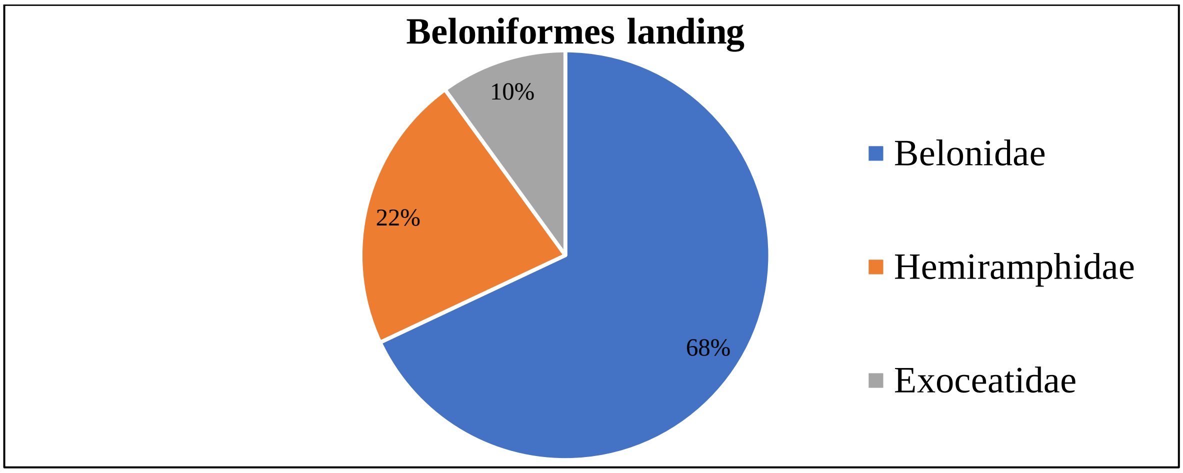
Order Beloniformes

The order Beloniformes is a large order of marine and freshwater epipelagic fishes represented worldwide by six families and 285 species, including:Rice and Duck-billed Fishes (Adrianichthyidae), Needle Fishes (Belonidae), Sauries (Scomberesocidae),Halfbeaks (Hemiramphidae), Flyingfishes (Exocoetidae) and Viviparous halfbeak (Zenarchopteridae). A total of 19 species (representing four families) have been reported from European waters and the Mediterranean Sea, including at least four species from Irish waters (Quigley, 2017).

Several authors reported the distribution of Beloniformes from Indian waters. 50 species belonging to 17 genera under three families along the Indian coast (Gopi and Mishra, 2015). Laxmappa and Bakshi (2016) reported four species belonging to three genera under three families from Telangana State. Venkataraman *et al*. (2014) reported nine species of Beloniform fishes belonging to 7 genera under three families along Digha coast in West Bengal. Joshi *et al*

Toji Thomas, Dona Jacob and E.M. Abdussamad *ICAR-Central Marine Fisheries Research Institute, Kochi, Kerala*

(*2016*) reported nine species of Hemiramphidae from the Gulf of Mannar. Shaji and Easa (2001) reported two species of Hemiramphidae from the rivers of the Western Ghats.



Family Hemiramphidae

Family *Hemiramphidae*, commonly called halfbeaks, is a fast growing, epipelagic, coastal fish with economic importance to commercial fisheries throughout its worldwide distribution in tropical and sub-tropical waters. It is the sister-group of the Exocoetidae, the flying fishes, forming the superfamily Exocoetoidea (Collette et al., 1986).

The family Hemiramphidae is having 62 valid species comprise of eight genera, namely *Arrhamphus*, *Chriodorus*, *Euleptorhamphus*, *Hemiramphus*, *Hyporhamphus*, *Melapedalion*, *Oxyporhamphus* and *Rhynchorhamphus*.

The halfbeaks are elongate, streamlined fish adapted to living in open water. Halfbeaks can grow to over 40 centimetres (16 in) SL in the case of *Euleptorhampus viridis*. The scales are relatively large, cycloid (smooth), and easily detached. There are no spines in the fins.A distinguishing characteristic is that the third pair of upper pharyngeal bones are fused into a plate. Halfbeaks are one of several fish families that lack a stomach, all of which possess a pharyngeal jaw apparatus . Most species have an extended lower jaw, at least as juveniles, though this feature may be lost as the fish mature, as with *Chriodorus*, for example.

As is typical for surface dwelling, open water fish, most species are silvery, darker above and lighter below, an example of countershading. The tip of the lower jaw is bright red or orange in most species.Halfbeaks carry several adaptations to feeding at the water surface. The eyes and nostrils are at the top of the head and the upper jaw is mobile, but not the lower jaw. Combined with their streamlined shape and the concentration of fins towards the back, these adaptations allow halfbeaks to locate, catch, and swallow food items very effectively.

Halfbeaks inhabit warm seas, predominantly at the surface, in the Atlantic, Indian, and Pacific oceans. A small number of species are found in the estuaries. Most species of marine halfbeaks are known from continental coastlines, but some extend into the western and central Pacific. *Hemiramphus* is a worldwide marine genus.

Marine halfbeaks are omnivores feeding on algae; marine plants such as seagrasses; plankton; invertebrates such as pteropods and crustaceans; and smaller fishes. For some subtropical species at least, juveniles are more predatory than adults. Some tropical species feed on animals during the day and plants at night, while other species alternate between carnivory in the summer and herbivory in the winter. They are in turn eaten by many ecologically and commercially important fish, such as billfish, mackerel, and sharks, and so are a key link between trophic levels.

Marine halfbeaks are typically pelagic schooling forage fish. Some marine halfbeaks, including *Euleptorhamphus velox* and *Euleptorhamphus viridis*, are known for their ability to jump out of the water and glide over the surface for considerable distances, and have consequently sometimes been called flying halfbeaks.

Hemiramphidae species are all external fertilizers. They are usually egg-layers and often produce relatively small numbers of fairly large eggs for fish of their size.

Relatively little is known about the ecology of juvenile marine halfbeaks, though estuarine habitats seem to be favoured by at least some species.

Halfbeaks are not a major target for commercial fisheries, though small fisheries for them exist in some places are caught by a variety of methods including seines and pelagic trawls, dip-netting under lights at night, and with haul nets.

They are utilized fresh, dried, smoked, or salted, and they are considered good eating. However, even where halfbeaks are targeted by fisheries, they tend to be of secondary importance compared with other edible fish species.In some localities significant bait fisheries exist to supply sport fishermen.

Halfbeaks forms a commercial fishery in southern coast of India, especially along the Kerala and Tamil Nadu coast. Information on the taxonomy, biology and fishery dynamics of the species is very limited

Scientific Classification

Kingdom : Animalia

Phylum : Chordata

Sub phylum : Vertebrata

Class : Actinopterygii

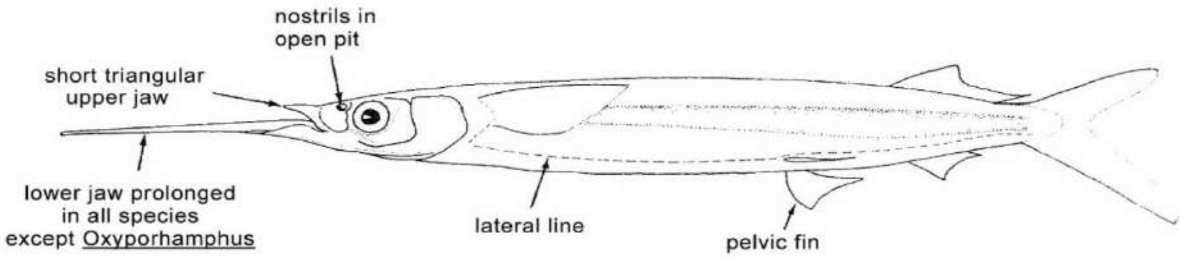
Sub class : Teleostei

Order : Beloniformes

Superfamily : Exocoetiodea

Family : Hemiramphidae

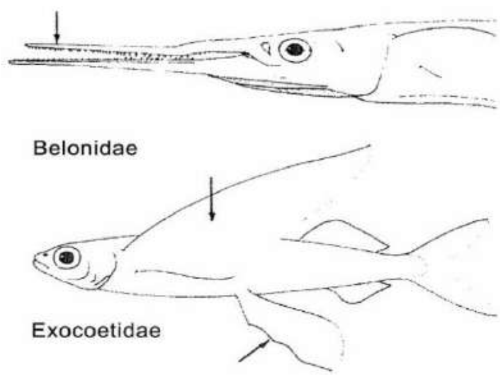
(TN gill, 1859)



SIMILAR FAMILIES OCCURRING IN THE AREA:

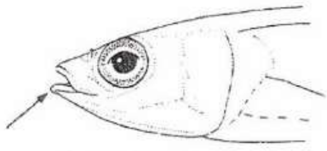
Belonidae (needlefishes): both upper and lower jaws elongated and armed with needle-sharp teeth.

Exocoetidae (flyingfishes): lack the prolonged lower jaw characteristic of most halfbeaks; pectoral fins or both pectoral and pelvic fins enlarged and used for aerial gliding.



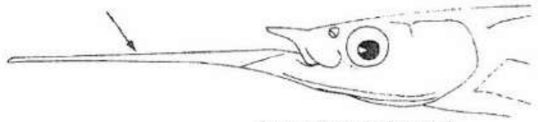
KEY TO GENERA OCCURRING IN THE AREA:

1a. Lower jaw not noticeably elongate (Fig.1); pectoral fins 30 to 35% of standard length .... Oxyporhamphus



Oxyporhamphus Fig.1

1b. Lower jaw distinctly elongate (Fig.2); pectoral fins less than 30% of standard length



lower jaw prolonged in all species except Oxyporhamphus Fig.2

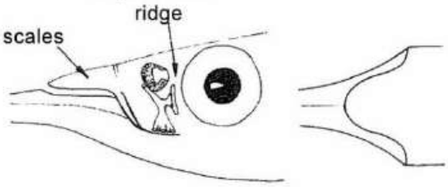
2a. Dorsal fin rays 20 to 25; anal fin rays 20 to 25 (Fig.3a); pectoral fins long, 25 to 28% of standard length; pectoral fin rays usually 7 to 9 .... Euleptorhamphus

2b. Dorsal fin rays 12 to 18; anal fin rays 10 to 19 (Fig.3b); pectoral fins short, less than 20% of standard length; pectoral fin rays 9 to 13

a) Euleptorhamphus b) Hemiramphus Fig.3

3a. Scales absent on snout; preorbital ridge absent (Fig.4a) .... Hemiramphus

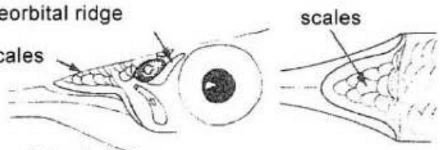
3b. Scales present on snout; preorbital ridge well developed (Fig.4b)



a) Hemlramphus

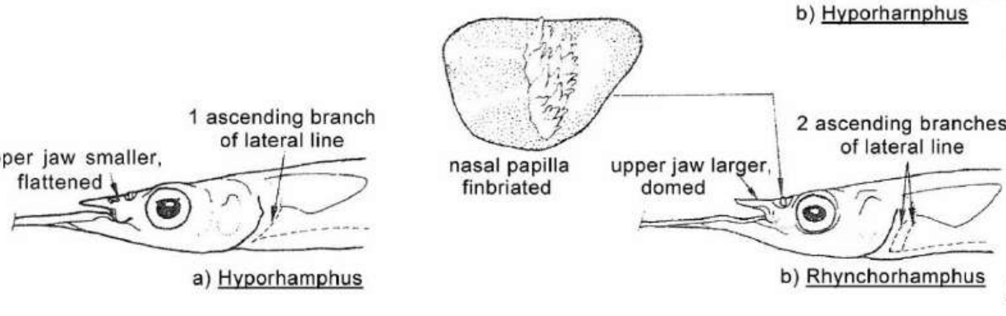
4a. Nasal papillae not fimbriate; upper jaw flat or nearly flat; gillrakers on first arch 19 to 47; lateral line with 1 branch ascending toward pectoral fin origin (Fig.5a).. Hyporhamphus

4b. Nasal papillae fimbriate; upper jaw arched; gillrakers on first arch 47 to 78; lateral line with 2 branches ascending behind opercle and pectoral fin origin (Fig.5b) .... Rhynchorhamphus



b) Hyporharnphus

Fig.4



a) Hyporhamphus b) Rhynchorhamphus Fig.5

1. **Genus *Hemiramphus***

Hemiramphus far (Forsskål, 1775)

Common name: Black-barred halfbeak

Dorsal spines and anal spines absent, Dorsal soft rays : 12-15, Anal soft rays: 10 – 12, Greatly prolonged, beak-like lower jaw, upper jaw short, triangular and without scales, preorbital ridge absent, total number of gill rakers on first gill arch 25-36, pectoral fins short, not reaching past nasal pit when folded forward, with 3-9 vertical bars on the sides, Color bluish dorsally, silvery on sides, 36-41 predorsal scales, Lower lobe of caudal fin longer than upper lobe, Dorsal and anal fins located posteriorly

Hemiramphus archipelagicus Collette & Parin, 1978

Common name: Jumping halfbeak

Dorsal spines and anal spines are absent, Dorsal soft rays : 12-15, Anal soft rays: 10 – 13, Greatly prolonged, beak-like lower jaw, upper jaw short, triangular and without scales, preorbital ridge absent, total number of gill rakers on first gill arch 25-32, dorsal fin without well-developed anterior lobe, pectoral fins short, not reaching past nasal pit when folded forward, no vertical bars on sides.

