

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
CENTRAL MARINE FISHERIES RESEARCH INSTITUTE



MARBIE 2

2024

TAXONOMY OF MARINE ORGANISMS



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Indian Council of Agricultural Research
Central Marine Fisheries Research Institute
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Know your Marine Biodiversity & Environment (MarBiE 2)

Taxonomy of Marine Organisms

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Foreword

Sustainable fisheries management aims to protect fishery resources to ensure the long-term viability of fish stocks and marine ecosystems. It combines theoretical disciplines, like population dynamics, with practical strategies, like avoiding overfishing and curbing illegal fishing practices. Correct taxonomy and systematics tools permit the classification of practically all fish species. This capacity is of particular value for fisheries management biological and ecological research as well as to issues related to fisheries products for human consumption. However, its usefulness is hindered by the lack of expertise in this area and the decrease in the number of taxonomists. Specimens have to be identified at species level using standard morphometric and meristic procedures applied by taxonomists.

With sustainability being the critical issue of the hour, developing a younger breed of qualified taxonomists in the different marine realm is of utmost importance. It is physically difficult to identify and collect data on every organism in an ecosystem; therefore, taxonomic studies focus exclusively on specific taxonomic groups, which highlights their significance. The application of contemporary techniques will enhance our understanding of evolutionary linkages. This can entail educating a new generation of specialists on the systematics of the relevant group or persuading more experienced experts to write assessments of the group. The credibility of species occurrence records from current databases and literature needs to be thoroughly evaluated. It is advised to proceed with caution when assigning importance to records if the veracity of the currently available records cannot be assessed. ICAR-Central Marine Fisheries Research Institute (ICAR - CMFRI) was established on February 3, 1947. ICAR - CMFRI focused its research efforts in the first half of its seven decades of existence on estimating landings and effort from marine fisheries, taxonomy of marine organisms, the bio-economic characteristics of the exploited shellfish and finfish stocks, and the development and promotion of mariculture systems for the sustainable growth of marine fish production in the Indian EEZ. It is only fitting that the Institute is holding a training in this capacity to mark its 75 years of research competence in the field of tropical marine fisheries, as its scientists have described over 221 new species.

I congratulate the Course Director, Dr. Rekha J Nair, Principal Scientist, Dr Grinson George, Head, Marine Biodiversity and Environment Management Division, and team for their efforts in bringing out the Manual on time and to arrange the programme in a befitting manner.

A handwritten signature in blue ink, appearing to read 'A. Gopalakrishnan', written over a horizontal line.

(Dr A. Gopalakrishnan)
Director

ICAR -Central Marine Fisheries Research Institute

May 2024

PREFACE

The study of marine organisms is a captivating journey into the vast and intricate world of the oceans. As we delve into the taxonomy of these organisms, we embark on a voyage of discovery, unravelling the complexities of their classification, evolution, and ecological significance. This training manual is designed to be a comprehensive guide for enthusiasts, students, and researchers eager to explore the rich diversity of marine life and understand the principles that underpin its classification.

Taxonomy of marine organisms forms the backbone of our understanding of oceanic ecosystems. By categorizing and organizing these organisms into groups based on their evolutionary relationships and shared characteristics, taxonomists provide us with a roadmap to navigate the immense variety of life beneath the waves. From microscopic plankton to majestic whales, each species has its place in this intricate web of life, and taxonomy helps us make sense of this diversity.

This manual is structured to provide a systematic and in-depth exploration of marine taxonomy. It covers the fundamental principles of classification, the history and development of taxonomic systems, and the tools and techniques used in modern taxonomic research. Through detailed descriptions, illustrations, and interactive exercises, readers will gain a deep understanding of the major taxonomic groups within the marine realm, including bacteria, algae, invertebrates, and vertebrates. Furthermore, this manual emphasizes the importance of taxonomy in conservation efforts, resource management, and our overall understanding of marine biodiversity. By learning about the different taxonomic groups and their ecological roles, readers will appreciate the interconnectedness of marine ecosystems and the need for informed stewardship of our oceans.

I hope that this training manual serves as a valuable resource for anyone passionate about marine life and eager to explore the fascinating world of taxonomy. Whether you are a student embarking on your first journey into marine biology or a seasoned researcher seeking to expand your knowledge, may this manual inspire you to delve deeper into the wonders of the ocean and contribute to the ongoing exploration and conservation of marine organisms.

I wish to place on record the guidance and support of Director, ICAR - Central Marine Fisheries Research Institute, (ICAR-CMFRI), Dr A Gopalakrishnan and Dr Grinson George, Head, Marine Biodiversity and Environment Management Division, ICAR -CMFRI in helping us organise this training. The support of the Organising team, Faculty and Scholars in the preparation of this Manual was commendable.

Happy exploring!

(Rekha J Nair)

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INTRODUCTION TO TAXONOMY

Dr Rekha J Nair

Principal Scientist, ICAR -CMFRI, Kochi

What Is Taxonomy?

Taxonomy is a study of organisms for their identification, description, naming and classification. This field classifies organisms into categories and groups based on their characteristics. It is therefore a methodology that helps in organising plants and animals in hierarchies of higher ranking and subordinate groups. The term is derived from the Greek *taxis* ("arrangement") and *nomos* ("law"). The taxonomic classification given by Carl Linnaeus in 1750 is globally accepted.

Historical Background

- People who live close to nature often have an excellent working knowledge of local fauna and flora. Biologists aim to view all living organisms with equal thoroughness, leading to the development of formal classifications.
- The **Linnaean system** of binomial nomenclature, created by Swedish naturalist Carolus Linnaeus, is internationally accepted for naming and classifying organisms.
- Ernest Haeckel studied about the unicellular eukaryotic organisms and classified them as a separate kingdom and named it Protista, and then the classification was made based on three kingdom classification.
- R.H. Whittaker gave the five kingdom classification (**Monera, Protista, Fungi, Plantae, and Animalia**) where all the organisms are classified based on their physiological structure, habitat, anatomical structure.

However, **Carolus Linnaeus is often regarded as the "Father of Taxonomy."** He is the one who devised a method for naming and organizing species. This method is being followed today. The starting date of binominal nomenclature is fixed as 1st January, 1758, the publication of 10th edition of *Systemae naturae* by Carl Linnaeus. His contributions to taxonomy were many.

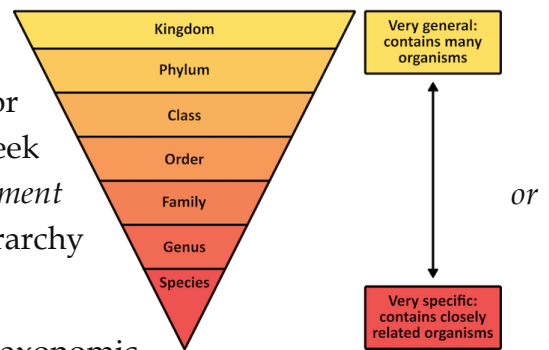
There are several stages of taxonomy such as

Alpha taxonomy: In this stage species are identified and characterized on the basis of gross morphological features.

Beta taxonomy: In this stage species are arranged from lower to higher categories, i.e., hierarchic system of classification.

Gamma taxonomy: In this stage intraspecific differences and evolutionary history are studied.

Taxonomic hierarchy is a system for classifying living species into successive levels of biological classification, called taxonomic categories or ranks. The word "taxonomy" comes from the Greek words "*taxis*" and "*nomos*", which mean "*arrangement*" and "*method*". The taxonomic hierarchy categories are:



- Class: The most general rank in the taxonomic hierarchy until phyla were introduced
- Order: A more specific rank than class
- Family: Includes various genera that share a few similarities
- Genus: A group of similar species
- Species: The lowest level of taxonomic hierarchy

Systematics: In biology, systematics is the study and classification of living things; in other words, grouping organisms based on a set of rules (or system). The word systematics is derived from the Latinized Greek word 'systema' applied to the system of classification developed by Carolus Linnaeus in the 4th edition of his historical book *Systema Naturae* in 1735.

Systematics can be divided into two closely related and overlapping levels of classification: taxonomic (known as the Linnaean System) and phylogenetic.

The typological species concept

For practical reasons, the typological species concept is still used to this day: a species is a set of individuals that are identical to each other and to the "type" specimen, i.e., the specimen used to describe and characterize the species in morphological terms. This type is deposited in a museum where it serves as a reference or a sort of standard for comparisons or future revisions

Type definitions

(EXTRACT OF THE INTERNATIONAL CODE OF ZOOLOGICAL NOMENCLATURE FOURTH EDITION -as adopted by the XX General Assembly of the International Union of Biological Sciences, December 1999)

type, n. A term used alone, or forming part of a compound term, to denote a particular kind of specimen or taxon. **allotype**, n. A term, not regulated by the Code, for a designated specimen of opposite sex to the holotype [Recommendation 72A].

cotype, n. A term not recognized by the Code, formerly used for either syntype or paratype, but that should not now be used in zoological nomenclature [Recommendation 73E].

genotype, n. A term not recognized by the Code, formerly used for type species, but that should not now be used in zoological nomenclature [Recommendation 67A].

hapantotype, n. One or more preparations consisting of directly related individuals representing distinct stages in the life cycle, which together form the name-bearing type in an extant species of protistan [Arts 72.5.4, 73.3]. A hapantotype, while a series of individuals, is a holotype that must not be restricted by lectotype selection; however, if a hapantotype is found to contain individuals of more than one species, components may be excluded until it contains individuals of only one species [Art. 73.3.2]. **holotype**, n. The single specimen (except in the case of a hapantotype, q.v.) designated or otherwise fixed as the name-bearing type of a nominal species or subspecies when the nominal taxon is established.

lectotype, n. A syntype designated as the single name-bearing type specimen subsequent to the establishment of a nominal species or subspecies [Art. 74].

neotype, n. The single specimen designated as the name-bearing type of a nominal species or subspecies when there is a need to define the nominal taxon objectively and no name-bearing type is believed to be extant. If stability and universality are threatened, because an existing name-bearing type is either taxonomically inadequate or not in accord with the prevailing usage of a name, the Commission may use its plenary power to set aside that type and designate a neotype. **paralectotype**, n. Each specimen of a former syntype series remaining after the designation of a lectotype [Art. 72.1.3, Recommendation 74F].

paratype, n. Each specimen of a type series other than the holotype [Recommendation 73D].

syntype, n. Each specimen of a type series (q.v.) from which neither a holotype nor a lectotype has been designated [Arts. 72.1.2, 73.2, 74]. The syntypes collectively constitute the name-bearing type.

topotype, n. (**topotypic**, a.). A term, not regulated by the Code, for a specimen originating from the type locality of the species or subspecies to which it is thought to belong, whether or not the specimen is part of the type series.

Sister species Sister species are biological species that have achieved reproductive isolation but are still difficult to discern based on morphology alone. These species probably result most frequently from recent speciation

Science of naming

Taxonomy is far from simple. A complicated, book devoted to all the rules that must be followed when giving an organism a name called the **International Code of Zoological Nomenclature** is to be followed. It is revised periodically and the latest edition, the Fourth, was published in 1999.

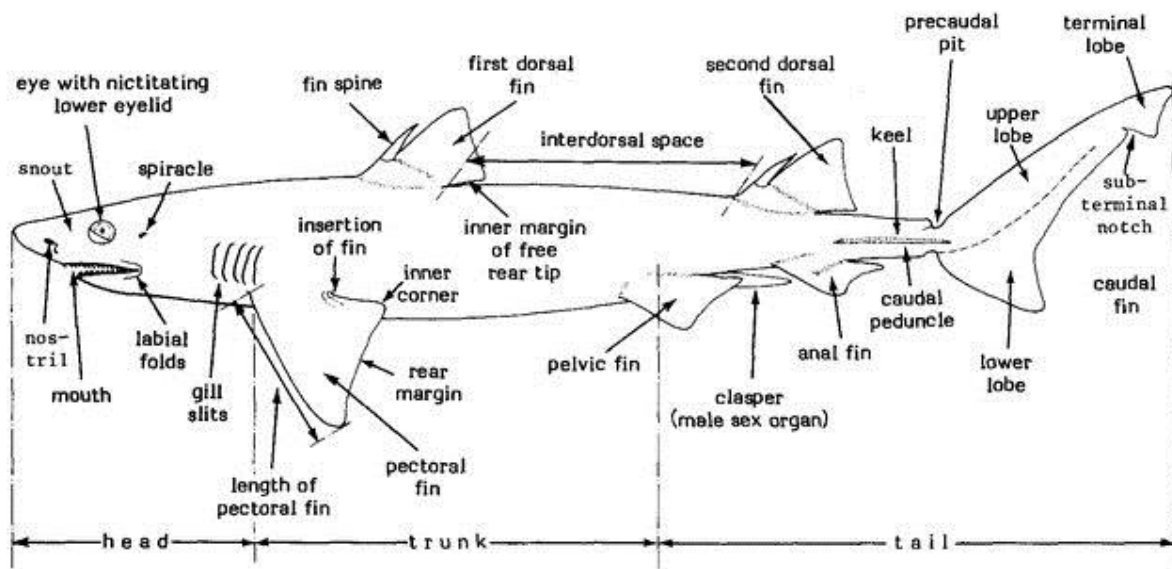
As stated, the full name of a species is given as two words: its genus (always capitalized) followed by the specific epithet (never capitalized)

Formation_of_names - (www.iczn.org)

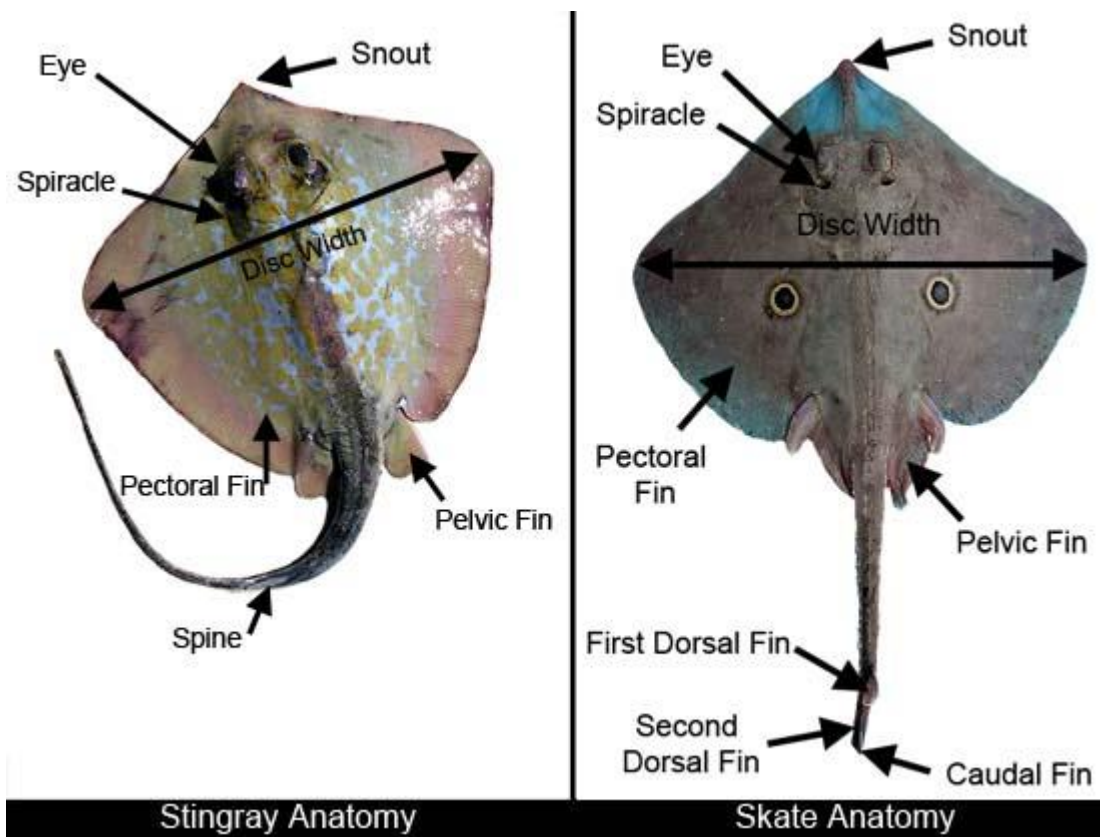
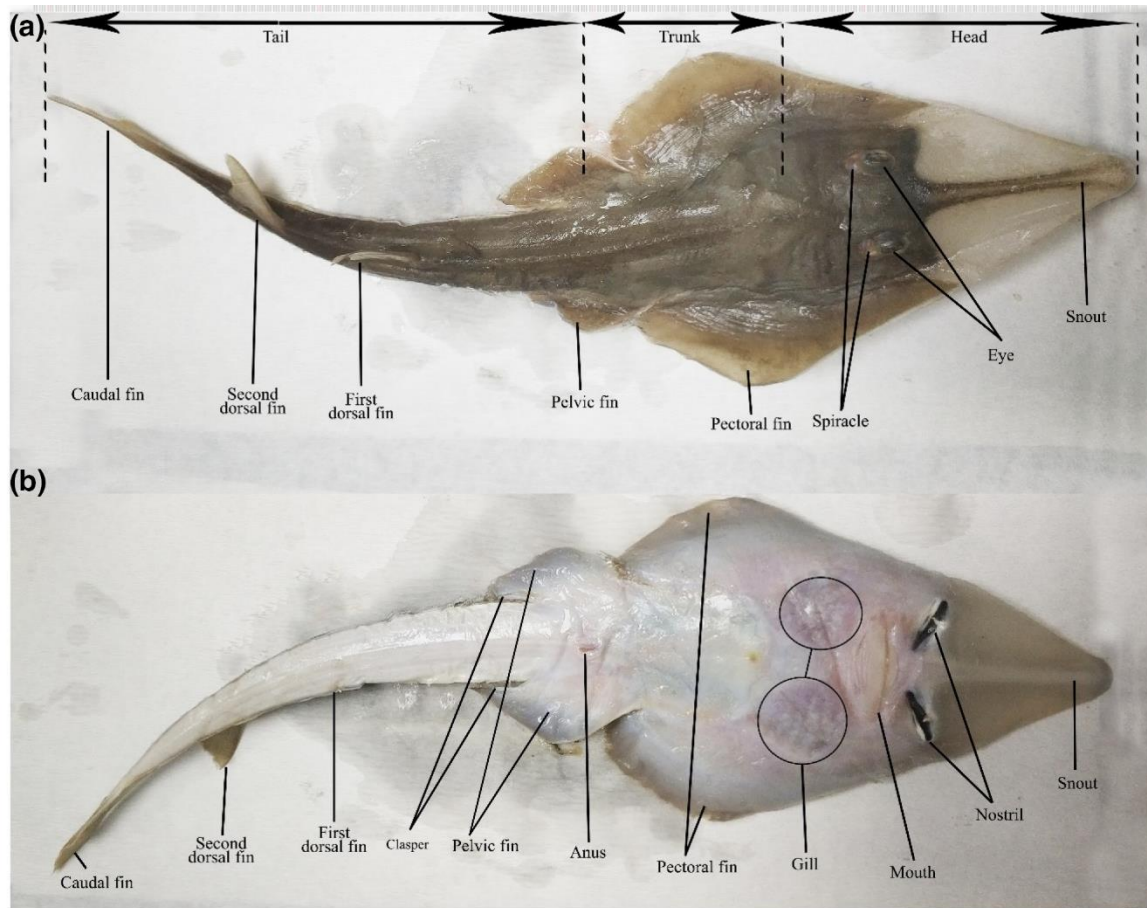
How to proceed in taxonomy

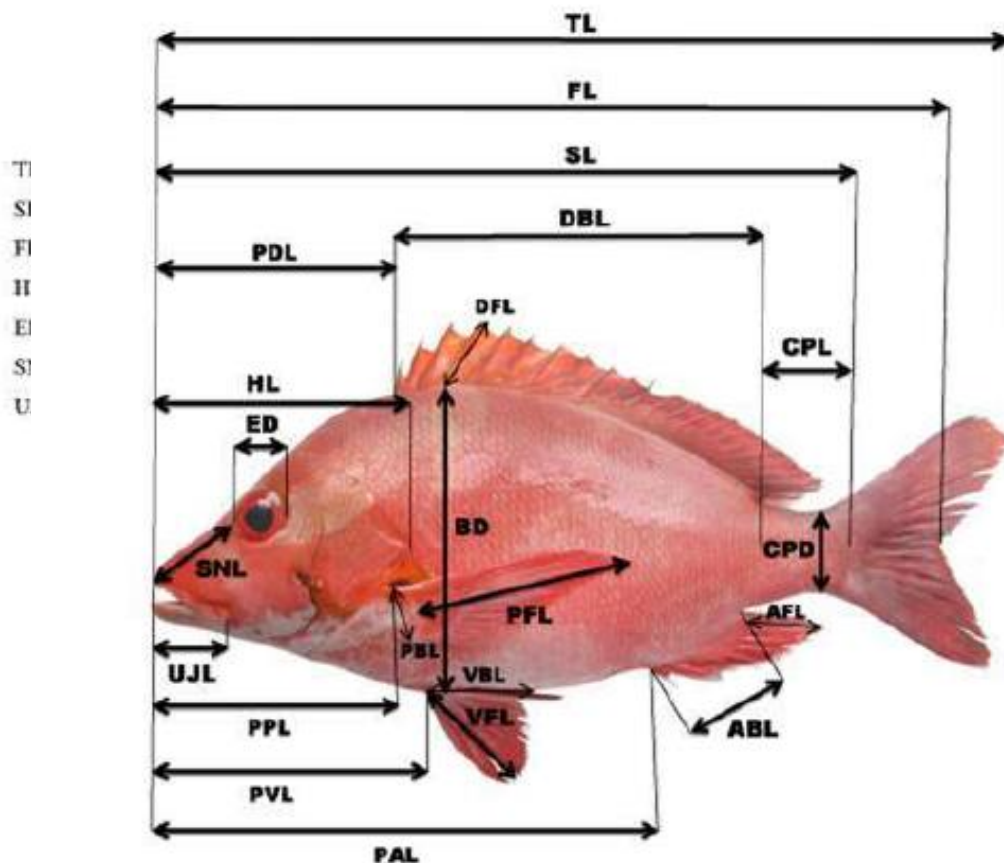
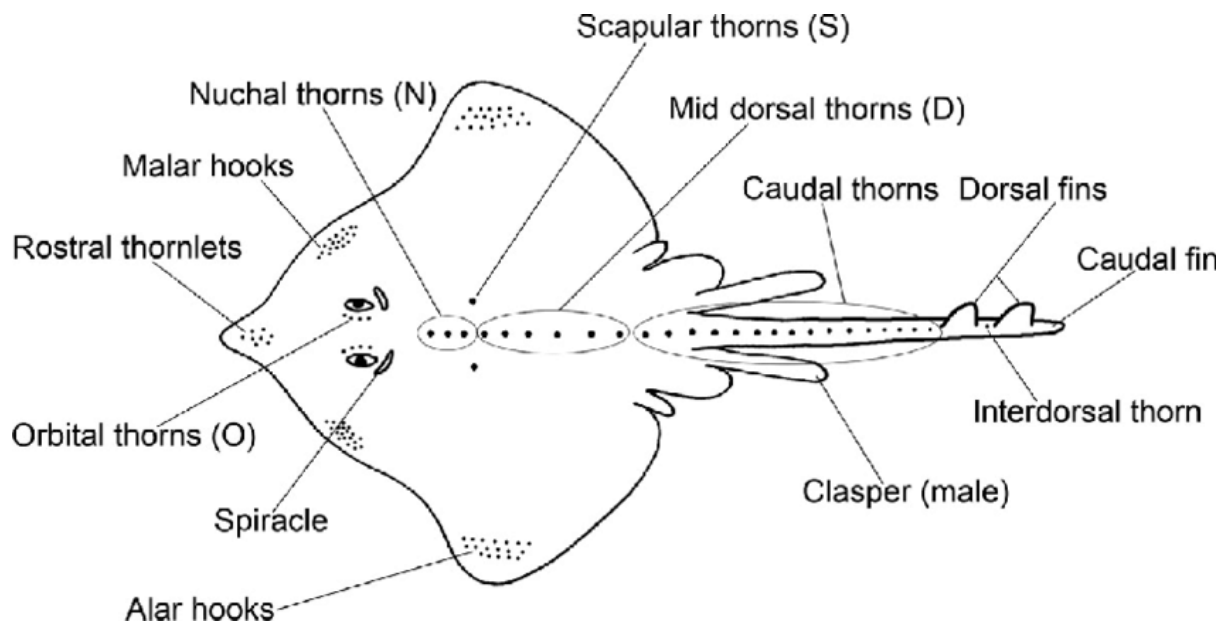
Steps:

1. Collection from wild/harbours
2. The fish is to be first cleaned well, with all debris and slime removed. It is then to be spread out on a thermocol with all fins expanded to get full coverage. A photograph is to be taken in fresh condition to note the colour in fresh
3. All external characters is to be noted down
4. The morpho and meristic features of the fish is to be measured (Figs)



(Source: FAO)





5. Descriptive characters in taxonomy to be noted are

a. 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.

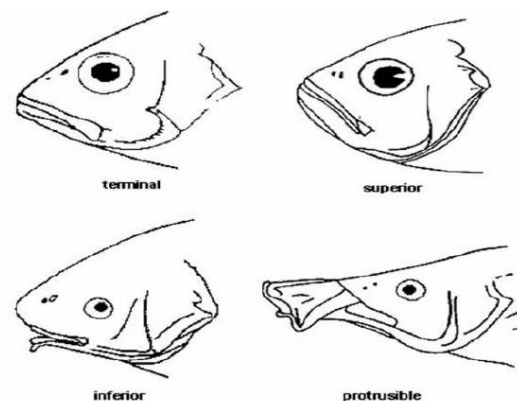
a. Mouth types:

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)

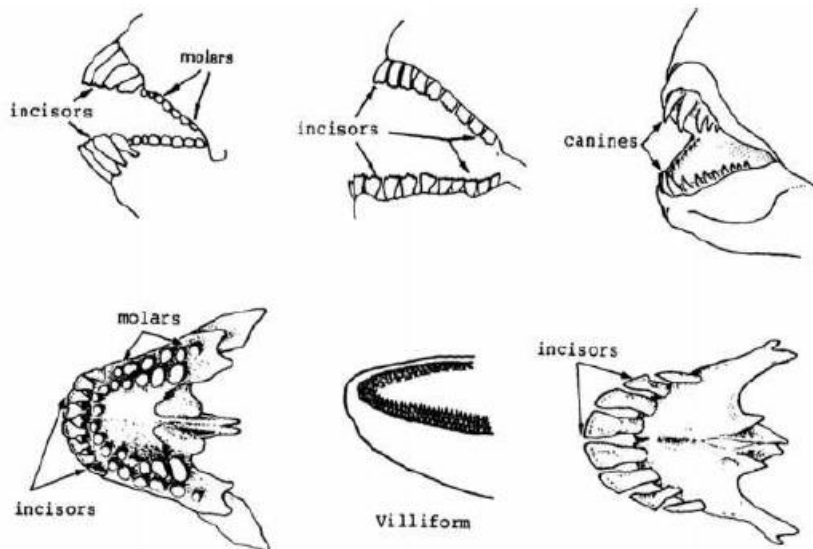
b. **Teeth:** These serve as a very important taxonomic character. Generally, five types of teeth are recognised in fish based on their cardiform, villiform, caniniform, incisiform and molariform.

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

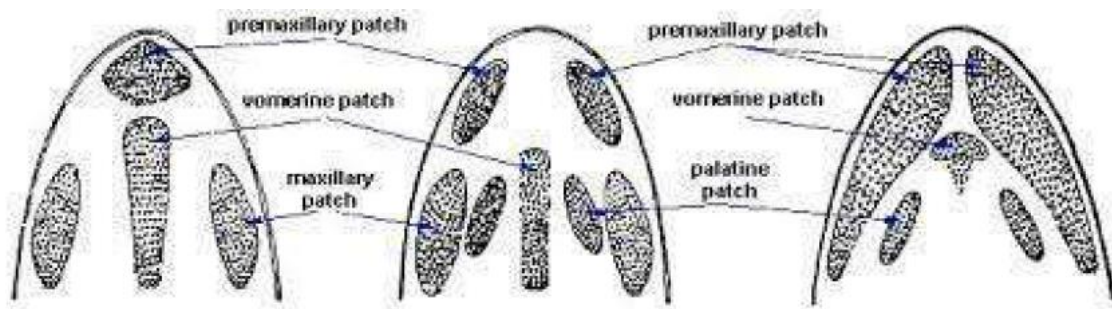
Incisor teeth: Incisors are used for cutting and they come in variety of shapes. These are flattened tooth with chisel like or saw edges.

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

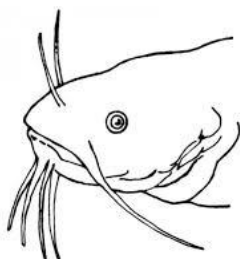
Villiform teeth: Villiform teeth are elongated teeth they are very long, slender and crowded having the appearance of velvet or fine bristles of a brush. They are more common on deep see fishes used for stabbing and direction.



Common Teeth patterns (Source: Edwards et al 2001)



c. **Barbels:** Barbels are slender, whisker like tactile organs near the mouth. They are found in fish like catfish, carps etc, they house the taste buds used by fish to find food.



d. **Body shapes:** Body shape is a dominating factor in taxonomy; deciding on how the fish lives and its domain.

Commonly the fish body is Torpedo - shaped. In a perfectly “stream lined” body form (if head pointed trunk broadened and gradually tapering towards the tail).

Fusiform: Fusiform, or streamlined fish like the barracuda or jack are capable of swimming very fast. They



usually live in open water.

Globiform - (Puffers of family Tetraodontidae)



Serpentine (Snake like Anguilliform - eels of family Anguillidae)



Thread like (spiny eel-Symbanchiformes)



Compressed- Strongly flattened from side (butterfly fishes, Chaetodontidae and flounders - Pleuronectidae)

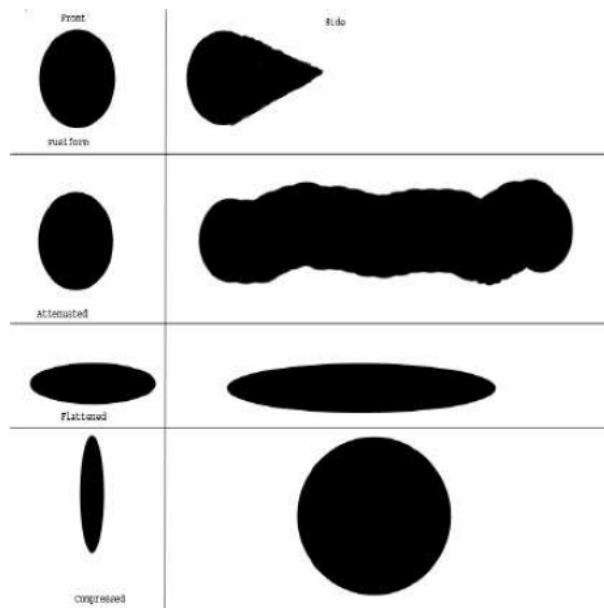


Flattened but greatly elongated (Trachipteriform - ribbon fishes, Trachipteridae)

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

In a cross section, these look like

Body Shapes



Gill Rakers:

The morphology of gill rakers is so diverse that they are often used as a taxonomic tool to identify and classify fish species. For example, plankton feeders have very tightly-packed, comb-like, gill rakers to efficiently filter their food from the water column. Omnivores or piscivores, on the other hand, have shorter, more widely-spaced gill rakers, better for larger prey items.

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.

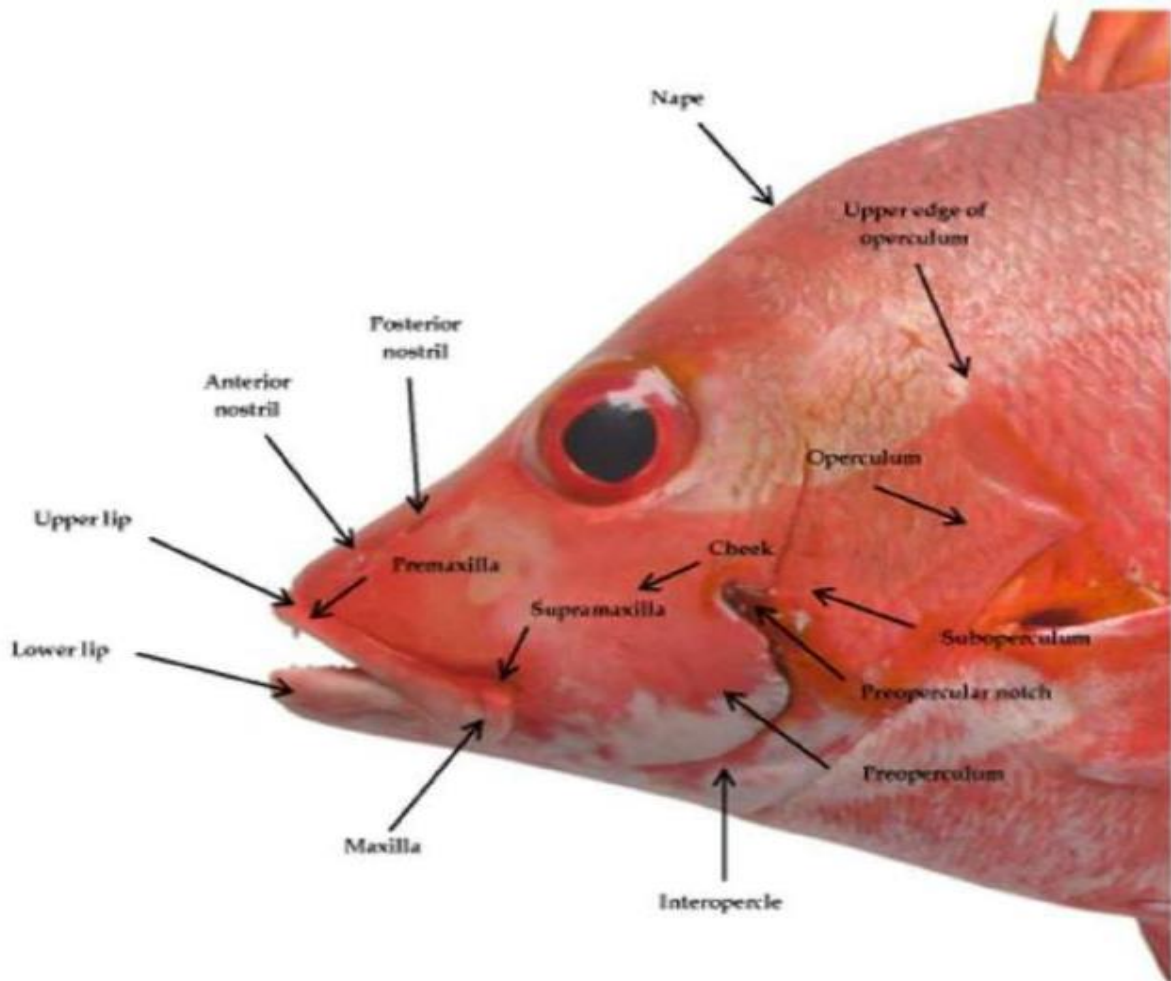
Mimicry

Here, nontoxic individuals mimic toxic individuals; non-aggressive fish look like aggressive species; predators can mimic prey species (ex. Sabertooth Blenny).

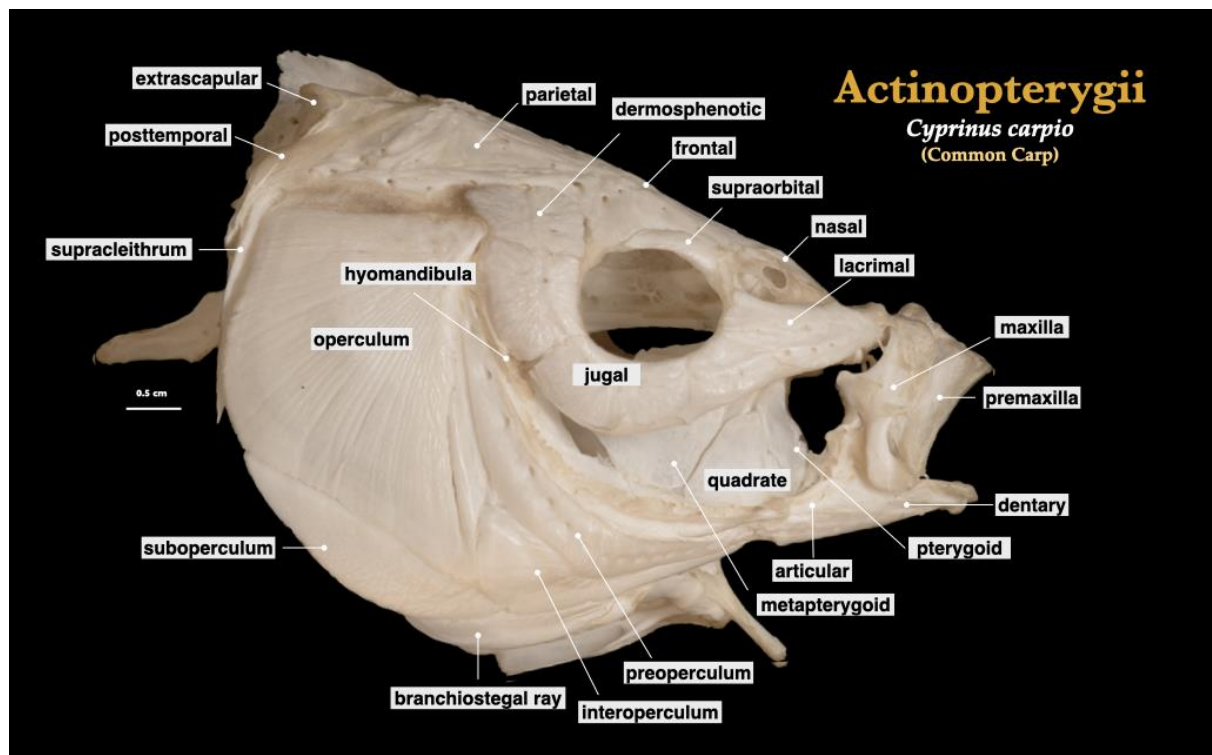
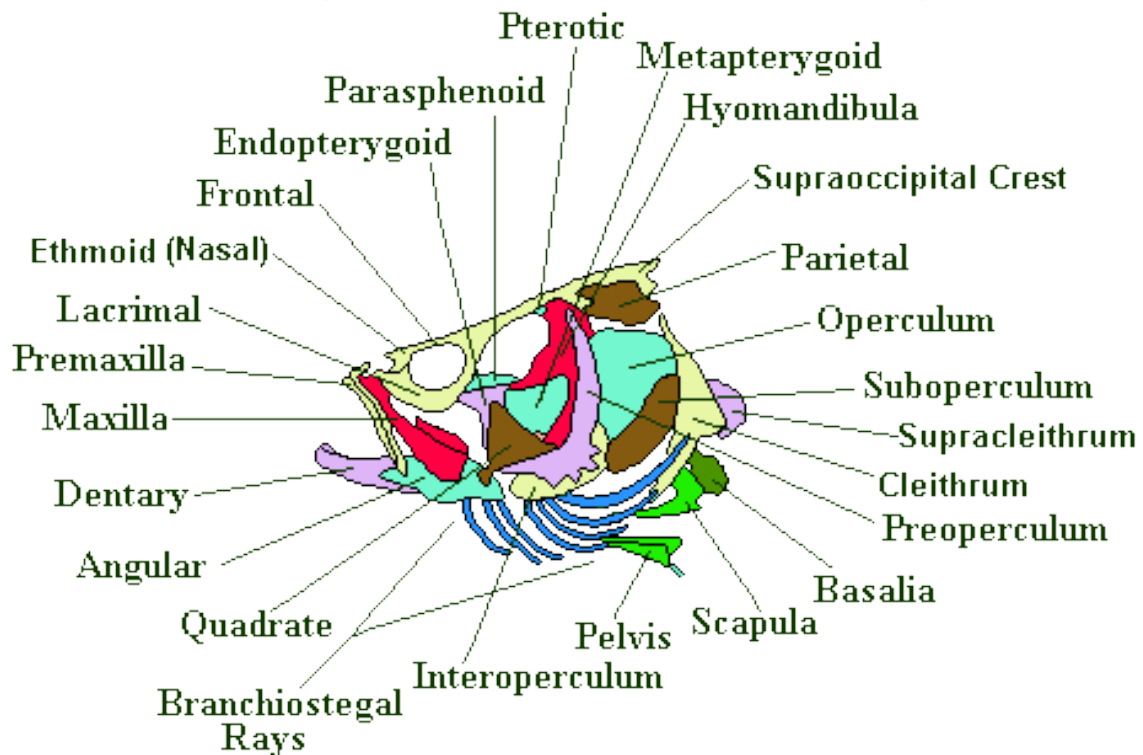


Eye spots are a form of mimicry. The eye spot, usually found near the tail, draws attention away from the real eye which is a target that a predator might strike. The eye spot may cause the predator to attack the wrong end and allow the fish to escape alive.

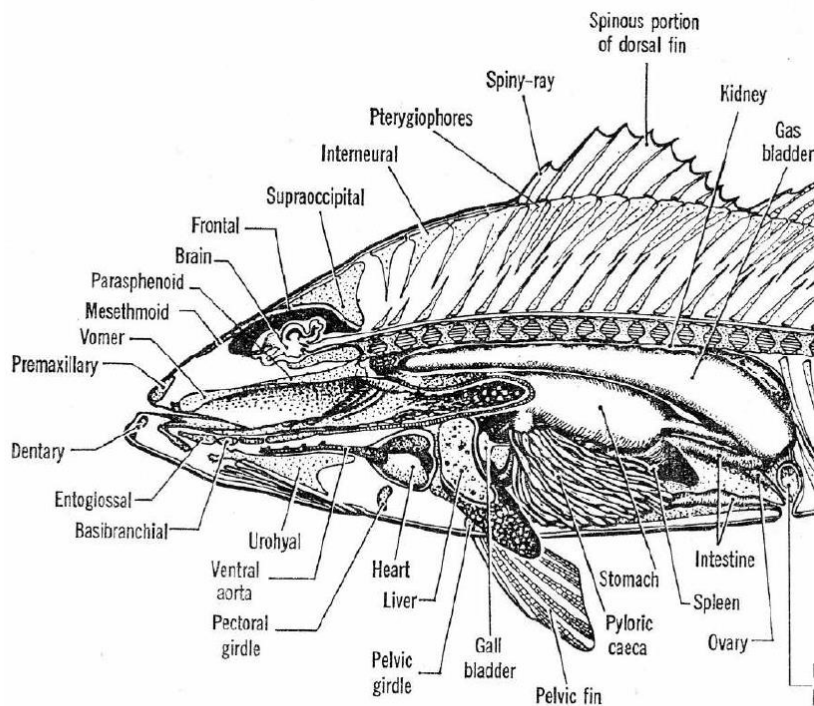
Head



A Generalised Representation of the Skull of a Ray-finned Fish



(Source: Berkeley Museum)



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

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

1. 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.

2. 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.

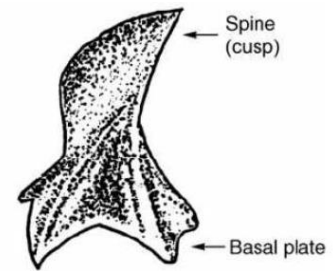
3. Rays are soft, flexible structures that may be branched or unbranched at the tips. The last ray of the dorsal and anal fins is sometimes branched at the base and is to be counted as one ray.

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. Scale types also affect the behaviour of a fish--larger, heavier scales providing more protection but restricting movement, while 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.

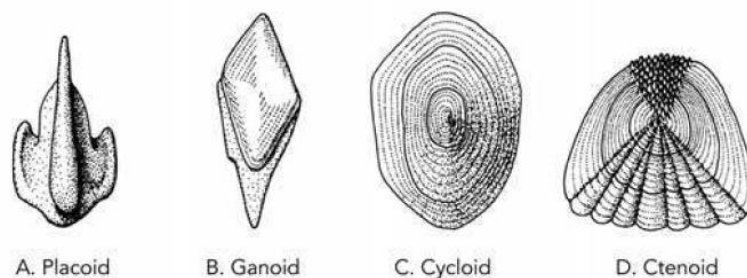


(Source: Diane Elliot, 2011)

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 teethlike 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.

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

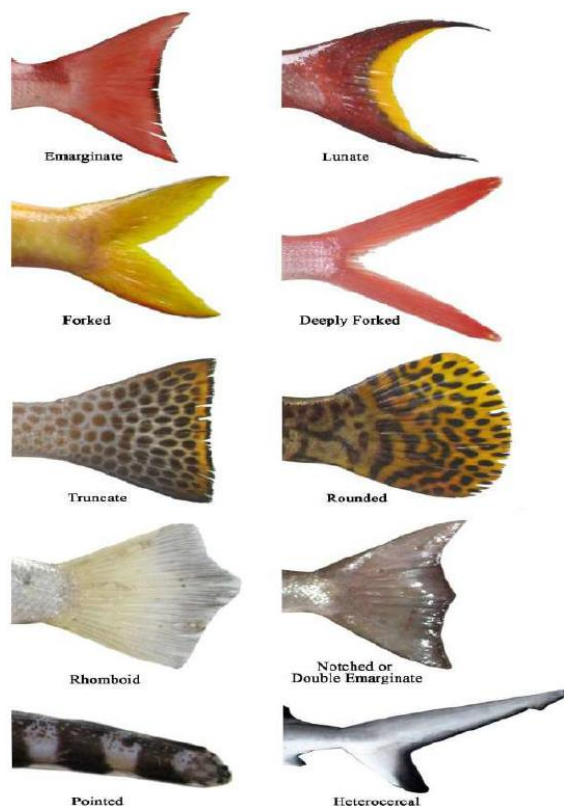
ii. Truncate: ending in vertical edge

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.



Measurements required for taxonomic work:

General measurements to be noted are the following; however, group wise changes/additions/deletions may be required

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 (BD1, BD2):* 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 (BD1). The second measurement for body depth is the distance from base of the first anal fin upwards on a perpendicular axis (BD2).

(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 (P1FL)*: 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 (V1FL)*: 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 (V1FB)*: 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.

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.



SAMPLE COLLECTION, PRESERVATION TECHNIQUES

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The Importance of Fish Collections

Fish collections in museums serve a multitude of purposes, ranging from scientific research and education to conservation and public outreach. They provide a tangible record of biodiversity, allowing researchers to study evolutionary patterns, track changes in species distributions, and delve into the intricacies of ecological relationships. Moreover, these collections play a vital role in taxonomic studies, helping to identify and classify new species and refine existing classifications.

Methods of Fish Collection

The process of fish collection begins with careful planning and ethical considerations. Fisheries scientists, ichthyologists, and museum curators often collaborate to design expeditions or obtain specimens through sustainable means such as bycatch from commercial fishing operations or donations from recreational anglers.

1. **Field Collection:** Field expeditions involve a range of techniques depending on the habitat and target species. These may include seine nets, trawls, electrofishing, and hand collection. Each method is tailored to minimize stress on the fish and ensure accurate representation of the local fauna. The major objective of the collection and documentation is to identify all the available species in the habitat using all the gear combinations. Two types of gears are employed can be divided in to two viz, active and passive categories. Passive gear is usually set and left stationary for a period and commonly used gear are gillnet and traps. Active gears used in the inventory are seine nets, trawl nets, dip nets, hooks and line and electric fishing. Different factors affect fish sampling such as water depth, conductivity, water clarity, water temperature, fish size and fish behaviour.
2. **Specimen Preparation:** Once collected, specimens undergo meticulous preparation. Sample specimens of fish species from different ecosystems covering the entire length range are to be collected and preserved in 2% formalin after injecting 5% formalin through the vent and dorsal musculature. The specimens should be preserved in a wide mouthed bottle in such a manner that the shape is not distorted during storage. Common preservation techniques include formalin fixation for wet specimens or ethanol preservation for genetic studies.
3. **Documentation:** Accurate data recording is paramount. Each specimen is tagged with essential information such as location, date of collection, habitat details, and

collector's name. Digital photographs and detailed field notes further enhance the specimen's scientific value.

4. Morphometric and meristic data are generally taken following Hubbs and Lagler (1947). Measuring linear dimensions of whole or parts of fish is probably the most widely used technique in taxonomic studies. Such observations are made with tapes and digital calipers. Measurements are usually but not always taken along straight lines.

Preservation Techniques

Preserving fish specimens for long-term storage involves a blend of traditional methods and modern technologies:

Wet Preservation: Specimens preserved in alcohol (ethanol or isopropanol) or formalin are ideal for maintaining soft tissues and external morphology. However, these methods can cause tissue shrinkage or color distortion over time and hence cause measurement errors.

Skeleton Preparation: For skeletal studies, specimens undergo maceration to remove soft tissues, followed by degreasing and drying. This process yields clean, articulated skeletons suitable for anatomical research.

DNA Preservation: With advances in molecular biology, DNA extraction and preservation have become crucial. Ethanol serves as a preferred medium for DNA storage, ensuring genetic material remains intact for future analyses.

Digital Archiving: In addition to physical specimens, high-resolution digital imaging and 3D scanning techniques are employed to create virtual archives. These digital replicas facilitate global access to fish diversity without compromising specimen integrity.

Labels and Labelling

Labels, giving all essential data, should be placed in the jar with the fishes when collected. Accurate information about the locality is as valuable as the specimens themselves; specimens without proper data are of little scientific value.

1. Labels should have at least the following information: Exact locality, coordinates, date collected, name of the collector, and any other information that seems pertinent, such as depth of water, method of capture any and all ecological data, etc.



2. Labels should be written with a soft lead pencil or permanent black ink (e.g., a Rapidograph pen) on 100% cotton or linen paper. Do not use ordinary paper because it will disintegrate in the liquid. Do not use a ball-point pen—the ink in most cases washes off in a matter of days.
3. Large fishes may be tagged, preferably through the lower jaw, with all essential data written on the tag, or a number may be used and the data recorded under the identical number in a notebook. Always keep a field notebook in which you record all the information about each collection made.

Accession: Museum specimens are all provided with an accession number which is the key to the classification and housing status of the fish

Curating. Specimens in the collection of fishes will be housed in a variety of receptacles, each designed for maximum resistance to environmental factors that would degrade or otherwise reduce the value of the preserved specimens. Small specimens are to be housed in plastic vials with slip caps or glass vials plugged with cotton or polyester fiber. In order to most effectively combat evaporation, such vials are to be stored in large glass jars. Large specimens are to be preserved well and transferred to glass boxes/cylinders to maximise visibility.

What makes a good scientific specimen for collections?

1. Generally a good specimen is one that isn't a duplicate and one that preserves as much of the character of the living specimen as possible.
2. The specimen should also be preserved in a way that allows particular kinds of analysis.
3. Scientific specimens also need reliable information about where and when a specimen was collected.



Preserving color.

Regardless of the preservative, the vibrant colours of fish aren't mostly preserved. Colour of fishes fade in sunlight, so collection rooms are usually windowless. Instead of turning lighter, the fishes in a collection appear to be shelves-upon-

shelves of jars filled with brown fishes in brownish-yellow liquid. Some fishes lose their color long before they arrive at collections

Educational Outreach and Public Engagement

Fish collections in museums transcend scientific research; they serve as powerful tools for education and public engagement. Exhibits showcasing diverse fish species, evolutionary adaptations, and ecological interactions captivate audiences of all ages, fostering a deeper appreciation for aquatic ecosystems and the need for conservation efforts.

In conclusion, fish collection and preservation for museum taxonomy represent a harmonious blend of scientific rigor, artistic skill, and conservation ethos. Through meticulous curation and responsible stewardship, these collections continue to unravel the mysteries of aquatic life, inspire future generations, and contribute to the global pursuit of biodiversity conservation.



UNDERWATER SAMPLING METHODS FOR MARINE BIODIVERSITY MONITORING

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Abstract

Marine ecosystems are vital for life on Earth, demanding urgent conservation efforts amidst increasing human encroachment. Sampling, essential for biodiversity monitoring, faces unique challenges in the dynamic underwater realm. This article delves into diverse sampling methods tailored for marine biodiversity monitoring. Traditional trawling and dredging, while informative, can harm sensitive habitats, driving the need for sustainable alternatives like dive-based surveys employing snorkelling and SCUBA techniques. Additionally, underwater videography and advanced technologies like ROVs and AUVs offer unprecedented insights. Citizen science initiatives further enhance data collection, despite quality concerns. Understanding these methods' strengths, limitations, and applications is crucial for effective marine conservation across ecosystems worldwide.

Introduction

Marine ecosystems including coastal and deep-sea habitats are essential for human life and existence of our planet. These ecosystems provide irreplaceable services to human race and human activities increasingly encroach upon marine habitats, the need for comprehensive monitoring and conservation efforts has never been more urgent. The underwater world remains a mystery for many including researchers as these are inhabited by countless species, from tiny plankton to massive whales. Understanding the intricacies of marine biodiversity is crucial not only for the preservation of fragile ecosystems but also for the sustainable management of ocean resources upon which millions of people depend.

At the heart of marine biodiversity monitoring lies the fundamental task of sampling – the systematic collection of data from various locations and depths to gain insights into the composition, distribution, and abundance of species. Scientific information derived from monitoring initiatives focused on marine ecosystems is frequently used to understand ecosystem condition and changing dynamics. Scientific monitoring systems require series of protocols for data gathering and these protocols are basically methods which describe 'how the information is collected'. However, conducting sampling in the dynamic and often remote marine environment poses unique challenges that require specialized techniques and methodologies.

In this article, the realm of underwater sampling methods tailored specifically for monitoring marine biodiversity are briefly described. From the rocky shores of coastal ecosystems to the depths of the open ocean, researchers employ a diverse array of tools and techniques to collect data and unravel the secrets of the sea.

Trapping Survey

Trapping survey is a method used in ecological research to assess the presence, abundance, or diversity of species within a particular area. In trapping surveys, researchers deploy traps or similar devices to capture and sample organisms of interest, such as small mammals, insects, or other animals. These traps are designed to attract target species using bait, pheromones, or other lures, and they are typically checked at regular intervals to collect captured individuals.

Limitation: The major limitation is that the sampling is biased towards species that are attracted to the bait or trap type used.

Trawl and Dredge surveys

Traditional sampling methods, such as trawling and dredging, have long been used to study marine life. These techniques involve dragging nets or dredges along the seafloor to capture organisms, providing valuable insights into the composition of benthic communities.

Limitations: These methods are destructive to sensitive habitats and often result in bycatch of non-target species.

Dive- based surveys

Since traditional methods were destructive to nature, researchers felt the necessity to measure the changes in the ecological processes on spatial and temporal scales, by directly observing the underwater ecosystem. This led to the use of snorkelling and SCUBA based dive techniques to do underwater visual surveys. Method includes the broad-scale insights offered by the Manta Tow and Timed Swim techniques to the nuanced observations facilitated by Transects and Quadrats surveys.

Manta Tow Technique: This technique involves pulling a snorkeler behind a boat at a steady pace, pausing periodically to gather data (each dive last approx. 2 minutes). It offers an excellent means of obtaining a comprehensive understanding of vast reef areas or evaluating notable changes in the abundance and distribution of organisms, along with major disturbances such as cyclones, Crown-of-Thorns starfish, and bleaching incidents. It proves highly effective for tracking variables over significant distances and assisting in the selection of strategic sites.



Fig.1. Manta Tow (Photo credit: Australian Institute for Marine Science (AIMS))

Timed Swim Technique: The Timed Swim technique involves a diver swimming for a set time or distance, giving a complete look at the whole site. It helps us understand where things are and what the area's environment is like.

Transect Methodology: Transects offer information on a medium scale. They are lines marked on the reef floor, where divers count benthic organisms. These lines can be tape measures, ropes, or chains of various lengths, with measurements taken at fixed points or where changes occur, like counting chain links or where benthic species change. The choice of length depends on the abundance and spread of what a researcher is monitoring and the variety of the site's features. Various transect survey methods include:

- a. **Line Transects:** In this method, a straight line is established and followed by observers who record all occurrences of the target organisms or features that intersect the line. This technique provides a standardized and efficient way to collect data on biological communities and their spatial patterns.



Fig. 2. Line Transect (Photo Credit: ICAR-CMFRI)

- b. **Point Intercept Transects:** Point Intercept Transects is a method used in ecological surveys to quantify the abundance and distribution of plant species within a specific area. In this method, transects, or linear paths, are established within the study area, and at regular intervals along these transects, observers record the presence or absence of plant species or other ecological features at predetermined points. The data collected can be used to assess species composition, density, and spatial distribution within the habitat under study.
- c. **Belt Transects:** Belt transects are a method used in ecological studies to sample and measure vegetation or other ecological features within a defined area. In a belt transect, a long, narrow strip of land or water is selected for study. Typically, this strip is marked out with parallel lines or markers. Researchers then systematically record data along the length of the transect. This may involve measuring the abundance, distribution, and characteristics of plants or other organisms within the belt, as well as environmental factors such as soil type, slope, or moisture content. Belt transects are often used to provide more detailed information about ecological communities than point-based methods, as they sample a broader area and provide data on vegetation structure and composition along a continuous gradient. Belt transect is facilitated by structures like PVC poles or T-bars.



Fig.3. Belt transect survey (photo credit: NOAA)

To demarcate transects, materials such as waterproof fiberglass tape on a spool with a winding handle, marked rope with coloured indicators or knots denoting distance, or plastic chains with links of known length are commonly utilized.

Quadrat Sampling: Quadrat sampling is a widely used technique in ecology for studying and assessing plant communities or other organisms within a defined area. In this method, the study area is divided into smaller, equally sized square or rectangular plots called quadrats. These quadrats serve as sampling units for collecting data on the presence, abundance, and distribution of plants or other organisms within them. Researchers randomly or systematically place quadrats throughout the study area to ensure representative sampling. Within each quadrat, they record various parameters such as the species present, their abundance (e.g., number of individuals), and sometimes additional characteristics like plant height or biomass. Quadrat sampling provides a standardized and efficient way to gather ecological data, allowing researchers to estimate species richness, diversity, and other community-level metrics. It is commonly used in a wide range of ecological studies, including biodiversity assessments, vegetation surveys, and monitoring ecosystem changes over time. Commonly, quadrats of 0.5-1m² or larger are employed for assessing species diversity, while smaller 25 cm by 25 cm quadrats are suitable for fine-scale investigations of sessile benthic juvenile recruits and other diminutive organisms. Permanent quadrats serve the purpose of longitudinally observing specific coral colonies.

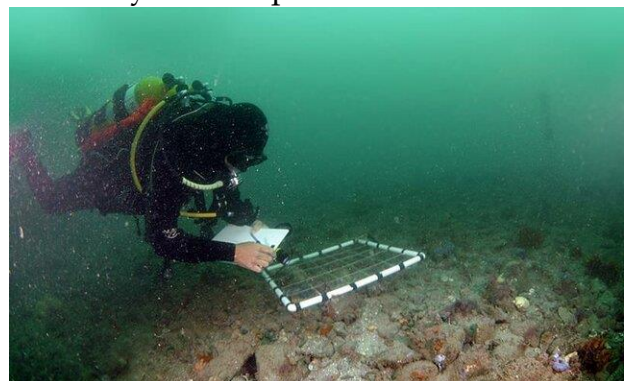


Fig. 4. Quadrat sampling of urchin (Photo credit: James et al., 2016)

Limitations: The major limitations of dive-based methods by humans, are that these surveys are limited to shallow depths. Deeper areas or remote locations may be inaccessible, leading to gaps in data. Poor visibility can hinder the ability of divers to do the survey accurately.

Underwater Videography

Dive-based surveys are limited by the endurance and physical limitations of divers, hence presently many researchers prefer underwater videography as they can maintain consistent sampling effort over time. Utilizing video footage to capture the general reef area offers qualitative insights. For quantitative studies, videos are particularly advantageous for large-scale ecological monitoring using techniques such as belt transects. The width of the belt in video transects is determined by the distance the camera is held from the coral reef benthos. Replicating the exact path, speed, and distance from the substrate for repeated video sampling poses challenges but is essential for maintaining consistency in data collection.

ROV and AUV based surveys

Advances in underwater robotics, including remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs), have opened up new frontiers in marine exploration. ROVs and AUVs can access habitats that may be inaccessible or too dangerous for human divers to reach, making them valuable tools for marine research and conservation. These robotic platforms enable researchers to collect high-resolution data from previously inaccessible depths, allowing for unprecedented insights into deep-sea ecosystems and the organisms that inhabit them.

- a. *ROVs (Remotely Operated Vehicle)*: An ROV (Remotely Operated Vehicle) based biodiversity assessment of marine ecosystems involves using unmanned underwater vehicles equipped with cameras and sensors to explore and document the diversity of life in the ocean. The ROV is launched from a research vessel and maneuverer to the designated survey locations. It is controlled remotely by operators on the surface using a tether, which provides power and communication between the ROV and the surface. As the ROV explores the underwater environment, it captures high-resolution video footage and still images using onboard cameras. Additionally, it may collect environmental data such as temperature, salinity, and depth using sensors. The ROV systematically surveys the seafloor, reefs, or other habitats within the study area, recording observations of marine life and habitat characteristics.

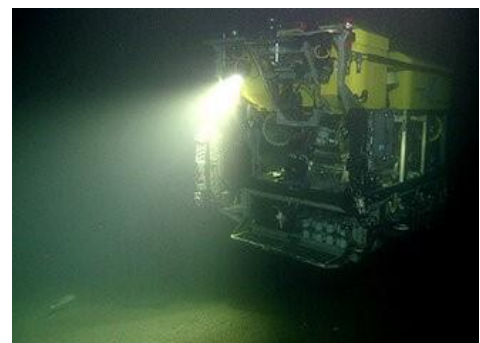
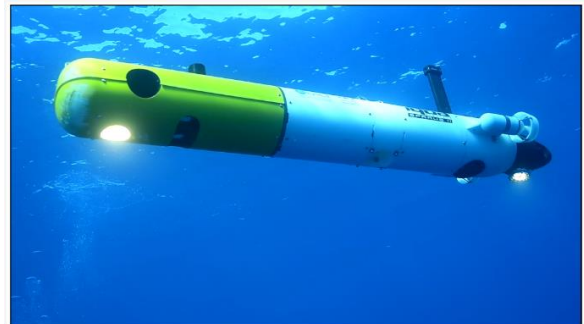


Fig.5. ROV Doc Ricketts to study animal communities (photo credit: MBARI)

- b. *Autonomous Underwater Vehicles (AUVs)*: AUVs are unmanned underwater vehicles designed to operate autonomously without direct human control. These vehicles are equipped with various sensors, navigation systems, and propulsion mechanisms to navigate underwater environments and perform specific tasks or missions. AUVs use a combination of sensors and navigation systems to determine their position,

orientation, and trajectory underwater. This typically includes inertial navigation systems (such as gyroscopes and accelerometers), GPS (Global Positioning System) when near the surface, acoustic positioning systems, and depth sensors. AUVs are outfitted with various sensors to collect data about the underwater environment. These sensors can include cameras, sonars (such as side-scan sonar or multibeam sonar), acoustic sensors for navigation and communication, environmental sensors (for measuring temperature, salinity, pressure, etc.), and instruments for measuring water quality parameters. AUVs are used for a wide range of applications in marine science, oceanography, defence, industry, and environmental monitoring. They can be deployed to study marine biodiversity, map the seafloor, conduct oceanographic surveys, monitor environmental conditions (such as pollution or climate change impacts), search for underwater objects or archaeological sites, and support offshore operations such as oil and gas exploration or pipeline inspection. AUVs are typically deployed from surface vessels or shore-based facilities using launch and recovery systems. Once deployed, they navigate autonomously to their designated survey area, execute their mission, and return to the surface for recovery or data transfer. Overall, AUVs offer significant advantages for underwater exploration and research by providing a cost-effective, efficient, and versatile platform for collecting data in challenging marine environments. Their autonomy and capability to operate in remote or hazardous areas make them valuable tools for advancing our understanding of the oceans and addressing various marine-related challenges.

Fig.6. Autonomous Underwater Vehicles (AUVs) (Photo credit: Gutnik et al., 2022)



Limitations: Both ROVs and AUVs are limited in the area they can cover during a single mission. Their usage is restricted by factors such as battery life, operational constraints during sampling. ROVs and AUVs have limited payload capacity for carrying scientific instruments, sensors, and sampling equipment. This can constrain the types and amount of data that can be collected during a single mission. ROVs and AUVs are sophisticated and expensive platforms that require significant investment in equipment, maintenance, and personnel. Cost considerations may limit the frequency and duration of ROV and AUV surveys, constraining their utility for long-term biodiversity monitoring.

Aerial Survey

An aerial survey is a method of data collection in which observations or measurements are made from an aircraft or other aerial platform. These surveys are often used in various fields such as environmental monitoring, wildlife management,

land-use planning, and geographic mapping. Aerial surveys can involve visual observations, photography, remote sensing, or other sensing technologies to gather information about the Earth's surface or atmosphere. They are particularly useful for covering large areas quickly and efficiently, providing a broad perspective that may not be possible with ground-based methods. Aerial surveys are commonly employed to assess land cover, monitor wildlife populations, map terrain features, monitor environmental changes, and conduct various research and monitoring activities.

Limitations: Aerial surveys are highly dependent on weather conditions. Adverse weather such as fog, clouds, rain, or high winds can limit visibility and disrupt data collection. Conducting aerial surveys can be expensive and hence limit the frequency and extent of surveys, especially in large or remote areas. Aerial surveys can provide an overview of large areas, they may lack the capability for detailed ground-level observations. Fine-scale features or subtle changes may be difficult to detect from an aerial perspective.

Citizen Science Initiatives

In addition to technological advancements, citizen science initiatives play a crucial role in marine biodiversity assessment and conservation by harnessing the collective efforts of volunteers, enthusiasts, and local communities to contribute valuable data and observations. Citizen scientists can contribute to marine biodiversity assessment by collecting data on marine species, habitats, and environmental conditions. This can include recording observations of marine life during beach walks, snorkeling or diving trips, or from shoreline vantage points. By engaging a large number of volunteers, citizen science initiatives can collect data over large spatial scales and time periods, providing valuable insights into marine biodiversity patterns and trends. Citizen scientists can help monitor the abundance, distribution, and behaviour of marine species, including both common and rare species. This information can contribute to understanding population dynamics, detecting changes in species distributions, and identifying areas of ecological importance or concern. Citizen science initiatives can assist in mapping and monitoring marine habitats such as coral reefs, seagrass beds, and mangrove forests. Citizen scientists can help monitor environmental parameters such as water quality, temperature, salinity, and pollution levels in marine ecosystems. By collecting and analyzing water samples or using simple monitoring tools, volunteers can contribute to ongoing efforts to track environmental changes, identify sources of pollution, and assess the impacts of human activities on marine ecosystems.

Limitations: One of the primary concerns with citizen science data is its quality and reliability. Since volunteers may have varying levels of expertise and training, there is a risk of inconsistencies or inaccuracies in the data collected. Citizen science projects may not always achieve comprehensive spatial or temporal coverage of the study area. Data collection efforts may be concentrated in easily accessible or popular locations, leading to biases in the data and gaps in our understanding of biodiversity patterns.

Identifying species accurately can be challenging, especially for non-experts participating in citizen science projects. Misidentifications or errors in species identification can introduce noise into the data and undermine the reliability of biodiversity assessments.

This chapter has explored the major sampling methods in greater detail, and examined their strengths, limitations, and applications in marine biodiversity monitoring. From the bustling coral reefs of tropical seas to the frigid waters of the polar regions, each ecosystem presents its own unique challenges and opportunities for exploration.

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MARINE MICROBES: TAXONOMY AND DIVERSITY

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Marine microbes: Taxonomy and diversity

Marine microorganisms form a diverse and intricate group crucial for marine ecosystems' functioning. They include bacteria, archaea, viruses, and microeukaryotes, each contributing uniquely to the dynamics and functions of marine environments. These microbes are believed to be the closest living descendants of early life forms that emerged in the oceans billions of years ago, laying the foundation for subsequent life forms. They serve as microscopic factories, catalyzing crucial chemical reactions within biogeochemical cycles. Their metabolisms, both aerobic and anaerobic, enable them to perform vital steps within these cycles, contributing to nutrient cycling, carbon sequestration, and sustaining life on our planet. Understanding and acknowledging the significance of marine microbes are crucial for preserving Earth's ecological balance and ensuring the continuity of life on our planet. The unique adaptability of microorganisms to thrive under diverse physicochemical conditions underscores their critical role in maintaining the delicate balance of ecosystems. Given their significance, it is crucial to comprehensively catalog the diversity of marine microbes. However, their microscopic size presents a challenge as they are invisible to the naked eye, requiring advanced techniques and technologies for effective classification. This challenge emphasizes the need for continuous advancements in microbiological research to uncover and understand the full extent of microbial diversity in marine environments.

Marine microbial habitats can be classified based on (i) presence of other organisms (Symbiotic, Free living and Biofilm); (ii) proximity to ocean surface or sediments (Euphotic: 0-150 m; Mesopelagic: 150 - 1000 m; Bathopelagic : >1000m; Benthos : sediments) and also based on (iii) concentration of nutrients and required growth substances (Oligotrophic, Mesotrophic, Eutrophic). Interfaces between different habitats are known to be biodiversity hotspots, including interfaces like air-water, water-sediment, water-ice, and the interfaces between host macroorganisms and water. However, these interface habitats present challenges for detailed study due to their sub-millimeter scale of physical and chemical variability. Advancements in technology and interdisciplinary approaches are essential for unraveling the complexities of these interface habitats and understanding their role in shaping marine microbial diversity.

The recent emphasis on biogeography within microbial diversity studies stems from the inherent challenges posed by the small size of microorganisms and the intricate nature of their environments. Environmental complexity plays a pivotal role in shaping microbial diversity, where spatial heterogeneity fosters the creation of numerous ecological niches within a given habitat. Modern tools like metagenomics

have revolutionized the understanding of microbial ecology by providing valuable nucleic acid sequence data. This technology enables direct identification of microorganisms and facilitates the comparison of microbial diversity profiles across different habitats. Within the realm of microbial diversity, several key concepts aid in understanding the intricacies of community structure and distribution:

1. Alpha diversity: This concept pertains to the diversity within a specific location or community. It encompasses the richness (number of different taxa) and evenness (relative abundance of each taxon) of microorganisms within a defined area.
2. Beta diversity: Beta diversity measures the differences in community composition between multiple locations or habitats. It helps elucidate how microbial communities vary across different environmental conditions and geographical areas.
3. Gamma diversity refers to diversity at a larger regional scale, encompassing continents, biomes, or other broad geographic regions. It provides insights into the overall diversity of microorganisms across extensive spatial extents.