Hemiramphus lutkei (Valenciennes, 1847)

Common name: Lutke's halfbeak

Dorsal spines and anal spines are absent, Dorsal soft rays (total): 12-15, Anal soft rays: 10 – 13, Vertebrae: 52 – 57, Greatly prolonged, beak-like lower jaw, upper jaw short, triangular and without scales, preorbital ridge absent, total number of gill rakers on first gill arch 33-46, pectoral fins long, reaching beyond anterior margin of nasal pit when folded forward, no spots or vertical bars on sides.

2. Genus Hyporamphus

Hyporhamphus affinis (Günther, 1866)

Common name: Tropical halfbeak

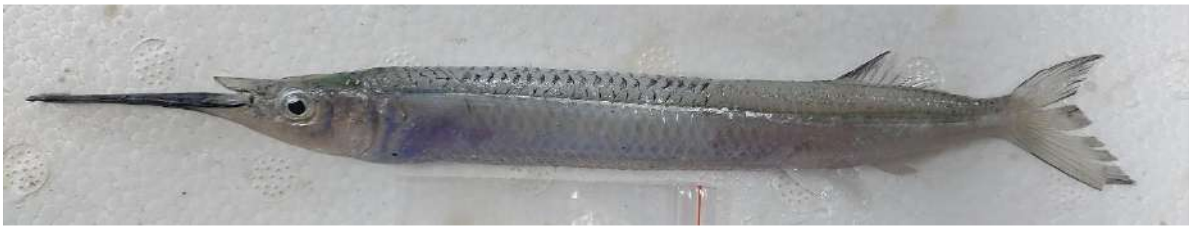
Dorsal spines and anal spines are absent, Dorsal soft rays: 14-17, Anal soft rays: 15 - 19 Vertebrae: 54 – 59, Body deep blue above, silvery stripe on side, silvery white below, caudal fin bluish, other fins unpigmented, tip and distal half of underside of lower jaw bright carmine red.

Hyporhamphus quoyi (Valenciennes, 1847)

Common name: Quoy's garfish

Dorsal spines and anal spines are absent, Dorsal soft rays : 14-17, Anal soft rays: 13 – 17 Vertebrae: 51 – 56, Prolonged, beak-like lower jaw, shorter than head length, its length contained in 4.7-8.6 times in SL and 1.2-2.0 times in head length, upper jaw short, scaly, blunt and rounded, its width contained in 0.5-0.6 times in its length, preorbital bone 1.75-2.15 times in diameter of orbit and 0.9-1.15 times in length of upper jaw, preorbital ridge present; posterior branch to preorbital lateral line canal present, Total number of gill rakers on first arch 26-39;Caudal fin forked, with lower lobe longer than upper.

Hyporhamphus xanthopterus (Valenciennes, 1847)



Common name: Red-tipped halfbeak/ vembanad halfbeak

Dorsal and anal spines are absent, Anal fin rays 14 - 16, Dorsal fin rays 13 - 15, A halfbeak with rounded nasal papilla, 41–53 gill rakers on first arch, upper jaw short, triangular and scaly, its width 0.8–1.0 times in its length, lateral line with one branch ascending towards pectoral fin base, fleshy tip of beak red, fins yellowish.

3. Genus Rhynchorhamphus

Rhynchorhamphus georgii (Valenciennes, 1847)

Common name: Long billed half beak

Dorsal spines and anal spines are absent, Dorsal soft rays : 13-17, Anal soft rays: 13 – 16, Vertebrae: 54 – 59, Very strongly pronounced domed upper jaw which is the longest and most arched of the four species of *Rhynchorhamphus*.

4. Genus Euleptorhamphus

Euleptorhamphus viridis (van Hasselt, 1823)

Common name: Ribbon halfbeak

Dorsal spines and dorsal spines are absent, Dorsal soft rays : 21-25, Anal soft rays: 20 – 25, Vertebrae: 70 – 75, Body very elongate; lower jaw very prolonged, upper jaw short, triangular, and scaly, teeth present on vomer and tongue, pectoral fins long, with 8 or 9 rays, back iridescent blue green, belly silvery, Fins unpigmented.

5. Genus Oxyporhamphus

Oxyporhamphus micropterus (Valenciennes, 1847)

Common name: Big wing halfbeak

Dorsal spines and anal spines are absent, Dorsal soft rays:13-15, Anal soft rays: 13 – 16, Vertebrae: 47 – 50, Adults with a single large chamber to the swim bladder, Average number of gill rakers on the first arch, 24 - 28, Branchiostegal rays: 11-14.

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LIST OF FACULTIES

S.No.	NAME	DESIGNATION
1.	Dr. E. Vivekanandan	Consultant, ICAR - CMFRI
2.	Dr. Prathibha Rohit	Principal Scientist & Head, PFD
3	Dr. Reeta Jayasankar	Principal Scientist & Head. FEMD
4.	Dr. P Laxmilatha	Principal Scientist & Head, MFD
5.	Dr. Josileen Jose	Principal Scientist & Head, CFD
6.	Dr. Joshi K.K	Principal Scientist & Head, MBD
7.	Dr J Jayasankar	Principal Scientist
8.	Dr. Sivadas Madhavan	Principal Scientist (Retd)
9.	Dr. Abdussamad. E.M	Principal Scientist
10.	Dr. Geetha Sasikumar	Principal Scientist
11.	Dr. Sujitha Thomas	Principal Scientist
12.	Dr. Rekha J. Nair	Principal Scientist
13.	Dr. T M Najmudeen	Principal Scientist
14.	Dr. Rajesh K M	Principal Scientist
15.	Dr. Sandhya Sukumaran	Principal Scientist
16.	Dr. Grinson George	Principal Scientist
17.	Dr. Rekhadevi Chakraborty	Principal Scientist
18.	Dr. Purushottama G. B	Senior Scientist
19.	Dr Shelton Padua	Senior Scientist
20.	Dr. Eldho Varghese	Scientist
21.	Dr. Subal Roul	Scientist
22.	Dr.Vidya R	Scientist
23.	Dr Kavita J	Scientist
24.	Dr.Ratheesh Kumar R	Scientist
25.	Dr. Mahesh V	Scientist
26.	Mrs Surya Ambareesh	Scientist
27.	Dr Sajikumar	Technical
28.	Mr. Aju K Raju	Technical
29.	Dr Sajeela K.A	Technical
30.	Dr. Ajmal Khan	External Expert
31.	Dr. Anil Mohapatra	External Expert
32.	Dr. Satish Sahayak	External Expert
33.	Dr. P. Anilkumar	External Expert
34.	Mr. Rahul G. Kumar	External Expert
35.	Dr K V Jayachandran	External Expert
36.	Dr. Abraham K J	External Expert
37.	Dr Manju Sebastian	External Expert
38.	Mr Toji Thomas	Research Scholar
39.	Ms. Ashley Gopinath	Research Scholar
40.	Mrs Sangeetha A T	Research Scholar
41.	Mrs. Vishnupriya K M	Research Scholar
42	Ms. Dona	Research Scholar

EXTERNAL EXPERTS (for online classes)

	**Franz Uiblein**	Research Professor, Institute of Marine Research, Bergen, Norway, World Expert on Goatfishes
	**Daniel Fernando**	Co-Founder and Director Blue Resources Trust, No 86, Barnes Place, Colombo 00700, Sri Lanka
	**P. Buddhi Maheshika**	Buddhi is working on the Sri Lanka Elasmobranch Project, Blue Resources Trust, No 86, Barnes Place, Colombo 00700, Sri Lanka
	**W. Sahan Thilakaratna**	He is working on the Sri Lanka Elasmobranch Project, Blue Resources Trust, No 86, Barnes Place, Colombo 00700, Sri Lanka
	**Christi Linardich**	Senior Research Associate Global Marine Species Assessment Marine Biodiversity Unit, IUCN Species Programme Old Dominion University, Norfolk, Virginia

	**Dr.Stuart G. Poss**	Research Associate, California Academy of Sciences World Expert on Scorpion fishes
	**Dr. Patricia Kailola**	Dr Patricia J Kailola Human Dignity Group Ltd Visiting Research Fellow, Institute of Applied Sciences, The University of the South Pacific Suva, FIJI

ദീപിക

04 January 2022

സിഎംഎഫ്ആർഐ വിന്റർ സ്കൂളിനു തുടക്കം

കൊച്ചി: സമുദ്രമത്സ്യ സമ്പത്തിന്റെ സംരക്ഷണവും സുസ്ഥിര പരിപാലനവുമായി ബന്ധപ്പെട്ട ശാസ്ത്രീയ പഠനങ്ങൾ ഗവേഷകരെ പരിശീലിപ്പിക്കുന്നതിനായി കേന്ദ്ര സമുദ്രമത്സ്യ ഗവേഷണ സ്ഥാപനം (സിഎംഎഫ്ആർഐ) സംഘടിപ്പിക്കുന്ന വിന്റർ സ്കൂളിനു തുടക്കമായി. യുഎൻ ഫുഡ് ആൻഡ് അഗ്രികൾച്ചർ ഓർഗനൈസേഷന്റെ (എഫ്എഒ) കീഴിൽ പ്രവർത്തിക്കുന്ന ബേ ഓഫ് ബംഗാൾ പ്രോഗ്രാം ഇന്റർ ഗവൺമെന്റൽ ഓർഗനൈസേഷൻ ഡയറക്ടർ ഡോ. പി. കൃഷ്ണൻ ഉദ്ഘാടനം ചെയ്തു.

21 ദിവസം നീണ്ടുനിൽക്കുന്ന വിന്റർ സ്കൂളിൽ ജമ്മു കാശ്മീർ, പഞ്ചാബ്, ത്രിപുര, ഉത്തർപ്രദേശ്, ഛത്തീസ്ഗഢ്, കർണാടക, തമിഴ്നാട്, കേരളം എന്നീ സംസ്ഥാനങ്ങളിൽ നിന്നുള്ള 21 ഗവേഷകർ പങ്കെടുക്കുന്നുണ്ട്. സമുദ്രമത്സ്യ ഗവേഷണവുമായി ബന്ധപ്പെട്ട വിവിധ വിഷയങ്ങളിൽ ഇന്ത്യക്കകത്തും പുറത്തുമുള്ള വിദഗ്ധരാണ് ഗവേഷകർക്ക് പരിശീലനം നല്കുന്നത്.

ചടങ്ങിൽ സിഎംഎഫ്ആർഐ ഡയറക്ടർ ഡോ. എ. ഗോപാലകൃഷ്ണൻ അധ്യക്ഷത വഹിച്ചു. വിന്റർ സ്കൂൾ കോഴ്സ് ഡയറക്ടർ ഡോ. രേഖ ജെ. നായർ, ഡോ. വി. മഹേഷ്, ഡോ. ആർ. രതീഷ് കുമാർ എന്നിവർ പ്രസംഗിച്ചു.

ദേശാഭിമാനി

04 January 2022

സിഎംഎഫ്ആർഐയിൽ വിന്റർ സ്കൂൾ തുടങ്ങി

കൊച്ചി

സമുദ്ര മത്സ്യസമ്പത്ത് സംരക്ഷണത്തിന്റെയും സുസ്ഥിര പരിപാലനത്തിന്റെയും ശാസ്ത്രീയ വിഷയങ്ങൾ ഗവേഷകരെ പരിശീലിപ്പിക്കുന്നതിനായി കേന്ദ്ര സമുദ്രമത്സ്യ ഗവേഷണ സ്ഥാപനം (സിഎംഎഫ്ആർഐ) സംഘടിപ്പിക്കുന്ന വിന്റർ സ്കൂളിന് തുടക്കമായി. 21 ദിവസം നീളുന്ന പരിശീലനപരിപാടിയിൽ ജമ്മു കശ്മീർ, പഞ്ചാബ്, ത്രിപുര, ഉത്തർപ്രദേശ്, ഛത്തീസ്ഗഢ്, കർണാടകം, തമിഴ്നാട്, കേരളം എന്നീ സംസ്ഥാനങ്ങളിൽനിന്നായി 21 ഗവേഷകർ പങ്കെടുക്കുന്നു. ഇന്ത്യയിലും വിദേശത്തുമുള്ള വിദഗ്ധരാണ് ഗവേഷകരെ പരിശീലിപ്പിക്കുന്നത്.

ബേ ഓഫ് ബംഗാൾ പ്രോഗ്രാം ഇന്റർ ഗവൺമെന്റൽ ഓർഗനൈസേഷൻ ഡയറക്ടർ ഡോ. പി കൃഷ്ണൻ ഉദ്ഘാടനം ചെയ്തു. സിഎംഎഫ്ആർഐ ഡയറക്ടർ ഡോ. എ ഗോപാലകൃഷ്ണൻ അധ്യക്ഷനായി.

കേരളകൗമുദി

04 January 2022

സി.എം.എഫ്.ആർ.ഐ വിന്റർസ്കൂളിന് തുടക്കം

കൊച്ചി: ശാസ്ത്രീയ പഠനങ്ങൾ ഗവേഷകരെ പരിശീലിപ്പിക്കുന്നതിനായി കേന്ദ്ര സമുദ്രമത്സ്യ ഗവേഷണ സ്ഥാപനം സംഘടിപ്പിക്കുന്ന വിന്റർസ്കൂളിന് തുടക്കമായി. യു.എൻ ഫുഡ് ആൻഡ് അഗ്രികൾച്ചർ ഓർഗനൈസേഷന്റെ (എഫ്.എ.ഒ) കീഴിൽ പ്രവർത്തിക്കുന്ന ബേ ഒഫ് ബംഗാൾ പ്രോഗ്രാം ഇന്റർ ഗവൺമെന്റൽ ഓർഗനൈസേഷൻ ഡയറക്ടർ ഡോ. പി. കൃഷ്ണൻ ഉദ്ഘാടനം ചെയ്തു. സി.എം.എഫ്.ആർ.ഐ ഡയറക്ടർ ഡോ. എ. ഗോപാലകൃഷ്ണൻ അദ്ധ്യക്ഷനായി. 21 ദിവസം നീണ്ടുനിൽക്കുന്ന വിന്റർ സ്കൂളിൽ ജമ്മു കാശ്മീർ, പഞ്ചാബ്, ത്രിപുര, ഉത്തർപ്രദേശ്, ചത്തീസ്ഗഢ്, കർണാടക, തമിഴ്നാട്, കേരളം എന്നീ സംസ്ഥാനങ്ങളിൽ നിന്നായി 21 ഗവേഷകരാണ് പങ്കെടുക്കുന്നത്. വിന്റർ സ്കൂൾ കോഴ്സ് ഡയറക്ടർ ഡോ. രേഖ ജെ. നായർ, ഡോ. വി.മഹേഷ്, ഡോ. ആർ. രതീഷ് കുമാർ എന്നിവർ സംസാരിച്ചു.

മാധ്യമം

04 January 2022

വിൻററർസ്കൂളിന് തുടക്കമായി

കൊച്ചി: സമുദ്രമത്സ്യ സമ്പത്തിന്റെ സംരക്ഷണവും സുസ്ഥിര പരിപാലനവുമായി ബന്ധപ്പെട്ട ശാസ്ത്രീയ പഠനങ്ങൾ ഗവേഷകരെ പരിശീലിപ്പിക്കുന്നതിനായി കേന്ദ്ര സമുദ്രമത്സ്യ ഗവേഷണ സ്ഥാപനം (സി.എം.എഫ്.ആർ.ഐ) സംഘടിപ്പിക്കുന്ന വിൻറർ സ്കൂളിന് തുടക്കമായി. 21 ദിവസം നീളുന്ന വിൻറർ സ്കൂളിൽ ജമ്മുകശ്മീർ, പഞ്ചാബ്, ത്രിപുര, ഉത്തർപ്രദേശ്, ചത്തീസ്ഗഢ്, കർണാടക, തമിഴ്നാട്, കേരള സംസ്ഥാനങ്ങളിൽ നിന്നായി 21 ഗവേഷകരാണ് പങ്കെടുക്കുന്നത്.

മലയാള മനോരമ
ESTABLISHED 1888

04 January 2022

വിന്റർ സ്കൂളിന് തുടക്കം

കൊച്ചി● സമുദ്രമത്സ്യ സമ്പത്തിന്റെ സംരക്ഷണവും സുസ്ഥിര പരിപാലനവുമായി ബന്ധപ്പെട്ട പഠനങ്ങളിൽ ഗവേഷകർക്കു ശാസ്ത്രീയ പരിശീലനം നൽകുന്നതിനായി കേന്ദ്ര സമുദ്രമത്സ്യ ഗവേഷണ സ്ഥാപനം (സിഎംഎഫ്ആർഐ) സംഘടിപ്പിക്കുന്ന വിന്റർ സ്കൂളിനു തുടക്കമായി.

21 ദിവസത്തെ വിന്റർ സ്കൂളിൽ ജമ്മു കശ്മീർ, പഞ്ചാബ്, ത്രിപുര, ഉത്തർപ്രദേശ്, ഛത്തീസ്ഗഡ്, കർണാടക, തമിഴ്നാട്, കേരളം എന്നീ സംസ്ഥാനങ്ങളിൽ നിന്നുള്ള 21 ഗവേഷകരാണു പങ്കെടുക്കുന്നത്. യുഎൻ ഫുഡ് ആൻഡ് അഗ്രികൾച്ചർ ഓർഗനൈസേഷന്റെ കീഴിൽ പ്രവർത്തിക്കുന്ന ബേ ഓഫ് ബംഗാൾ പ്രോഗ്രാം ഇന്റർ ഗവൺമെന്റൽ ഓർഗനൈസേഷൻ ഡയറക്ടർ ഡോ. പി. കൃഷ്ണൻ ഉദ്ഘാടനം ചെയ്തു. സിഎംഎഫ്ആർഐ ഡയറക്ടർ ഡോ. എ ഗോപാലകൃഷ്ണൻ അധ്യക്ഷത വഹിച്ചു. വിന്റർ സ്കൂൾ കോഴ്സ് ഡയറക്ടർ ഡോ. രേഖ ജെ. നായർ, ഡോ. വി. മഹേഷ്, ഡോ. ആർ. രതീഷ് കുമാർ എന്നിവർ പ്രസംഗിച്ചു.

മാതൃഭൂമി

04 January 2022

സി.എം.എഫ്.ആർ.ഐ. 'വിന്റർ സ്കൂൾ' തുടങ്ങി

കൊച്ചി▸ കേന്ദ്ര സമുദ്രമത്സ്യ ഗവേഷണ സ്ഥാപനം (സി.എം.എഫ്.ആർ.ഐ.) സംഘടിപ്പിക്കുന്ന 'വിൻറർ സ്കൂളി'ന് തുടക്കമായി. സമുദ്രമത്സ്യ സമ്പത്തിൻെറ സംരക്ഷണവും പരിപാലനവുമായി ബന്ധപ്പെട്ട് ഗവേഷകരെ പരിശീലിപ്പിക്കുന്നതാണ് പദ്ധതി. 21 ദിവസത്തെ വിൻറർ സ്കൂളിൽ വിവിധ സംസ്ഥാനങ്ങളിൽ നിന്നുള്ള 21 ഗവേഷകർ പങ്കെടുക്കും. ഡോ. പി. കൃഷ്ണൻ ഉദ്ഘാടനം ചെയ്തു. സി.എം.എഫ്.ആർ.ഐ. ഡയറക്ടർ ഡോ. എ. ഗോപാലകൃഷ്ണൻ അധ്യക്ഷനായി. ഡോ. രേഖ ജെ. നായർ, ഡോ. വി. മഹേഷ്, ഡോ. ആർ. രതീഷ് കുമാർ എന്നിവർ സംസാരിച്ചു.

മെട്രോ വാർത്ത

04 January 2022

വിന്റർ സ്കൂളിന് തുടക്കം

കൊച്ചി: സമുദ്രമത്സ്യ സമ്പത്തിന്റെ സംരക്ഷണവും സുസ്ഥിര പരിപാലനവുമായി ബന്ധപ്പെട്ട ശാസ്ത്രീയ പഠനങ്ങൾ ഗവേഷകരെ പരിശീലിപ്പിക്കുന്നതിനായി കേന്ദ്ര സമുദ്രമത്സ്യ ഗവേഷണ സ്ഥാപനം (സിഎംഎഫ്ആർഐ) സംഘടിപ്പിക്കുന്ന വിന്റർ സ്കൂളിന് തുടക്കമായി. 21 ദിവസം നീണ്ടുനിൽക്കുന്ന വിന്റർ സ്കൂളിൽ ജമ്മു കാശ്മീർ, പഞ്ചാബ്, ത്രിപുര, ഉത്തർപ്രദേശ്, ഛത്തീസ്ഗഢ്, കർണാടക, തമിഴ്നാട്, കേരളം എന്നീ സംസ്ഥാനങ്ങളിൽ നിന്നായി 21 ഗവേഷകരാണ് പങ്കെടുക്കുന്നത്.

സമുദ്രമത്സ്യ ഗവേഷണവുമായി ബന്ധപ്പെട്ട വിവിധ വിഷയങ്ങളിൽ ഇന്ത്യക്കകത്തും പുറത്തുമുള്ള വിദഗ്ധരാണ് ഗവേഷകരെ പരിശീലിപ്പിക്കുന്നത്. യുഎൻ ഫുഡ് ആന്റ് അഗ്രികൾച്ചർ ഓർഗനൈസേഷന്റെ (എഫ്എഒ) കീഴിൽ പ്രവർത്തിക്കുന്ന ബേ ഓഫ് ബംഗാൾ പ്രോഗ്രാം ഇന്റർ ഗവൺമെന്റൽ ഓർഗനൈസേഷൻ ഡയറക്റ്റർ ഡോ.പി.കൃഷ്ണൻ വിന്റർ സ്കൂൾ ഉദ്ഘാടനം ചെയ്തു. സിഎംഎഫ്ആർഐ ഡയറക്റ്റർ ഡോ.എ.ഗോപാലകൃഷ്ണൻ അധ്യക്ഷത വഹിച്ചു. വിന്റർ സ്കൂൾ കോഴ്സ് ഡയറക്റ്റർ ഡോ.രേഖ ജെ.നായർ, ഡോ.വി.മഹേഷ്, ഡോ.ആർ.രതീഷ് കുമാർ എന്നിവർ പ്രസംഗിച്ചു.