By employing these concepts, researchers can gain a comprehensive understanding of the distribution patterns and compositional variations of microbial communities across diverse marine habitats. This knowledge is crucial for elucidating ecological processes, predicting responses to environmental changes, and conserving microbial biodiversity. Within ocean-surface bacterioplankton communities, the dominant clade is the heterotrophic SAR11, representing a highly successful group of bacteria that play a crucial role in marine ecosystems. Meanwhile, non-photosynthetic protists of diverse origins play a regulatory role in picoplankton populations and nutrient supply, contributing significantly to marine food webs. Collectively, bacterial, archaeal, and protist communities account for over 90% of oceanic biomass and are responsible for a staggering 98% of primary production in marine environments. Archaea are particularly noteworthy for their remarkable ability to thrive in extreme environments, showcasing unique adaptations and differing notably from bacteria due to the absence of peptidoglycan in their cell walls. Both archaea and bacteria play pivotal roles in shaping marine environments, contributing significantly to ecological processes and nutrient cycling essential for sustaining marine life.

Over the past two decades, advancements in molecular studies utilizing gene sequences encoding the small subunit rRNA (SSU rDNA) have revolutionized our understanding of marine microbial diversity. These studies have unveiled a vast array of new marine microorganisms, contributing to a sense of continual discovery among marine microbiologists. However, despite these advancements, much of this newfound diversity remains largely undescribed due to the challenges associated with requiring pure cultures to define a species accurately. The ongoing exploration of marine microbial diversity offers a glimpse into a vast and complex world, underscoring the ongoing importance of research and technological advancements in uncovering the intricacies of marine ecosystems. This era of continual discovery fuels

excitement and curiosity among researchers, with the realization that there is still much to learn and explore in the realm of marine microbiology. Recent explorations into microbial diversity have unveiled a treasure trove of previously unknown microorganisms, many of which play pivotal roles in oceanic processes. Among these groundbreaking discoveries are vast populations of picoplankton, encompassing diverse groups such as diatoms, dinoflagellates, picoflagellates, and cyanobacteria. These picoplankton acts as primary drivers of carbon fixation, orchestrating nitrogen cycling, and forming the foundational base of the traditional marine food web.

The advent of modern technologies, including advanced molecular techniques and automated fluorescence cell sorting, has revolutionized our comprehension of microbial life in the oceans. These technological leaps have allowed scientists to uncover the immense abundance and diversity of microbial forms, particularly through the application of DNA sequencing methods to environmental genomes. Metagenomics has become an indispensable tool in studying microbial communities, especially considering that an estimated 99% of the microbial population remains uncultivable using conventional methods. One of the standout revelations from molecular techniques is the identification of SAR11 as a dominant clade within ocean-surface bacterioplankton communities. Bacteria belonging to the SAR11 clade, specifically within the Pelagibacteraceae family, make up approximately one-third of cells at the ocean's surface. Remarkably, SAR11 bacteria are estimated to represent between a quarter and half of all prokaryotic cells in the ocean, underscoring their remarkable prevalence and ecological significance. Within the SAR11 clade, the highly abundant marine species *Candidatus Pelagibacter ubique* has garnered significant attention for its ubiquity and ecological importance in marine environments. Although this species has not yet been officially published, the strain HTCC1062 has been successfully isolated in pure culture, marking an important milestone in understanding the taxonomic and functional attributes of SAR11 bacteria. These discoveries highlight the ongoing exploration and appreciation of microbial diversity in marine ecosystems, showcasing the intricate and vital roles that microorganisms play in sustaining oceanic processes and overall ecological balance.

Taxonomic classification of marine microbes

In modern microbial taxonomy, an integrated approach known as polyphasic taxonomy is employed to define microbial species. This approach combines both phenotypic and genotypic characteristics, ensuring a comprehensive understanding of microbial diversity and evolutionary relationships. When proposing a new taxon, it is imperative to isolate the organism in pure culture and thoroughly evaluate its characteristic features under standardized conditions. Consistency in phenotypic traits among all strains within a species is fundamental for accurate classification. The designation of a type strain within a species serves as the benchmark specimen for that species, aiding in comparative studies and taxonomic reference. The utilization of 16S rDNA sequences plays a pivotal role in species delineation within microbial

taxonomy. Organisms with 16S rDNA sequences exhibiting $\leq 98.5\%$ similarity are typically considered members of distinct species. However, for uncultured microbes whose phenotype remains unknown, classification into specific species is challenging. Instead, they may be denoted as 'Candidatus' provided their 16S rRNA sequence aligns with established species identity principles, indicating a potential new taxon awaiting further characterization. An important concept within microbial taxonomy, especially below the strain level, is the notion of ecotypes. Ecotypes refer to microbial populations that occupy specific ecological niches and have adapted to the prevailing environmental conditions within those niches. This adaptation often results in genetic and phenotypic divergence, highlighting the diverse ecological roles microorganisms fulfill in their respective habitats. The recognition of ecotypes underscores the dynamic nature of microbial communities and their capacity to evolve in response to environmental pressures, contributing to the overall biodiversity and functional diversity within ecosystems.

Numerical taxonomy

Numerical taxonomy stands as a comprehensive method in microbial classification, incorporating a wide array of biochemical, morphological, cultural, and susceptibility traits. These traits encompass diverse range of observable traits such as colony morphology, cell shape and size, cell wall composition, pigmentation patterns, growth requirements, metabolic capabilities, protein profiles, responses to antibiotics, inorganic compounds, and other environmental factors. Typically, each organism is assessed based on 50 to 200 traits, providing a robust dataset for comparison and analysis. The process involves calculating the degree of similarity between strains, with each strain representing a unique isolate from a sample. This similarity is expressed as a coefficient or percentage, reflecting the extent of shared traits and characteristics between organisms. Utilizing these similarities, a dendrogram or similarity matrix is constructed, visually organizing individual strains into groups based on their degree of similarity. The dendrogram serves as a graphical representation of the relationships between different strains and groups. It arranges groups that exhibit higher similarity closer together, highlighting clusters of organisms with shared traits and evolutionary relationships. This approach offers a systematic and quantitative method for understanding microbial diversity, facilitating the classification and organization of microbial taxa based on measurable and objective criteria. The significance of 16S rDNA sequences in delineating species uniqueness cannot be overstated, as they provide crucial insights into the genetic makeup and evolutionary relationships of microorganisms. However, numerical taxonomy, which leans on phenotypic traits spanning a wide spectrum of species, remains a stalwart and robust approach in microbial classification. In fact, it stands out by offering several advantages and aligning seamlessly with modern taxonomy practices.

In essence, numerical taxonomy stands as a robust and enduring methodology in microbial classification, offering a nuanced and comprehensive perspective on species relationships and uniqueness based on observable traits and behaviours. Its integration of diverse characteristics makes it a valuable tool in modern microbial taxonomy practices, working hand in hand with genotypic data to unravel the complexities of microbial diversity and evolution.

Polyphasic taxonomy

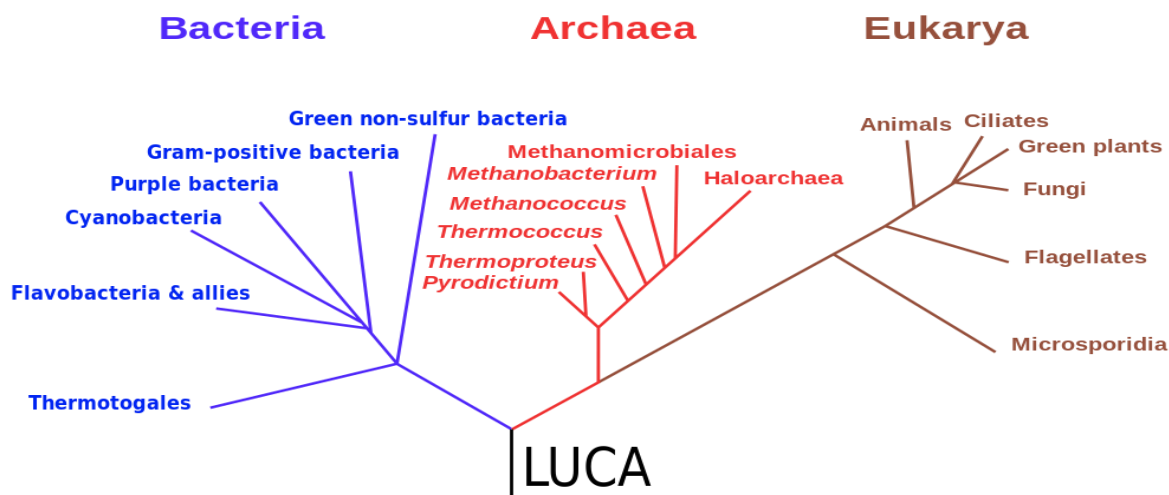
The polyphasic approach to microbial taxonomy represents a comprehensive and multifaceted strategy aimed at providing a detailed description of organisms by integrating various types of data. This approach recognizes that a single criterion or method may not capture the full complexity and diversity within microbial taxa. Instead, it combines multiple sources of information to paint a more complete picture of microbial diversity and relationships. Phenotypic characteristics form a critical component of the polyphasic approach. These phenotypic traits serve as tangible and readily observable markers that aid in the initial identification and characterization of microbial species. Genotypic features, derived from nucleic acids such as DNA and RNA, provide a deeper insight into the genetic makeup of organisms. Molecular techniques like DNA sequencing allow researchers to examine specific genes or regions of the genome, revealing genetic similarities and differences among organisms. For instance, genes like 16S rRNA (bacteria), 18S rRNA (fungi), or 23S rRNA (bacteria) are often used in phylogenetic analyses to elucidate evolutionary relationships and construct phylogenetic trees. DNA barcoding approach has emerged as a promising method for assessing microbial diversity, although there are challenges regarding the availability of comprehensive datasets, particularly for eukaryotic microbes. Despite these limitations, advancements in sequencing technologies have significantly enhanced the speed and cost-effectiveness of genetic analysis, thereby improving the accessibility and accuracy of genetic information crucial for microbial taxonomy.

Phylogenetic information is crucial in the polyphasic approach, as it helps place organisms within evolutionary contexts and infer their evolutionary histories. By comparing sequence similarities in phylogenetically informative genes, researchers can discern evolutionary relationships and identify distinct clades or groups within microbial taxa. Various molecules and techniques are employed in the polyphasic approach to delineate and describe taxa. Certain components, such as 16S rRNA genes, phenotypic traits, and chemotaxonomic markers, are considered essential and are typically included in taxonomic descriptions. Optional components may include more advanced techniques like amino acid sequencing of specific proteins or DNA-DNA hybridization, which are utilized as needed to achieve accurate taxonomic classifications and descriptions. Overall, the polyphasic approach represents a holistic

and integrative strategy that leverages phenotypic, genotypic, and phylogenetic data to provide a comprehensive understanding of microbial diversity, relationships, and taxonomy. This approach acknowledges the multifaceted nature of microbial organisms and aims to capture their complexity through a combination of diverse methodologies and information sources.

Marine microbes across the three domains of life

The vast diversity of microbial life in the sea encompasses organisms from all three domains of life viz., archaea, bacteria, and eukarya, along with viruses, although the latter are often not considered living organisms by many authorities. These groups exhibit distinct differences in morphology, physiology, and phylogeny, spanning both prokaryotic and eukaryotic domains. The three-domain system, introduced by Carl Woese *et al.* (1990), revolutionized taxonomic classification by categorizing all cellular life into three domains viz., Archaea, Bacteria, and Eukarya. Unlike earlier classifications such as the two-empire system and the five-kingdom classification, this system notably separated Archaea (formerly known as "archaebacteria") from Bacteria as distinct organisms.



Phylogenetic tree depicting the divergence of bacteria, archaea, and eukarya based on rRNA data, as proposed by Carl Woese *et al.* (1990), along with the conceptual depiction of the Last Universal Common Ancestor (LUCA)

1. Domain Bacteria

The Domain Bacteria, stand as one of the earliest branches on the evolutionary tree of life, distinctly separate from archaea (Domain Archaea) and eukaryotes (Domain Eukarya). Their omnipresence in marine environments underscores their fundamental role in sustaining life on Earth. Bacteria are instrumental in the recycling of essential nutrients within marine food webs, a process vital for ecosystem functioning. Despite

their critical importance, our knowledge of bacterial biology in marine settings remains somewhat limited. This limitation primarily stems from the fact that only a fraction, averaging around 1%, of marine bacteria can be successfully cultured under laboratory conditions. Consequently, our understanding of the vast majority of bacterial diversity and their ecological roles in marine ecosystems is hindered. Within marine environments, the majority of bacterial isolates belong to five major phyla, each contributing uniquely to ecosystem dynamics.

i. Phylum Proteobacteria: This diverse group of Gram-negative bacteria encompasses Alpha-, Beta-, Gamma-, Delta-, and Epsilon-Proteobacteria, each with distinct metabolic capabilities and ecological roles. They play significant roles in nutrient cycling, bioremediation, and symbiotic relationships with marine plants and animals. Some Proteobacteria are medically important due to their pathogenic nature, highlighting the diverse ecological impacts of this phylum.

ii. Phylum Cyanobacteria: These autotrophic Gram-negative bacteria are crucial contributors to primary production in marine ecosystems through photosynthesis. Certain Cyanobacterial species also perform nitrogen fixation, a process vital for maintaining nitrogen levels in marine environments. However, under certain conditions, Cyanobacteria can lead to harmful algal blooms (HABs) due to rapid population growth and toxin production.

iii. Phylum Firmicutes: Comprising Gram-positive bacteria with the ability to form spores, Firmicutes are adept at responding to environmental stresses by entering a dormant stage. Their adaptability allows them to swiftly respond to favourable conditions, facilitating growth and proliferation in marine habitats.

iv. Phylum Bacteroidetes: Known for their capacity to degrade complex organic compounds, Bacteroidetes play a crucial role in nutrient cycling and ecosystem stability. Their metabolic versatility makes them significant contributors to marine ecosystem functioning.

v. Phylum Actinobacteria: Predominantly found in marine sediments, Actinobacteria are vital for organic material decomposition and nutrient cycling. They are renowned for producing various bioactive compounds, including antibiotics and anticancer agents, contributing to ecosystem resilience and biodiversity.

In marine ecosystems, bacteria play a significant role in the decomposition of organic matter, contributing to nutrient recycling and energy transfer within marine food webs. Organic particles sinking through the water column are primarily composed of bacteria, serving as a vital food source for bottom-dwelling marine organisms. Additionally, symbiotic relationships between bacteria and other marine organisms

have led to the evolution of organelles in eukaryotic organisms, highlighting the interconnectedness of marine life forms. Bacteria are indispensable for the functioning of marine ecosystems, contributing significantly to nutrient cycling, energy transfer, and ecosystem resilience. Their diverse metabolic capabilities and ecological roles underscore their importance in maintaining the delicate balance of marine environments.

2. Domain Archaea

Archaea, represent some of the earliest life forms known to science. The discovery of 3.8 billion year-old fossils resembling archaeal structures underscores their ancient lineage and potential significance in shaping the early evolution of life on Earth. These prokaryotic organisms are unicellular, lacking a nucleus and membrane-bound organelles, distinguishing them from eukaryotic cells. Originally labelled "Extremophiles" due to their prevalence in extreme terrestrial environments like hot sulphur springs, saline lakes, and highly acidic or alkaline conditions, archaea have since been found to thrive in various marine habitats. They endure extreme pressures in deep-sea environments, ranging from 300 to 800 atmospheres, and some even flourish in the scorching temperatures of hydrothermal vents, with certain species incapable of growing below 70-80°C. Remarkably, a specific hydrothermal vent archaeon has demonstrated survival at an astonishing 121°C, earning it the title of the most heat-tolerant organism known to date. The diverse habitats where archaea are found highlight their resilience and adaptation to extreme conditions, offering valuable insights into the limits of life and the potential for life to exist in extreme environments. The majority of archaea in marine environments, constituting over 80% of their population, belong to several major phyla with distinctive characteristics and ecological roles.

i. Phylum Euryarchaeota: This extensive and diverse archaeal phylum is prevalent in marine settings, known for its ability to thrive in extreme conditions such as high salinity, high temperatures, and anaerobic environments. Members of Euryarchaeota exhibit diverse metabolic capabilities, including methanogenesis, sulphate reduction, and acetogenesis, contributing significantly to nutrient cycling and ecosystem functioning.

ii. Phylum Thaumarchaeota: Particularly prominent in oceanic waters, Thaumarchaeota play a vital role in the nitrogen cycle, specifically in the oxidation of ammonia to nitrite. This process, known as ammonia oxidation, is crucial for nitrification processes in marine ecosystems, influencing nutrient dynamics and ecosystem stability.

iii. Phylum Crenarchaeota: A diverse group found in various marine habitats, including deep-sea environments and hydrothermal vents. Adapted to extreme

conditions like high temperatures and acidic pH levels, some Crenarchaeota are involved in sulphur metabolism, ammonia oxidation, and other metabolic pathways essential for marine ecosystems.

iv. Phylum Nanoarchaeota: This intriguing yet lesser-studied phylum includes extremely small and symbiotic organisms associated with other microorganisms, particularly thermophilic archaea. Their ecological roles and metabolic functions in marine environments are areas of ongoing research and discovery.

v. Phylum Korarchaeota: Although primarily identified in high-temperature environments like hydrothermal systems, the presence and significance of Korarchaeota in marine ecosystems are still areas of active investigation.

Archaea possess a diverse array of metabolic capabilities, encompassing photosynthesis, chemosynthesis, and heterotrophy. Methanogens, a significant proportion of archaea, are anaerobic organisms capable of metabolizing organic matter to produce energy, with methane as a byproduct. Among archaea, the Halobacteria are notable photosynthetic organisms thriving in high-salinity environments, utilizing bacteriorhodopsins to trap light energy and facilitate photosynthesis. The adaptation of archaea to varied environmental niches, coupled with their unique metabolic capabilities, contributes to nutrient dynamics, energy flow, and ecosystem stability in marine habitats. Understanding the intricate roles and interactions of these archaeal groups is fundamental for deciphering marine microbial communities and their profound impact on global biogeochemical cycles.

3. Domain Eukarya (Microbial Eukaryotes)

Marine microbial eukaryotes represent a diverse and essential component of marine ecosystems, spanning various kingdoms such as Protista, Fungi, Plantae, and Animalia. Unlike prokaryotes, which are predominantly unicellular, eukaryotes comprise both unicellular and multicellular organisms, contributing significantly to the complexity and functionality of marine environments. The Kingdom Protista harbours the majority of marine microbial eukaryotes, playing pivotal roles in primary production, nutrient cycling, and trophic interactions within marine food webs. This diverse group encompasses organisms capable of both autotrophy (self-feeding) and heterotrophy (external nutrient intake), exhibiting a wide array of ecological roles and adaptations.

Marine microbial eukaryotes have representatives from the following groups:

i. Marine fungi: Although less studied compared to terrestrial fungi, play essential roles in nutrient cycling, decomposition processes, and symbiotic associations with

other organisms contributing to the breakdown of organic matter and recycling in marine ecosystems

ii. Protozoans: Protozoans like ciliates, foraminiferans, and radiolarians are essential components of microeukaryotic communities. They contribute to nutrient recycling, predation dynamics, and microbial interactions in marine environments

iii. Microscopic animals: Microscopic animals including zooplankton like copepods and rotifers as well as nematodes are important components of microeukaryotic communities. They contribute to nutrient cycling, trophic interactions, and energy transfer in marine food webs

iv. Algae: Algae are fundamental primary producers in marine ecosystems, contributing significantly to photosynthesis and oxygen production and play crucial roles in nutrient cycling and carbon fixation. They encompass diverse groups including phytoplankton such as microalgae, diatoms, dinoflagellates, zooxanthellae as well as coccolithophores.

The diversity and ecological significance of marine microbial eukaryotes underscore their importance in marine food webs, nutrient cycling, and overall ecosystem dynamics. Their interactions and contributions are integral to maintaining the balance and resilience of marine ecosystems, highlighting the intricate web of life in the ocean.

Viruses

Viruses, often deemed non-living entities, are pivotal players in marine ecosystems, exercising a profound influence on the intricate web of life within the marine food web. Composed primarily of nucleic acids encapsulated in a protein coat, viruses operate as obligate parasites, reliant on living cells for their replication and propagation. While lacking the autonomy for independent cell division or DNA duplication machinery, viruses excel at exploiting host cells, hijacking their resources to produce new viral particles. In contrast to organisms categorized under the three domains of life, viruses do not neatly fit into these classifications due to their unique characteristics and life cycle. However, their impact on genetic diversity across all life forms cannot be overstated. Through mechanisms like horizontal gene transfer, viruses actively contribute to the genetic repertoire of bacteria, archaea, and eukaryotes, fostering biodiversity and evolutionary resilience within marine ecosystems.

One of the most remarkable roles of viruses in marine environments is their involvement in shaping microbial populations and biogeochemical cycles. By infecting bacteria and plankton, viruses instigate a cascade of events that profoundly influence nutrient dynamics and community structure. Upon infecting a host cell, viruses trigger

the release of organic matter into the ocean, fuelling microbial activity and nutrient production. This influx of organic material not only sustains microbial life but also facilitates the cycling of essential nutrients vital for the functioning of marine ecosystems. Studies have illuminated the significant role of viruses in regulating microbial populations, with estimates suggesting that viruses may be responsible for up to half of bacterial mortality in aquatic ecosystems. Moreover, viruses exert substantial influence on phytoplankton populations, contributing to population control and nutrient recycling. Their abundance in marine environments mirrors the abundance of their microbial hosts, underscoring their pivotal role as regulators of microbial communities. Despite their non-living status in the traditional sense, viruses are indispensable components of marine ecosystems, orchestrating nutrient cycling, fostering genetic diversity, and maintaining the delicate balance of microbial communities. Their intricate interactions within the marine food web highlight the interconnectedness and complexity of life in the ocean, showcasing the multifaceted contributions of viruses to marine ecology and biogeochemical processes.

Factors shaping the diversity of marine microbes

Marine microbial diversity is intricately shaped by a myriad of factors that span physical, chemical, and biological realms, creating a dynamic tapestry of interactions within marine ecosystems. These influential factors collectively contribute to the richness and composition of microbial communities, illuminating the complex dynamics that govern marine microbial diversity.

i. Physical variables: Turbulence, light availability, temperature gradients, and solar influx are fundamental physical factors that influence marine microbial communities. Turbulence, for instance, affects the distribution of nutrients and organisms, shaping community structure. Light availability dictates the presence and activity of photosynthetic microorganisms, impacting primary production and trophic interactions. Temperature gradients create ecological niches, influencing the distribution of thermophilic and psychrophilic organisms.

ii. Chemical parameters: Nutrient levels, including nitrogen and phosphorus concentrations, play a critical role in regulating microbial diversity. Variations in nutrient availability can lead to shifts in community composition, affecting primary productivity and nutrient cycling. Salinity variations, pH levels, redox potential, and metal concentrations also exert selective pressures on microbial communities, influencing their abundance and diversity.

iii. Biological interactions: The presence of macroorganisms such as invertebrates and macroalgae creates microhabitats and nutrient hotspots, influencing microbial colonization and diversity. Surfaces and interfaces, including sediments and

boundaries between water layers, serve as important niches for microbial communities, fostering diverse assemblages.

iv. Global pressures: Climate change emerges as a significant top-down force shaping marine microbial communities, primarily through alterations in ocean temperatures. These changes can lead to shifts in species distribution, community structure, and metabolic activities, impacting ecosystem functioning. Pollution, particularly anthropogenic nitrogen inputs, contributes to the emergence of dead zones and harmful algal blooms, altering microbial community dynamics and ecosystem health.

Understanding the intricate interplay of these factors is paramount for predicting and managing changes in marine microbial diversity. Ongoing research endeavours seek to unravel the specific roles and interactions of these variables across different environmental contexts, aiming to inform effective strategies for conservation, mitigation of anthropogenic impacts, and sustainable management of marine ecosystems in the face of global environmental challenges.

Conclusion

The study of marine microbial taxonomy and diversity serves as a cornerstone for comprehending the intricate workings, resilience, and functionality of marine ecosystems. Technological advancements, particularly in molecular techniques, have revolutionized our capacity to delve into these diverse microbial communities, offering insights into their ecological significance, interrelations, and responses to environmental shifts. The abundance of sequence data, encompassing 16S rRNA sequences, genome sequences, and metagenomes, coupled with innovative methodologies like Fluorescent In Situ Hybridization (FISH) targeting rRNA, has led to the identification of numerous novel bacterial taxa. In the domain of marine microbial genomics, ranging from in-depth genomic studies of model organisms to diverse meta-omics approaches such as metagenomics, metatranscriptomics, and metaproteomics, researchers have made remarkable progress in deciphering the pivotal roles played by microbes in marine ecosystems. Recent technological leaps hold promise in transforming how we analyze, characterize, and explore microbial communities. Cutting-edge tools like microbial ecological DNA microarrays such as PhyloChip and GeoChip have been devised to comprehensively assess microbial community structure and function. These microarrays provide a high-throughput platform for scrutinizing microbial diversity and metabolic potentials within marine environments. Another groundbreaking methodology, Single Cell Genomics, stands out for its ability to amplify and sequence DNA from individual cells directly sourced from environmental samples. This approach proves invaluable for unravelling genomes from uncultured microbial phyla, offering glimpses into the genetic makeup and potential functionalities of previously enigmatic microbial groups. The advent of

Single Cell Genomics holds transformative potential, reshaping the landscape of microbiology by enabling the in-depth study of individual cells within intricate microbial consortia.

Future research endeavours dedicated to unravelling the complexities of marine microbial diversity are poised to make substantial contributions to marine conservation, biotechnology, and ecosystem management. The continual exploration of microbial taxonomy and diversity not only enhances our understanding of marine ecosystems but also paves the way for harnessing microbial capabilities for sustainable practices, innovative biotechnological applications, and informed conservation strategies in marine environments.

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SCLERACTINIAN CORALS

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Introduction

The tropical regions of the oceans are often referred to as the "oceanic deserts" because they share similarities with terrestrial deserts, characterized by barrenness and relatively low productivity. The reason for this phenomenon is that the surface waters of the tropical oceans are so warm. Thus they tend to float on top of the colder water underneath, inhibiting nutrient upwelling from the deep which brings nutrients to the ocean surface. Nevertheless, coral reefs stand out as a remarkable exception to the typical scarcity of life in tropical oceans, earning them the title of "oases" within the oceanic deserts. If we consider the area of coral reefs, it comprises less than 0.2% of the world's ocean, yet it is home to a wide array of marine organisms. Karlson and Cornell (1999) note that when considering the entire marine ecosystem, coral reefs exhibit the greatest diversity per unit area. It is estimated that almost 4-5% of all species or about 91,000 are found on coral reefs. We can find 32 out of 34 recognized animal phyla in coral reefs where there are only 9 phyla in the tropical rainforests (Porter and Tougas, 2001). Although corals are found in polar and temperate waters, coral reefs only develop in the tropics. This is primarily because there are two types of corals: hermatypic corals, which produce reefs, and ahermatypic corals, which do not form reefs. While ahermatypic corals have a worldwide distribution, hermatypic corals are found only in the tropics.

Coral reefs are vital ecosystems, economically and ecologically. They provide a source of income, food, and coastal protection to millions of people who depend on them daily. Studies have shown that the goods and services provided by coral reefs amount to an annual net benefit of US\$30 billion (Cesar and Chong, 2003). Additionally, corals fulfill their ecological role by providing a habitat for a wide variety of marine organisms. Unfortunately, these bizarre and beautiful coral reefs are also among the world's most vulnerable ecosystems. Various threats, including bleaching, overfishing, pollution, improper waste disposal, coastal development, SCUBA diving, anchor damage, outbreaks of predators, invasive species, epidemic diseases, sedimentation, and river runoff, collectively undermine the health and resilience of coral reefs. About 70% of the world's corals are threatened, and 20% of that is damaged beyond repair (Wilkinson, 2004).

Coral Biology

Understanding coral reef biology is key to understanding reef ecology. Coral reef formations are the product of a symbiotic relationship between coral polyps and the photosynthetic microorganisms called zooxanthellae. The zooxanthellae which

reside inside the gastrodermal tissue of coral polyps capture the sun's energy and pass a portion of it to their host. Leveraging the additional energy obtained from their symbiotic algae, the corals produce calcium carbonate to construct protective shells around their bodies. This ongoing process results in mineral deposition that expands both upward and outward. While only the outermost layer of the structure supports living polyps, the interior of the coral reef comprises a complex network of abandoned polyp dwellings accumulated over eons.

Coral anatomy

Hundreds of thousands of coral polyps like this one (Fig: 1) form most of the corals except some corals like mushroom coral which are only formed by a single polyp. The size range of coral polyps varies from one to three millimeters in diameter. These are anatomically very simple organisms, most of their body is taken up by their digestive system. Like all coelenterates, the body wall is mostly made up of two cell layers: the interior gastrodermis and the exterior ectodermis. The mesoglea, initially acellular, separates these layers and may evolve to incorporate various cells following initial development, serving as a divider between layers. In corals possessing tiny corallites, the mesoglea appears extremely thin under a microscope, whereas in certain species, such as the large corallite varieties of *Lobophyllia*, it can reach thicknesses of several millimeters and has a robust structure. Polyps, when extended, resemble anemones in appearance. Typically, the mouth is slit-shaped and can be encircled by an oral cone. The area between the cone or mouth might form into an oral disc.

The tentacles are tubular, sharing the same dual tissue layers as the rest of the polyp, meaning their internal cavity is an extension of the coelenteron. In corals that consume detritus, the tentacles are smooth, whereas those that rely on defence or capturing food typically possess stinging cells. These stinging cells, known as nematocysts, are minuscule but are often clustered together in visible, wart-like formations called nematocyst batteries, which can be seen underwater.

There is only one opening through which they collect food and expel waste. Food capturing and waste expelling is done with the help of a ring of tentacles surrounding the opening (Mouth). Most of the food is captured with the help of specialized stinging cells known as nematocysts which are located inside the polyp's outer epidermis. Reef-building coral polyps secrete calcium carbonate which forms a protective cup-like structure known as the calyx upon which the coral polyp sits is called the basal plate. Calyx is surrounded by a wall known as theca. Each polyps are connected to the neighboring ones with the help of coenosarc which is a thin band of living tissue and this helps the polyps to become a successful colonial organism.

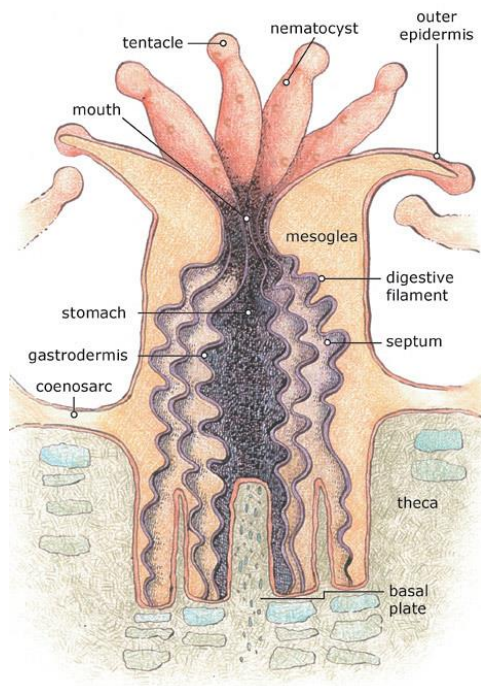


Fig.1 Anatomy of coral polyp (Image: NOAA)

The structure of corallite

Corals are colonial animals, a single individual is known as a polyp, and a polyp's skeleton is known as a corallite. This is a tube with vertical plates extending from the centre. Structural alignment of the coral polyps can be used to identify different corals. Some examples are Plocoid corallites which have their separate walls, Phaceloid colonies also have separate corallites but they are tubular shaped. Cerioid Corallites are divided into polygonal sections, with each corallite keeping its wall. Meandroid corallites have walls shared and valleys enclose many mouths. Thamnasteroid corallites are with confluent septa and lack defined boundaries (Fig. 2).

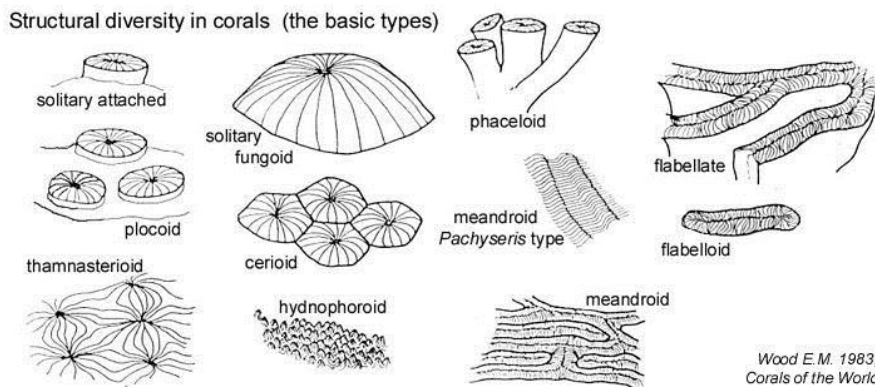


Fig.2 Structural diversity of corallites (Image: Wood E.M. 1983)

Coral Growth Forms

As colonies of hard coral grow and spread, they can evolve into various shapes or growth patterns. Typically, these patterns are identified as encrusting (forming a thin

layer over surfaces), branching (developing branches), arborescent (resembling a tree), columnar (forming columns), laminar (resembling plates, sometimes in layers), free-living or solitary corals that do not form colonies and finally massive corals which are often large and solid often form hemispherical to spherical shapes (Fig. 3).

Growth rates are usually measured as linear extension of the coral branches, plates, or upward expansion of massive corals. The growth rate in coral can greatly differ among species. Under ideal tropical conditions, certain species like the branching *Acropora sp.* can exhibit rapid growth, advancing 10-20 cm annually, whereas other species, like *Porites*, expand at a much slower pace, approximately 1 cm each year.

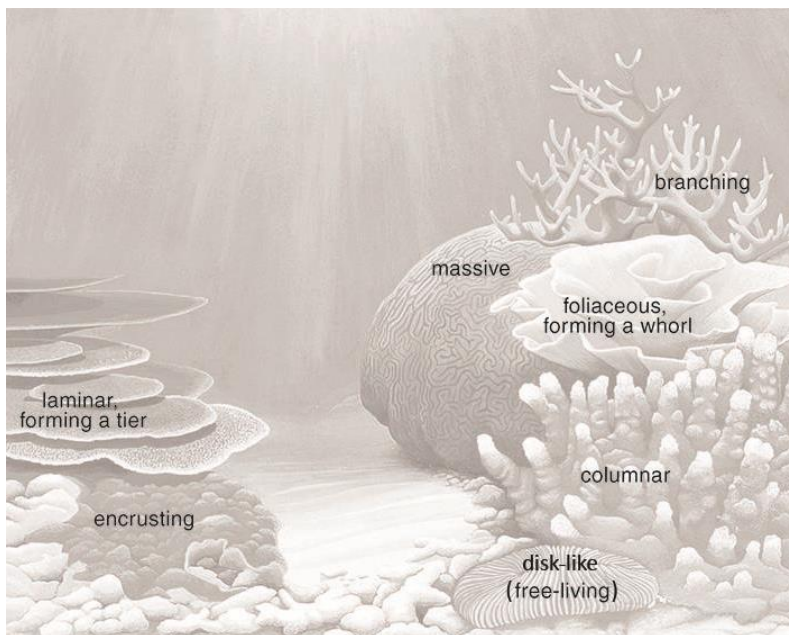


Fig:3. A range of tropical coral growth forms (Veron, corals of the world)

Coral Nutrition

It has long been known that reef corals are carnivores, like most other cnidarians. Most corals feed at night, capturing mainly small planktonic organisms with their tentacles, which are equipped with nematocysts, also known as stinging cells. These cells are capable of delivering powerful toxins that are often lethal to their prey (Barnes, R.D., 1987). Coral reefs are recognized as colonial organisms due to their vast number of colonies and the extensive area available for feeding. In addition to their nematocysts, coral's ciliated outer epidermis produces mucus. This ciliary mucus mechanism helps corals rid themselves of sediments settling on their surface and, in some cases, aids in feeding as well.

Given the large numbers of corals and the nutrient-poor surrounding ocean, how corals obtain enough food has puzzled generations of coral biologists. Johannes et al. (1970) calculated that demersal plankton is only sufficient to satisfy 5-10% of corals' total nutrient requirements. The remainder of their food comes from zooxanthellae found in the coral tissue. Further experimental studies conducted on large tentacled

corals kept in the dark showed that they would expel their symbionts but could survive for a few weeks without them. This survival is possible because corals can capture microorganisms and feed on them. Corals obtain zooxanthellae either directly from the parent or indirectly from the environment. Initially, it was thought that there was only one type of zooxanthellae, but later studies revealed there are 16 clades of zooxanthellae, each with different properties. Some are more heat tolerant, some are capable of fixing more energy, and corals harboring these types of zooxanthellae are capable of growing at a faster rate. Therefore, different zooxanthellae may also characterize different reef microclimates.

Coral Growth and Calcification

Light is the primary factor for active coral growth. Without it, or if corals are kept in shaded areas, their growth ceases. Long-term deprivation of light can lead to the death of the coral organism. This phenomenon is closely related to the role of zooxanthellae, which require light to fix energy, significantly enhancing the calcification and growth rate of coral reefs.

The growth rate of corals varies by species, reef location, and the age of the colony. Young colonies grow faster than older ones. Moreover, corals vary in morphology, which influences their growth rates. Generally, branched corals grow faster than massive corals. The growth rate is also influenced by the location within the reef, with the same species of coral growing in shallow water and deep water exhibiting differences. Deepwater corals are often thinner and more fragile than those in shallow water, likely due to reduced calcification. Furthermore, wave action causes branching corals to form shorter and stubbier branches, while ocean currents influence the arrangement of branches in branching corals.

Coral reef structures

Coral reefs are typically categorized into three principal types based on their structural features. The first one is fringing reefs, which is the most commonly found type, stretching outward from the shoreline, occasionally separated by a slim waterway or lagoon. They usually exist in shallow waters, with the reef flats becoming visible during low tide. The second one is barrier reefs, which lie parallel to the coast but are separated from it by a sizable lagoon that can be quite deep. These reefs often consist of a complex of individual reef formations, including fringing reefs that extend from islands situated offshore. Finally, the atolls are coral islands that form a ring or horseshoe shape around a central lagoon.

Coral Reproduction

Corals exhibit both sexual and asexual modes of reproduction, mirroring the life history of a typical sedentary animal. Dispersal primarily occurs through small planktonic larvae, often called planulae, which are produced in large numbers. After

existing briefly in this motile form, a planula larva settles and metamorphoses into a polyp. Once it has grown to a certain size, the polyp divides, forming an ever-expanding clone. Asexual reproduction is achieved when new individuals bud off from the parent. Observations by Highsmith (1982) indicated that fragmentation plays a significant role in starting new colonies in some species. While most corals are broadcast spawners, releasing eggs and sperm into the open water, a few species act as brooders, retaining fertilized eggs in the gastrovascular cavity until they develop into planula larvae.

Taxonomy and Diversity of corals

Coral Taxonomy & Classification

The term "coral" is often used interchangeably to refer to both "soft" and "hard" corals. It occasionally encompasses other colonial animals within the phylum Cnidaria, also known as Coelenterata. Corals refer to marine invertebrates within the phylum Cnidaria and the class Anthozoa, possessing either external or internal calcareous skeletons. These skeletal structures, known as coral, can be found both externally and internally within these organisms. Corals typically manifest as small polyps, akin to other members of the Cnidaria group, often forming colonies attached to solid surfaces. While they share a close kinship with sea anemones, which fall under the Anthozoa class, sea anemones are classified in the Actiniaria order. Corals and sea anemones belong to Anthozoa, a class within the invertebrate phylum Cnidaria. The name of this phylum is derived from cnidocytes, specialized cells that contain stinging organelles.

The classification of corals

- ❖ Kingdom: Animalia (Animals)
- ❖ Phylum: Cnidaria (Cnidarians)
 - Class Hydrozoa (Hydroids)
 - Order Anthoathecata (Fire corals)
 - Order Anthoathecata (Athebate hydroids)
 - Class Scyphozoa (Jellyfish)
 - Class Cubozoa (sea wasps)
 - Class Anthozoa (Anthozoans)
 - Subclass: Octocorallia (Colonial polyps with 8-fold symmetry)
 - Order Helioporacea (The blue coral is the only extant species)
 - Order Alcyonacea (soft corals, sea fans, and sea whips)
 - Order Pennatulacea (sea pens)
 - Subclass: Hexacorallia (Hard corals and sea anemones)

- Order Actiniaria (Sea anemones)
- Order Zoanthidea (Zoanthids)
- Order Corallimorpharia (They are closely related to stony corals)
- Order: Scleractinia (True hard corals)
- Order: Alcyonacea (Soft corals)
- Order Rugosa (Extinct order of Palaeozoic corals)
- Order Tabulata (Extinct order of Palaeozoic corals)

Coral Diversity

Scleractinian Diversity in India

Coral reefs represent invaluable ecosystems in India, serving as habitats for a diverse array of marine life and playing a critical role in shoreline protection from erosion. Despite India's extensive coastline of approximately 8,000 km, significant reef formations are primarily concentrated in specific regions, notably the Gulf of Mannar, Palk Bay, the Gulf of Kutch, Andaman and Nicobar Islands, and the Lakshadweep Islands.

India hosts three main types of coral reefs: atoll, fringing, and barrier. The reefs in Lakshadweep are predominantly atolls, while those in other locations, such as the Andaman and Nicobar Islands, consist mainly of fringing reefs, with some barrier reefs present. Among these formations, the Andaman and Nicobar Islands stand out as the most diverse and species-rich, whereas the Gulf of Kutch exhibits the lowest species diversity. Research conducted by Pillai documented a total of 199 species across 37 genera from India, encompassing both hermatypic (reef-building) and ahermatypic corals found in the four major coral reef regions of the country. This underscores the significant biodiversity harboured within India's coral reef ecosystems. A more recent study by Venkataraman et al. (2003) identified 15 families, 60 genera, and 208 species of Scleractinia (solely reef-building, hermatypic corals) from these locations, including the Gulf of Kachchh having 36 species, 20 genera, Lakshadweep hosts 91 species spanning 34 genera, while the Gulf of Mannar and Palk Bay is home to 82 species across 27 genera. The Andaman and Nicobar Islands boast an even richer diversity with 177 species distributed among 57 genera.

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CORAL REEF FISHES

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Introduction

Coral reefs are mainly found in tropical regions of the world and cover approximately 284300 sq.km or 0.1% of the world oceans. However, they harbor about 25% of the marine fish fauna.

The Indo-Pacific harbours about 92% of the reefs. The major reef areas of the world are as below:

The Golden Triangle region in Southeast Asia: The reefs surrounding Thailand, Malaysia, Indonesia, Philippines, Papua, New Guinea, Sumatra, Java, Andaman and Nicobar harbor 32% of world coral reefs and the greatest diversity of marine life. They are considered as the crucible of evolution and diversification of coral reef fishes.

The Great Barrier Reef: Located off the east coast of Australia in the Coral Sea, it is the world's most extensive coral reef system, encompassing over 2,900 individual reefs and 900 islands, stretching for an impressive 2,500 kilometers and covering an area of 216236 sq km.

Red Sea Coral Reef: This 1900 km long reef is located between Africa and Asia and borders the countries of Israel, Egypt and Djibouti.

Chagos-Laccadive Ridge: Consisting a chain of atolls from Seychelles to Lakshadweep, Maldives, Chagos and Diego Garcia this region in the Western Indian Ocean harbours

The Greater Caribbean Reefs: These include several reef formations from *Florida Reef Tract* to the *Great Mayan Reef* or the Mesoamerican Barrier Reef System which stretches from the coast of Mexico to Belize and Guatemala upto the Honduras (1126 km reef; the largest in the Western Hemisphere) and the *Andros Barrier reef* along with several fringing reefs of the Caribbean islands in the Coral Sea.

The New Caledonian Barrier Reef: Situated around the Grand Terres island in the South Pacific this 1500 km reef is the third largest in the world after the Great Barrier Reef and the Great Mayan Reef.

An estimated 6000-8000 species of fishes inhabit the coral reefs of the world. The fish fauna of the Indo-Pacific reefs is significantly different from that of the western tropical Atlantic or the Greater Caribbean.

Indian diversity

A total of about 2810 species of fishes inhabit the coral reef regions of India though not all are strictly coral reef fishes. Considering only those fishes closely associated with coral reefs alone, the currently known diversity in Andaman and Nicobar is about 166

species, Lakshadweep islands 116, Gulf of Mannar 84 and Gulf of Kutch 42 species. Besides there are around 40-50 species of coral reef fishes reported from fringing reefs along the coastline and coastal islands of India.

Body shape and coloration

The great diversity in colour, shape, size and structure of the coral reef fishes is a function of and adaptation to their niches in the coral reefs. A large number of coral reef fishes have flat, laterally compressed bodies which is an adaptation that gives them distinct advantage in **maneuverability**. Long, strong fins and such a body shape allow them to negotiate crevices and close formations of their coral habitat efficiently. Another important aspect is the **feeding habit** of the coral reef fishes which particularly defines the design of the head, mouth, and teeth. **Camouflage** or **behavioural adaptations** for predator avoidance also reflect on the size, shape and colouration of many coral reef fishes, so also peculiar armature. Coral reefs are crowded environs with the density of fishes being particularly high. Distinctive colouration also facilitates easy **identification** of members of the same species as well as **mate location and selection**. Some species are strikingly coloured to advertise their unpalatability or **toxicity** as visible warning signals.

Common groups coral reef fish fauna in India

Coral reef fishes comprise about 30 families. The most numerous of these on the coral reefs are chaetodontids, pomacentrids, labrids, gobioids, acanthurids and scarids.

Chaetodontids (Butterflyfishes): These typical coral reef fishes have a global diversity of 12 genera and 136 species. The Indian diversity records 31 species. *Chaetodon* is the most common genus, with *Heniochus* and *Forcipiger* being others. They are distributed in the Atlantic, Indian and Pacific Oceans with a greater number of species in the Indo-west Pacific. They are bony fishes belonging to the order Acanthuriformes. They are mostly coloured white, bright yellow, and/or orange with black bands or markings and have flattened pancake-like bodies. They have extended, protrusible, tubular mouths with brush-like teeth. Dorsal fins are continuous and have spines ranging from 6-16 numbers and 15-30 soft rays. Anal spines are usually 3 though ranging upto 5, with 14-23 soft rays. Scales are present on dorsal and anal fins. Caudal fins are rounded to emarginate with 15 rays. They are found in heterosexual pairs and feed on coral polyps, small invertebrates, filamentous algae and plankton.





Pomacentrids (Damselfish): Globally this family consists of 30 genera and 419 species. They are found in all tropical seas, mainly the Indo-Pacific region. The Indian diversity consists of 47 species. *Abudefduf*, *Chromis*, *Chrysiptera*, *Amphiprion*, *Dascyllus*, *Pomacentrus* and *Stegastes* are the common genera. These deep-bodied bony fishes of the order Ovalentaria/misc have small mouths and incomplete or interrupted lateral lines. Anal fins usually have two spines. Males brood benthic eggs. Their larval life is short. They also display aggressive territorial behavior. Most of them are omnivores or planktivores.

Labrids (Wrasses): The global diversity of labrids consists of 70 genera and 562 species. They are found in the Atlantic, Indian and Pacific Oceans. The Indian diversity consists of 55 species. *Halichoeres* and *Thalassoma* are the most speciose genera. These bony fishes belong to the order Eupercaria/misc. Dorsal fins have 8-21 spines (usually less than 15), soft rays 6-21. Anal fin has 4-6 spines (often 3) and 7-18 soft rays. Scales are cycloid. Several labrids change colour between their juvenile and mature phases. They are protogynous hermaphrodites where the initial phase consists of males and females and the terminal phase consists of often brilliantly coloured large dominant males, which females can also transform into. One male dominates several females. Labrids exhibit territorial displays, vigorously defending their areas of the reef. Most have a burrowing habit. They can be either benthic carnivores or planktivores.



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Acanthurids (Surgeonfishes): Globally there are 06 genera 84 species inhabiting the Atlantic, Indian and Pacific Oceans. The Indian diversity consists of 11 species of which *Acanthurus*, *Ctenochaetus*, *Naso*, *Paracanthus* and *Zebrosoma* are the most common genera. Acanthurids belong to the order Acanthuriformes and have deeply compressed bodies, an unnotched dorsal fin and long preorbital bone. The eyes are placed high on the head. They have characteristic sharp caudal spines on the caudal peduncle that are flashed erect when the fish feels threatened and are capable of inflicting scalpel-like injuries giving the family its common name as surgeonfishes.



Acanthurids are predominantly herbivores; some may be planktivores or detritivores or a combination of all these.

Scarids (Parrotfishes): 12 genera and 136 species inhabit the Atlantic, Indian and Pacific Oceans. The Indian diversity comprises of 05 genera and 17 species. *Scarus* is



the most common genus. Dorsal fin consists of 9 spines and 10 soft rays. The anal fin has three spines and 9 soft rays. Caudal fin has 11 branched rays. The lateral line usually has 22-24 scales. The fused teeth are akin to parrot-beaks giving them the common name of parrotfishes. The body is covered with large cycloid scales mostly in bright green, blue or pink hues. Scarids are herbivores that scrape algae off coral rocks

including dead coral rocks. Like labrids, their initial phase is males or females and terminal phase consists of large males. A single male dominates over several females.

Pomacanthids (Angelfishes): The global diversity of this family encompasses 08 genera and 91 species. They are found in the tropical Atlantic and Indo-west Pacific. The Indian diversity accounts for 09 species. *Apolmichthys*, *Centropyge* and *Pomacanthus* are common genera in this family belonging to the order Acanthuriformes. With their laterally compressed bodies, they live closely associated with the coral formations. Dorsal and anal fins usually have extensions. A strong spine is present



on the angle of the preopercle and there are three spines in the anal fin. They have striking colour patterns with juveniles often having marked colour differentiation from adults. They are mostly planktivores and/or herbivores and some feed on sessile invertebrates.

Lutjanids (Snappers): 17 genera and 113 species of this family belonging to the order Eupercaria/misc are represented globally in the Atlantic, Indian and Pacific Oceans. The Indian diversity consists of 38 species. *Lutjanus*, *Aprion*, *Paracaesio*, *Pinjalo* and *Etilis* are common genera. The dorsal fin is continuous or slightly notched with 10-12 spines and 10-17 soft rays. Anal fin is with 4 spines and 7-11 soft rays. They are typically schooling fish. They feed on crustaceans and fishes; some are planktivorous. Snappers are food fishes.



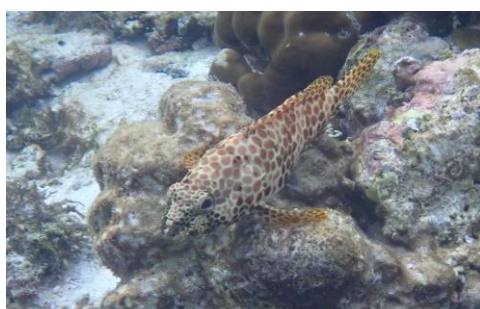
Muraenids (Moray eels): The global diversity of the family Muraeinidae belonging to the order Anguilliformes consists of 16 genera and 211 species distributed in the Atlantic, Indian and Pacific Oceans. The Indian diversity currently consists of 32 species. *Echidna*, *Gymnothorax* and *Uropterygius* are the most common genera. These fishes have a large mouth with canine teeth. The dorsal fin origin is well before the gill opening; anal fin is confluent with the caudal fin. Pectoral and pelvic fins are absent. They are scaleless. They lie in wait in crevices and holes within the coral formations and feed on cephalopods, small fishes and crustaceans.



Caesoinids (Fusiliers): The family Caesionidae belonging to the order Eupercaria/misc consists of 04 genera and 23 species. They are mainly distributed in the Indo-west Pacific. The Indian diversity consists of 12 species with all four genera of present. They have oblong to fusiform bodies, small mouths, large eyes, and deeply forked tail which are all adaptations for a planktivorous diet. Dorsal fin consists of 10-15 slender, weak spines and 8-22 soft rays. Anal spines number three and soft rays 9-15. Dorsal and anal fins have scales. Scale rows on the body run horizontally. These active schooling fish feed on zooplankton.



Siganids (Rabbitfishes): 01 genera 29 species of this family belonging to the order Acanthuriformes is found in the Indo-Pacific and eastern Mediterranean. The Indian diversity consists of 12 species. Dorsal fin has 13 strong spine sand 10 soft rays. Anal fin has 7 spines and 9 soft rays. Pelvic fin is with three soft rays between two spines. The spines are poisonous. Juveniles form large schools. They are predominantly herbivorous, feeding on algae and seagrass



Epinephelids (Groupers): The 16 genera and 170 species of this family belonging to Perciformes/Serranoidei are found in the Atlantic, Indian and Pacific Oceans. The Indian diversity consists of 06 genera and 42 species. *Epinephelus*, *Athaloperca*, *Cephalopholis*, *Variola*, *Plectropomus* are the genera common in Indian waters. They are protogynous hermaphrodites.

All fins are rounded. Carnivorous.

Balistids (Triggerfishes): The 12 genera and 42 species of this family belonging to the order Tetraodontiformes are found in the Atlantic, Indian and Pacific Oceans. The Indian diversity has 11 species. *Balistoides*, *Balistapes*, *Odonus*, *Sufflamen* are the common genera. Skin tough and leathery with large scales forming distinguishable units. First of the three dorsal spines can be locked erect by the second. Mouth is small and terminal with eight teeth in outer row of both jaws. Females aggressively guard eggs. Triggerfishes may be diurnal, solitary carnivores feeding on shelled molluscs or sea urchins or planktivores.

Mullids (Goatfishes): These fishes belonging to the order have 06 genera and 100 species distributed in the Atlantic, Indian and Pacific Oceans. The Indian diversity has 03 genera *Upeneus*, *Parupenaeus* and *Mulloidichthys* and 16 species. The dorsal fins are located far apart. Two chemosensory chin barbels are used to probe food. They feed on benthic invertebrates and small fishes.

Carangids (Jacks, pompanos, trevallys): A diverse family belonging to the order



Carangiformes with 39 genera and 148 species widely distributed in the Atlantic, Indian and Pacific Oceans. Large juveniles and adults with 2 dorsal fins, the first with 3-9 spines and the second having 1 spine and 18-37 soft rays. The first two spines of the three anal fins are separate and placed separately from the third in the abdomen. Anal soft rays are 15-31. The caudal fin is deeply forked with slender caudal peduncles,

designed for fast swimming. In some species lateral line scales modified into scutes and also in some there are finlets along the posterior margins of the body. Small cycloid scales render the bodies silvery. Carangids are carnivorous or planktivorous. They are major food fishes.

Scorpionfishes: The order Perciformes/Scorpeinoidei consisting of 20 families has some of the most venomous fishes as its members. They are found in all seas. The family **Scorpaenidae** has 25 genera and 233 species distributed in all tropical and temperate seas and **Synanceiidae (stonefishes)** 9 genera and 40 species and are especially found in lying camouflaged as rocks in coral reefs. Fishes of Scorpanidae have a single dorsal fin and ridges and spines. Dorsal fin is single and deeply notched. Dorsal, anal and pelvic fins have venom glands. Synanceiidae have a single dorsal fin with 11-17 spines and 4-14 soft rays and anal fin with 2-4 spines and 4-14 soft rays and a body covered with warts. The sharp needle-like dorsal spines have neurotoxic venom glands at their base.

Diodontids (Porcupinefishes): This family belonging to the order Tetraodontiformes has 7 genera and 18 species distributed in the Atlantic, Indian and Pacific Oceans. The Indian diversity consists of 04 species belonging to *Diodon* and *Cyclithis* genera. There are two fused teeth parrot like in jaw. Body greatly inflatable with ingestion of water. Body is covered with spines which are erected at the time of inflation. Adults found near reefs and the juveniles are pelagic. They are usually found in heterosexual pairs. They feed on hard shelled invertebrates.

Sygnathids (Seahorses): 59 genera 304 species.

Atlantic, Indian and Pacific Oceans. Indian diversity 10 species. *H. trimaculatus*, *H. kuda* and *H. kellogi* are the common species. Body with tubular snout, bony rings on body and prehensile caudal peduncle. The single dorsal fin has 15-60 soft rays. Anal fin is very small with 2-6 soft rays. Pectoral fins have 10-23 soft rays. Dorsal, anal, and pectoral fins may be lacking in adults



of some species. No pelvic fins are present. Branchiostegal rays are 1-3 and gill openings very small. Basisphenoid and supracleithrum are lacking. Swimming ability is very reduced. Male broods eggs in pelvic pouch and give birth to live young. They feed on minute invertebrates sucked into mouth. They are found in calm shallow regions.

Gobiidae (Gobies): The Gobiidae, or gobies, are the largest family of fish, with over 2,000 described species in more than 200 genera. They are typically small, bottom-dwelling fish with big heads and tapered bodies. One of their most characteristic features is their fused pelvic fins, which form a suction cup that allows them to cling to rocks or other surfaces in strong currents. Gobies are also known for their wide variety of colors and patterns, which can help them camouflage themselves in their environment. Most gobies are carnivores and feed on small invertebrates, such as worms, crustaceans, and insects. Some species are also known to clean parasites off other fish. Gobies are an important part of the marine ecosystem, and they play a role in keeping coral reefs and other habitats healthy.



Blenniidae (Combtooth Blennies): The Blenniidae family, are another interesting group of fish closely related to gobies. Their namesake feature is their specialized teeth. Unlike gobies, blennies have numerous, closely packed teeth that resemble a comb. This toothy apparatus is perfect for scraping algae and other encrusting organisms off rocks and corals. Blennies typically have elongated, slender bodies that allow them to navigate through crevices and tight spaces in rocky reefs, their preferred habitat. Their large eyes provide excellent vision in these often dimly lit environments.

Blennies can have a variety of fin shapes and sizes. Some sport long dorsal fins, while others have flamboyant, fan-like pectoral fins used for display or stability. They cling to rocks and coral using a combination of their body shape, fins, and sometimes even suction from their mouths. Many blennies are masters of camouflage, able to rapidly change their color and blend in with their surroundings to avoid predators. This quick color-shifting ability makes them fascinating inhabitants of the reef. Blennies can exhibit a range of social behaviors. Some species are territorial and quite aggressive, while others live in small groups or pairs. Certain blennies even form cleaning symbioses with other fish, similar to some gobies.

Elasmobranchs: Around 31 species of elasmobranchs (sharks and guitarfish (21 species) and rays and skates (10 species)) are commonly found in the Indian coral reefs. Some sharks such as *Trienodon obesus* (whitetip reef shark), *Carcharhinus melanopterus* (blacktip reef shark) and *Chilloscyllum indicum* (bamboo shark) are frequently encountered on the reefs.

The unique fish assemblages of the coral reefs form a vibrant and ecologically inter-related community with structural and behavioural adaptations and occupying every available niche. Pomacentrids and gobioids are an important prey base in the reef food chain. The acanthurids and scarids along with siganids are vital to keeping algal growth on the reefs in check through herbivory, preventing the algae from proliferating and taking over coral formations. Other reef organisms including the corals are dependent on the fishes for continued ecological sustenance as much as the fishes depend upon them for varied life processes.

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TAXONOMY OF ALGAE WITH SPECIAL REFERENCE TO SEAWEED

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What are Algae?

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. Around 7000 species of red algae, 2000 species of brown, 1800 species of green and 1500 species of blue green are recorded so far. They vary from small, single-celled to complex multicellular forms. The microscopic algae are called as phytoplankton whereas large benthic algae are called as macroalgae or seaweed. The life history of algae is complicated, and this is what really differentiates them from plants. In fact, macroalgae can pass through life stages so distinct that, in the past, they have been mistaken for separate species. Algae are found in the fossil record dating back to approximately 3 billion years in the Precambrian. 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.

What are Seaweeds?

Seaweeds are nothing but marine macroalgae found from the intertidal area to deep Ocean. The life history of algae is complicated, and this is what really differentiates them from plants. In fact, macroalgae can pass through life stages so distinct that, in the past, they have been mistaken for separate species. 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. Seaweed reproduction can involve either exclusively sexual or asexual phases, while some species display an alternation of generations that involves both in succession. In the former, the seaweed produces gametes (egg and sperm cells) with a single set of chromosomes and, in the latter, spores containing two sets of chromosomes. Some species can also reproduce asexually by fragmentation. 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 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 chl *a*. Similarly other pigments like xanthophyll, phycobiloprotein also present in seaweed and these pigments provides beautiful colours for seaweed.

The red macroalgae normally grow at the greatest depths, typically as far as 30 meters down, the green macroalgae thrive in shallow water, and the brown algae in between. This distribution of species according to the depth of the water is somewhat imprecise, however; a given species can be found at a location where there are optimal conditions with respect to substrate, nutritional elements, temperature, and light. In exceptionally clear water, one can find seaweeds growing as far as 250 meters below the surface of the sea. It is said that the record is held by a calcareous red alga that was found at a depth of 268 meters, where only 0.0005 percent of the sunlight penetrates. Even though the waters at that depth may appear pitch-dark to human eyes, there is still sufficient light to allow the alga to photosynthesize. In turbid waters, seaweeds grow only in the top, well-lit layers of water. Despite of the undeserved negative connotation associated with such a name, seaweeds play a fundamental role in marine ecosystems, where they have a multitude of beneficial effects.

Classification of algae

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 & 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". They are 1. Chlorophyceae 2. Xanthophyceae 3. Chrysophyceae 4. Bacillariophyceae 5. Cryptophyceae 6. Dinophyceae 7. Chloromonadineae 8. Euglenineae 9. Phaeophyceae 10. Rhodophyceae 11. Myxophyceae.

Papenfuss (1946) included the suffix 'phyco' to the divisions of algae and named chlorophyta as Chlorophycophyta

G.M. Smith (1950) classification based on the morphology and physiological structure of algae and the classes reduced to seven combining Chlorophyceae and Charophyceae in one group like chlorophyta Similarly Xanthophyceae, Chrysophyceae and Bacillariophyceae under Chrysophyta mostly based on the pigmentation thus the classes are 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 and Eukaryota keeping Cyanophyta under Prokaryota and all other like Chlorophyta Euglenophyta Charophyta Parsinophyta Xanthophyta Haptophyta Dinophyta Bacillariophyta Chrysophyta Phaeophyta Rhodophyta Cryptophyta under Eukaryota

Bold and Wynne (1978, 1985) recognised ten divisions of algae retaining the nomenclature given by Papenfuss (1946) except for the blue green algae. They considered Cyanophyceae as a division and called it Cyanochloronta whereas Papenfuss had included it in phylum Schizophyta as a class.

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.

- Prokaryotic algae (Cyanophyta)
- Eukaryotic algae with chloroplast surrounded by the two membranes: Glaucophyta, Rhodophyta, Chlorophyta
- Eukaryotic algae with chloroplast surrounded one membrane of chloroplast endoplasmic reticulum: Euglenophyta, Dinophyta
- 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 divisions.

Phylum	Pigment constituents	Storage food	Cell wall
Cyanobacteria	Chl a, phycocyanin, allophycocyanin, phycoerythrin, β carotene and Xanthophyll	Cyanophycean starch, granules and glocogen	Peptidoglycan
Glaucophyta	Chla, 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	Chla, phycoerythrin 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 (Phaeophyta), 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, Gelidiella, Hypnea, Kappaphycus

Brown algae (Phaeophyta):

- It is a large group of algae consisting of 240 genera and over 1,800 species
- 32 genera and 93 species are reported from India.
- About 99.7% members are marine and a few grow in fresh water.
- They range from simple microscopic heterotrichous filament (Ectocarpus) to largest alga like *Macrocystis pyrifera*, which attains a length of 60-90 meters.

- 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
- The brown colour of the algae due to the dominance of xanthophyll pigments like fucoxanthin
- It masks the other pigment like chl a & c (no chl b in phaeophyta), β carotene and other xanthophylls.
- It 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 harvested biomass (wild and farmed) comes from few number of *Laminariales* & *Fucales*

Fritsch (1935, 45) classified the Class. Phaeophyceae into 9 orders.

1. Ectocarpales : *Ectocarpus*, *Haiiothrix*.
2. Tilopteridales : *Ptilopteris*.
3. Cutleriales : *Cutleria*
4. Sporochnales : *Sporochnus*.
5. Desmarestiales : *Desmarestia*..
6. Laminariales : *Laminaria*.
7. Sphacelariales : *Sphacelaria*.
8. Dictyotales : *Dictyota*.
9. Fucales : *Sargassum*



Ptilopteris



Ectocarpus



Sphacelaria



Desmarestia



Macrocyctis pyrifera



Sargassum wightii



Laminaria digitata



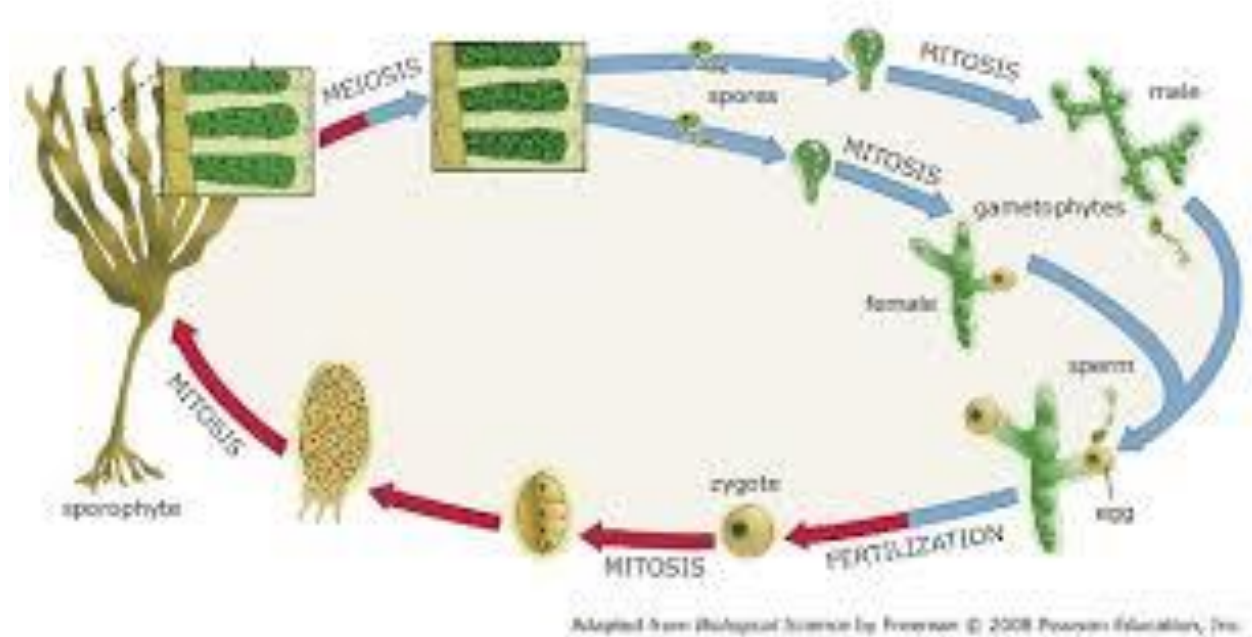
Sargassum longifolium



Padina tetrastromatica



Turbinaria ornata

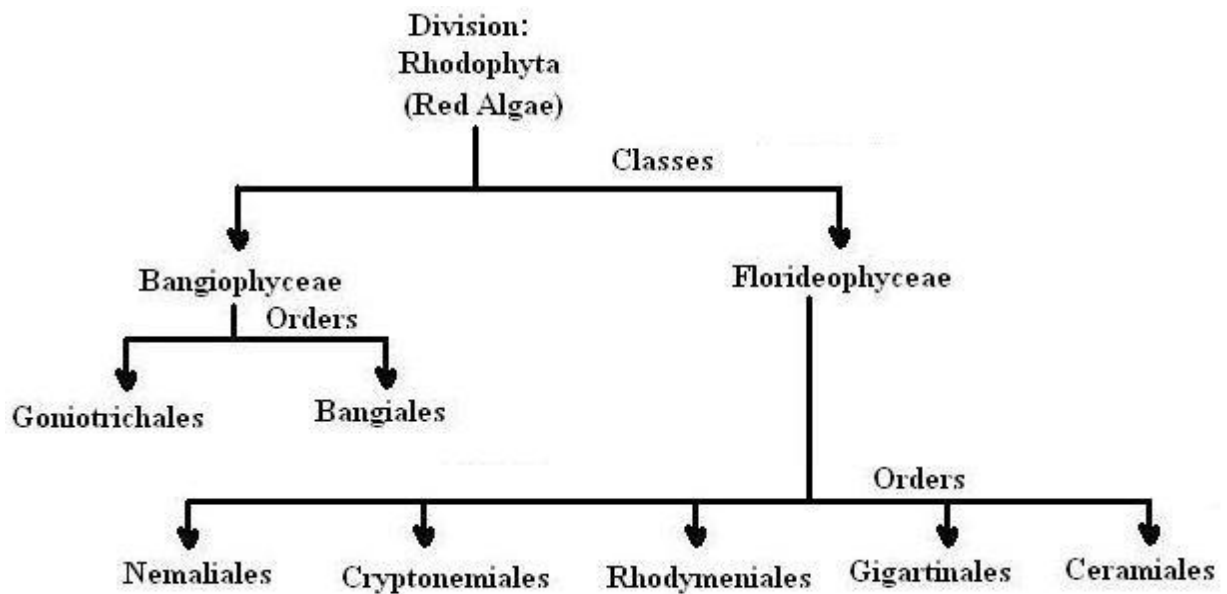


Life cycle of *Laminaria* Courtesy: Adapted by Biological Sciences Freeman 2008

Red algae (Rhodophyta)

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* sp. 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.



Amphiroa

Grateloupia

Botryocladia

Hypnea

Laurencia



Gracilaria edulis

G. crassa

Sarconema filiforme

3. In recent years, based on DNA sequence data green algae do not form a homogeneous and coherent entity.
4. They are part of a larger group called Viridiplantae, in which the land plants are also included (Lewis & McCourt, 2004).
5. However, all marine green algae are classified in a common class, called Ulvophyceae.
6. The Ulvophyceae are a very diverse group and include about 920 species, which are distributed in all seas of the world.
7. In the green seaweeds, the body of the alga shows a great range of variation in morphology but usually its morphology vary from thin filamentous as found in *Cladophora* and *Chaetomorpha* or in the form of sheets in *Ulva* or siphonaceous like *Caulerpa*
8. 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.
9. Siphonalean green algae are classified in two orders, Bryopsidales and Dasycladales, and are among the most ecologically successful seaweeds.
10. The body of these algae is formed by one single giant cell, which contains numerous nuclei.
11. There are few green algae which are calcareous like *Halimeda*.