സുപ്രഭാതം

04 January 2022

സി.എം.എഫ്.ആർ.ഐ വിന്റർ സ്കൂളിന് തുടക്കം

കൊച്ചി

സമുദ്ര മത്സ്യസമ്പത്തിന്റെ സംരക്ഷണവും സുസ്ഥിര പരിപാലനവുമായി ബന്ധപ്പെട്ട ശാസ്ത്രീയ പഠനങ്ങൾ ഗവേഷകരെ പരിശീലിപ്പിക്കുന്നതിനായി കേന്ദ്ര സമുദ്ര മത്സ്യ ഗവേഷണ സ്ഥാപനം (സി.എം.എഫ്.ആർ.ഐ) സംഘടിപ്പിക്കുന്ന വിന്റർ സ്കൂളിന് തുടക്കമായി. 21 ദിവസം നീണ്ടുനിൽക്കുന്ന വിന്റർ സ്കൂളിൽ ജമ്മു കശ്മീർ, പഞ്ചാബ്, ത്രിപുര, ഉത്തർപ്രദേശ്, ഛത്തീസ്ഗഢ്, കർണാടക, തമിഴ്നാട്, കേരളം എന്നീ സംസ്ഥാനങ്ങളിൽ നിന്നായി 21 ഗവേഷകരാണ് പങ്കെടുക്കുന്നത്.

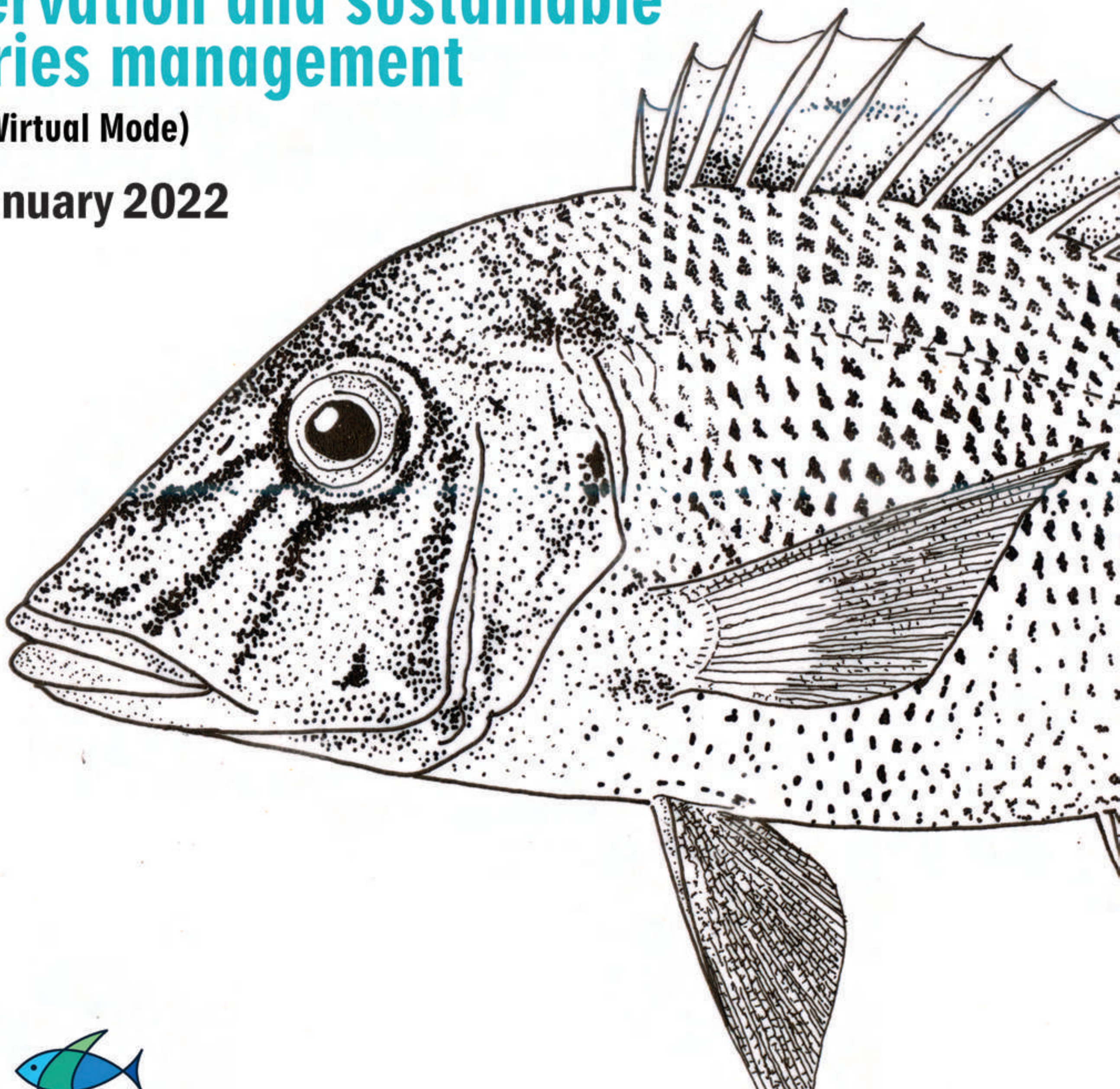
സമുദ്ര മത്സ്യ ഗവേഷണവുമായി ബന്ധപ്പെട്ട വിവിധ വിഷയങ്ങളിൽ ഇന്ത്യക്കകത്തും പുറത്തുമുള്ള വിദഗ്ധരാണ് ഗവേഷകരെ പരിശീലിപ്പിക്കുന്നത്. യു.എൻ ഫുഡ് ആൻഡ് അഗ്രികൾച്ചർ ഓർഗനൈസേഷന്റെ (എഫ്.എ.ഒ) കീഴിൽ പ്രവർത്തിക്കുന്ന ബേ ഓഫ് ബംഗാൾ പ്രോഗ്രാം ഇന്റർ ഗവൺമെന്റൽ ഓർഗനൈസേഷൻ ഡയരക്ടർ ഡോ. പി. കൃഷ്ണൻ വിന്റർ സ്കൂൾ ഉദ്ഘാടനം ചെയ്തു. സി.എം.എഫ്.ആർ.ഐ ഡയരക്ടർ ഡോ. എ. ഗോപാലകൃഷ്ണൻ അധ്യക്ഷനായി. വിന്റർ സ്കൂൾ കോഴ്സ് ഡയരക്ടർ ഡോ. രേഖ ജെ. നായർ, ഡോ. വി. മഹേഷ്, ഡോ. ആർ. രതീഷ് കുമാർ സംസാരിച്ചു.

ICAR Sponsored Winter School on

Recent development in taxonomic techniques of marine fishes for conservation and sustainable fisheries management

(Through Virtual Mode)

3-23 January 2022

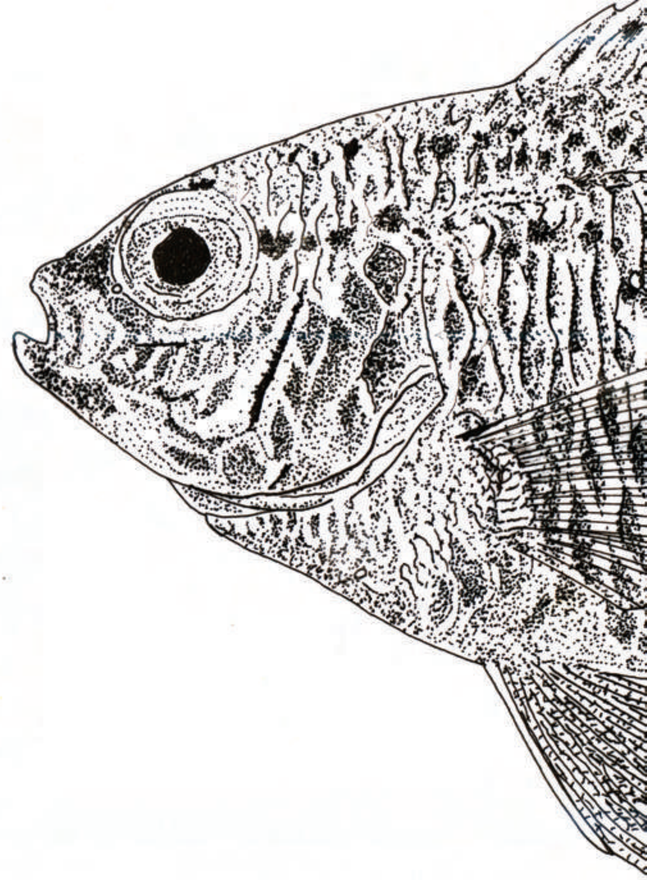


Organised by

ICAR-Central Marine Fisheries Research Institute

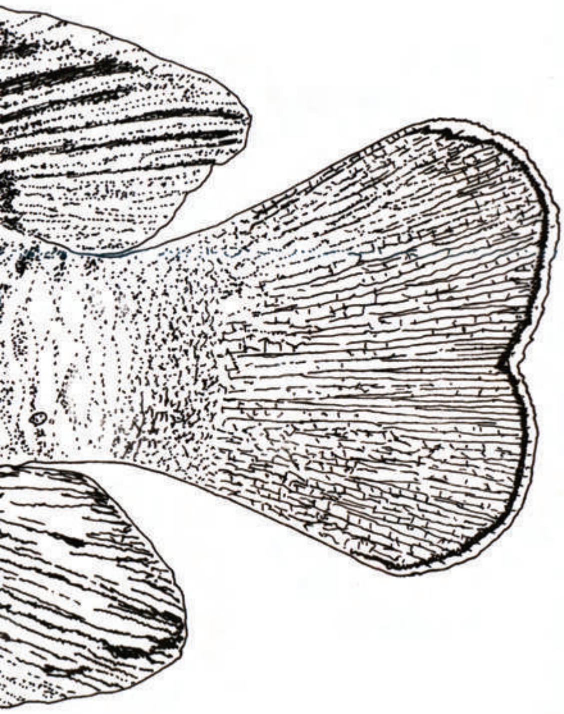
Post Box No. 1603, Ernakulam North P.O., Kochi-682 018
Kerala, India

Background



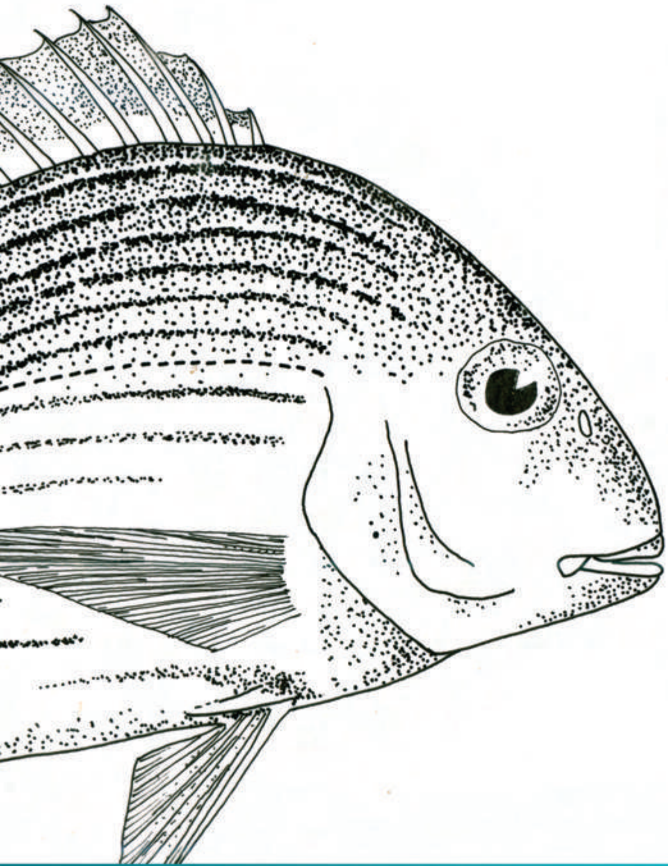
Fisheries are crucial to global food security and nutrition, and they offer development pathways to contribute to a more prosperous, peaceful and equitable world. With many fisheries collapsing worldwide, it is increasingly clear that fisheries resources can no longer sustain the rapid and often unfettered advances in fishing effort, and therefore new approaches to fisheries management embracing conservation and environmental considerations are urgently needed. Careful management of global marine fisheries resources and biodiversity for a sustainable future is the key answer for all this. Marine biodiversity is critical to the health of people and our planet. Over a billion people depend on marine and coastal biodiversity for their livelihood. The health of the ocean is intimately tied to our health.