Enteromorpha intestinalis



Ulva lactuca



Chaetomorpha antennina



Codium tomentosum



Boergesnia forbesii



Halimeda gracilis

Life cycle of *Ulva lactuca*

Importance of marine algae (Seaweed)

- ✓ Seaweeds play a major role in marine ecosystems.
- ✓ As the first organism in marine food chains, they provide nutrients and energy for animals directly or indirectly by decomposition.
- ✓ Marine algae have more than 60 odd elements for health and nutritional security
- ✓ Seaweed are the souce of phycocolloids like agar,align and carrageenan. Besides mannitol, iodine and other vitamins.
- ✓ It is source for food, fodder and fertilizer, bioplastic, biofuel and cosmetic product
- ✓ It is used in pharma industries, textile, cosmetic and other industries like dairy, meat
- ✓ seaweeds as a potential climate change mitigation by sequestering carbon dioxide.
- ✓ It also helps in bio mitigating pollution through bioremediation.
- ✓ It is the best nursery ground for fish and shellfish larvae providing very good oxygen to the young one and by reducing the temperature of the nursery ground.
- ✓ Seaweed should be used in daily diet.



TAXONOMY AND DIVERSITY OF COMMERCIALY IMPORTANT CRUSTACEANS

Dr Ratheesh Kumar R
Scientist, ICAR -CMFRI, Kochi

Crustaceans: A Wondrous Array of Armored Invertebrates

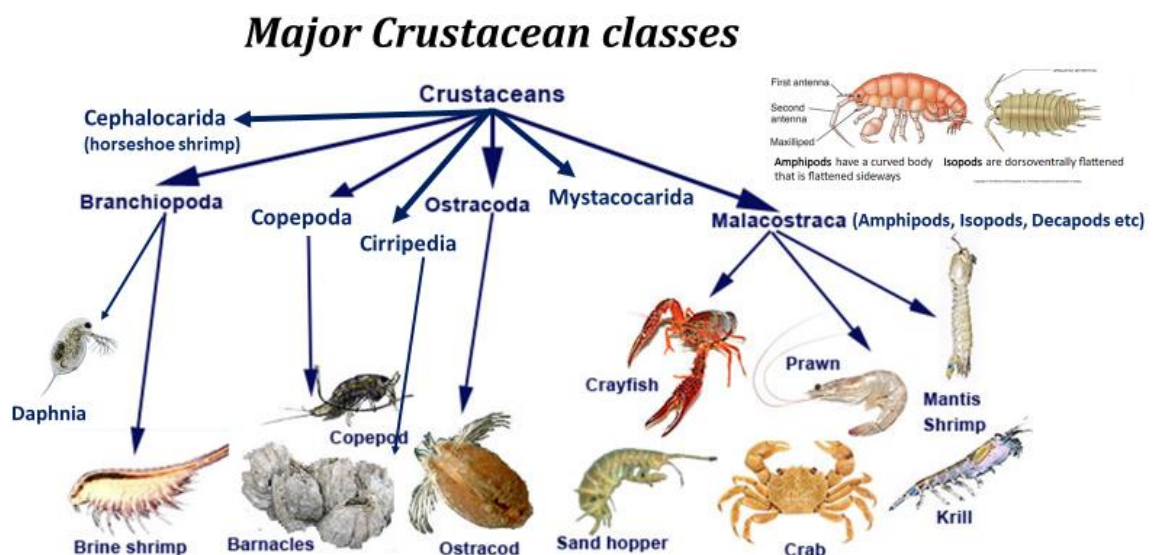
Crustaceans are a remarkable group of shelled animals (arthropods) that thrive in almost all watery habitats, with a few even exploring land. This incredibly diverse group boasts over 65,000 species found across the globe. Sizes range from microscopic creatures a mere tenth of a millimeter long to gigantic crabs, lobsters, and isopods reaching lengths of 4 meters and tipping the scales at 20 kilograms.

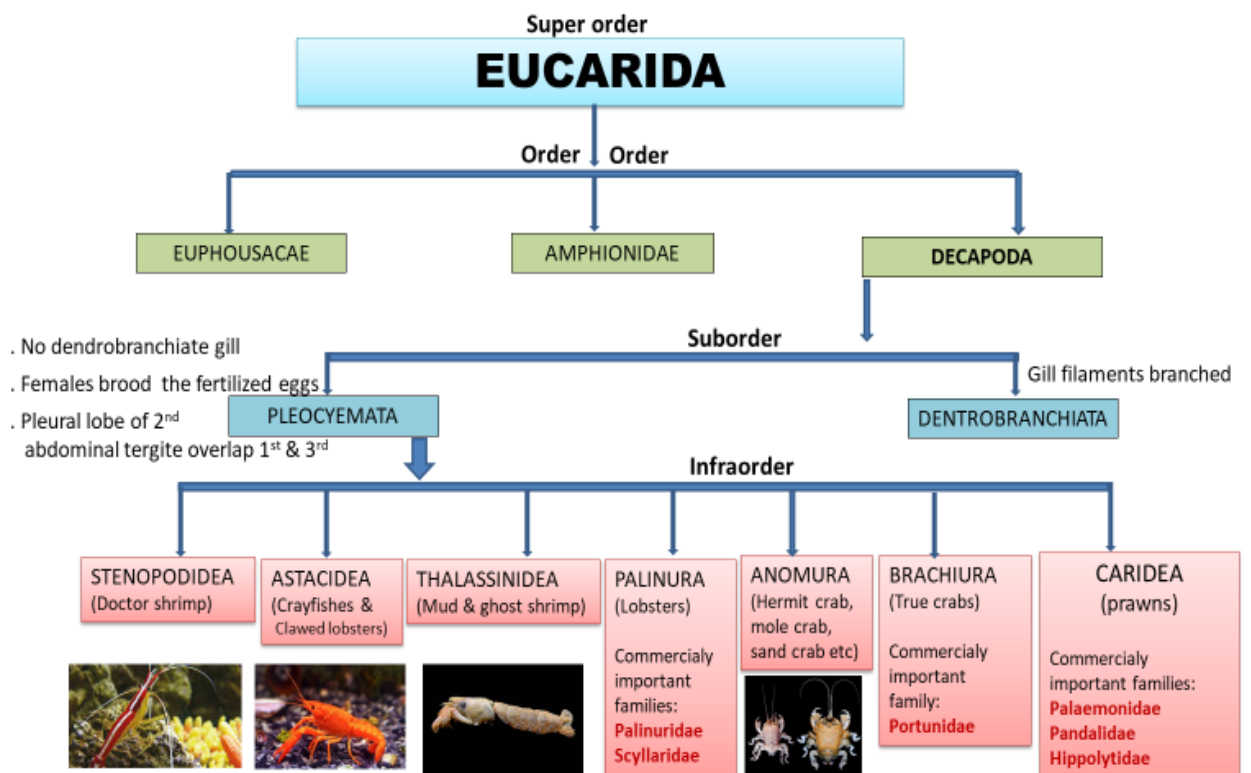
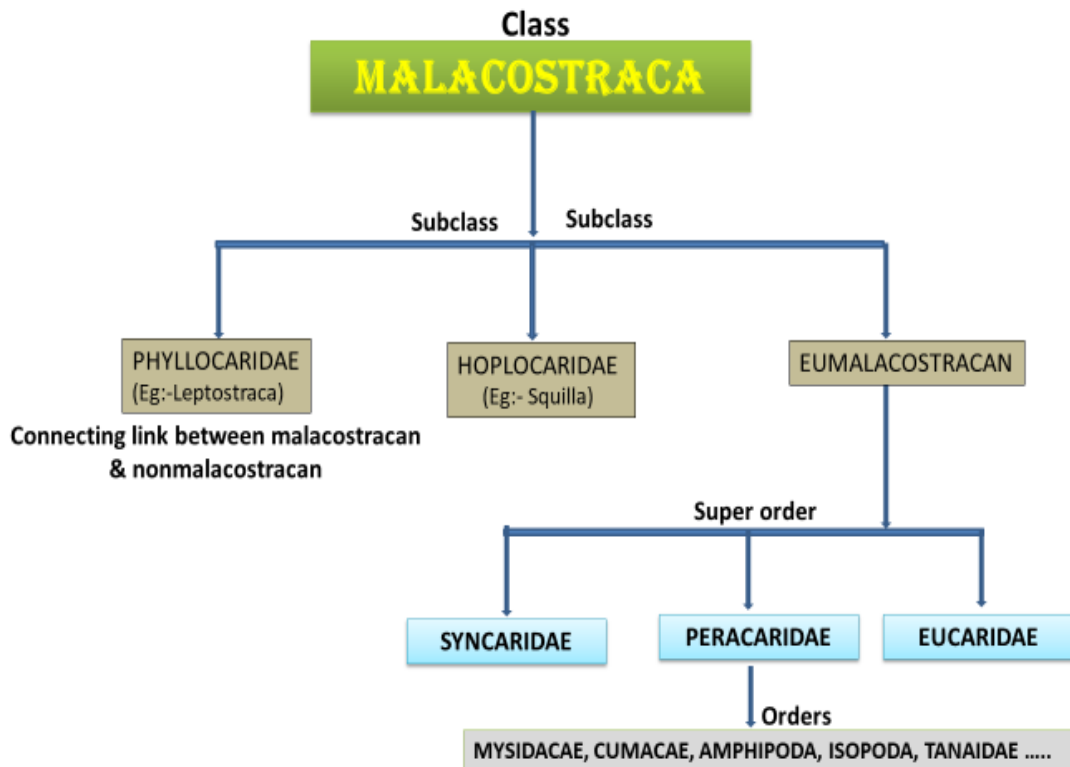
From the energetic scuttling of crabs and the graceful gliding of lobsters to the shrimp's powerful swimming and the tiny krill's filtering, crustaceans encompass a vast array of lifestyles. This group also includes the fascinating copepods, amphipods, and the more stationary barnacles. Just like other arthropods, crustaceans wear an external suit of armor made of chitin, which they must shed periodically to grow larger..

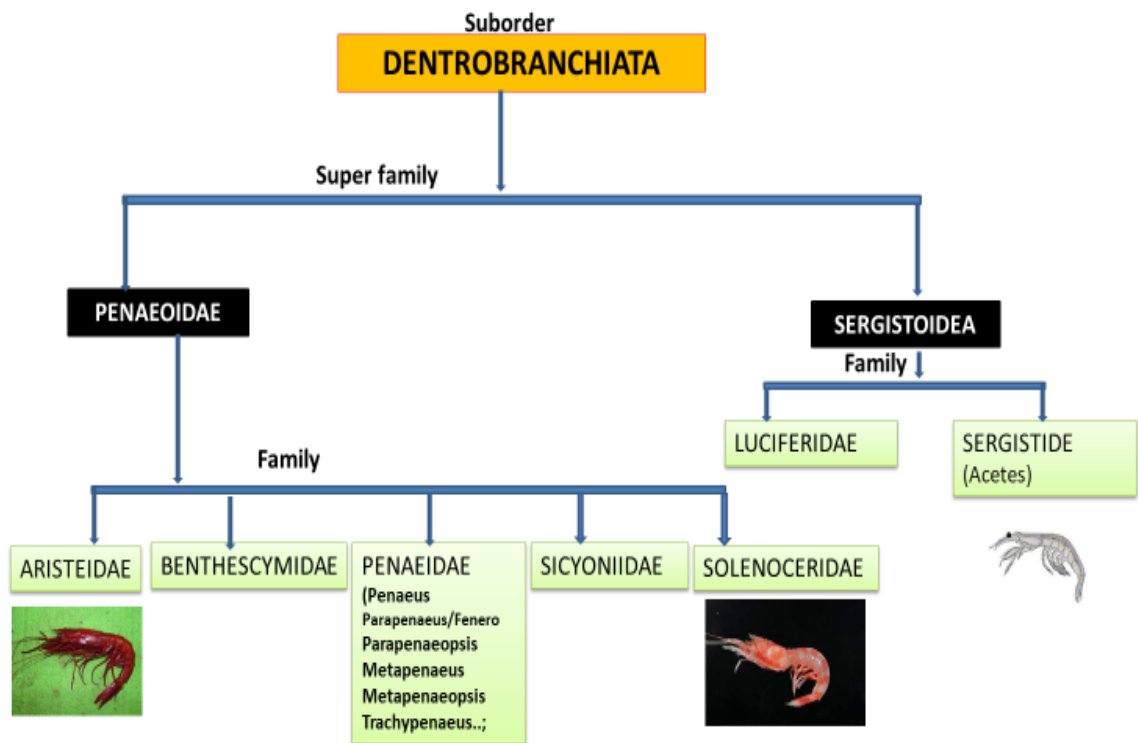
General characteristics of crustaceans:

- They have a hard, but flexible exoskeleton or shell
- Two pairs of antennae
- A pair of mandibles (which are appendages used for eating)
- Two pairs of maxillae on their heads (additional mouth parts)
- Two compound eyes, often on stalks
- Segmented bodies (3 regions – cephalic, thoracic & abdominal) with appendages on each body segment

Crustacean Classification:







The decapod crustaceans belonging to the class Malacostraca are the most popular invertebrates due to their commercial value, of which the most important are shrimp species belonging to the five penaeidean families Solenoceridae, Aristeidae, Penaeidae, Sicyoniidae and Sergestidae and three caridean families - Pandalidae, Crangonidae and Palaemonidae. Among these, the families Penaeidae and Palemonidae contain species of capture and culture importance. The features which are generally used for taxonomic analysis include the rostrum, carapace with its spines and carina, carina of the abdomen, pleurae, telson appendages, petasma, appendix masculine, and thelycum. Shrimps/Prawns come under the order Decapoda Latrielle, 1980, an order which derives the name from the presence of five pairs (10 numbers) of walking legs (deca = ten).

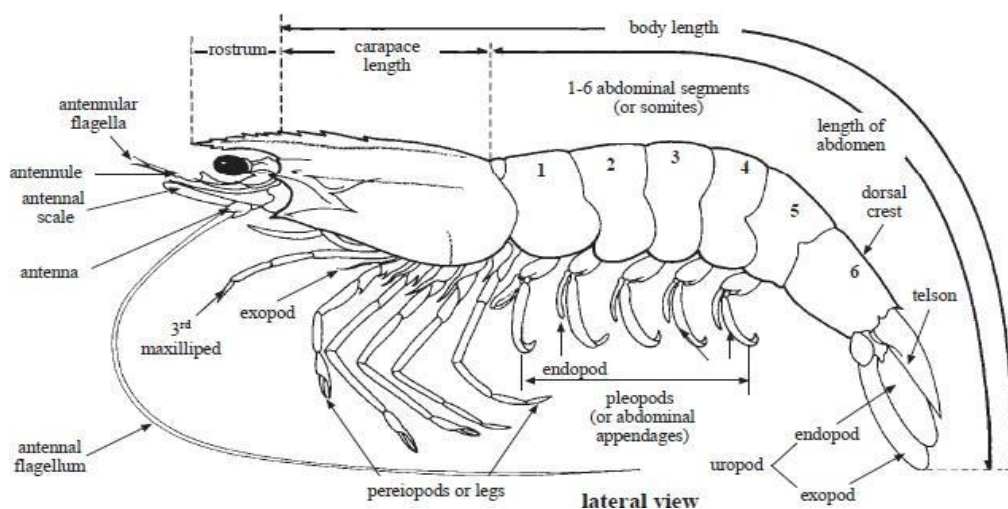
The order Decapoda is characterized by –

- The body can be divided into three broad regions – cephalic, thoracic, and abdominal regions with five, eight, and six segments respectively.
- The last five pairs (10 nos.) of appendages are pereopod and are walking legs.
- Gills are of three different types, namely, dendrobranchs, trichobranch and phyllobranch.

MORPHOLOGY OF PRAWN/SHRIMP

The shrimp/prawn possesses an elongated, segmented body divided into three main sections: the cephalothorax, abdomen, and telson. The 'head' region, or cephalothorax, has a roughly cylindrical shape. The abdomen is compressed along the sides and contains six segments. The telson has a flattened appearance. In total, there are 19 segments, plus a pre-oral and post-anal region (the telson). Each segment has a corresponding pair of appendages, including: antennule, antenna, mandible, maxillula, maxilla, first through third maxillipeds, first through fifth pereopods, and uropods.

A chitinous exoskeleton protects the body. On the cephalothorax, the exoskeleton forms a structure called the carapace. The carapace extends forward into the rostrum, a laterally compressed segment with teeth on its edges. The carapace surface also features various spines, grooves, and ridges. The cephalothorax comprises 13 segments (five in the head, eight in the thorax). The abdominal segments have clearly defined exoskeletons. The top plate is the tergum, the bottom plate is the sternum, and they enclose the body. Extending below the sternum is the pleuron. The telson is a cone-shaped structure, wide at the base and narrowing to a point. It is not considered a true segment, as it lacks internal organs and hemocoel.

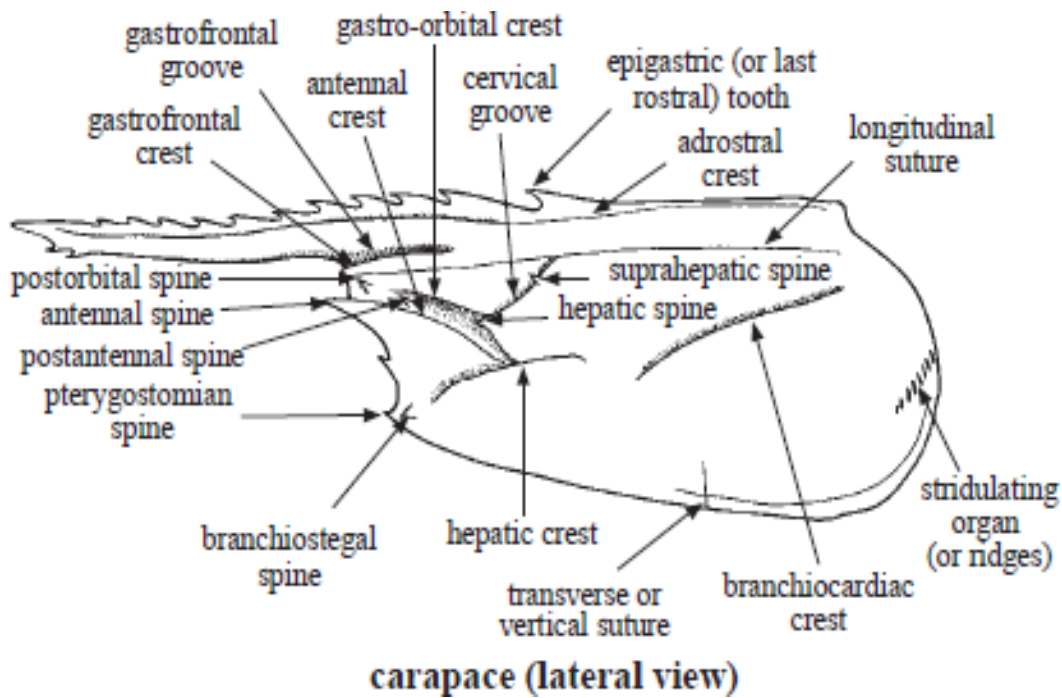


APPENDAGES OF A SHRIMP/PRAWN

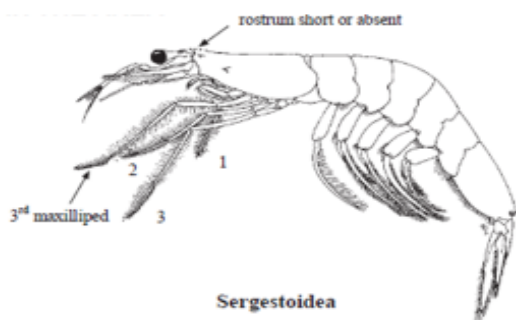
There are 19 pairs of appendages and these are classified as follows –

1. Cephalic (5 pairs) : antennule, antenna, mandible, maxillula, maxilla
2. Thoracic (8 pairs): first maxilliped, second maxilliped, third maxilliped, first pereopod, second pereopod, third pereopod, fourth pereopod, fifth pereopod
3. Abdominal (6 pairs): first pleopod, second pleopod, third pleopod, fourth pleopod, fifth pleopod and uropod

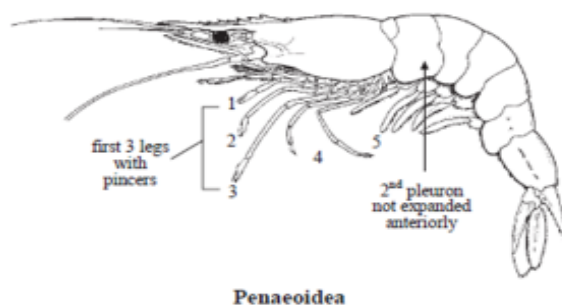
Technical terms:



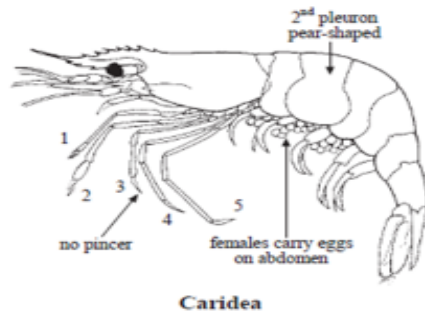
Important superfamilies



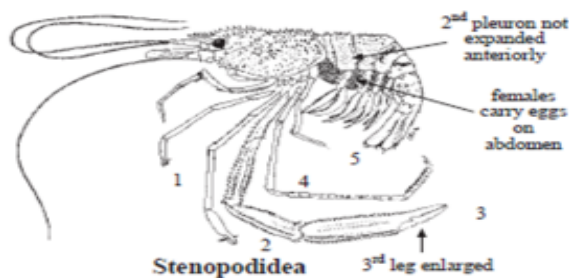
Sergestoidea : Small to microscopic. Rostrum and last 2 pairs of legs (pereiopods) reduced (absent in Luciferidae). Abdomen with posterior part of pleura (lateral plates) covering anterior part of succeeding pleura. Males bear petasma on first pair of pleopods. Eggs released directly into the water (eggs carried on second pair of legs in Luciferidae).



Penaeoidea: Small to large. All 5 pairs of pereiopods well developed & first 3 pairs forming a pincer, none of the pincers large. Abdomen with posterior part of pleura covering anterior part of succeeding pleura. Males bear large specific petasma on first pair of pleopods and thelycum on posterior thoracic sternites in females. Eggs releases directly into the water, not retained by the females.



Caridea: Very small to large. All 5 pairs of legs (pereiopods) well developed & first 2 pairs with or without pincers but third pair never bear pincer. Second abdominal pleuron greatly expanded and overlapping posterior part of first pleuron and anterior part of third pleuron. Males & females without large copulatory organ of first pair of pleopod. Females carry eggs on the abdomen until hatching.



Stenopodidea: Usually small. All 5 pairs of legs (pereiopods) well developed & first 3 pairs forming a pincer, third pair huge and massive. Abdomen with posterior part of pleura covering anterior part of succeeding pleura. Males and females without large specific copulatory organ on first pair of pleopods or posterior thoracic sternites. Females carry the eggs on the abdomen until hatching.

Major families under Penaeodea:

Aristeidae: Eyestalk with a tubercle on inner border; upper antennular flagella strikingly shorter than lower and inserted near posterior border of third article. Telson bearing movable spines; endopods of second pair of pleopods in males bearing appendix masculina and appendix interns but no lateral projection.

Penaeidae : Eyestalk without tubercle on inner border; cervical groove much shorter, ending well below dorsal midline of carapace. Endopods of second pair of pleopods in males bearing appendix masculina only. A single well developed arthrobranch on penultimate thoracic segment. Telson sharply pointed, with or without fixed or movable spines on side.

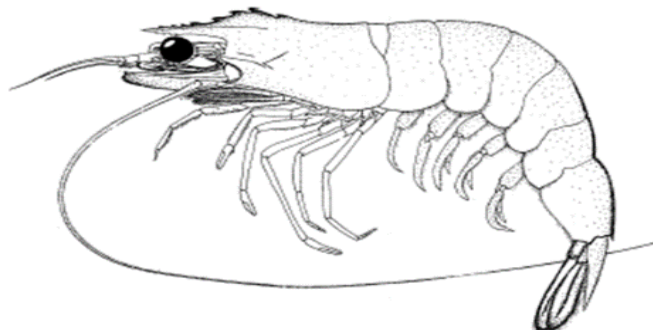
Sicyoniidae: Body thick stony in appearance; cervical groove very faint or absent. Abdomen with deep grooves and numerous tubercles; third and fourth pairs of pleopods single branched.

Solenoceridae : Eyestalk with a tubercle on its inner border; carapace with postorbital spine. Cervical groove long extending to or close to dorsal midline of carapace. Endopods of second pair of pleopods in males bearing appendix masculina, appendix interna and lateral projection. Telson with a fixed spine on each side of tip. Two well developed arthrobranches on each side of penultimate thoracic segment.

IDENTIFICATION OF THE FAMILY PENAEIDAE

Penaeidae (Penaeid Prawns)

(includes Penaeus, Metapenaeus, Parapenaeopsis, Metapenaeopsis, Trachypenaeus)



Penaeus : Carapace without lateral keels; cutting portion of mandible short and massive. Rostrum toothed on dorsal as well as on ventral margin.

Metapenaeus : Rostrum without lower teeth. Telson without large subapical fixed lateral spines. Third maxilliped without epipod; male petasma symmetrical. **Fifth pereopod without exopod** (carapace without longitudinal or vertical sutures). Pleurobranch present on penultimate thoracic segment.

Parapenaeopsis : Rostrum without lower teeth. Telson without large subapical fixed lateral spines. Third maxilliped without epipod; male petasma symmetrical. Fifth pereopod with exopod. Carapace with both longitudinal and vertical sutures; second leg without ischial spine; eyes large. **Body naked**, with crests and grooves on carapace distinct; longitudinal suture usually long and **epipod absent on third pereopod**.

Metapenaeopsis : Rostrum without lower teeth. Telson with a pair of large subapical fixed lateral spines. Carapace without longitudinal or transverse sutures Body densely covered with short hairs, with grooves and crests on carapace obscure; **petasma asymmetrical**.

Trachypenaeus : Rostrum without lower teeth. Telson without large subapical fixed lateral spines. Third maxilliped without epipod; male petasma symmetrical. Fifth pereopod with exopod. Carapace with both longitudinal and vertical sutures; second leg without ischial spine; eyes large. **Body usually hairy**, with crests and grooves on carapace obscure; longitudinal suture short; **third leg generally with epipod**.

Key for the identification of the commercially important families of prawns

1.	Pleura of 2 nd abdominal segment overlapping those of the proceeding (1 st) and succeeding (3 rd) segments; no chela on 3 rd pereopods; gills phyllobranchiate.....	2
	Pleura of 2 nd abdominal segment overlapping that of the succeeding (3 rd) but not of the preceding (1 st) segment; 3 rd pereopod chelate.....	3
2.	Carpus of second pair of pereopods entire; epipodites absent; upper antennular flagellum bifid; 3 rd maxilliped normal..... Palaemonidae	
	Carpus of second pair of pereopods divided into two or more articles; 1 st pair of pereopods non chelate or with a microscopic chela..... Pandalidae	
3	Last two pairs of walking legs well developed, gills many dendrobranchiate..... Penaeidae	
	Last one or two pairs of walking legs reduced or absent; gills few or wanting Sergastidae	

Classification of the Family Penaeidae

Subphylum : **Crustace** Brunnich,1772
 Class : **Malacostraca**Latreille, 1802
 Subclass : **Eumalacostraca**Grobben, 1892
 Order : **Decapoda**Latereille, 1802
 Suborder :**Dendrobranchiata** Bate, 1888
 Superfamily : **Penaeoidea** Rafinesque, 1815
 Family :**Penaeidae** Rafinesque, 1815

Key to Genera Under Family Penaeidae From Indian waters

1.	Rostrum serrated only on the dorsal margin.....	5
	Rostrum serrated on the dorsal and ventral margins.....	2
2.	Adrostral carina and sulcus extends as far as the level of epigastric tooth, gastro frontal carina absent.....	3
	Adrostral carina and sulcus extends behind epigastric tooth; gastro frontal carina present.....	4

3.	<p>Hepatic carina generally absent, if present, only feeble.....<i>Femmeropenaeus</i></p> <p>Hepatic carina present and prominent.....<i>Penaeus</i></p>	
4.	<p>Gastro-frontal sulcus not markedly bifid posteriorly; thelycum with pair of lateral plate on sternite XIV shielding sac like seminal receptacle opening along midline.....<i>Melicertus</i></p> <p>Gastro-frontal sulcus markedly bifid posteriorly; thelycum with a ventral undivided plate on sternite XIV infolded laterally, forming pouch opening anteriorly.....<i>Marsupenaeus</i></p>	
5.	<p>Telson with a pair of fixed subapical spines preceded by one to three pairs of movable spines; antennal peduncle usually bearing parapenaeid spine.....</p> <p>Telson generally without fixed subapical spine, but usually with movable lateral spines; antennular peduncle lacking parapenaeid spine.....</p>	<p>6</p> <p>8</p>
6.	<p>Carapace with longitudinal sutures (extending from post orbital region to almost posterior margin of carapace) and transverse sutures; telson with only one pair of minute lateral spines anterior to subapical spines<i>Parapenaeus</i></p> <p>Carapace without longitudinal sutures; telson with two or more pair of conspicuous spines anterior to subapical spines.....</p>	<p>7</p>
7.	<p>Third maxilliped and second peraeopod with basal spine; petasma asymmetrical.....<i>Metapenaeopsis</i></p> <p>Third maxilliped and second peraeopod without basal spine; petasma symmetrical.....<i>Penaeopsis</i></p>	
8	<p>Pleurobranch present on somite XIII; exopods on maxillipeds and anterior four pairs of pereopods; fifth pereopod without exopod.....<i>Metapenaeus</i></p> <p>Pleurobranch absent on somite XIII; exopod present on all pereopods.....</p>	<p>9</p>

9	Carapace without longitudinal and transverse sutures; telson with subapical pair of lateral movable spines mounted on elongated shoulder; epipods not furcated; petasma with ventrao-lateral lobule produced into three flaps; anterior plate of thelycum as long as wide..... <i>Trachypenaeopsis</i>	
-	Carapace with either longitudinal and / or transverse sutures ;telson without lateral spines or with movable ones not mounted on elongate shoulders; petasma with ventro-lateral lobule not produced into distal flaps.....	10
10	Carapace without longitudinal sutures; second pereopod with ischial spine; hepatic spine present; petasma not constricted distally; anterior plate of thelycum rounded posteriorly..... <i>Atypopenaeus</i>	
-	Carapace with longitudinal sutures; second pereopod without ischial spine	11
11	Third pereopod without epipod body slender, integument thin ... <i>Parapenaeopsis</i>	
-	Third pereopod with epipod; body thick set; third maxilliped lacking basialspine.	12
12	Thelycum with plate on sternite XIV very short medially, deeply excavate, embracing extremely long caudal extension of median protuberance. Petasma with disto-lateral projections either moderately broad to rather narrow basally and extending laterally tomesially or forward directed hook like tip or extremely broad basally but narrowing rapidly, ending in forward directed tip <i>Megokris</i>	
-	Thelycum with plate on sternite XIV shallowly emarginated or occasionally produced in small median prominence, not continuous with medial protuberance; petasma with disto lateral projections tapering gently from relatively narrow base, extending almost straight laterally or curving slightly backwards <i>Trachysalambria</i>	

Key to species under the genus *Fenneropenaeus*

1.	Gastro-orbital carina absent or not reaching hepatic spine and occupying the middle 1/3 rd distance between hepatic spine and orbital angle..... Gastro- orbital carina occupying the posterior 2/3 distance between hepatic spine and orbital angle; dactyle of third maxilliped about as long as propodus; rostral crest may be elevated but not triangular in profile	2
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 <i>indicus</i>	
2.	Dactyl of third maxilliped of adult male 0.5-0.6 times propodus; adrostral carina not reaching as far as epigastric tooth; rostrum broad basally, directed anteriorwards, basal part much elevated into a triangular in profile <i>merguiensis</i> Dactyl of third maxilliped of adult male much longer than propodus; adrostral carina reaching just beyond epigastric tooth; rostrum slender, sharply directed downwards, basal part not much elevated <i>penicillatus</i>	

Key to species under the genus *Melicertus*

Adrostral carina and groove long, extending almost posterior region of carapace, groove wide, anterior plate of thelycum forming two subaccuminate, posterior process triangular; telson without movable spines; body with cross bands..... <i>canaliculatus</i>
Adrostral carina and groove extending almost to posterior region of carapace; anterior plate of thelycum forming two subtriangular processes at the distal end at the apex ; telson with 3 pairs of movable spines; body without cross bands..... <i>latisulcatus</i>

Key to species under the genus *Metapenaeus*

1.	Disto-medianpetasmas projection with fully developed or vestigial apical filament; impregnated thelycum usually with white conjoined pads.....	2
-	Disto-medianpetasmas projection without apical filament; thelycum of impregnated females without white conjoined pads	3
2	Posterior part of rostrum with distinctly elevated crest; basal spine on male third pereopod simple, disto median projection of petasma with a long and slender apical filament; thelycum with a large square and grooved anterior plate and lateral plates boomerang shaped, enclosing two pear shaped plates <i>brevicornis</i>	
-	Posterior part of rostrum without distinctly elevated crest ; basal spine on male third pereopod long and barbed; disto median projection of petasma with short filament on dorsal and ventral sides; anterior thelycum plates tongue like, lateral plates horse shoe shaped	

 <i>dobsoni</i>	
3.	Ischial spine on first pereopod distinct	4
-	Ischial spine on first pereopod small or absent	6
4.	Disto-median petasmas directed forwards convoluted, greatly swollen and lateral thelycal plates with raised lateral ridges, each with a posterior inwardly curved triangular plate, anterior plate of thelycum long a deeply groove	5
	Disto-median petasmas directed antero-ventrally anterior thelycal plate tongue like.....	
5.	Lateral thelycal plates with salient and parallel ear shaped lateral ridges; disto median petasmas hood-like..... <i>monoceros</i>	
	Lateral thelycal plates without lateral ridges; disto-median petasmas not hood-like <i>kutchensis</i>	
6.	Branchio-cardiac carina feeble or ill-defined, anterior end not exceeding posterior third of carapace; distal margin of anterior thelycal plate convex to indistinctly triangular; petasma with laminose and strongly diverging disto-median projections, disto lateral projections directed antero-ventrally; anterior thelycal plate flask-shaped, distal end with three tubercles of subequal size, lateral plates kidney shaped	
- <i>moyebi</i> Branchio-cardiac carina distinct, extending from posterior margin of carapace almost to hepatic spine; anterior thelycal plate longitudinally grooved, wider posteriorly than anteriorly; disto median petasmas crescent shaped, leaning on disto lateral projections and concealing them partly or completely..... <i>affinis</i>	

Key to species under the genus *Parapenaeopsis*

1	Epipods present on first and second pereopods.....	2
.	Epipods absent on first and second pereopods.....	3
2	Telson with pair of fixed apical spines; atleast distal half free portion of rostrum unarmed.....	3
	Telson without fixed subapical spines, with or without lateral movable spines; distal third or less part of rostrum	

	edentulous..... <i>hardwickii</i>	
3	<p>Petasma long with disto lateral projections slender, horn like, slightly curved directed anterior ventrally with ventro external openings; telson 4 pairs of fixed distal spines..... <i>stylifera</i></p> <p>Petasma long with disto lateral projections slender, horn like, slightly curved directed laterally with external openings; telson with one or two pairs of fixed spines.....<i>coromandelica</i></p>	

Key to species under the genus *Penaeus*

<p>Adrostral carina and groove do not extend up to epigastric tooth; antennal crest very prominent ending above middle of hepatic carina, hepatic carina horizontally straight; fifth pereopod without exopodite..... <i>monodon</i></p>
<p>Adrostral carina and groove beyond epigastric tooth; antennal crest very prominent ending above posterior third of hepatic carina, hepatic carina inclined antero ventrally; fifth pereopod with small exopodite..... <i>semisulcatus</i></p>

IDENTIFICATION OF THE FAMILY PALAEMONIDAE

Classification of the Family Palaemonidae

Subphylum : **Crustace** Brunnich, 1772
 Class : **Malacostraca** Latreille, 1802
 Subclass : **Eumalacostraca** Grobben, 1892
 Order : **Decapoda** Latreille, 1802
 Suborder : **Pleocyemata** Burkenroad, 1963
 Superfamily : **Palaemonoidea** Rafinesque, 1815
 Family : **Palaemonidae** Rafinesque, 1815

Palaemonids are commonly called as freshwater prawns. The important genera under this family are *Palaemon* and *Macrobrachium*. Many species of prawns under the genera complete their life cycle in estuaries. The two genera could be identified based on the key below-

Carapace with antennal and Branchiostegal spines; mandible with palp, eyes pigmented; propodus of pereopod 5 with transverse rows of setae on the distal part of posterior margin; dactylus of last three pereopods simpleGenus <i>Palaemon</i> Weber
Carapace with antennal and hepatic spines; eyes pigmented, prpodus of pereopod 5 without transverse rows of setae on the distal part of posterior margin; dactylus of last three pereopods simple Genus <i>Macrobrachium</i> Bate

Key to species under the genus *Macrobrachium* Bate

1.	Carpus of pereopod 2 longer than merus.....	2
	Carpus of pereopod 2 subequal to or shorter than merus.....	8
2.	Rostrum with a distinct basal crest.....	3
	Rostrum without distinct basal crest.....	6
3.	Tip of telson reaching beyond tip of longer posterior spines.....	5
	Posterior spines over reaching tip of telson; distal part of rostrum without dorsal teeth	
4.	Carpus of pereopod 2 in male longer than ½ length of chela, its dactylus nearly as long as palm <i>M.rosenbergii</i> (<i>de Man</i>)	
	Carpus of pereopod 2 in male variable in length and proportion to chela, its dactylus shorter than ½ length of palm..... <i>M.villosimanus</i> (Tiwari)	
5.	Basal crest of rostrum shallow; palm of pereopod 2 normal , its dactylus shorter than palm <i>M. lamarreilamarrei</i> (Milne Edwards)	
	Basal crest of rostrum elevated; palm of pereopod 2 aollen, its dactylus longer than palm	
6.	Cutting edges of male 2 nd pereiopod with two proximal tubercles and all joints of this appendage pubescent..... <i>M. rude</i>	7
	Cutting edges of male 2 nd pereiopod with two proximal tubercles and all joints	

	of this appendage non-pubescent.....	
7.	Rostrum nearly straight with 9-12 dorsal teeth, two of which behind orbit; carpus of male pereopod 2 longer than chela..... <i>M. idella</i> (Hilgendorf) Rostrum curved with 9-12 dorsal teeth, three of which behind orbit; carpus of pereopod 2 shorter than chela..... <i>M. equidens</i> (Dana)	
8.	Pereopod 5 longer than 4; dorsal rostrum with many teeth closely arranged..... <i>M. mirabile</i> (Kemp) Pereopods 4 & 5 subequal in length	9
9.	Dactylus of male pereopod 2 with 4 or more tubercles at regular interval..... <i>M. scabriculum</i> (Heller) Dactylus of male pereopod with 1-2 tubercles..... <i>M. javanicum</i> (Heller)	

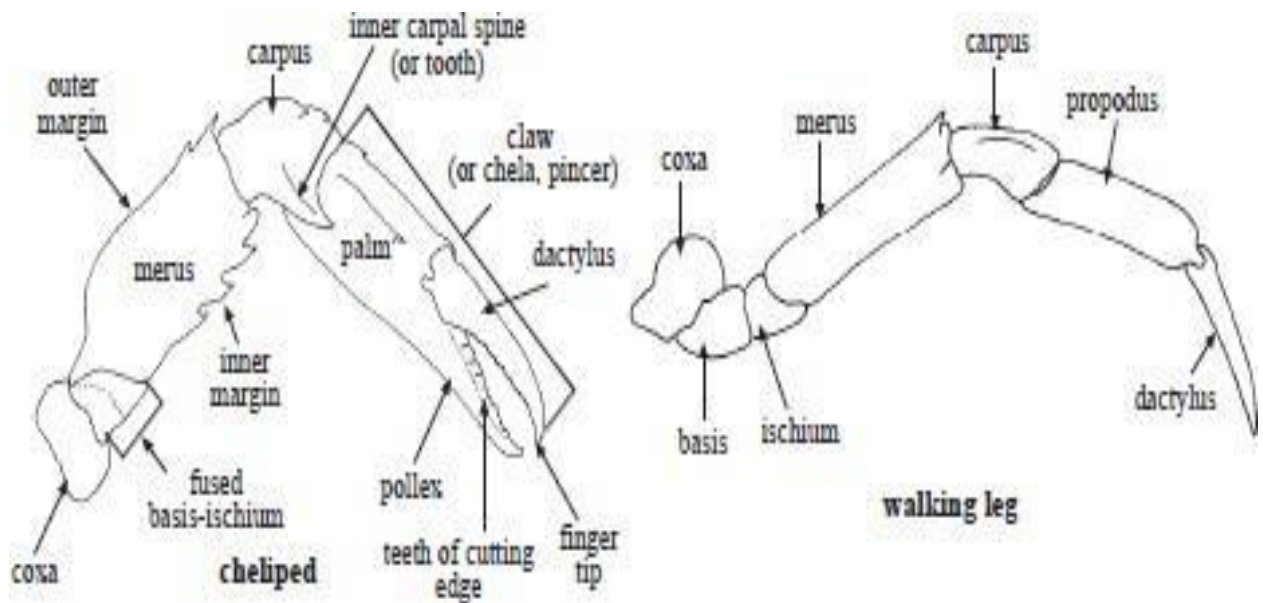
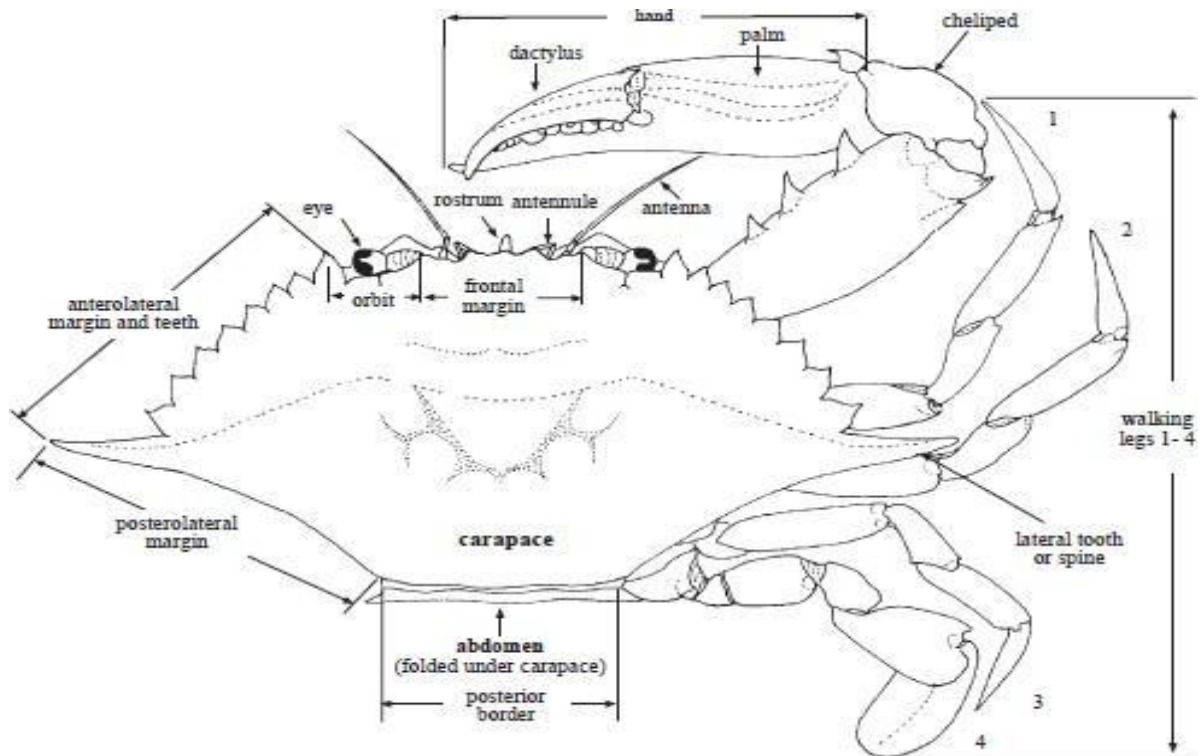
CRABS OF COMMERCIAL IMPORTANCE

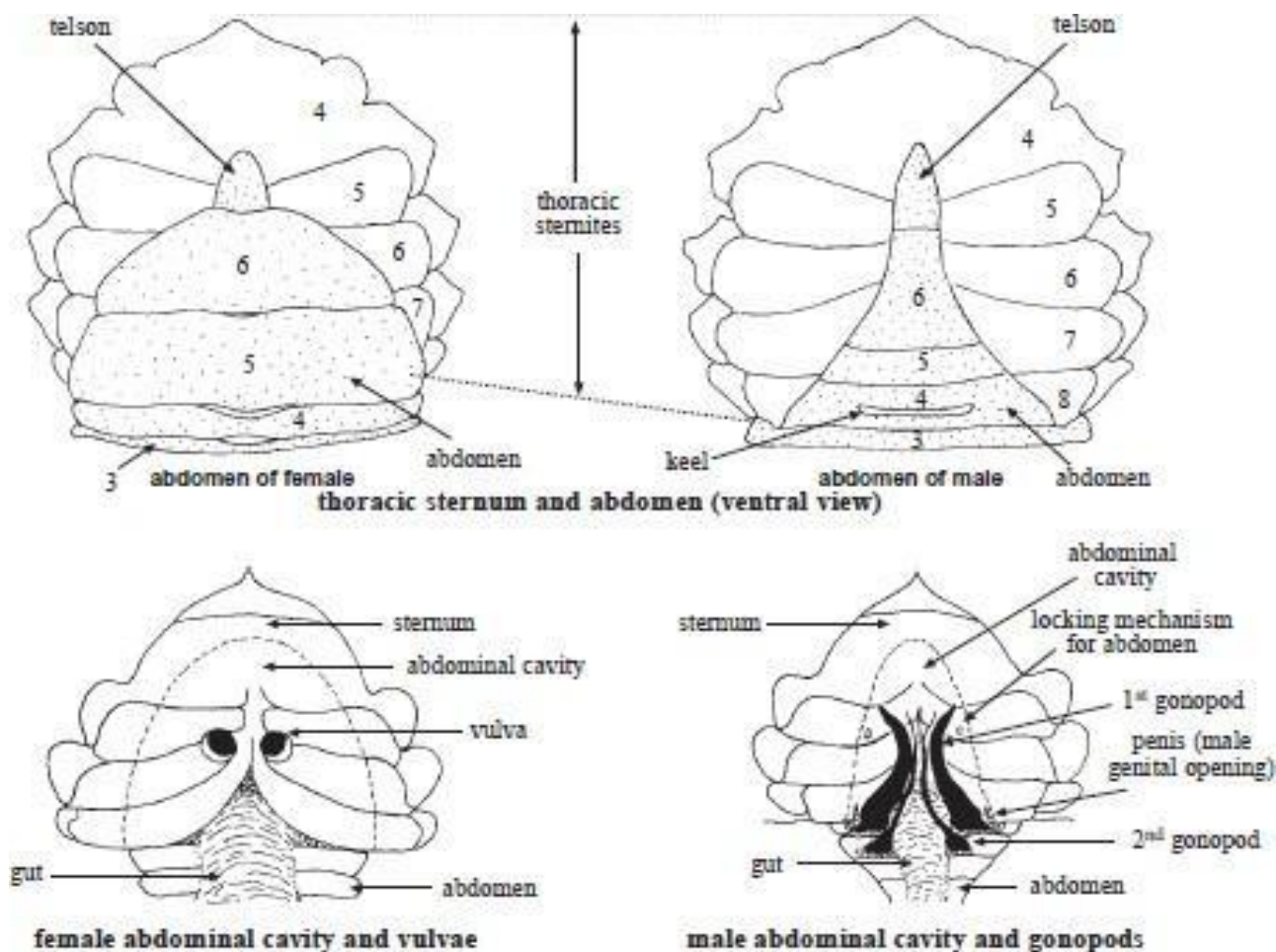
More than 600 species of crabs have been reported from India, of which a few species are commercially important. Many have been confined to sea and a few have invaded into the estuaries, but migrate to sea for breeding. The carapace is high, flattened with the antero lateral margins serrated. Abdomen is highly reduced and this structure is highly dimorphic. Abdominal appendages are also modified sex-wise. (two pairs in males and four pairs in females).

Classification of family Portunidae

- Subphylum : **Crustacea** Brunnich, 1772
- Class : **Malacostraca** Latreille, 1802
- Subclass : **Eumalacostraca** Grobben, 1892
- Superorder : **Eucarida** Calman, 1904
- Order : **Decapoda** Decapoda Latreille, 1802
- Suborder : **Pleocyemata** Burkenroad, 1963
- Superfamily : **Portunoidea** Rafinesque 1815
- Family : **Portunidae** Rafinesque 1815

Technical terms: Structure of Carapace and cheliped of a crab





Key for the identification of some of the common species are given below

1.	Antero lateral borders of carapace cut into nine teeth.....	2
-	Antero lateral borders of carapace cut into six teeth..... <i>Charybdis</i>	4
2	Teeth on the antero lateral borders equal sized, green in colour <i>Scylla serrata</i>	3
-	Last tooth on the antero lateral borders enlarged in the form of a prominent large long spine..... <i>Neptunus</i>	
3	No spines on the posterior border of the arm of the chelipeds, carapace with three blood red spots..... <i>Neptunus sanguinolentus</i>	
	A spine at the far end of the posterior border of the arm of the chelipeds <i>Neptunus pelagicus</i>	

4	<p>First tooth on the antero- lateral borders anteriorly truncated and notched. Sixth abdominal tergum of male with curved and gradually convergent sides. One or two inconspicuous denticles near the far end of the posterior border of the protopodites of the last pair of legs. A brown cross marking on the carapace.....</p> <p><i>Charybdis cruciata</i></p>
-	<p>First tooth on the antero- lateral borders acute, Sixth abdominal tergum of male with its sides parallel or even slightly divergent. Posterior border of the protopodites of the last pair of legs strongly serrated through out. 4 whitish spots on the carapace.....<i>Charybdis lucifera</i></p> <p>First tooth on the antero- lateral borders acute, Sixth abdominal tergum of male with its sides parallel. Posterior border of the protopodites of the last pair of legs serrated in a larger part of its extent. Legs with annular bands.<i>Charybdis annulata</i></p>

COMMERCIALY IMPORTANT LOBSTERS OF INDIA

The importance of lobsters in our marine products export trade is only second to that of prawns. The increasing demand of ‘frozen lobster tails’ has brought the Indian lobster to the limelight. About half a dozen species of spiny lobsters are recorded from the Indian region, belonging to the genera – *Panulirus*, *Palinustus* and *Peurulus*.

Diagnosis of Families

Palinuridae: Moderate to large-sized crustacean. The carapace is rounded (sub-cylindrical) in section, without a distinct median rostrum, ornamented with spines and granules of various sizes: each eye is protected by a strong, spiny frontal projection of carapace (frontal horns). Antennae are long and whip-like, antennules slender each consisting of a segmented peduncle.

Synaxidae: Carapace covered with small rounded granules but without enlarged spines; a small median triangular rostrum present; first pair of legs at least twice as thick as the second; entire body hairy and bright orange or red.

Nephripidae: Body tubular, a well-developed rostrum present; first 3 pairs of legs ending in true pincers, first pair much larger than the others.

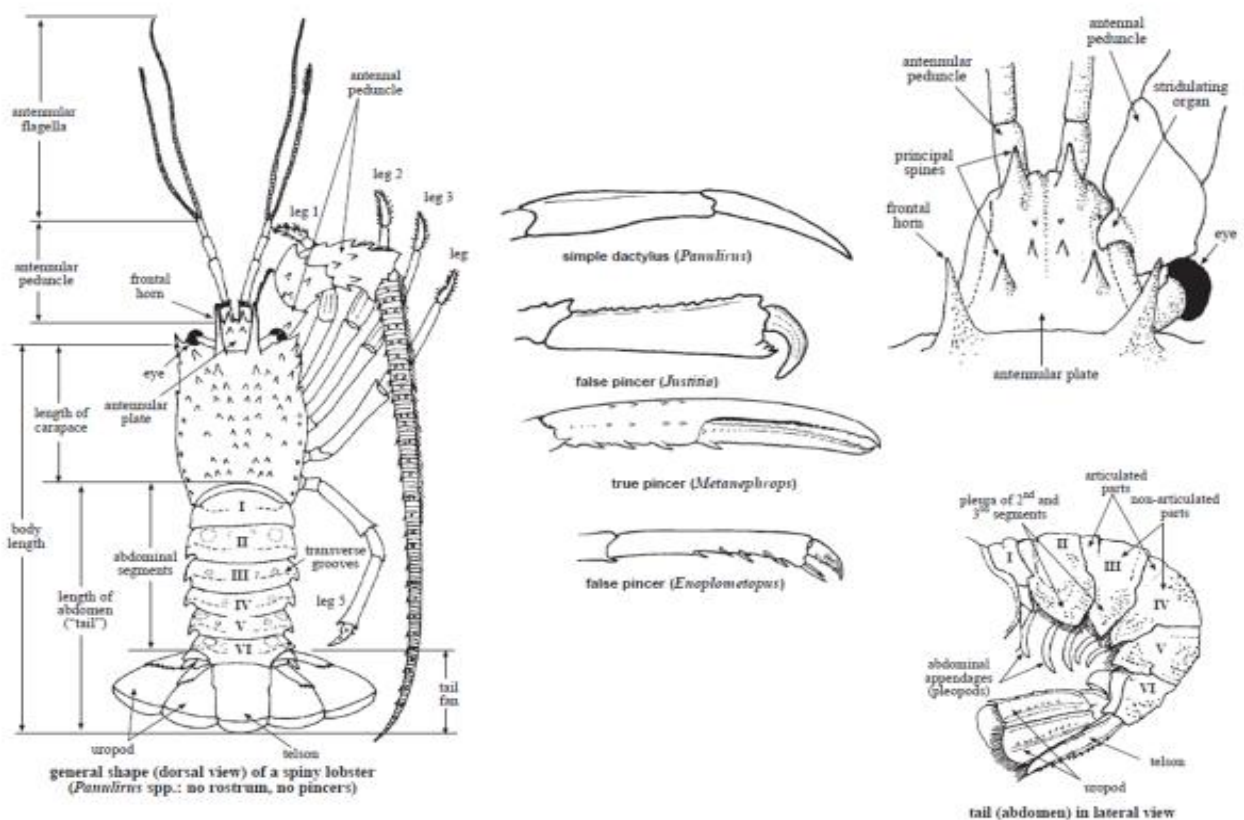
Scyllaridae: Body flattened, firm: rostrum rudimentary or absent; first 4 pairs of legs without pincers, antennae plate-like, without pincers, antennae plate-like, without flagellum.

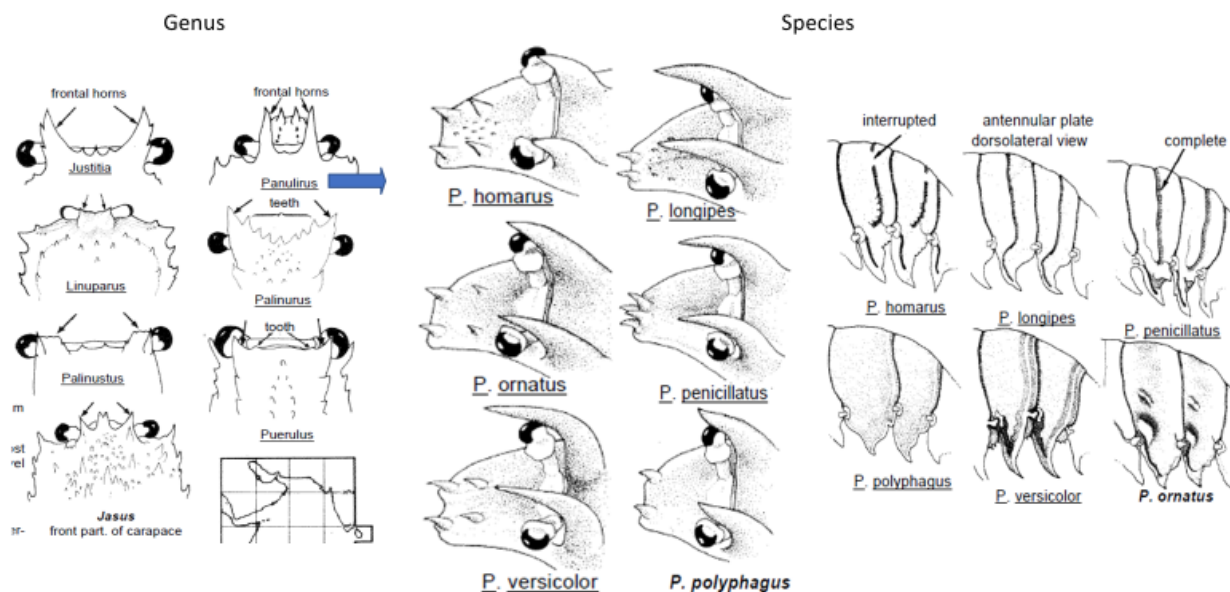
Polychelidae: Body flattened, soft: rostrum absent or rudimentary: first 4 pairs of legs with pincers; the first greatly elongated; antennal whip-like. Deep sea inhabitants.

Classification of family Palinuridae

Subphylum	: Crustacea	Brunnich, 1772
Class	: Malacostraca	Latreille, 1802
Subclass	: Eumalacostraca	Grobben, 1892
Superorder	: Eucarida	Calman, 1904
Order	: Decapoda	Decapoda Latreille, 1802
Suborder	: Pleocyemata	Burkenroad, 1963
Superfamily	: Palinuroidea	Latreille, 1802
Family	: Palinuridae	Latreille, 1802

Technical terms:





Key for the identification of 6 species of Lobsters under the genus *Panulirus*

1.	Each abdominal segment with transverse groove.....	2
-	Abdominal segments without transverse groove.....	4
2.	Anterior margin of abdominal grooves scalloped..... <i>P. homarus</i> (Linnaeus)	3
-	Anterior margin of abdominal grooves not scalloped.....	
3.	Antennular plate with 4 equal principal spines fused at base ... <i>P. penicillatus</i> (Olivier)	
-	Antennular plate with 2 principal spines and some smaller spines behind <i>P. longipes</i> (Milne Edwards)	
4.	Flagellum of exopod of 2 nd maxilliped small or absent.....	5
-	Flagellum of exopod of 2 nd maxilliped well developed ,multiarticlar <i>P. polyphagus</i> (Herbst)	
5.	Conspicuous transverse white band posteriorly on each abdominal segment, legs with longitudinal white lines..... <i>P.versicolor</i> (Latreille)	
-	No transverse white band on abdominal segments, but a conspicuous white spot on lateral portion, legs with alternative yellow and black mottling ... <i>P.ornatus</i> (Fabricius)	



MARINE MAMMAL DIVERSITY AND TAXONOMY

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INTRODUCTION

Marine mammals are warm-blooded, aquatic vertebrates within the class Mammalia. They breathe air, use fins and flippers for movement, and nurse their young with milk. There are four taxonomic groups: **cetaceans** (whales, dolphins, and porpoises), **sirenians** (manatees and dugongs), **pinnipeds** (walruses, seals, and sea lions), and **fissipeds** (polar bears and sea otters). Cetaceans and sirenians live their entire lives in water, while other marine mammals may come ashore for parts of their life cycle.

Marine mammals are keystone species, and their decline can have cascading effects on the entire marine ecosystem and even human communities. These large predators inhabit diverse environments – tropical, subtropical, temperate, and polar oceans – shaping marine food webs and ecosystem structure. They influence the behavior of prey and other predators, recycle nutrients, and even modify habitats.

In recent years, marine mammals have encountered various threats to their survival. These include accidental fatalities among coastal populations caused by becoming entangled in fishing gear, colliding with powered vessels, and becoming trapped in water regulation devices. Marine mammals face numerous threats: entanglement in fishing gear, vessel strikes, pollution, ocean acidification, infectious diseases, harmful algal blooms, disturbances from seismic activities and ocean warming pose significant stressors to these organisms⁴.

Conservation and management of marine mammals are vital to maintain their health and that of the ocean. Taxonomy is a key tool, helping identify units of conservation and inform species protection efforts.

Worldwide, there are 135 recognized marine mammal species across 21 families (8 monotypic) and four taxonomic groups. Sadly, the IUCN lists 25% of these species as threatened, highlighting the urgent need for conservation measures.

MARINE MAMMAL DIVERSITY OF THE WORLD¹⁰

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

MARINE MAMMALS DIVERSITY OF INDIA

Indian seas are home to a rich diversity of marine mammals, comprising both cetaceans and sirenians. A total of 28 species (12 cetaceans and 4 sirenians) have been documented. This impressive number represents approximately 25% of the world's known marine mammals and a significant 8% of India's total mammalian fauna. The sirenian group is represented exclusively by the Dugong dugon. In recognition of their

importance, all marine mammal species in India receive the highest level of protection under Schedule I of the Wildlife (Protection) Act of 1972.

TAXONOMY OF MARINE MAMMALS

Marine mammal identification relies on a combination of approaches. These include traditional morphology-based taxonomy, acoustic detection, and advanced molecular techniques. Molecular methods encompass DNA barcoding (using markers like COI and 16s rRNA), collagen peptide mass fingerprinting, and environmental DNA (eDNA) analysis with droplet digital PCR. Next-Generation Sequencing (NGS) is used to study current cetacean populations, yielding full mitochondrial genomes, genomic SNPs, and complete nuclear genomes. This data supports robust models of evolutionary relationships and population histories.

Molecular techniques play a significant role in global cetacean research, including DNA barcoding, eDNA analysis, whole genome sequencing, mitogenomics, and market sample identification. While powerful, these methods can be expensive, and fresh tissue samples may be difficult to obtain. Therefore, visual identification based on morphology remains a common and practical method.

Key morphological features for identifying marine mammal specimens include body shape and color, patterns, head shape, flippers, dorsal fin shape and position, fluke shape, flipper-to-body-length ratio, throat groove extent, teeth count, and blowhole position. In visual surveys, blow patterns are critical for species-level identification. Dorsal fin and fluke photographs enable individual cetacean identification through photo-identification. This technique is invaluable for studying pod size, structure, and species composition. Long-term photo-monitoring in specific areas helps track resident and migratory populations and assess reproductive success. Sea-based species identification is inherently more challenging than its land-based counterpart. Observers often only have fleeting glimpses of splashes, blows, dorsal fins, heads, flippers, or backs, potentially from a distance¹.

CLASSIFICATION

ORDER: ARTIODACTYLA

INFRAORDER: CETACEA¹⁴

- All cetaceans possess a similar streamlined body structure
- The blow hole, consisting of one nostril in odontoceti and two in mysticeti, is located on the top of the head
- Propulsion is achieved through the up and down movement of tail, which ends with a flattened paddle like cartilaginous fluke

- Telescoping in skull refers to a restructuring process that pushes the nasal passages posteriorly in the cetacean skull¹⁵
- They have a well-developed blubber layer that envelops their bodies.
- Unique boneless structures, such as tail flukes and dorsal fins or ridges, have evolved in cetaceans.

PARVORDER: MYSTICETI (BALEEN WHALES) ¹⁶

- This group includes the largest animal on the planet. Antarctic blue whale, weighing up to 181 tonnes (equivalent to approximately 33 elephants) and reaching lengths of up to 98 feet
- Paired nostrils or blowholes are longitudinal slits located at the top of the cranium, resulting in a V-shaped blow
- the wing like movement of their flipper helps in the propelling the body
- Presence of baleen (keratinaceous baleen plates (or "whalebone")) instead of teeth in their mouths, used to filter planktonic organisms from the water
- The family Balaenopteridae represents Indian baleen whales

KEY CHARACTERISTICS FOR WHALE IDENTIFICATION

- Shape of head
- Dorsal fin characteristics (shape and position)
- Body coloration and patterns
- Colour of baleen plates
- Number of ventral (throat) grooves
- Flipper length and shape
- Ratio of girth to length
- Ratio of head length to body length

FAMILY: BALAENOPTERIDAE

- Members of this family, commonly known as rorquals, include the largest animals to ever exist.
- In Indian waters, the Balaenopteridae family encompasses 6 species distributed across 2 genera: Balaenoptera and Megaptera.
- With the exception of the humpback whale, other members possess a streamlined body adorned with long pleats extending from the snout tip to as far back as the navel on the ventral surface.
- Lunge feeding is an intense, rapid, and active feeding technique. Their anatomical structure enables them to accelerate to high speeds before opening their jaws wide and expanding their throats to engulf large quantities of water during feeding.

- The baleen plates of Balaenopteridae species are moderately sized and possess fine fringes. Variations in density, fringe diameter, plate number, and width-to-length ratio serve as diagnostic characteristics among species.
- Dorsal fins are positioned behind the midpoint of the back, typically at around 2/3rd to 3/4th of the total body length.
- Pleated throat grooves are distinctive features that differentiate Balaenopteridae species from other whales.

BALAENOPTERA MUSCULUS (LINNAEUS, 1758) - Blue whale



- Dorsal fin: Very small, approximately 1% of body length, positioned at 3/4 of total length.
- Baleen plates: Each side contains 260 to 400 black baleen plates with black bristles, with all three sides of each plate roughly equal in length.
- Body color: Bluish or light grey body color with grey patches on the dorsal surface.
- Ventral grooves: 60-80 ventral grooves extending near to the navel.
- Maximum body length: 33 meters.
- Adult sizes: Most adults measure between 23 to 27 meters, while newborns measure about 7-8 meters.
- IUCN status: Endangered.

BALAENOPTERA PHYSALUS (LINNAEUS, 1758) - Fin whale



- Head shape: V-shaped from above, pointed at the tip.
- Mouth ridges: A ridge on the upper side of the mouth and another prominent ridge between the dorsal fin and fluke.
- Baleen plates: 260 to 480 grey baleen plates with white streaks on the side.
- Coloration: Asymmetrical head coloration (left side grey, much of right side white); back is dark with light streaks; belly is white.
- Dorsal fin: Tall and falcate (curved), positioned farther forward on the caudal peduncle.
- Ventral grooves: 50-100 ventral grooves extending up to the navel.
- Maximum size: Adults reach a maximum size of 27 meters in the southern hemisphere and 24 meters in the northern hemisphere.
- IUCN status: Vulnerable.

BALAENOPTERA BOREALIS LESSON, 1828- Sei whale¹⁷



- Rostrum: Pointed, snout slightly down, and turned at the tip.
- Pectoral fins: Relatively short, comprising only 9%–10% of body length, and pointed at the tips.
- Ventral pleats: 32 to 60 in number, with the longest extending past the flippers but well short of the navel.
- Baleen plates: 300 to 380 pairs of black baleen plates with many whitish bristles, each less than 80 cm long.
- Flippers: All dark in color.
- Median ridge: A single median ridge present.
- Maximum body length: 19.5 meters.
- IUCN status: Endangered.

BALAENOPTERA EDENI ANDERSON, 1878- Bryde's whale



- Head shape: Pointed with three prominent ridges on the dorsal side of the rostrum.
- Ventral pleats: 40 to 70 ventral pleats extending to the umbilicus.
- Baleen plates: 250 to 370 slate-grey baleen plates per side, with white to light grey fringes.
- Head coloration: Symmetrical.
- Dorsal fin: Tall and well-falcate (curved).
- Body coloration: Dark grey on the dorsal profile and light ventrally. The tip of the lower jaw is dark.
- Maximum body length: 14 meters.
- IUCN status: Least Concern.

BALAENOPTERA ACUTOROSTRATA LACEPEDE, 1804- Common Minke whale



- Head shape: Sharply pointed and V-shaped with a prominent ridge on the upper rostrum.
- Dorsal fin: Tall and falcate, located at two-thirds of the body length.
- Body coloration: Dark grey with shades on the lateral side of the body.
- Throat grooves: 50-70 throat grooves extending just past the flippers.

- Baleen plates: 231 to 360 cream-colored baleen plates with coarse bristles per side, less than 21 cm long. They are mostly white or yellowish-white, sometimes with a dark margin along the outer edge. Often, conspicuous white bands are present on the upper surface of the flippers.
- Maximum body length: 9 meters.
- IUCN status: Least Concern.

MEGAPTERA NOVAEANGLIAE (BROWSKI, 1781) - Humpback whale



- Body shape: Robust and stocky.
- Head features: Covered with knobs, with a prominent cluster of knobs at the tip of the lower jaw. Prominent tubercles near the lips and chin.
- Flippers: Elongated, comprising one-fourth to one-third of the body length, with knobs on the leading edge.
- Dorsal fin: Small and usually located at the top of an obvious hump.
- Coloration: Black and dark grey.
- Ventral grooves: 14-35 ventral grooves extending beyond the navel.
- Baleen plates: 270 to 400 black to olive-brown baleen plates with grey bristles per side, each less than 80 cm long.
- Flukes: With irregular trailing edges.
- Maximum body length: 16 meters.
- IUCN status: Least Concern.

PARVORDER: ODONTOCETI (TOOTHED WHALES)¹⁸

- Represented by 6 families in India.
- Generally small to medium-sized cetaceans, except for sperm whales, with males capable of growing at least 18 meters in length.
- 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, a narrow underslung lower jaw, and functional teeth only in the lower jaw (which fit into sockets 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”.
- Spermaceti organ: A large oil-filled reservoir located within the head.
- Capable of very deep and long dives.

PHYSETER MACROCEPHALUS (LINNAEUS, 1758) - Sperm whale



- Head: Squarish and large, comprising 20 to 30% of the body length.
- Lower jaw: Narrow.
- Flippers: Short and broad.
- Dorsal hump: Small, thick, and round, followed by a series of crenulations along the midline.
- Teeth: 18-26 pairs of teeth present only in the lower jaw, fitting into sockets in the upper jaw.
- Body coloration: Black to charcoal grey, with white lips and inside of the mouth.
- Throat grooves: 2-10 short throat grooves present.
- Blowhole: S-shaped blowhole located at the left side of the front of the head.
- Maximum size: 18 meters.
- IUCN status: Vulnerable.

FAMILY: KOGIIDAE²⁰

- Blunt squarish head not exceeding 15% of the body length, with a 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 sockets in the upper jaw.
- Similar to sperm whales, Kogiidae also possess spermaceti in their head.
- Body size is typically less than 4 m.

KOGIA BREVICEPS (BLAINVILLE, 1838) - Pygmy sperm whale



- Lower jaw: Tiny underslung lower jaw.
- Head: Small and squarish.
- Dorsal hump: A hump on the dorsal side between the blowhole and dorsal fin.
- Dorsal fin: Well-curved and set behind the midpoint of the body.
- Flipper: Set near to the head.
- Throat creases: Generally absent; dorsal fin is short (< 5% of body length).
- Snout to blowhole distance: Greater than 10.3% of the total length.
- Teeth: 12 to 16 (rarely 10 to 11) sharp fang-like teeth in each half of the lower jaw.
- Maximum body length: 3.5 meters.
- IUCN status: Least Concern.