Why is taxonomy so important?



Taxonomy is becoming more important as scientists struggle to identify species in order to understand the subtle relationships and complex reactions of ecosystems threatened by human pursuits. The study of taxonomy provides a solid foundation for the research needed for the conservation of marine life it also helps us categorize organisms so that we can more easily communicate biological information. Taxonomy uses hierarchical classification as a way to help scientists understand and organize the diversity of life on our planet. Despite the on-going biodiversity crisis, the number of new species described per scientist has not increased in the past 60-70 years. This is having a huge impact on conservation science. Many species will become extinct before they are described and we remain continually unaware of the total numbers of species that comprise global biodiversity. This is acknowledged by the Convention of Biodiversity and its signatories as a "taxonomic impediment".

In the light of SDG14 (which seek to further the sustainable management and protection of marine and coastal ecosystems) and the importance of the diversification of resources for capture and culture, it is imperative that new fishery resources must be explored and identified. Correct identification is the pillar to the fisheries world and classical taxonomy is the basis for any conservation activity. Rules for conservation, IUCN activities, WLPA, CITES all work on the basis of correct taxonomy. Hence training on these lines is very essential not only to conserve biodiversity but also to diversify fisheries in India.

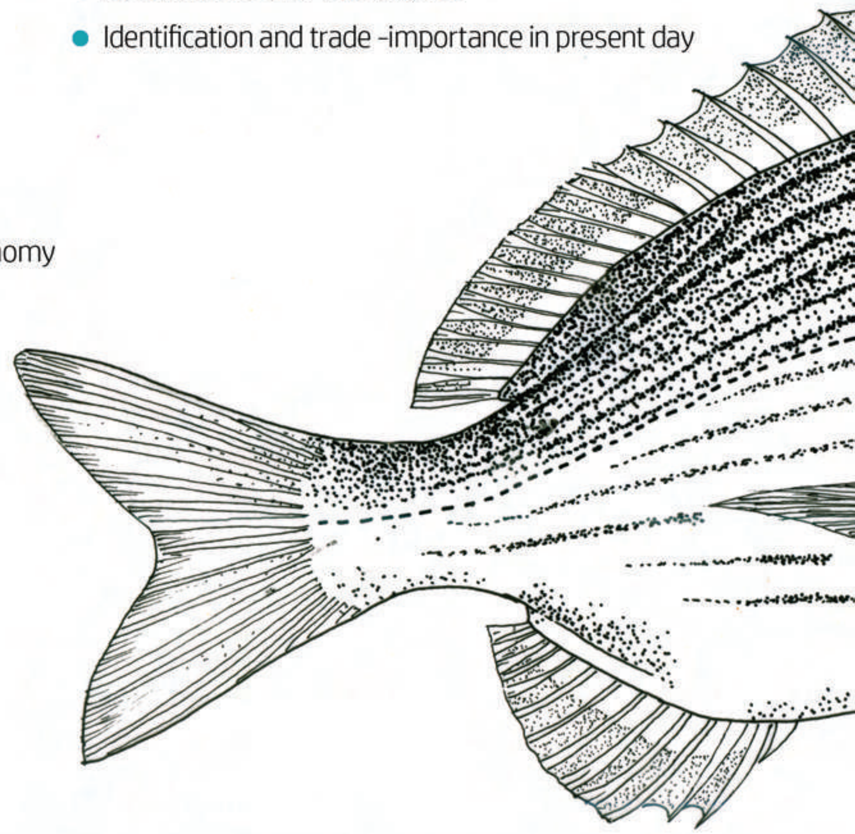


Objectives

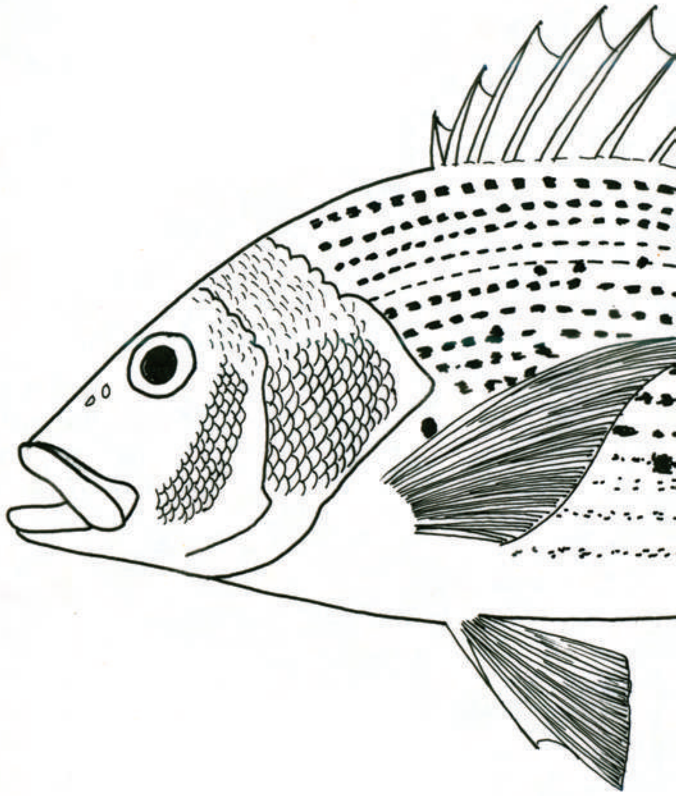
- To sensitize entry and middle level National Agricultural Research System (NARS) professionals and students about the concept of taxonomy and it's use in fisheries development.
- To enhance the competency of NARS professionals in using various tools and techniques of taxonomy, its applications and its importance in the UN Decade of the Oceans.
- To impart appropriate skills for the use of taxonomy, using different softwares.

Main Themes

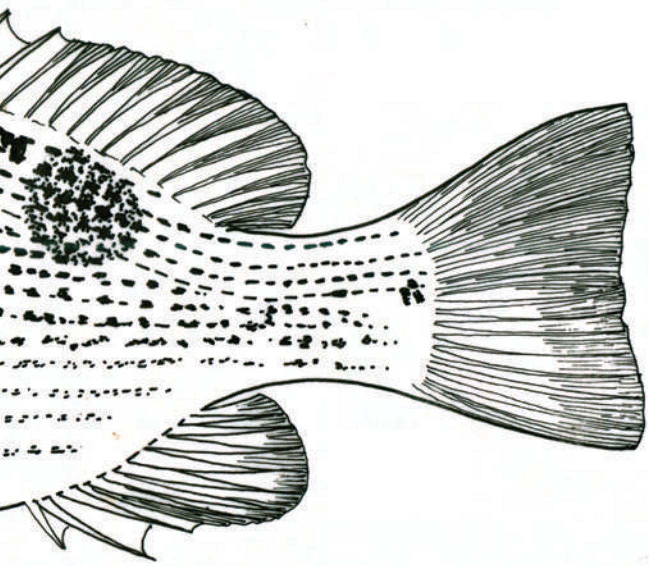
- Marine Fisheries of India
- Pelagic Fisheries
- Demersal Fisheries
- Crustacean Fisheries
- Molluscan Fisheries
- Basic techniques in fish/shellfish taxonomy
- Analytics in fish taxonomy
- Fish otolith -theory -implications
- Shark/Rays/Guitarfish taxonomy
- Grouper/Snapper/Pigfacebreams/Flatfish Taxonomy
- Sciaenids/Goatfish/Silverbelly Taxonomy
- Clupeids/Baraccuda/Halfbeak Taxonomy
- Carangid/Sailfish/Scombrid Taxonomy
- Cephalopod/Bivalve/Gastropod taxonomy
- Statolith/otolith-species identification
- Crab/Lobsters/Shrimp taxonomy
- Coral reef fish taxonomy
- Mammal taxonomy
- Analytical methods using softwares
- Barometer of Life
- International tools in conservation
- Diversity analysis using R
- ICZN -Nomenclature rules
- History of taxonomy
- Recent molecular techniques
- Identification and trade -importance in present day



About Host



The ICAR-Central Marine Fisheries Research Institute (CMFRI) established by the Government of India on February 3rd 1947 under the Ministry of Agriculture and Farmers Welfare has now emerged as a leading tropical marine fisheries research institute in the world. This year the Institute completes its glorious 75 years and is celebrating its semi-sesquicentennial along with the country when it celebrates *Azadi ka Amrit Mahostav*. Since its inception, the ICAR-CMFRI has grown significantly in its size and statute and built up adequate research infrastructure and recruited qualified staff. During the first half of the seven decades of its existence, the CMFRI devoted its research attention towards the estimation of marine fisheries landings and effort, taxonomy of marine organisms and the bio-economic characteristics of the exploited stocks of finfish and shellfish. This year we are revisiting our taxonomic techniques where we started our research, polishing them and upscaling them with newer technologies to be at par with modern techniques of the world. With over 221 new species described by the Scientists of this Institute, it is only apt that a training of this capacity is being organised by the Institute to commemorate its 75th year of research expertise in the area of tropical marine fisheries.



Duration and Venue

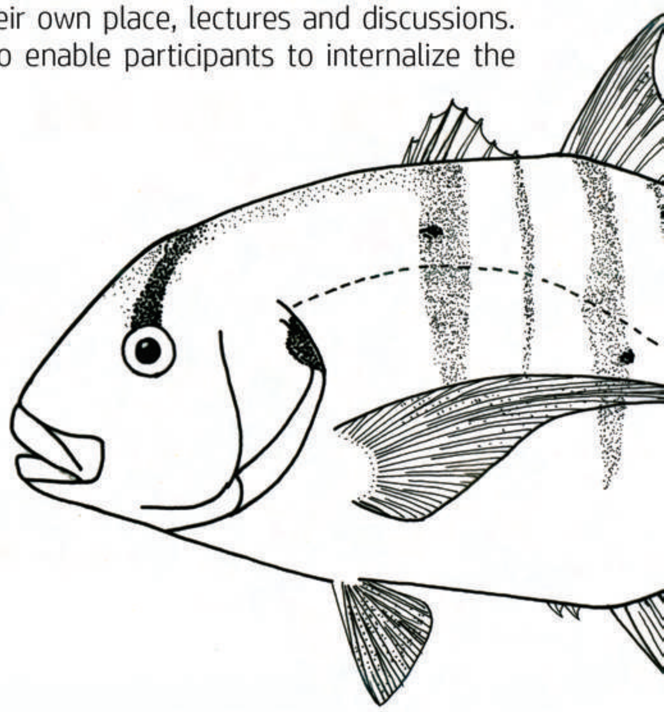
The course is offered during January 03 to 23, 2022 through **Virtual mode**. The participants are expected to login a day previous to download the necessary proforma and follow the procedures. The programme will be hosted by ICAR–Central Marine Fisheries Research Institute (CMFRI), Kochi 682018, Kerala, India (online).

The Winter School is sponsored by Indian Council of Agricultural Research (ICAR), New Delhi

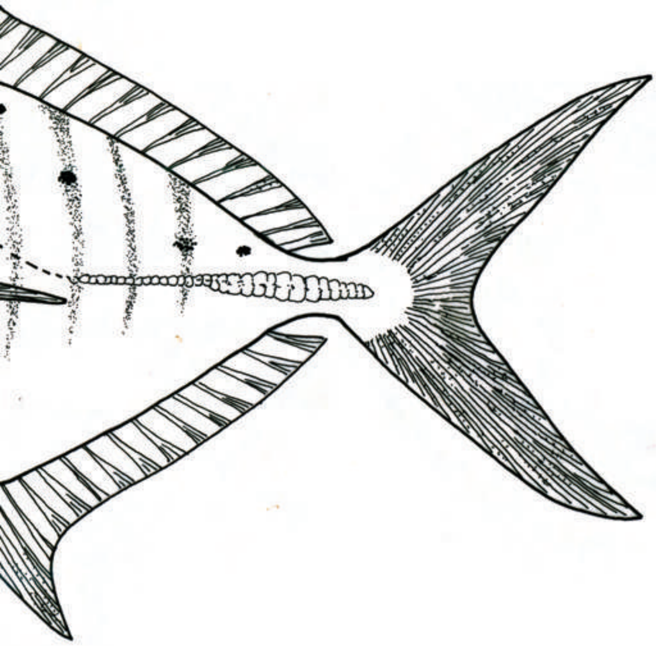
Core Content

The course will provide an excellent opportunity to have a theoretical and practical exposure to understand the concept of taxonomic techniques used for research, analysis, conservation, sustainability and future development. Since the course involves statistical analyses also each participant would be sensitized about the importance of statistical analyses in taxonomy and various ways of considering its use in fisheries research and development. The course consists of a blend of online practicals which can be handled by attendees at their own place, lectures and discussions. However, the course emphasizes on hands-on-exercises to enable participants to internalize the knowledge and skills imparted in the training.

Eligibility



The ICAR sponsored winter school programme is mainly targeted at entry and middle level NARS professionals including that of KVKs, who are actively involved in teaching, research or extension working not below the rank of Assistant Professor and equivalent in the concerned subject under State University/ICAR Institute/Central/State Fisheries Universities working on related topic.



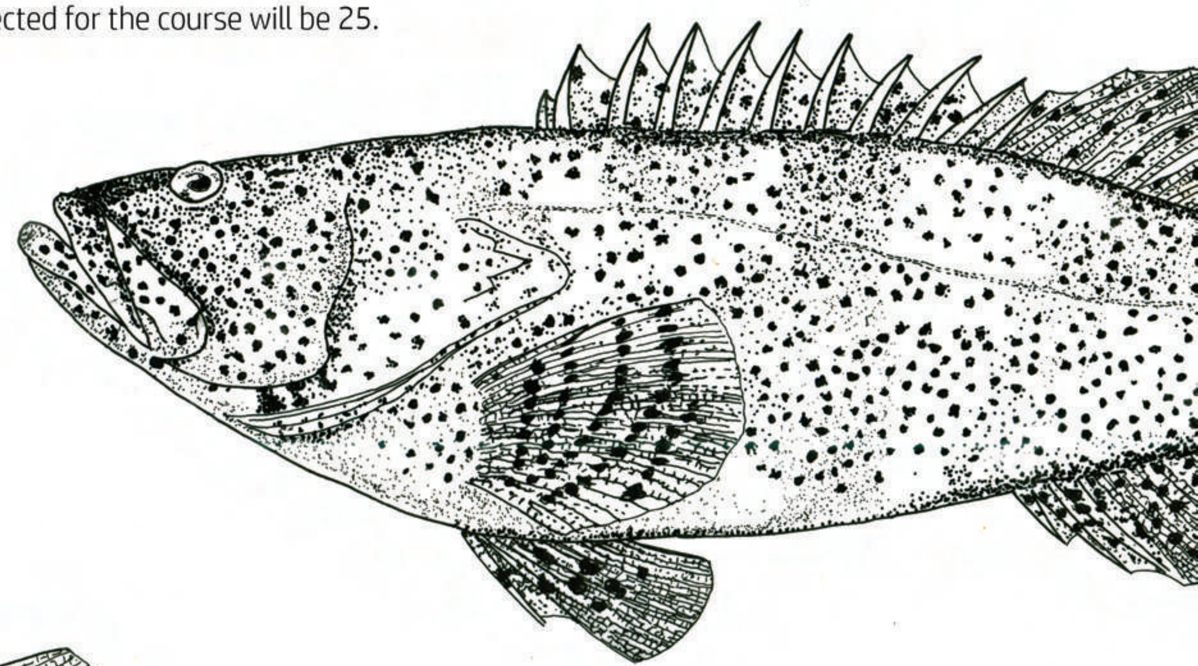
Selection of Participants

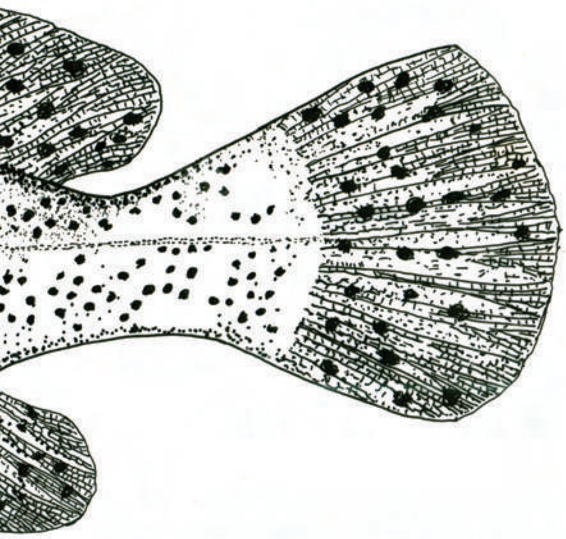
Maximum intake for the programme is 25 participants. As per the eligibility criteria, participant's selection would be based on first-cum-first basis. Selection of candidates is a matter of discretion of the competent authority of ICAR-CMFRI. Participants' nomination from the respective heads of organizations does not entail confirmed participation in the programme. A formal confirmation letter indicating the selection of candidates will be sent by ICAR-CMFRI a week after the last date for the receipt of nominations.

Registration of participants

The participants should submit their application online using CBP portal of Agricultural Education Division, ICAR (https://cbp.icar.gov.in). After filling up the online application, take a print out of application form and get it approved by the competent authority of your organization. Upload the approved form (scan copy) on CBP portal. The original copy along with ₹ 50/- in the form of a Demand Draft/Indian Postal Order (Non-refundable) in favour of Director, CMFRI, **payable at SBI Ernakulam** Branch, Kochi should be sent to Dr. Rekha J. Nair, Winter School Director, Demersal Fisheries Division, ICAR-Central Marine Fisheries Research Institute, Post Box No. 1603, Ernakulam North P.O., Kochi – 682 018, Kerala, India. **The DD/PO should be valid for 6 months till May 2022.**

An advance copy of the application (scan copy) may be sent to the Course Director (fishtaxonomy2022@gmail.com) to overcome any postal delay. However, the candidature for final selection will be considered only after receipt of the approved original copy. The detail guidelines for participating in the ICAR summer/winter schools can be downloaded from the CBP portal. The number of participants selected for the course will be 25.





Dates to Remember

Last date for receipt of applications	: 15 December 2021
Intimation to selected candidates	: 20 December 2021
Confirmation of participation	: 23 December 2021

Mode of Participation

The training will be organized in 4 quadrants *i.e.*

1. Lecture through video conference.
2. Preparing delivered material that can be downloaded/ printed.
3. Self-assessment tests through google classroom assignment/tests/quizzes.
4. An online discussion forum for clearing the doubts.

The above cited steps have to be taken to enrich the learning experience by using audio-video and multi-media state of art pedagogy/technology. In order to ensure that best quality content lecture is delivered course director and his coordinators will monitor the whole training course.

All such candidates who will participate in this 21 day winter school through video conferencing will be deemed to have attended the 21 Days Winter School and as per the course guideline will be provided certificate of participation.

For more information contact

Dr. A Gopalakrishnan
Director
ICAR-Central Marine Fisheries Research Institute
Post Box No. 1603, Ernakulam North P.O.
Kochi – 682 018, Kerala, India
Ph. No. 0484-2394867
Fax No. 0484-2394909
Email: director@cmfri.org.in

Course Director:

Dr. Rekha J Nair
Principal Scientist
Demersal Fisheries Division
ICAR-Central Marine Fisheries Research Institute
Post Box No. 1603, Ernakulam North P.O.
Kochi – 682 018, Kerala, India
Email: fishtaxonomy2022@gmail.com
Mobile: +91-9446415736
Office: +91-484-2394867; Ext. No. 292
Fax No: +91-484-2394909/2396685

Co Course Directors:

Dr. Mahesh V
Scientist
Calicut RS of ICAR-CMFRI, Calicut
Email: fishtaxonomy2022@gmail.com

Dr. Ratheesh Kumar R
Scientist
ICAR-CMFRI, Kochi
Email: fishtaxonomy2022@gmail.com

Dr. Subal Kumar Roul
Scientist
Digha RS of ICAR-CMFRI, Digha
Email: fishtaxonomy2022@gmail.com

IT Coordinator:

Dr. J Jayasankar
Principal Scientist,
FRAD, ICAR-CMFRI, Kochi

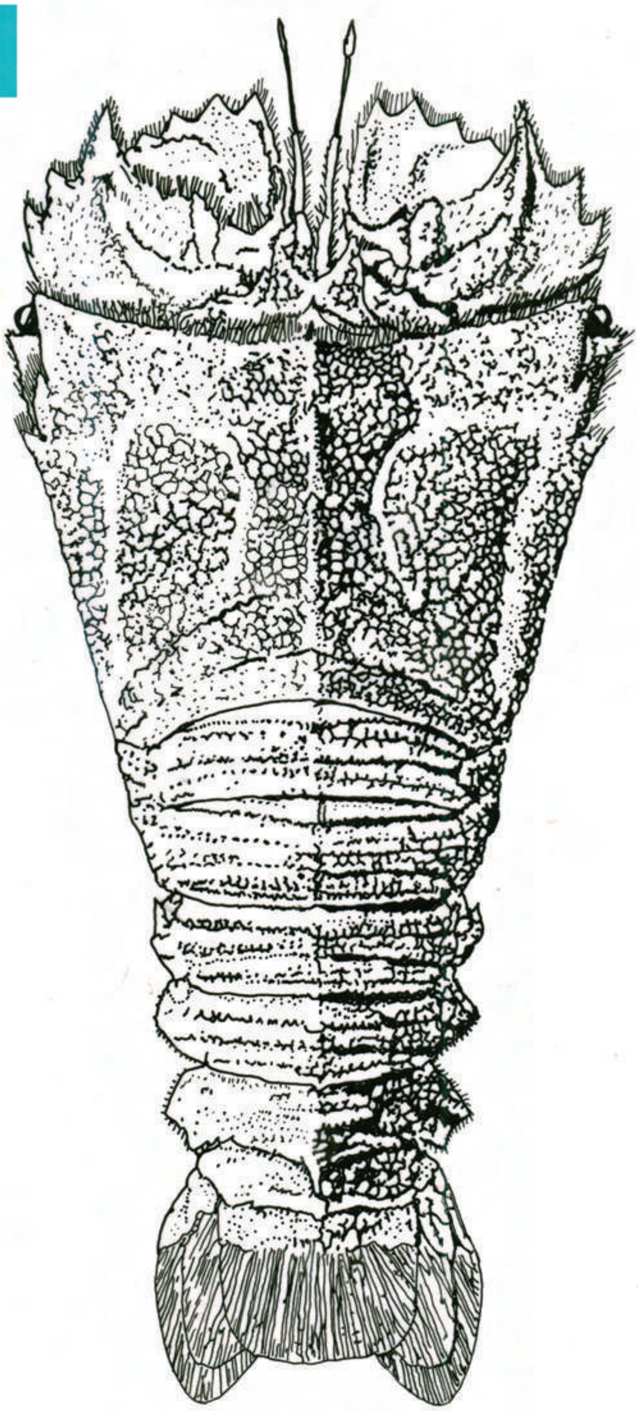
Team members:

Mr. Manu V K
Technical Coordinator
(Virtual Workbench)

Mr. Manjesh R
Technical Coordinator
(Networking and Digital Interaction moderation)

Mr. Arun Surendran
Technical Coordinator
(Data repository and dissemination)

Mr. Abhilash P R
Technical Coordinator
(Image repository and Hands-on session virtulization)



Applications may be sent to:

Dr. Rekha J Nair
Course Director

Illustrations: K M David, Artist, CMFRI, Kochi

Application Form for Winter School on

Recent development in taxonomic techniques of marine fishes for conservation and sustainable fisheries management

(03-23 January 2022)

Full name (in Block letters): ....

Designation: ....

Present employer & Address: ....

....

....

Address for communication: ....

....

....

Email Address: ....

Mobile No: .... Date of Birth: ....

Sex (Male/Female): ....

Teaching/Research/Professional experience

(Mention posts held during last 5 years and number of publications):

....

....