KOGIA SIMA OWEN, 1866- Dwarf sperm whale



- Lower jaw: Tiny underslung lower jaw.
- Head: Triangular or squarish.
- Dorsal hump: No hump on the dorsal side between the blowhole and dorsal fin.
- Dorsal fin: Tall and slightly falcate.

- Throat grooves: A pair of short throat grooves.
- Flipper: Small with a blunt tip, positioned near the head.
- Teeth: Sharp fang-like 7-12 pairs of teeth present on the lower jaw.
- Snout to blowhole distance: Greater than 10.2% of the total length.
- Maximum body length: 2.7 meters.
- IUCN status: Least Concern.

FAMILY: ZIPHIIDAE

- Beaked whales are medium size cetaceans (4 to 13 m length).
- 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, with the notch is absent in the tail fluke.
- Not more than 1 or 2 pairs of exposed teeth in the lower jaw, found in males only.
- The blubber of these whales is predominantly composed of wax ester, which is a unique characteristic of this family²¹.

INDOPACETUS PACIFICUS -Longman's beaked whale



- Body: Large and robust.
- Head: Bulging foreheads and moderate tube beaks.
- Teeth: Beak with a single pair of oval teeth at the tip of the lower jaw.
- Dorsal fin: Large and falcate, located behind the midpoint of the body.
- Flukes: Broad with straight trailing edges.
- Flippers: Small and blunt.
- Throat grooves: A pair of V-shaped grooves on the throat.
- Coloration: Umber brown to bluish.
- Maximum size: 6 meters.
- IUCN status: Least Concern.

ZIPHIUS CAVIROSTRIS CUVIER, 1823 - Cuvier's beaked whale



- Body: Slender and relatively robust compared to other beaked whales.
- Head: Short relative to body size, with a poorly distinct beak.
- Forehead: Smoothly sloping, slightly concave in front of the blowhole.
- Coloration: Light rusty brown with a lighter area around the head.
- Mouth: Mouth line gently slopes upwards.
- Flippers: Small and rounded.
- Throat grooves: Single paired V-shaped throat grooves.
- Dorsal fin: Small falcate dorsal fin set near to the hind end of the body.
- Teeth: A single pair of teeth directed forward and upward at the tip of the lower jaw, exposed only in adult males.
- Maximum body length: 6 meters.
- IUCN status: Least Concern.

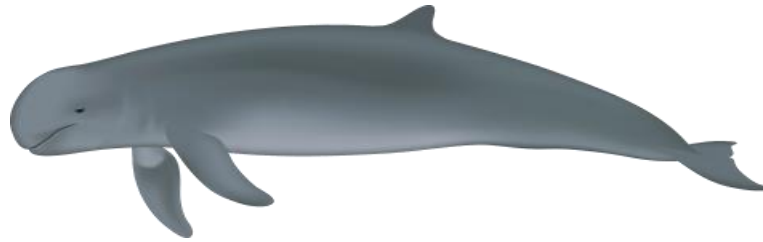
KEY CHARACTERISTICS FOR IDENTIFICATION OF DOLPHINS

- Shape and location of dorsal fin.
- Shape of flipper.
- Shape of head.
- Colour and pattern of body.
- Teeth count.

FAMILY: DELPHINIDAE²²

- Delphinids range in size from 1 to 10 meters. Many small to medium sized odontocetes of various forms have been lumped together in this group, and so the family has been referred to as “taxonomic trash basket”.
- Most delphinids share the following characteristics
 - ☐ Inhabit marine environments.
 - ☐ Typically have a noticeable beak.
 - ☐ Conical teeth.
 - ☐ A large falcate dorsal fin, which is set near the middle of the back.

ORCAELLA BREVIROSTRIS (GRAY, 1866) - Irrawaddy dolphin



- Body: Moderately robust.
- Head: Blunt and bulbous with no beak and a straight mouthline.
- Dorsal groove: Present between the neck and the falcate dorsal fin.
- Dorsal fin: Set just behind the midpoint of the body.
- Neck: Indistinct neck crease.
- Blowhole: U-shaped and open towards the front.
- Coloration: Gray on the dorsal and lateral sides with a white belly.
- Teeth: 8 to 19 pairs present in the upper jaw and 11-18 in the lower jaw.
- Maximum size: 2.4 meters.
- IUCN status: Endangered.

ORCINUS ORCA (LINNAEUS, 1758) - Killer whale



- Body: Robust and spindle-shaped.
- Dorsal fin (Male): Very tall and straight, often erect or triangular.
- Dorsal fin (Female): Slightly shorter and falcate, with a pointed or round tip.
- Eye patches: White oval-shaped patches behind the eyes.
- Saddle patch: A light gray saddle patch behind the dorsal fin.
- Flipper: Large and oval-shaped with blunt tips.
- Coloration: Peculiar black and white coloration, including post-ocular patches, a white lower jaw, white ventrolateral field, and a light gray saddle patch behind the dorsal fin.
- Teeth: 10 to 14 pairs of large oval teeth in each jaw.
- Maximum body length: 8 meters.
- IUCN status: Data Deficient.

PSEUDORCA CRASSIDENS (OWEN, 1846) - False killer whale



- Body: Long, slender, and cigar-shaped.
- Head: Rounded and overhanging melon with no discernible beak.
- Dorsal fin: Moderate height with a rounded tip.
- Flipper: Slightly curved with a distinct hump on the leading edge located near the midpoint of the back.
- Coloration: Predominantly dark grey or black.
- Teeth: 7 to 12 pairs of large teeth in each half of both jaws.
- Maximum body length: 6 meters.
- IUCN status: Near Threatened.

PEPONOCEPHALA ELECTRA (GRAY, 1846) - Melon headed whale



- Body: Moderately robust.
- Head: Triangular and sharply pointed bulbous.
- Beak: Extremely short and indistinct, may be present in younger animals.
- Cape: Faint cape that dips low below the tall and falcates dorsal fin.
- Lower jaw: Lip of the lower jaw is white.
- Coloration: Body is charcoal gray to black with a white urogenital patch.
- Teeth: 20-25 pairs of teeth per side of each jaw.
- Flippers: Sickle-shaped with sharply pointed tips.

- Maximum body length: 2.75 meters.
- IUCN status: Least Concern.

FERESA ATTENUATA -Pygmy killer whale²³



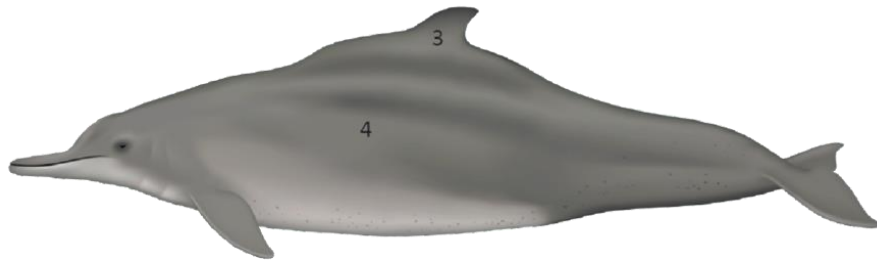
- Head: Short and rounded.
- Body coloration: Dark gray to black on the cape with a sharp change to lighter gray on the sides.
- White patches: White patches on the belly and lips of the jaw white.
- Dorsal fin: Rounded-tipped.
- Teeth: Higher teeth count, with approximately 48 teeth, consisting of 22 on the upper jaw and 26 on the lower jaw.
- IUCN status: Least Concern.

SOUSA CHINENSIS (OSBECK, 1765) - Indo- Pacific humpback dolphin



- Body: Robust, typically grey with bluish, cream, or pink tinge, and a light belly.
- Beak: Long and well-defined, with no distinct crease.
- Dorsal fin: Small and wide, based on a mid-dorsal hump.
- Dorsal ridge: Absent.
- Color change: Light-colored calves become grey or brown as adults.
- Teeth: 31-39 pairs in the upper jaw and 29-38 pairs in the lower jaw.
- Maximum size: Up to 2.5 meters.
- IUCN status: Vulnerable.

SOUSA PLUMBEA (G. CUVIER, 1829) – Indian Ocean humpback dolphin



- Body: Robust.
- Beak: Long and well-defined.
- Dorsal fin: Small, sits on a dorsal hump.
- Color: Brown/grey, sometimes with white/pink on the dorsal fin.
- Teeth: Upper jaw has 33-39 teeth in each tooth row, while the lower jaw has 31-37 teeth.
- Maximum size: Up to 2.8 meters.
- IUCN status: Endangered.

STENO BREDANENSIS (LESSON, 1828) - Rough toothed dolphin



- Body: Robust, dark grey to black above and white below, with many scratches and spots.
- Head: Long and conical.
- Beak: Long, with no distinct crease between the melon and the beak.
- Cape: Dark grey cape below the slightly falcate dorsal fin.
- Coloration: Belly, lips, and lower part are white with spots.
- Flippers: Very large and set farther back.
- Teeth: 19 to 28 slightly wrinkled teeth in each half of both jaws.
- Maximum body length: 2.5 meters.
- IUCN status: Least Concern.

GRAMPUS GRISEUS (CUVIER, 1812) - Risso's dolphin



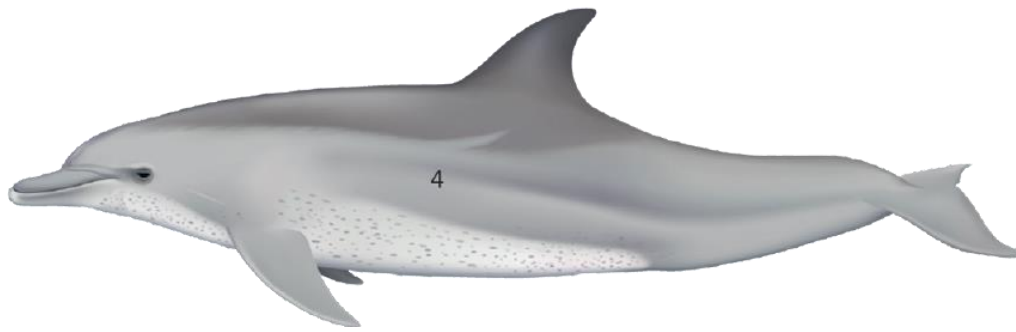
- Body: Robust.
- Head: Blunt head with no beak and a vertical crease on the front of the melon.
- Dorsal fin: Very tall, slender, and dark, falcate with a pointed tip.
- Mouthline: Slopes upwards.
- Teeth: 2 to 7 pairs of teeth at the front of the lower jaw only, with 1 to 2 pairs in the upper jaw. Teeth may be absent or extensively worn.
- Coloration: Body is grey to white, covered with scratches and splotches in adults, while young ones are relatively unmarked.
- Flippers: Long, pointed, and sickle-shaped.
- Maximum body length: 3.8 meters.
- IUCN status: Least Concern.

GLOBICEPHALA MACRORHYNCHUS GRAY,1846 -Short-finned pilot whale



- Head: Bulbous and round, with sloping mouth lines and a short or no prominent beak.
- Flipper: Long and sickle-shaped.
- Teeth: 7 to 9 pairs of short, sharply pointed teeth present.
- Dorsal fin: Round and broad-based, situated near the fore end of the body.
- Coloration: Black in color with a white cape below the dorsal fin.
- Size: Adults grow up to 5 meters.
- IUCN status: Least Concern.

TURSIOPS ADUNCUS (EHRENBERG, 1833) – Indo-Pacific bottlenose dolphin



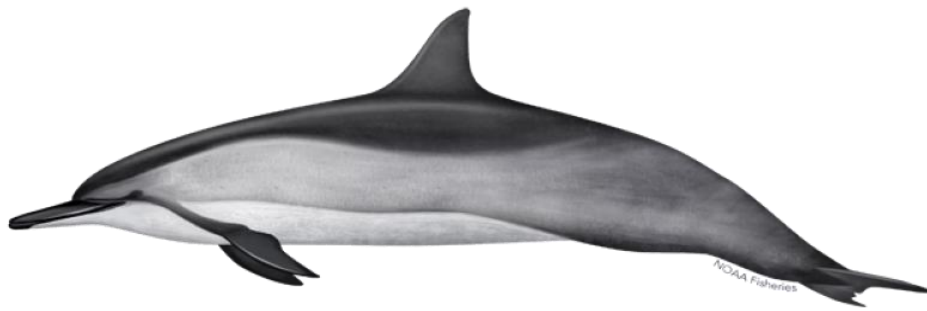
- Body: Moderately robust.
- Beak: Short, set off by a distinct crease.
- Dorsal fin: Tall, slightly falcate, and broader.
- Coloration: Gray body with a white belly. Prominent black spots or flecks on bellies.
- Teeth: 20 to 26 teeth in each half of the upper jaw, and 18 to 24 in the lower jaw.
- Maximum body length: Up to 2.7 meters.
- IUCN status: Near Threatened.

STENELLA ATTENUATA (GRAY, 1846) - Pantropical spotted dolphin



- Body: Fairly slender.
- Beak: Long and slender, with a white tip separated from the melon by a distinct crease.
- Flipper: Slender and strongly curved.
- Stripe: Dark stripe from gape to flipper.
- Dorsal fin: Narrowly curved falcate dorsal fin with a pointed tip.
- Coloration: Body heavily spotted, with a dark grey band between the eye and the apex of the melon. Adults may have light to extensive spotting and grey bellies, with spotting sometimes absent.
- Teeth: 34 to 48 teeth in each jaw.
- Maximum size: 2.1 meters.
- IUCN status: Least Concern.

STENELLA LONGIROSTRIS (GRAY, 1828) - Spinner dolphin



- Body: Slender.
- Beak: Long and slender, with a black tip.
- Dorsal fin: Erect and triangular or slightly falcate, located in the mid-body region.
- Coloration: Dark grey cape followed by light grey sides and a white belly.
- Stripe: Dark strip present between the eye and the origin of the flipper.
- Teeth: 40 to 62 very fine, sharply pointed teeth per tooth row.
- Maximum size: 1.8 meters.
- IUCN status: Least Concern.

STENELLA COERULEOALBA (MEYAN, 1833) - Striped dolphin



- Snout: Moderate, black in color.
- Beak: Moderate length, with a distinct crease between the melon and beak.
- Stripes: Prominent dark stripes from the eye to the anus and from the eye to the flipper.
- Coloration: Black to dark grey on the back, white on the belly. Light grey spinal blaze extending to below the dorsal fin (not always present).
- Palatal grooves: Shallow palatal grooves are often present.
- Teeth: 40 to 50 pairs of slender and pointed teeth present in each jaw.
- Maximum size: 2.4 meters.
- IUCN status: Least Concern.

DELPHINUS CAPENSIS (GRAY, 1828) – Long-beaked common dolphin



- Rostrum: Elongated.
- Beak: Deep crease present between beak and melon.
- Dorsal fin: Tall and slightly falcate, with a distinctive V shape present below.
- Stripe: Extends from chin to origin of flipper.
- Flipper: Recurved and pointed at tips.
- Coloration: Dark back and white belly. Tan to buff thoracic patch and light grey streaked tail stock from an hourglass pattern that crosses below dorsal fin.
- Teeth: 47 to 67 sharp and pointed teeth in each jaw; palate with two deep longitudinal grooves.
- Maximum size: 2.4 meters.
- IUCN status: Data Deficient.

FAMILY: PLATANISTIDAE²⁴

- 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 dolphin²⁴



- National aquatic animal.
- Body: Tan, chocolate brown, or light blue, with a lighter or pinkish belly.
- Blowhole: Slit-like, single blowhole.

- Beak: Long, with sharp and pointed teeth protruding outside the closed mouth at the front half.
- Teeth: 26 to 39 teeth in each row.
- Dorsal fin: Rectangular, ridge-like.
- Maximum size: Up to 2.5 meters.
- IUCN status: Endangered.

FAMILY: PHOCOENIDAE¹⁸

- 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.
- The Dorsal fin is either short and triangular or absent.
- These exhibit sexual dimorphism where the females are larger than males.

NEOPHOCAENA PHOCAENOIDES (CUVIER, 1829) - Finless porpoise



- Forehead: Round and rises steeply from the snout tip, devoid of a beak.
- Dorsal Fin: True dorsal fin is absent, replaced by a narrow dorsal ridge covered in thick skin bearing several lines of tiny tubercles.
- Bumps: Tiny bumps on the dorsal side behind the forehead.
- Body Color: Grey or black, with a lighter belly.
- Teeth: 15 to 22 teeth present in each jaw.
- Flipper: Large, with rounded tips.
- Fluke: Fluke with a concave trailing edge.
- Maximum Size: 1.7 meters.
- IUCN Status: Vulnerable.

ORDER: SIRENIA²⁵

- These are herbivorous groups 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 are absent.
- Forelimbs modified as flippers and hind limbs are absent.
- 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 which are similar to cetaceans.
- Rostrum is deflected downwards, with the presence of erupted tusks in males.
- Absence of nails on the flippers.

DUGONG DUGON (MULLER, 1776) - Sea cow or dugong



- Habitat: Found in the Indo-Pacific region.
- Body Shape: Streamlined body shape resembling cetaceans.
- Nostrils: Valve-like nostrils on top of the snout.
- Teeth: Incisors present in the form of tusks.
- Head: Muzzle deflected downward, ending in a "rostral disk" with short and dense bristles.
- Dorsal Fin: Absent.
- Skin: Smooth skin sprinkled with short hairs.
- Flippers: Paddle-shaped flippers containing no nails.
- Tail: Split into flukes, with a median notch; tail stock laterally compressed into a peduncle.
- Maximum Size: 3.3 meters.
- IUCN Status: Vulnerable.

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SEA TURTLE DIVERSITY AND TAXONOMY

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INTRODUCTION

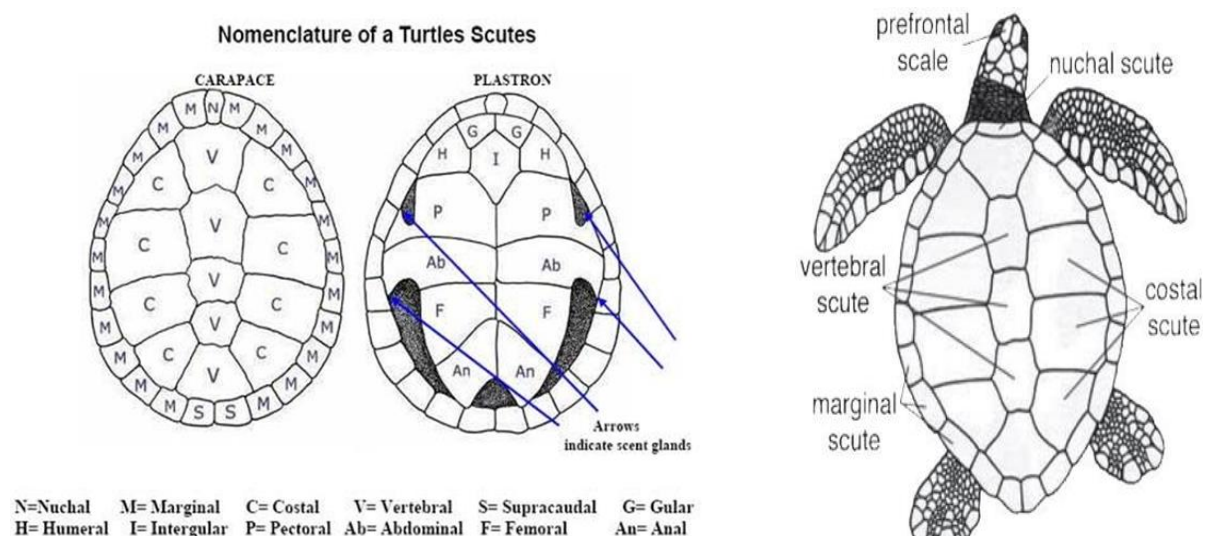
There are seven species of sea turtles found worldwide, belonging to six genera and two families. Five of these species inhabit India's coastline: olive ridley (*Lepidochelys olivacea*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta*), and leatherback (*Dermochelys coriacea*). Sadly, sea turtle populations face global decline due to factors such as over-exploitation, pollution, habitat loss, vessel strikes, and accidental bycatch in fishing gear.

The coasts of Tamil Nadu and Orissa are critical marine habitats for sea turtles in India. Tamil Nadu supports all five species, while Orissa's Gahirmatha beach is the world's largest nesting site for olive ridley turtles. The Indian Wildlife (Protection) Act of 1972 offers protection to all five species. However, conservation efforts need to be strengthened, focusing on involving local communities and finding alternative ways of earning a living.

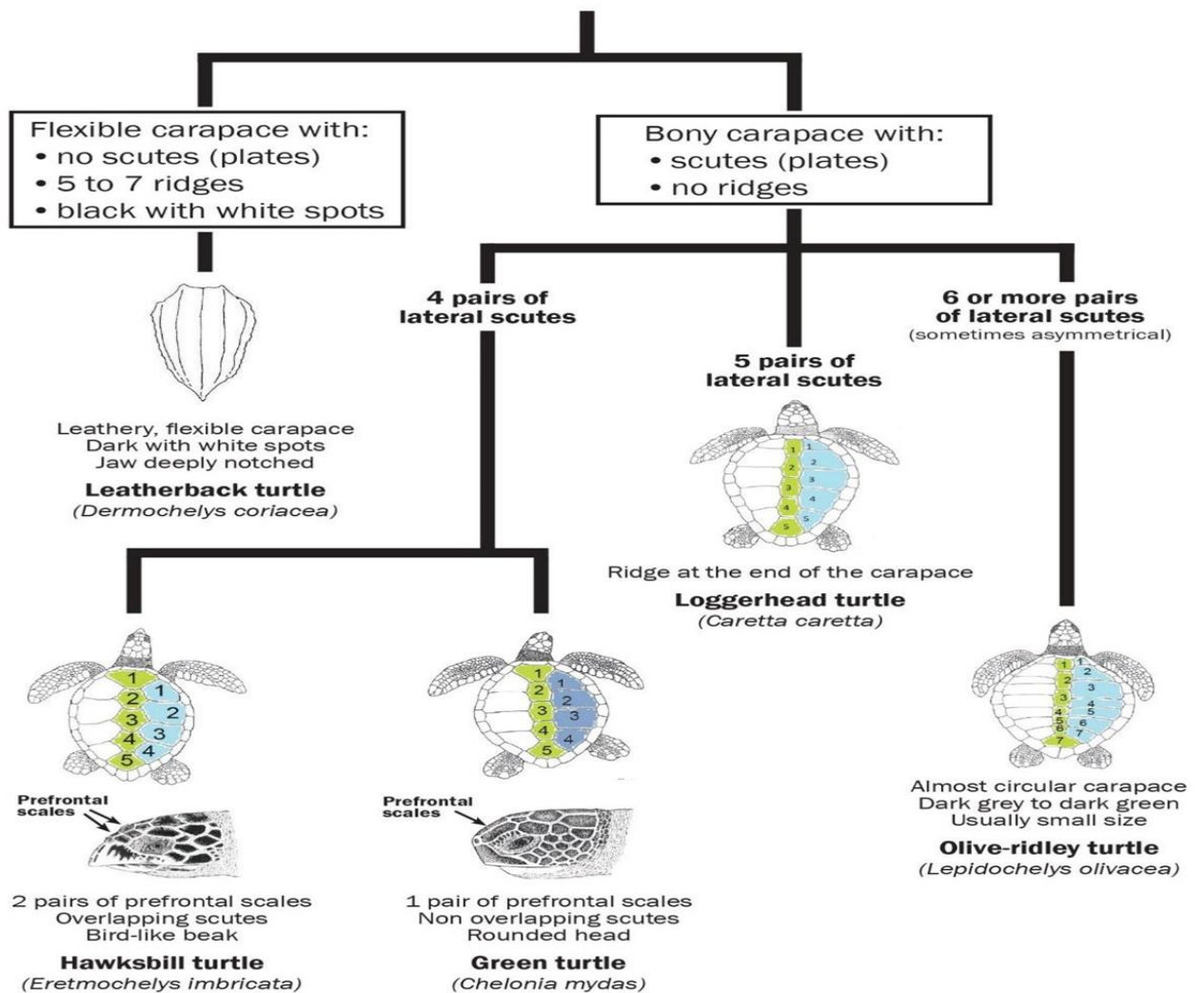
Turtle Excluder Devices (TEDs) have proven successful in reducing sea turtle deaths caused by trawling. Implementing TEDs in trawl fisheries, along with government regulation and enforcement, is vital for their protection (Boopendranath *et al.*, 2006).

To identify sea turtle species in Indian waters, experts look at features such as carapace length, the shape of costal scutes, prefrontal scales, and vertebral scutes. Clear photographs of the turtle's shell and head are essential for accurate identification.

Technical terms



MARINE TURTLES IDENTIFICATION KEY



Species Accounts

1. Olive ridley

The Olive ridley turtle (*Lepidochelys olivacea*) is a globally distributed species found in tropical waters. They prefer nesting sites along tropical mainland coasts and barrier islands, often near river mouths. In India, they nest extensively on the mainland, including the Andaman and Nicobar Islands, and less frequently in the Lakshadweep Islands.

Adult Olive ridleys weigh approximately 50 kg and have a short, wide, and smooth carapace with a raised, tent-like shape. Their coloration is olive green, and they are easily recognized by 6-9 pairs of asymmetrical costal scutes. They have a triangular head, a creamy yellow plastron (underside), two claws per flipper, and pores near the edges of their shell.

These turtles nest at night, laying 1-3 clutches of 100-120 eggs per season (each egg about 4 cm in diameter). They typically re-nest every 20-28 days, and return to nest

every 1-2 years. Their distinctive 70-80 cm wide tracks show asymmetrical forelimb marks with little to no tail drag.

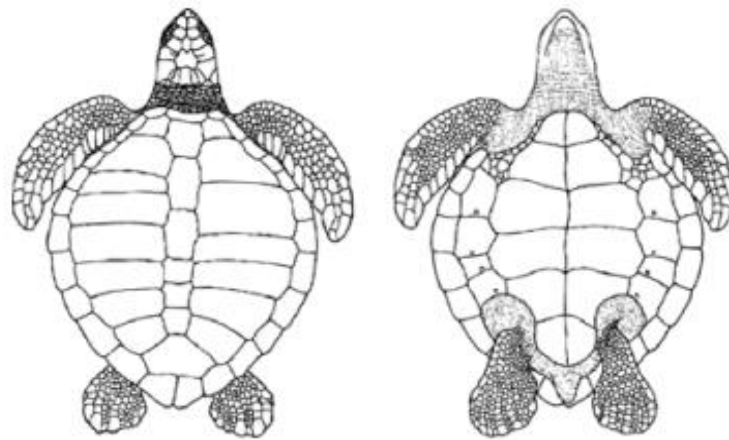


Figure 1. Olive ridley turtle: dorsal (left) and ventral (right) view
(Illustrated in Sea Turtles of India, 2011)



Figure 2. Live Olive ridley turtle (*Lepidochelys olivacea*) sighted in the offshore survey off Maharashtra (Jayasankar et al., 2022)

2. Green turtle

Green turtles (*Chelonia mydas*) inhabit tropical and subtropical waters worldwide. These distinctive turtles prefer to nest on tropical beaches, both on mainland coasts and remote islands. Major nesting sites in India occur along the Gujarat mainland and on beaches across the Lakshadweep and Andaman Islands. Adult Green turtles can reach weights of about 250 kg. Their broadly oval carapaces have scalloped, non-serrated edges. Coloration varies: juveniles often show brown tones with radiating streaks, while adults have more diverse patterns. Key identifying features include four

pairs of costal scutes, a rounded head shape, and a single claw on each flipper. Hatchlings have white plastrons that gradually turn yellowish with age. Their large central scutes prevent the first costal scute from touching the nuchal scute.

Green turtles are nocturnal nesters. Females lay between 4 and 6 clutches of 100 to 120 eggs each season. Their nesting tracks are 100 to 130 cm wide and show symmetrical diagonal flipper imprints. Look for a continuous or interrupted central line marking the tail drag.

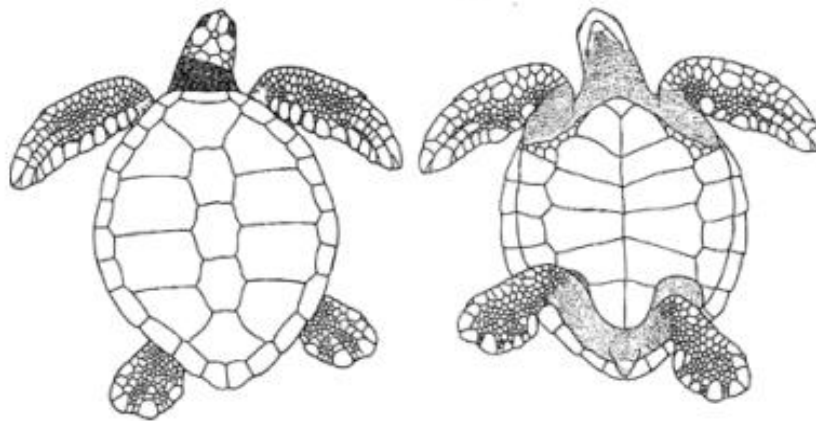


Figure 3. Green turtle: dorsal (left) and ventral (right) view
(Illustrated in Sea Turtles of India, 2011)

3. Hawksbill turtle - A Unique and Globally Distributed Sea Turtle

Hawksbill turtles (*Eretmochelys imbricata*) are found across the globe, preferring to nest on tropical beaches, especially on secluded islands. In India, they favor Lakshadweep, the Andamans, and certain Nicobar beaches like Indira Point. Unlike ridleys, who like open sands, hawksbills often choose to nest beneath trees and vegetation.

Adult hawksbills are on the smaller side, averaging around 150 kg. They are easily recognized by their oval shell with its saw-like back edge and thick, overlapping scales (scutes). Their beautiful brown shells have striking amber and brown patterns. You can identify them by their four pairs of costal scutes (along the side of the shell), narrow and pointed beak, and two claws per flipper.

Hawksbills are adaptable nesters, laying eggs both during the day and at night. They produce 3 to 5 clutches per season, each holding around 120-150 eggs (sometimes even

up to 180!). Their eggs are about 3.5 cm across and they'll nest every 2 to 5 years. When they come ashore, their tracks are 70-85 cm wide with uneven marks from their flippers. While their tracks might look a bit like ridley turtles, the beaches they choose for nesting are very different.

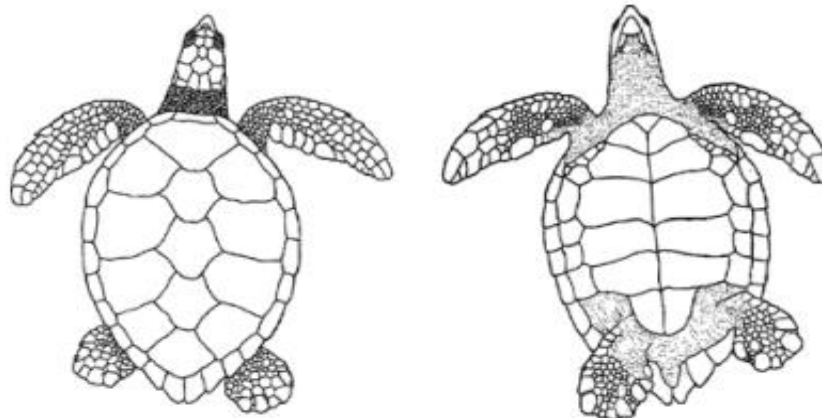


Figure 4. Hawksbill turtle: dorsal (left) and ventral (right) view
(Illustrated in Sea Turtles of India, 2011)

4. Loggerhead turtle

Loggerhead turtles (*Caretta caretta*) inhabit tropical oceans across the globe. They nest mainly in temperate regions, but their nesting range can extend into subtropical and tropical areas. In areas like Sri Lanka, they find ideal nesting grounds, but they are not known to nest in India. Loggerheads seek out expansive beaches on the mainland or on barrier islands for nesting.

Adult Loggerheads are large, weighing around 200 kg. In younger turtles, the moderately wide shell (carapace) has a slightly jagged back edge. Adults may have a thickened area at the base of the 5th vertebra. Their coloring is usually reddish-brown without markings. They are easily identified by their large triangular head, five pairs of scales (costals) on each side of the shell, two claws per flipper, and a yellow-orange underside (plastron). The narrow central scales (vertebrae) leave a space where the first costal scale touches the nuchal scale, a feature unique to Loggerheads.

Loggerheads nest at night. During a single season, they lay 3-5 clutches, each holding 100-120 eggs. Eggs are about 4 cm across. They will nest again after 12-16 days, and usually return to the same nesting area every 2-3 years. Their tracks on the beach measure 70-90 cm wide and are moderately deep. The tracks show diagonal marks from their front limbs, but usually lack a tail drag mark.

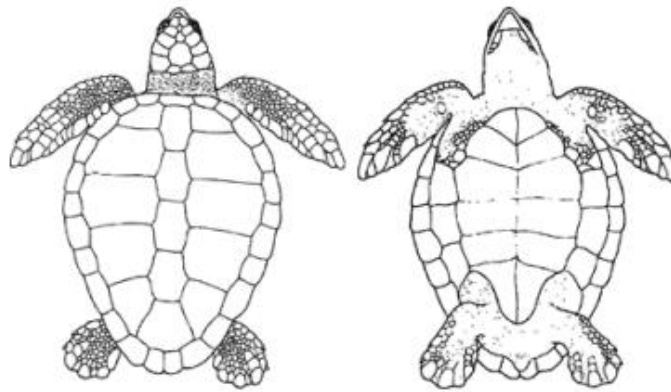


Figure 5. Hawksbill turtle: dorsal (left) and ventral (right) view
(Illustrated in *Sea Turtles of India*, 2011)

5. Leatherback turtle

The leatherback turtle (*Dermochelys coriacea*) is a globally distributed species, inhabiting oceans from sub-arctic to tropical regions. These large turtles prefer tropical beaches for nesting, favoring sites with wide stretches of sand, steep slopes, and easy access to deep, obstacle-free water.

In India, leatherback turtles primarily nest in the Andaman and Nicobar Islands. Key nesting locations include Galathea on the east coast, as well as several beaches on the west coasts of Great Nicobar, Little Nicobar, and Little Andaman Islands.

Adult leatherbacks can weigh over 500 kg. They have an elongated, tapered shell with seven distinct ridges, lack the scales (scutes) typical of other sea turtles, and possess a triangular head with two cusps on the upper jaw. Their coloration is primarily black with white speckles, and they have notable pink or blueish spots at the base of the neck and flippers.

Leatherbacks have a unique nesting pattern. They lay eggs at night, producing 4-6 clutches per season with 80-100 eggs each. Their nesting tracks are distinctive - 150 to 200 cm wide with symmetrical diagonal marks from their forelimbs and a deep central groove created by their dragging tail.

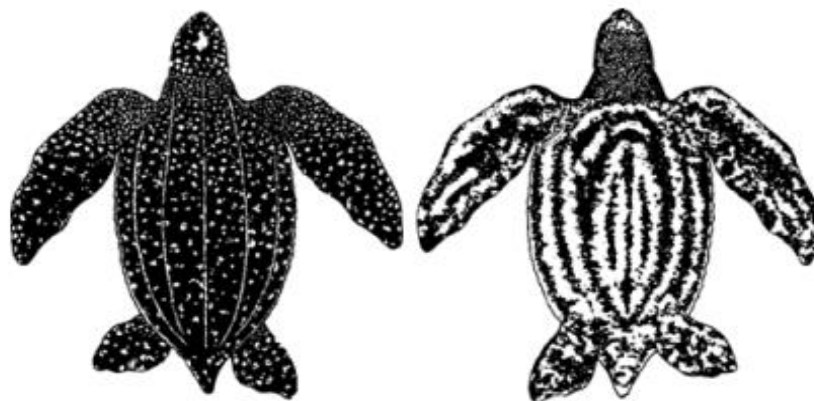


Figure 5. Leatherback turtle: dorsal (left) and ventral (right) view
(Illustrated in *Sea Turtles of India*, 2011).