Mention if you have participated in any training programme, Winter/Summer School, Short Course, etc. during the previous years under ICAR/Other organizations:

....

....

Postal Order/ Demand Draft drawn in favour of ICAR unit-CMFRI

(No.: .... Dated: ....)

For ₹ 50/- (Non Refundable) as Registration fee, payable at Ernakulam

Examination Passed	Subjects Main/Subsidiary	Year	Division	University/Institution
Degree				
Post Graduate				
Doctoral				
Others				

Date: (Signature of the Applicant)

Place:

Countersigned

Sponsoring Authority (Director/Dean/Head of Regional Station)

Director and Staff of
ICAR-Central Marine Fisheries Research Institute
Ernakulam North P.O., Kochi 682 018

Cordially invite you for
the Inaugural function of

ICAR Sponsored
Winter School on

Recent Development in Taxonomic Techniques of Marine Fishes for Conservation and Sustainable Fisheries Management

(Through Virtual Mode during 3-23 January 2022)

On 3rd January, 2022 at 10.30 am

Dr. P. Krishnan
Director
Bay of Bengal Programme (BoBP-IGO-FAO), Chennai
will be the **Chief Guest**

Join Zoom Meeting
https://zoom.us/j/92369410697?pwd=NFpyd25XRXFPb2FZaFZ1b0dCcG5rZz09
Meeting ID : 923 6941 0697
Passcode : 555491

Programme
10.30 am - 11.30 am

ICAR Title song

Welcome Address : **Dr. Rekha J. Nair**
Principal Scientist
Demersal Fisheries Division
ICAR-Central Marine Fisheries Research Institute

Introduction of Course : **Dr. V. Mahesh**
Scientist
Demersal Fisheries Division
ICAR-Central Marine Fisheries Research Institute

Presidential Address : **Dr. A. Gopalakrishnan**
Director
ICAR-Central Marine Fisheries Research Institute

Inaugural Address by the Chief Guest : **Dr. P. Krishnan**
Director
Bay of Bengal Programme (BoBP-IGO-FAO)
Chennai

Vote of Thanks : **Dr. Ratheesh Kumar R.**
Scientist
Fishery Environment Management Division
ICAR-Central Marine Fisheries Research Institute

National Anthem

Valedictory Function of

Winter School on

Recent Development in Taxonomic Techniques of Marine Fishes for Conservation and Sustainable Fisheries Management

23 January, 2022
3.00 pm -3.30 pm

ICAR Title song

Welcome Address : **Dr. V. Mahesh**
Scientist
Demersal Fisheries Division
ICAR-Central Marine Fisheries Research Institute

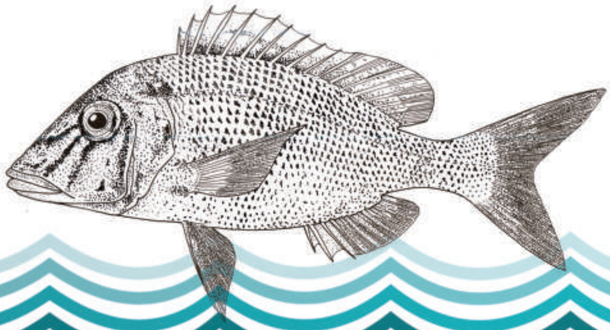
Presidential Address : **Dr. A. Gopalakrishnan**
Director
ICAR-Central Marine Fisheries Research Institute

Comments by IT Coordinator, Team Winter School : **Dr. J. Jayasankar**
Principal Scientist,
FRAD, ICAR-CMFRI, Kochi

Feedback by the participants

Vote of Thanks : **Dr. Rekha J. Nair**
Principal Scientist
Demersal Fisheries Division
ICAR-Central Marine Fisheries Research Institute

National Anthem



EVALUATION FORM

1. **Name of Participant**

2. **Affiliation**

3. **How did you know about the course/training**

4. **What were your perceptions about the course**

5. **Did the course help you achieve your perceptions?**

6. **Since this was a Virtual Winter School did you feel that there would not be any practical**

7. **Did the virtual practical classes help you gain knowledge**

8. **Did you except the international talks?**

9. **Please mention your overall comments on the method of conduct of class, suggestions for improvement if any**

10. **Suggestions for new topics to be included in Winter School**

Winter school on *“Recent development in taxonomic techniques of marine fishes for conservation and sustainable fisheries management”* from January 3 -23, 2022 on a Virtual mode at CMFRI Kochi

Day	Name & Address	Topics	Date	Time schedule	Email	Meeting Link
	Inauguration		January 3, 2022	10-11 am		https://zoom.us/j/92369410697?pwd=NFpyd25XRXFPb2FZaFZ1b0dCcG5rZz09 Meeting ID: 923 6941 0697 Passcode: 555491
	Introduction of candidates/Introduction to programe mode/conduct			11.15 -12 pm	Winter School Team/Interactive Session	
1	Dr. E. Vivekanandan Consultant, ICAR-CMFRI	Marine Fisheries of India -Outlook and Challenges ahead	January 3, 2022	2.30-4.30 pm	evivekanandan@hotmail.com	https://zoom.us/j/92262094105?pwd=VEpFcUZNYk1NN004ZGtwTTNsdEovQT09 Meeting ID: 922 6209 4105 Passcode: 815095
2	Dr. Prathibha Rohit Principal Scientist & Head, PFD	Pelagic fisheries of India	January 4, 2022	10–11 am	rohitprathi@yahoo.co.in	https://zoom.us/j/91609459844?pwd=Z2J2dmRHM1hrdHVuYml4cGNPVzZxQT09 Meeting ID: 916 0945 9844 Passcode: 914332
2	Dr Rekha J Nair	An overview of CMFRI	January 4, 2022	11.15-12 pm		
2	Dr.P Laxmilatha Principal Scientist & Head, MD,	Molluscan Fisheries- present status	January 4, 2022	12.15-1 pm	laxmil@yahoo.com	
2	Dr.Geetha Sasikumar Principal Scientist	Taxonomy of cephalopods	January 4, 2022	2-3 pm	gs.pallath@gmail.com	https://zoom.us/j/92091427226?pwd=cXdVR2RZR3RCdFl2MG50VVNoWEJHdz09 Meeting ID: 920 9142 7226 Passcode: 281736
2	Dr Sajikumar	Cephalopod aging using hard parts(C+P)	January 4, 2022	3-4 pm	kksajikumar@yahoo.co.in	

3	Dr. Rekha J Nair Principal Scientist, Vishnupriya KM	History of Ichthyology	January 5, 2022	9.30-10.30 am	rekhacmfri@gmail.com	https://zoom.us/j/97696707208?pwd=aHdiQ0VHdUtBeWNQSkxpRDlZdGZLZz09 Meeting ID: 976 9670 7208 Passcode: 243164
3	Dr.Geetha Sasikumar Principal Scientist	Taxonomy of cephalopods (P)		11.15-12.15 pm	gs.pallath@gmail.com	
3	Dr.Vidya R. Scientist & Dr Jasmine F Scientist	Taxonomy of Bivalves	January 5, 2022	2-3 pm	vidya.panicker@gmail.com jasmin.f.cmfri@gmail.com	https://zoom.us/j/98498262686?pwd=WDk3SmRKYm5QMHJUTm9pTWZoYjUyQT09 Meeting ID: 984 9826 2686 Passcode: 038680
3	Dr Kavita J Scientist	Taxonomy of Gastropods/ Importance of taxonomy/ID in shell trade	January 5, 2022	3-4 pm	kavifish@gmail.com	
4	Dr. Josileen Jose, Principal Scientist & Head, CFD,	Overview of Crustacean Fisheries & Crab Taxonomy in India	January 6, 2022	10–11 am	drjoslin@gmail.com	https://zoom.us/j/96377629385?pwd=Q1lRdlg0Nng2VDlHdDU3UFdjV0J2UT09 Meeting ID: 963 7762 9385 Passcode: 081634
4	Dr. Josileen Jose, Principal Scientist & Head, CFD,			11.30-12.30 pm		
4	Dr. Josileen Jose, Principal Scientist & Head, CFD,			2–3 pm		https://zoom.us/j/96955375184?pwd=TldhLzBYNWJxa25WZ3pvWFNHYlIwdz09 Meeting ID: 969 5537 5184 Passcode: 019970
4				3-4.30 pm		

5	Dr. Joshi K K Principal Scientist & Head, MBD,	Ichthyofaunal diversity of India-& Challenges	January 7, 2022	9.30-11 am	joshyguru@gmail.com	https://zoom.us/j/99667090286?pwd=akhhSnlsZGFiOWZPWUJmNWh6S0lVdz09 Meeting ID: 996 6709 0286 Passcode: 784776
5	Dr. Grinson George	Taxonomy/Modelling		11.15-12.pm		
	Dr. Mahesh V	Basic techniques in Fish taxonomy		12.15-1 pm	mahesh.fishco@gmail.com	
5	Dr. Ajmal Khan External Expert	PRIMER		2-4.30 pm	seyedajmal@gmail.com	https://zoom.us/j/95567056709?pwd=d3l5VmJ1NzBIdVJPS2dnOWxvQWNRUT09 Meeting ID: 955 6705 6709 Passcode: 454369
	SECOND SATURDAY		January 8, 2022			
	SUNDAY		January 9, 2022			
6	Dr. Reeta Jayasankar Principal Scientist & Head, FEMD,	Seaweed taxonomy and its importance today	January 10, 2022	9.30 -11 am	reetajayasankar@yahoo.com	https://zoom.us/j/97392266245?pwd=ek1IYjdFSnh4VnlWRVNuaFU2cXlqUT09 Meeting ID: 973 9226 6245 Passcode: 660966
6	Mr. K M Sreekumar, Mr. Aju K Raju, Museum,	Techniques in fish (P) preservation		12.10-1 pm	ajukrajuifs@gmail.com	https://zoom.us/j/94127361521?pwd=b0srU2lPdDhZcXVuYS9aSXVVT1NnUT09 Meeting ID: 941 2736 1521 Passcode: 155302

6	Dr Sajeela K.A	Analytical techniques in fish taxonomy (Molecular)		2-4 pm	sajeelaka@gmail.com	https://zoom.us/j/95440425319?pwd=SUtYNnFGWWRHNHVqSkRaMmxGYW9lQT09 Meeting ID: 954 4042 5319 Passcode: 974329
7	Dr. Abdussamad. E.M. Principal Scientist	Carangid Taxonomy	January 11, 2022	10-11 am	emasamadg@gmail.com	https://zoom.us/j/91783174886?pwd=ejZGNEhuUHVaeTFjNGFoVGhQaTRxUT09 Meeting ID: 917 8317 4886 Passcode: 023732
7	Dr. Sivadas Madhavan Principal Scientist (Retd)	Taxonomy of Clupeids		11.15-12.30 pm	sivadasmadhav@yahoo.com	
7	Dr. Rajesh KM Principal Scientist	Taxonomy of Large Pelagics		2-3.15 pm	rajeshmkm3@rediffmail.com	https://zoom.us/j/93025593155?pwd=V3N4UWN5YzQwb1FYRWVOVEFOeGhaUT09 Meeting ID: 930 2559 3155 Passcode: 143474
7	Mr Toji Thomas	Taxonomy of Halfbeaks, Flying fishes (c+p)		3.30-4.30 pm		
8	Dr Christi Linardich	Red Listing and IUCN	January 12, 2022	8.30 am - 10 am	clina001@odu.edu	https://zoom.us/j/95031908822?pwd=dFlGeFlkWWhIN0lna1ppYjdmdmZpZz09
8	Dr. Subal Roul Scientist	Taxonomy of Belonids		10 am -11 am	subalroul@gmail.com	

8	Ms. Ashley	Taxonomy of Anchovies (C+P)		11-11.45 am		Meeting ID: 950 3190 8822 Passcode: 990519
8	Mrs Surya Ambareesh Scientist	Billfish Taxonomy		12-1 pm	revandasurya@gmail.com	
8	Ms. Ashley Gopinath	Taxonomy of Anchovies (c+p)		2-4 pm		https://zoom.us/j/97470839923?pwd=cktBV2tybGprR0xDK3Y0Um5qK3k3QT09 Meeting ID: 974 7083 9923 Passcode: 150802
9	Dr. ANIL MOHAPATRA External Expert	Eel taxonomy	January 13, 2022	10-11 am		https://zoom.us/j/95604674139?pwd=dUZMYmdzeWF1TUEwbFlocGhCbjdjdz09 Meeting ID: 956 0467 4139 Passcode: 108726
9	Dr. Purushottama G.B Senior Scientist	Classification of Guitar fishes/Skates/		11.30-1 pm	puru44@gmail.com	
9	Sunil KTS ICAR-CMFRI	Shark measurements (Practical)		1-2 pm		https://zoom.us/j/96828964695?pwd=UTlteis1UXJ2dERzQXRRYlluR2xsUT09 Meeting ID: 968 2896 4695 Passcode: 424091
9	Sunil KTS & Dr. Rekha J Nair	Ray measurements (Practicals)		3-4 pm		
10	Ms Buddhi Maheshika	Mobulid Species and Gill Plate Identification".	January 14, 2022	9-10 am		

	Blue Resources Trust					https://zoom.us/j/99889982850?pwd=SE45b2l3c1Q0ZkNmdHpDTlY4aTd0dz09 Meeting ID: 998 8998 2850 Passcode: 942602
10	Mr Sahan Thilakaratna **Blue Resources Trust**	Mobulid Biology, Threats, Trade		10-11am		
10	Dr. Sujitha Thomas Principal Scientist	Taxonomy of sharks		11.30 am - 12.30 pm	sujithacmfri@yahoo.co.in	
10	Dr. Satish Sahayak External Expert	Balistid Diversity in India		2-3 pm	satishsahayak@yahoo.co.in	https://zoom.us/j/99965720654?pwd=ZVBPQXFNd0E2QUdCdmpjN0lrMzA4dz09 Meeting ID: 999 6572 0654 Passcode: 047337
10	Dr. Abraham K J External Expert	Taxonomy of Silverbellies		3.15-4.30 pm	abrahamkj71@gmail.com	
11	Dr Patricia Kailola	Taxonomy of catfishes	January 15, 2022			https://zoom.us/j/96432835848?pwd=STB6Uno3K0RzTGZCZGNrdHVWR2xsZz09 Meeting ID: 964 3283 5848 Passcode: 277866
	Dr. Rekha J Nair Principal Scientist ICAR-CMFRI	Taxonomy of Groupers & Snappers		10-11.15 am	rekhacmfri@gmail.com	
11	Mrs Sangeetha AT	Sciaenid Diversity using otolith & airbladder		11.30–12.30 pm	sangeethaat129@gmail.com	
11	Sunil KTS/Rekha Nair	Groupers & Snappers (P)		2-3 pm		https://zoom.us/j/96500786116?pwd=Y3I0bWFjc21nSjZNSm5VMTVDRU51QT09 Meeting ID: 965 0078 6116 Passcode: 341144
11	Dr Manju Sebastian	Taxonomy of Myctophid		3-4 pm	sebmanju@gmail.com	

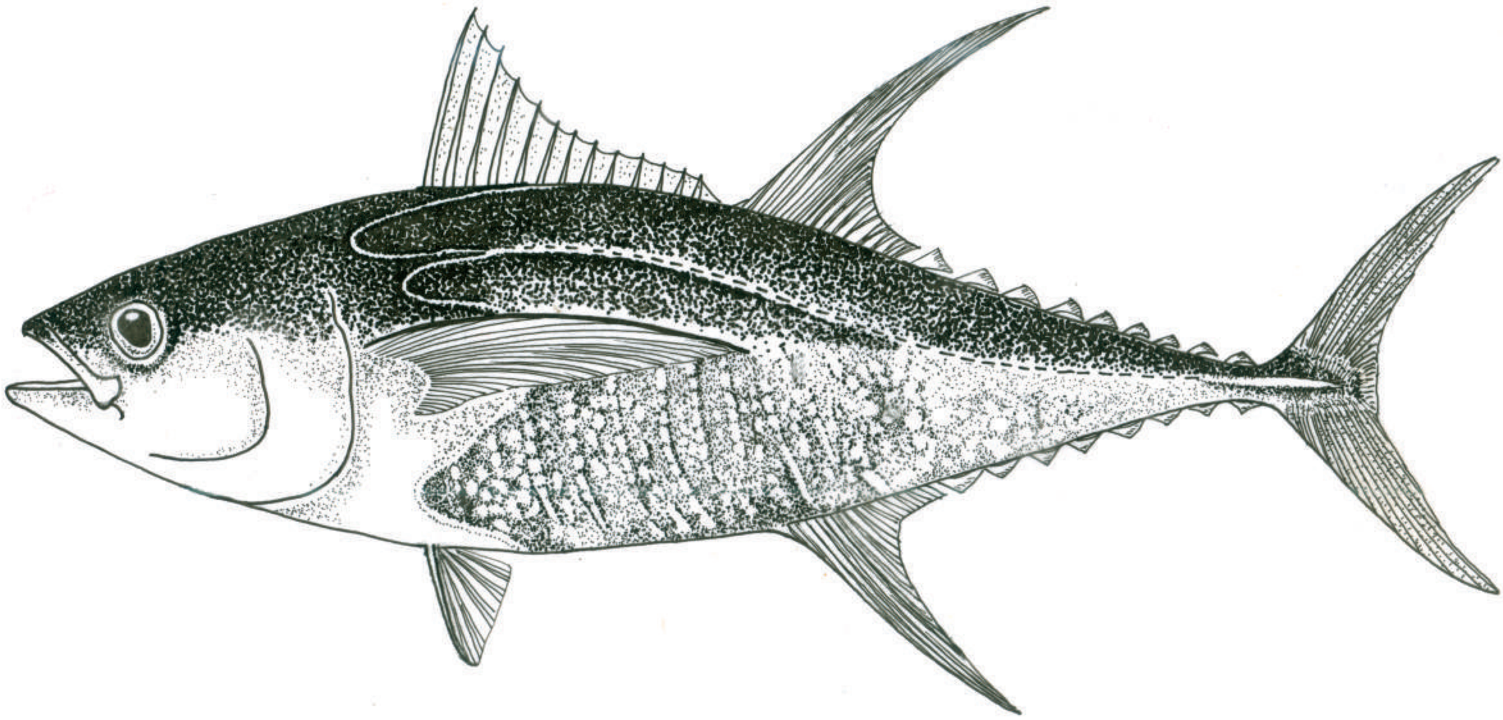
12	Dr. Stuart Poss	Scorpaeniformis	January 17, 2022		velvetfish1@hotmail.com	https://zoom.us/j/91950310923?pwd=U3Zjc1o0WFgzK01oNmVnaFhUS0piUT09 Meeting ID: 919 5031 0923 Passcode: 247958
	Dr. Mahesh V Scientist	Priacanthid and Nemipterid Taxonomy		10–11.30 am	mahesh.fishco@gmail.com	
12		Practicals		12-12.30 pm		
12	Dr. Rekha J Nair Principal Scientist	Flatfish taxonomy		2-4 pm	rekhacmfri@gmail.com	https://zoom.us/j/99106067760?pwd=d0VHcjYvZml4T3YveUQ4YlRpMmh2UT09 Meeting ID: 991 0606 7760 Passcode: 410418
13	Dr. T M Najmudeen Principal Scientist	Pigface bream Taxonomy	January 18, 2022	9.30-10.30 am	najmudeentm@yahoo.com	https://zoom.us/j/94536390554?pwd=c0pvakRaSFJDcmlyZmxzdko4cTYwdz09 Meeting ID: 945 3639 0554 Passcode: 991087
13	Dr.Abdussamad. E.M. Principal Scientist	Fish otolith extraction - importance in taxonomy (C+P)		10.45-11.45 am	emasamadg@gmail.com	
13	Dr. Rekha J Nair Principal Scientist	Flatfish taxonomy (P)		12pm -1 pm	rekhacmfri@gmail.com	
13	Dr. Franz Uiblein External expert	Taxonomy of Goatfishes		2.30pm	franz.uiblein@hi.no	https://zoom.us/j/96276276993?pwd=WWJtRXN3cUxlZ3lpalFsamNwRkM0dz09 Meeting ID: 962 7627 6993 Passcode: 285775

14	Dr Shelton Padua Scientist	GIS in Marine Ecosystem Mapping	Jan19, 2022	10-12.30 pm	sheltonpadua@gmail.com	https://zoom.us/j/99310757293?pwd=eUJvY01HcEVHWnZhcjNUN3BlMTFRZz09 Meeting ID: 993 1075 7293 Passcode: 052457
14		Practicals		2-4 pm		https://zoom.us/j/97024435484?pwd=ckpERHE0eExSWG5LN05kTFV6NUZmQT09 Meeting ID: 970 2443 5484 Passcode: 202575
15	Dr J Jayasankar Principal Scientist	Software solutions to Biodiversity analytics	January 20, 2022	9.30-11 am	jjsankar@gmail.com	https://zoom.us/j/94065275940?pwd=KzlyNzFTRjRiTUZLUXRTSitobk5VUT09 Meeting ID: 940 6527 5940 Passcode: 503578
15	Dr. Eldho Varghese Scientist	Diversity analyses using R		11.15 -4 pm	eldhoiasri@gmail.com	
16	Dr. P. Anilkumar External Expert	Importance of Taxonomic ID in trade	January 21, 2022	9-10.30 am	anilkumarp@mpeda.gov.in	https://zoom.us/j/98724590132?pwd=R2VqekJxM25HdXNjL1hKYngxSUxTdz09

16	Rahul G. Kumar External Expert	Type rules and Taxonomic Paper preparation		10.45-12.30 pm	cichlidiot@gmail.com	Meeting ID: 987 2459 0132 Passcode: 833702
16	Dr K V Jayachandran External Expert	ICZN rules		2-3 pm	jayachandrancmlre@gmail.com	https://zoom.us/j/99140920840?pwd=NlJ0RzYxMmR4ekdKZXZWcFljVEgzQT09 Meeting ID: 991 4092 0840 Passcode: 549218
16	Dr. Rekha Chakraborthy	Truss analysis		2-4.30 pm		
17	Dr. A Gopalakrishnan Director, ICAR-CMFRI Dr Sandhya Sukumaran	New approaches to molecular taxonomy	January 22, 2022	9.30-12.30 pm	director.cmfri@icar.gov.in agopalkochi@gmail.com	https://zoom.us/j/98582331165?pwd=TnRnUExqRHQxakNrUFlTVE5vQm5Idz09 Meeting ID: 985 8233 1165 Passcode: 038936
17	Dr.Ratheesh Kumar R	Marine Mammal Taxonomy		2-3 pm	ratheeshkl4u2@gmail.com	https://zoom.us/j/99805461455?pwd=aExEdkd2YkRrbWIyNTFLYlBiVi9IZz09 Meeting ID: 998 0546 1455 Passcode: 207536
17		Length weight analysis		3-4.30 pm		
18		Discussion & Evaluation	January 23, 2022	10-12.30 pm		https://zoom.us/j/92925714999?pwd=VWlCbXZBUDZPbVdmY1hOM0VxaG0zQT09 Meeting ID: 929 2571 4999 Passcode: 837697
18		Valedictory		2 pm		https://zoom.us/j/91431569800?pwd=MzFzOXppWG1aS0kwZFZkWXFESTU2dz09

						Meeting ID: 914 3156 9800 Passcode: 369544

आज़ादी का
अमृत महोत्सव



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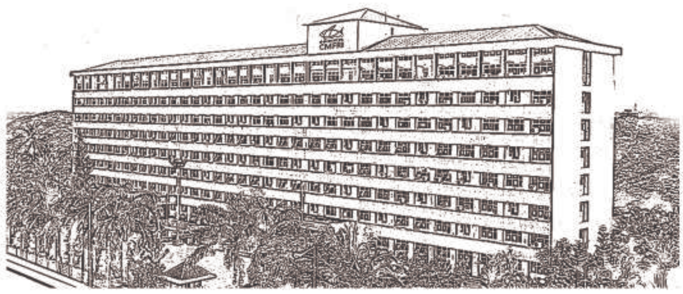

Organised by
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