Conclusion

Sea turtles are ancient marine creatures vital to the health of our oceans. Their global nesting habits on tropical beaches are an essential part of complex marine ecosystems. However, sea turtles face serious threats, including over-exploitation, habitat loss, and accidental capture in fishing gear (bycatch). This makes strong conservation efforts crucial. Laws like the Indian Wildlife (Protection) Act of 1972 offer a legal basis for protection, but success depends on cooperation between multiple groups, including local communities and research organizations. We must address ongoing issues like habitat destruction, human development near nesting areas, and widespread bycatch. By working together – governments, NGOs, and local communities – we can protect these ancient animals and create sustainable practices that benefit both marine ecosystems and people. Our responsibility as stewards of the ocean is to conserve sea turtles. Success stories in some regions show that positive change is possible with dedicated effort..

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TAXONOMY AND DIVERSITY OF JELLYFISHES

Dr. R. Saravanan

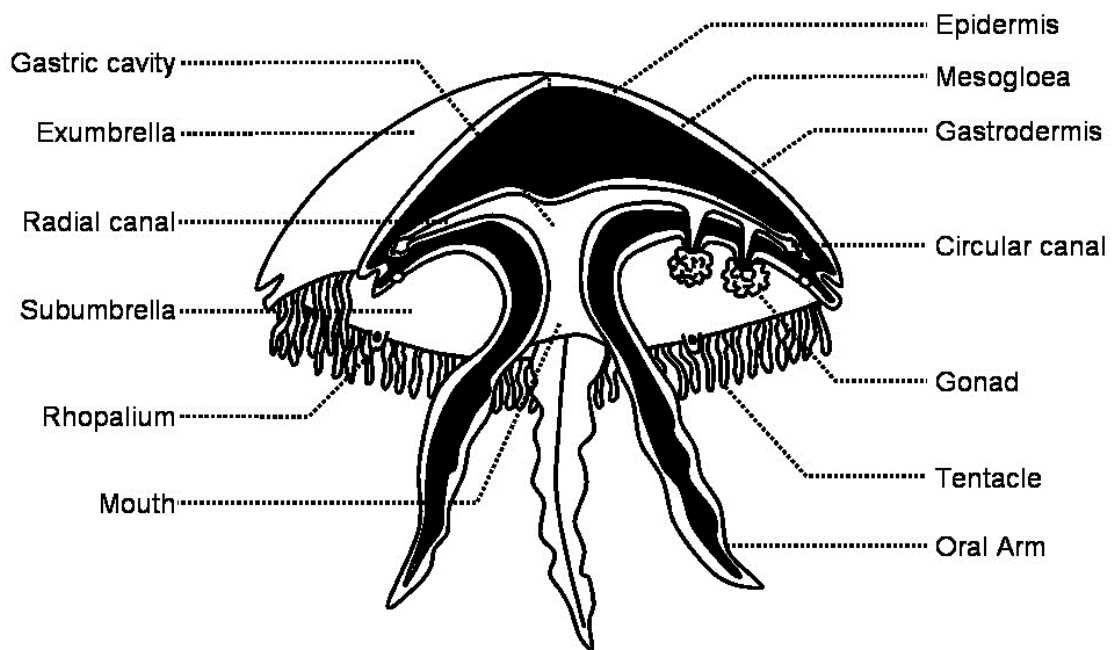
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1. Introduction

Jellyfish is a common term used for any gelatinous animal in marine waters. These include a wide variety of stinging and non-stinging jellyfishes. Jellyfish are the oldest animal on planet Earth, dating from the pre-Cambrian period, and have passed through 500 million years of natural selection. The word "jellyfish" is usually used for a group of jelly-like zooplankton that includes planktonic members of the phylum Ctenophora, Salps and Pyrosomes, and medusae from the phylum Cnidaria (scyphomedusae, hydromedusae, cubomedusae, and siphonophores). The true jellyfish come under the three Cnidarian classes, viz., Hydrozoa, Scyphozoa, and Cubozoa, and seasonally swarm in the coastal waters. Among the three classes, representatives of Scyphozoa and Cubozoa jellyfish range in size from 2 mm to 2 m in bell diameter, however, most of the hydrozoan jellyfish are smaller than 2 mm in bell diameter and belong to the mesoplankton. The biodiversity of pelagic scyphozoa jellyfishes and cubozoa jellyfishes is largely ignored in India, other than a few works in this line. The first work on scyphozoa medusae was published way back in 1930, in which the scyphomedusae of Madras were described with illustrations (Menon, 1930). Subsequent to this publication, the above author has brought out the scyphomedusae of Kurusadai Island (Menon, 1936). These are the two classic works that describe the taxonomic features and distribution of scyphomedusae along the south-east coast of India. Since then, there has been a long gap in the study of scyphomedusae in India. The scyphomedusae available in India were listed as 34 by Chakrapany (1984). The Medusae of the Travancore waters was studied by Nair (1951) and assessed for its impact on fisheries.

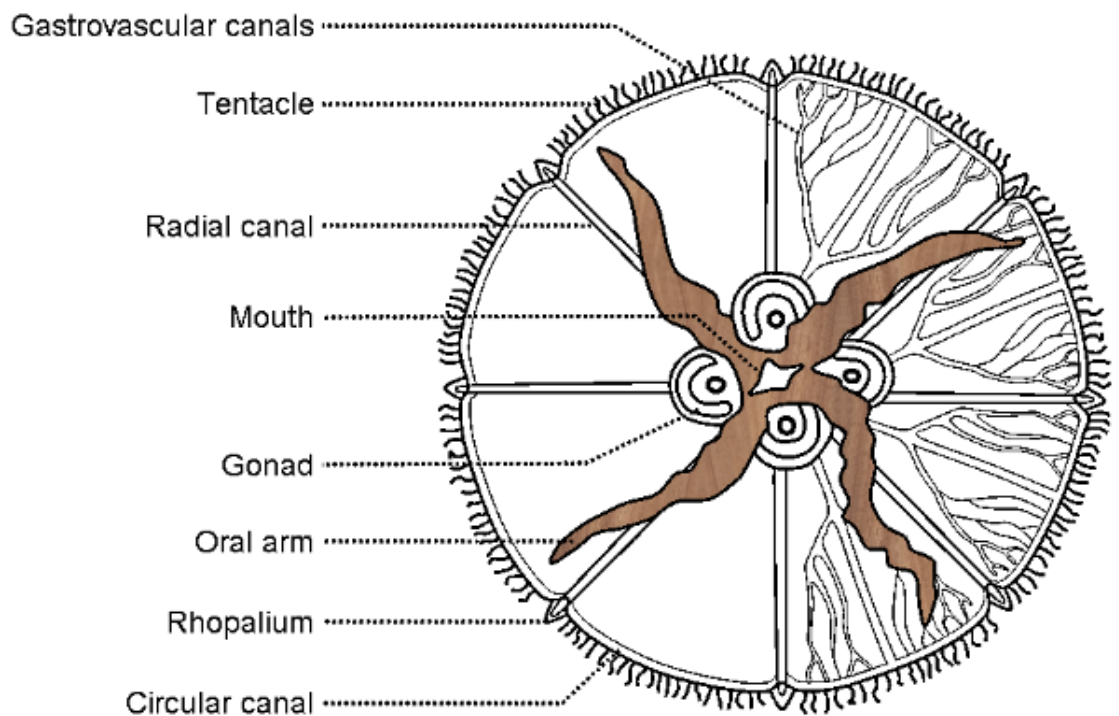
2. Morphometric features of Jellyfishes

Jellyfishes are simple organisms with three layers of tissue, viz., endoderm, ectoderm, and mesoderm. The body is composed of over 90 percent water. The umbrella shaped body, which is called the bell, and the underside are covered with oral arms, or tentacles. In jellyfish, differences in the bell margin are used as a differentiating characteristic between different groups. The members of the order Semaestomeae have tentacles on the bell margin, whereas the members of the order Rhizostomeae have tentacles on the tip of their oral arms. Jellyfish are 97% water and are semi-transparent.



Aurelia medusa – cutaway diagram

Image based on: <https://cronodon.com/BioTech/Jellyfish.html>



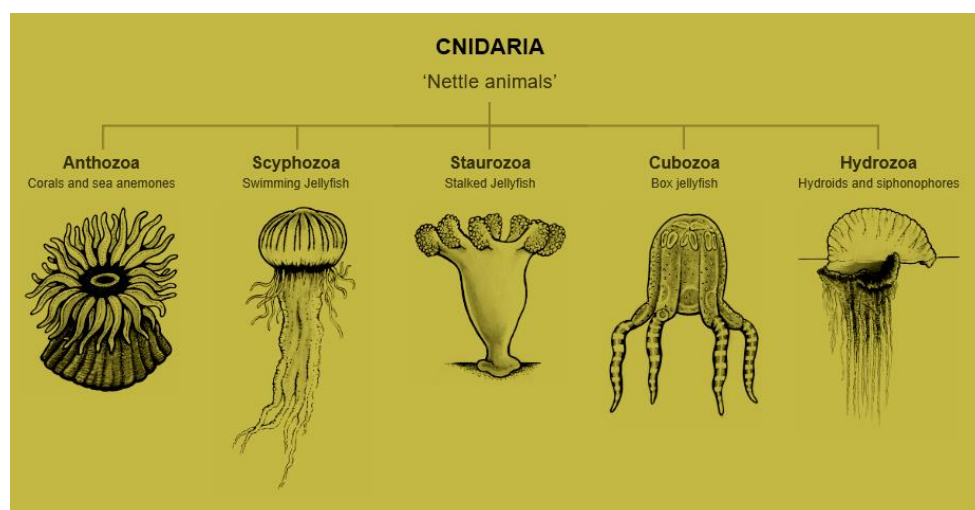
Aurelia medusa – subumbrella view

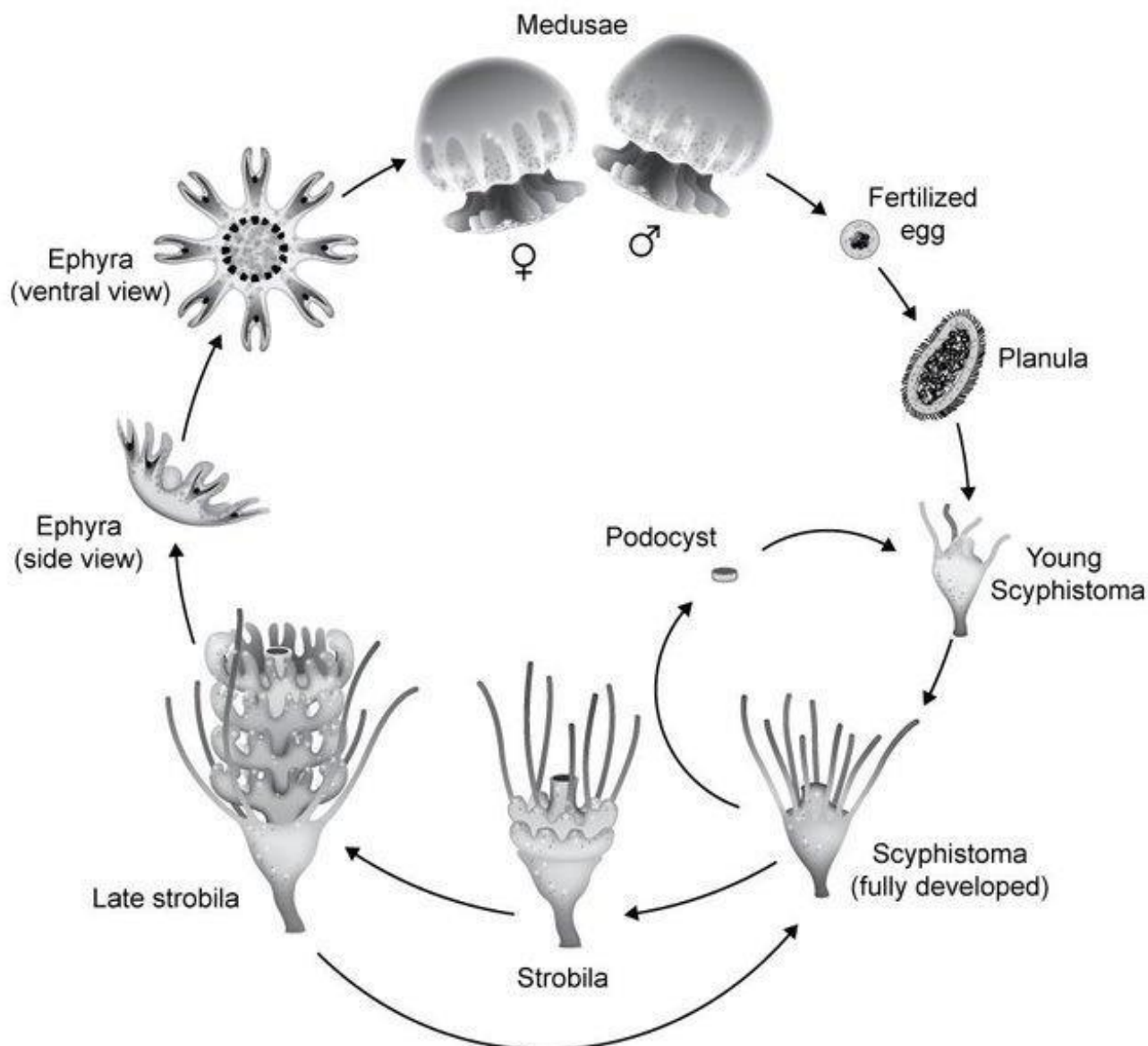
Image based on: <https://cronodon.com/BioTech/Jellyfish.html>

Jellyfish have two body layers: the outer layer, the epidermis and the interlayer, the gastrodermis. Between both layers is a thick layer of mesoglea, which consists of fibres embedded in a hydrated matrix that contains cells. These layers of tissues make up the umbrella of the jellyfish, which is usually bell-shaped; thus, the umbrella is also known as the bell. The scyphozoan jellyfish are tetradially symmetrical, meaning they have many structures in multiples of four. It contains a simple gastrovascular cavity that acts as the stomach. They are also characterised by having gastric filaments in the stomach. Some scyphozoan jellyfish, such as Semaestomeae, contain an opening, or mouth, at the subumbrella. There are four to eight oral arms near the mouth, which function as arms to capture and transport food to the gastrovascular cavity. Jellyfish lack eyes but possess many sensory receptors capable of detecting light, pressure, temperature, and gravity. These sensory receptors are concentrated in the marginal sense organ that contains the rhopalium (Nakanishi, 2015). Not all jellyfish possess tentacles. For Semaestomeae jellyfish, tentacles can be found at the margin of the bell or at the subumbrella, whereas tentacles are absent from the Rhizostomeae jellyfish. Jellyfish contain a network of canals that usually anastomose with each other and form various patterns.

3. Life cycle and biology

Cnidarian jellyfish, also called medusae, have complex life cycles that often involve a benthic stage: the polyp and the pelagic stage: the medusae or jellyfish. This bipartite life cycle alternates between an asexual, benthic polyp and a sexual, pelagic medusa. Medusae typically are produced asexually in abundance and grow rapidly in seasons (Russel, 1970).





Life cycle of the cannonball jellyfish *Stomolophus meleagris*; based on Calder (1982)

4. Diversity and distribution of jellyfishes in India

Class Scyphozoa is ascribed to four orders, namely Stauromedusae, Coronatae, Semaestomeae, and Rhizostomeae, with 65 genera and over 187 species globally. The diversity of scyphozoan jellyfish along the Indian coastal waters has been reported at 29; however, given the poor research attention given to this group, there may be more species to be recorded in the coming years.

Order Semaestomeae

The order Semaestomeae composed of three families, four subfamilies, 18 genera and 56 species (Kramp, 1961). Semaestomeae jellyfish are characterized by four oral arms around the mouth. Tentacles are found at the umbrella margin. (Arai, 1997). The two important families of Semaestomeae are Cyaneidae and Pelagiidae.

Order Rhizostomeae

The order Rhizostomeae is composed of two suborders, 10 families, 25 genera, and approximately 89 species (Kramp, 1961). Rhizostomeae jellyfish are characterised by having a bell margin cleft into a lappet, with no tentacle on the bell margin, without a central mouth, and with eight oral arms extended from the subumbrella, where each oral arm bears numerous secondary mouths. A network of canals is found beyond the stomach. (Kramp, 1961; Arai, 1997). The important orders of this family are Mastigiidae, Versurigidae, Lychnorhizidea, Catostylidea, Lobonematidae, and Rhizostomatida.

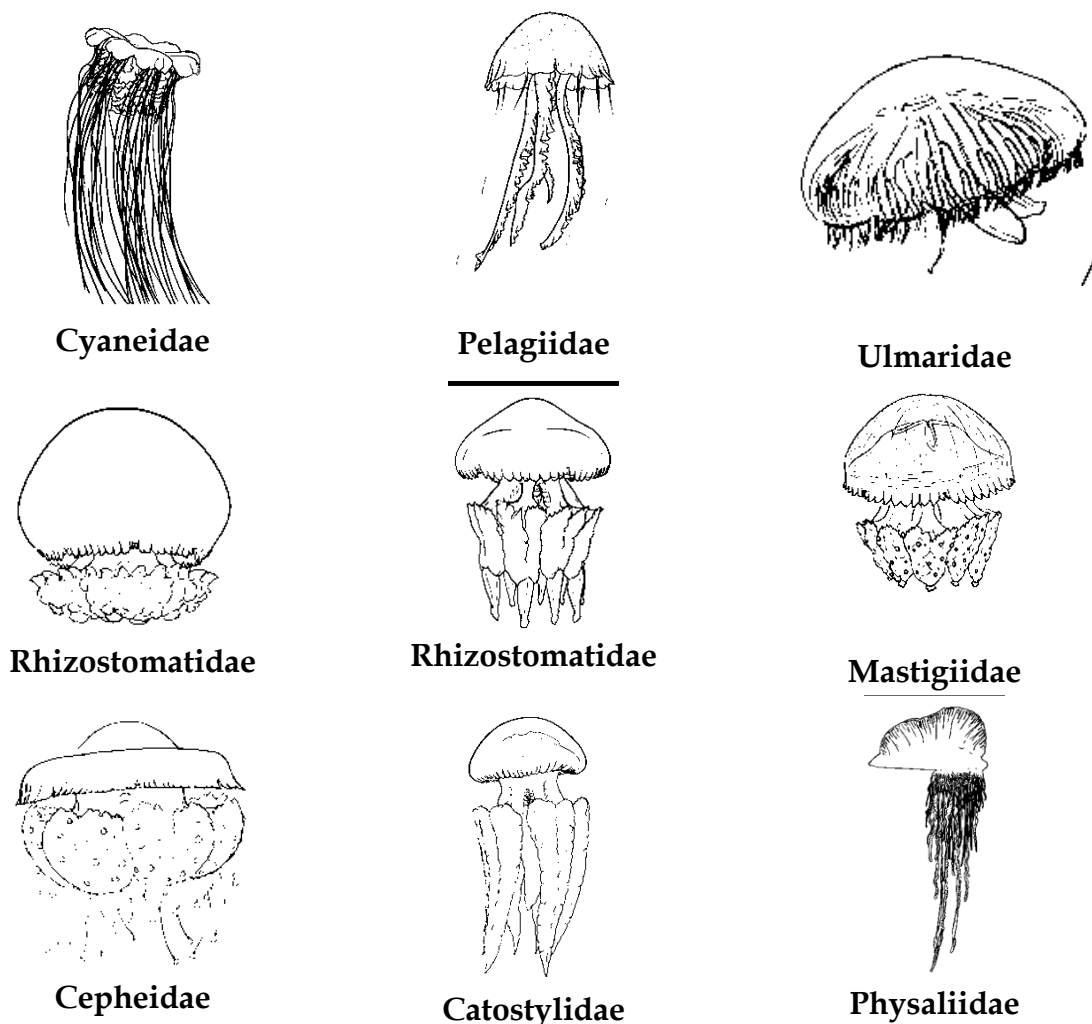
5. List of Scyphozoan jellyfishes Occuring in Indian waters

- *Atolla wyvillei* Haeckel, 1880
- *Nausithoe punctata* K lliker, 1853
- *Periphylla periphylla* (P ron & Lesueur, 1810)
- *Cyanea nozakii* Kishinouye, 1891
- *Pelagia noctiluca* (Forssk l, 1775)
- *Aurelia aurita* (Linnaeus, 1758)
- *Acromitus flagellatus* (Haeckel)
- *Acromitus maculosus* Light, 1914
- *Catostylus mosaicus* (Quoy & Gaimard, 1824)
- *Crambionella orsini* (Vanh ffen)
- *Crambionella annandalei* Rao, 1931
- *Lobonema smithii* Mayer, 1910
- *Lobonemoides robustus* Stiasny, 1920
- *Lobonemoides sewelli* Rao, 1931
- *Lychnorhiza malayensis* Stiasny, 1920
- *Rhopilema hispidum* (Vanh ffen, 1888)
- *Cassiopea andromeda* (Forssk l, 1775)
- *Cassiopea xamachana* Bigelow 1892
- *Cephea cephea* (Forssk l, 1775)
- *Marioagia stellata* Galil & Gershwin, 2010
- *Netrostoma coerulescens* Maas, 1903
- *Netrostoma setouchianum* (Kishinouye, 1902)
- *Mastigias papua* (Lesson)
- *Versuriga anadyomene* (Maas)
- *Phyllorhiza punctata* Lendenfeld, 1884
- *Thysanostoma loriferum*
- *Thysanostoma thysanura* Haeckel, 1880

6. List of Cubozoan Jellyfishes occurring in Indian waters

- *Alatina alata* (Reynaud, 1830)
- *Alatina madraspatana* (Menon, 1930)
- *Tamoya gargantua* Haeckel, 1880
- *Chiropsalmus quadrumanus* (F. Muller, 1859)
- *Chiropsoides quadrigatus* (Haeckel, 1880)
- *Chiropsoides buitendijki* (van der Horst, 1907)
- *Chironex indrasaksajiae* Sucharitakul, 2017

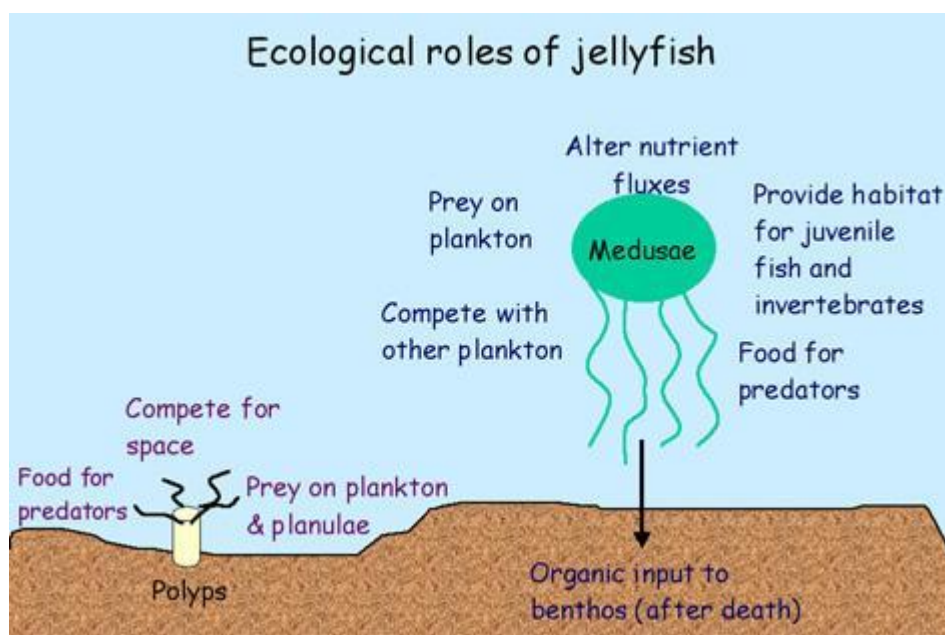
Morphology of different jellyfishes- taxonomic family-wise



7. Ecosystem importance of Jellyfishes

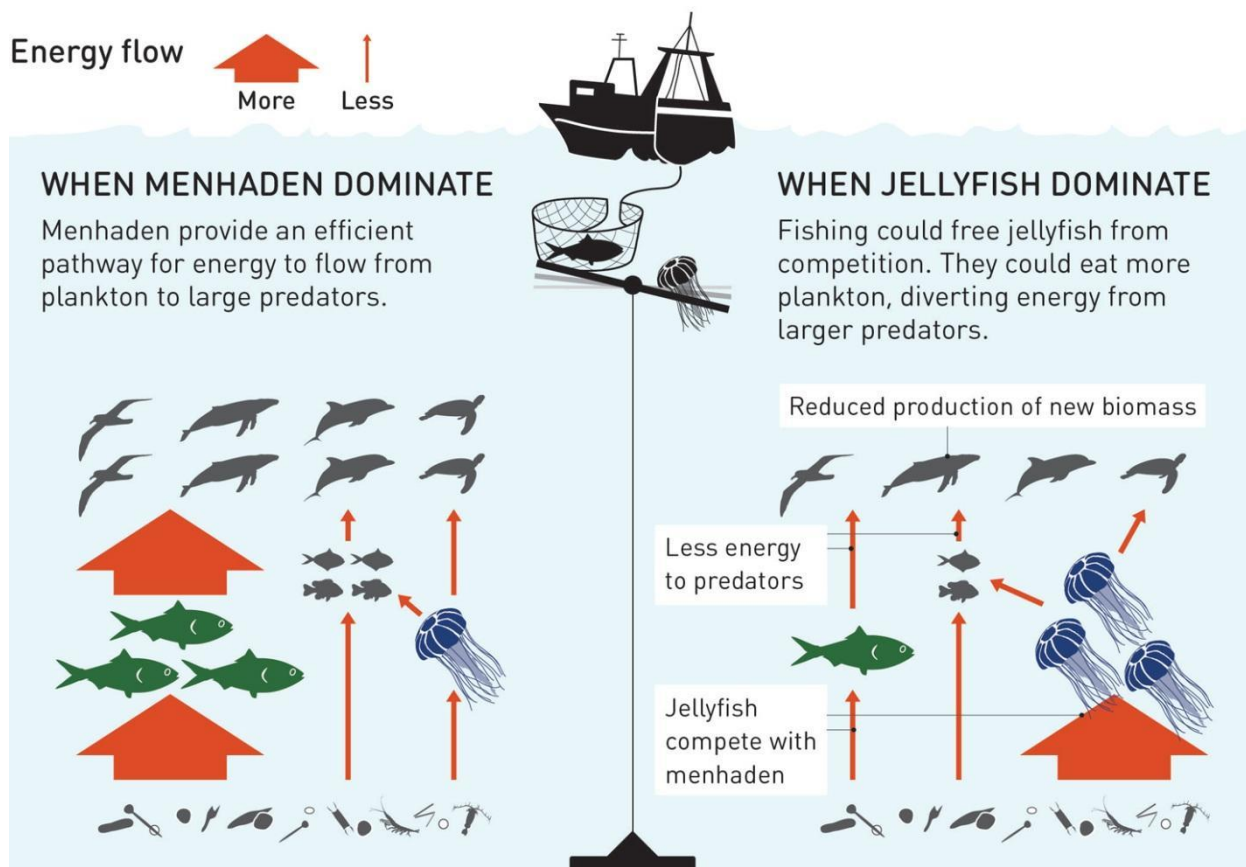
Jellyfishes are distributed globally and often form swarms under favourable conditions that last for weeks to months before they collapse. Though jellyfish population swarms occur in many places at an increasing trend, the lack of time series data on their distribution and abundance along the Indian coast prevents us from concluding their population dynamics. Establishing time series data around the Indian subcontinent and island territories on jellyfish abundance is difficult due to the fact that, in most cases, these jellyfish get damaged in bottom trawls and zooplankton tows

and are not properly recorded. Jellyfish directly interfere with many human activities (reviewed by Purcell et al., 2007; Richardson et al., 2009), specifically through stings (beach closures, tourism impacts, injuries, deaths), clogging intakes (coastal power and desalination plants, mining and military operations, shipping, aquaria), interference with fishing (clogged and split nets, spoiled catch, stung fishers, damaged gear, capsized boats), aquaculture (fish deaths, pens fouled by polyps), and marine biological surveys (interference with trawls and acoustic surveys). Jellyfish also have ecosystem impacts with indirect effects on fisheries resources that are difficult to quantify, such as their roles as predators of zooplankton, fish eggs, and ichthyoplankton, as vectors for parasites, as food for fish, and as refugia and food for some species of juvenile fish.



Ecological roles of medusae and polyps. Adapted from Kingsford et al. 2000

Invasive species of jellyfish are reported in 21 of 45 LMEs. For the most part, invasive species were not responsible for the observed increases reflected in the results; however, the widespread detections demonstrate that jellyfish are truly global invaders of significant concern. Thriving populations of invasive jellyfish in systems like the Mediterranean and Black Seas should serve as warnings for other ecosystems around the globe, and it is likely that far more invasions have occurred than are reported (Holland et al., 2004). It is considered that the drivers of the change in jellyfish population, including overfishing, aquaculture, climate change, habitat modification, and the introduction of alien species, suggest that human-caused coastal deterioration may have benefited jellyfish and led to their increasing populations.



Potential ecosystem shifts due to fishing - From fish dominated to jellyfish dominated

(Robinson et al. 2015)

8. Gut content studies of Jellyfishes

In order to study the gut content of jellyfish, their gastric pouches are excised, opened, and the contents rinsed through a 100- μ m mesh sieve. This is a common procedure for concentrating gut contents and handling samples of large medusae. The collection of jellyfish for gut content studies should be preferably done in the night. All medusae should be studied within 35 minutes of collection, which is less than published prey digestion times (Arai 1997).

9. Global Jellyfish Fisheries

Dried jellyfish is considered a delicacy in many Asian countries. Jellyfish are also purported to have beneficial medicinal properties and are traditionally used to treat ailments such as arthritis, hypertension, and back pain (Hsieh et al., 2001). Jellyfish

have been harvested off the coast of China for more than 1700 years (Omori & Nakano, 2001).

Only jellyfish belonging to the order Rhizostomeae are harvested for food. The rhizostomes are preferred because they are typically larger and have more rigid bodies than other scyphozoan orders. When processed, the rhizostomes produce a product that has a desirable, almost crunchy texture. Some species considered to be edible are:

Cepheidae	<i>Cephea cephea</i>
Catostylidae	<i>Catostylus mosaicus</i> , <i>Crambione mastigophora</i> , <i>Crambionella orsini</i> , <i>Crambionella annandalei</i>
Lobonematidae	<i>Lobonema smithi</i> , <i>Lobonemoides gracilis</i>
Rhizostomatidae	<i>Rhopilema esculentum</i> , <i>Rhopilema hispidum</i> , <i>Rhizostoma pulmo</i>
Stomolophidae	<i>Stomolophus meleagris</i> , <i>Stomolophus nomurai</i>

10. Indian Jellyfish fisheries

There are active jellyfish fisheries along Kerala, Gujarat, and Andhra Pradesh, and four species support jellyfish fisheries in India, viz., *Crambionella annandalei*, *C. orsini*, *Catostylus perezii*, and *Rhopilema hispidum*, which are processed and exported to overseas markets.

11 Guidelines for Jellyfish studies

11.1 Preservation Method

Scyphozoans are typically preserved for morphological analyses in a solution of 4% formalin in seawater with the appropriate label (i.e., 4 parts formalin [37% w/v] and 96 parts seawater). Place the jellyfish in a plastic container with a label (waterproof paper) and pour formalin until the organism is completely covered.

If you are using a plastic bag, place the organisms in a bag, fill it with formalin, twist the bag, and use a rubber band to wrap the plastic bag. When it is tight enough, fold the tip of the plastic bag, and with the last part of the rubber band, secure the folded part of the bag. An excess of 4% formalin solution is used, and it can be renewed after two weeks to ensure successful fixation.

11.2 Tissue storage for DNA studies

1. Flush the oral arms or bell margin with tap water. Repeat several times to displace all the debris.
2. Using clean forceps or scissors, cut a half-fingernail-sized piece of tissue from the oral arm or bell margin.

3. Preserve the tissue in one vial of preservative. (Make sure there is excess preservative; guard against diluting the preservative with too much water.)
4. With forceps, hold a piece of oral arm and cut it with clean scissors or razor blades.
5. Place the piece of tissue in a vial with 95% ethanol.

11.3 Specimen Information to be collected

Geographic location

Depth

Date (of collection)

Collector (e.g. your name)

Photograph

Whole jellyfish preserved? (yes/no; where)

Conditions

11.4 Photograph of the following features

Bell

Differences in the bell margin can be useful to distinguish orders of medusae. For example, the semaeostomeae, in contrast to the rhizostomeae, have tentacles on the bell margin.

Canal

Canal structure inside the bell

Cnidae

In jellyfish, most cnidae are located in and around the tentacles and/or oral arms. Their shape is used for identification.

Mouth-arms

Differences in the form of the mouths distinguish orders of scyphomedusae. The Rhizostomeae have many small mouths distributed over their oral arms in contrast to semaeostomes, for example, which have a single, much larger, central mouth. The form and distribution of mouths over the oral arms can also be useful for distinguishing taxa within the Rhizostomeae.

Rhopalia

Rhopalia (singular rhopalium) are the most obvious sensory structures of scyphozoan jellyfish. They include specialised structures for sensing light (eyespot) and movement or direction with respect to gravity (statoliths).

Table .1 Checklist to study the Morphological features of Scyphozoan and Cubozoan Jellyfishes

1	Tentacles present on umbrella (on margin or underside) (or) Tentacles lacking on umbrella	
2	Umbrella almost spherical (or) Umbrella not spherical	
3	Umbrella without prominent white spots (or) umbrella with numerous prominent white spots	
4	Mouth-arms with stout finger-like appendages (or) Mouth-arms with long and slender filaments basally	
5	Tentacles on underside of umbrella (or) Tentacles on margin of umbrella	
6	Tentacles in a wide band around underside of umbrella; medusae large (or) Tentacles in 8 U-shaped clusters on underside of umbrella	
7	Colour of the Umbrella	
8	Umbrella cuboid or not cuboid	
9	Umbrella higher than a hemisphere (or) Umbrella decidedly flattened.	
10	Tentacles round noodles like or pasta like flattened	



Rhopilema hispidum



Crambionella orsini



Chrysaora sp.



Chiropsoides sp.



Lobonemoides robustus



Mastigias papua



Cyanea sp.



Cassiopea xamachana

Jellyfish sting advisory board at tourist beaches

First aid kit developed by ICAR-CMFRI



Terminology

- **Adradius, adradial:** four body axes that lie mid-way between the perradius and the interradius; do not run through opposite rhopalia.
- **Anastomose:** joining and fusing.
- **Bell:** the umbrella or body of the medusa. Maybe saucer-shaped, cuboidal or hemispherical.
- **Bell Diameter (Scyphozoa):** distance between opposite rhopalia or lappets of Scyphozoa and opposite margins of Hydrozoa.

- **Bell Height** (Scyphozoa and Cubozoa): vertical height from apex of umbrella to bell margin. Precise measurements may be taxon specific.
- **Bell Width** (Cubozoa): distance between opposite pedalia on a flattened specimen, at the height where the pedaliu joins the exumbrella of the bell.
- **Circular canal**: canal running around bell margin of hydrozoans, linking the distal ends of radial canals.
- **Cnida (s), Cnidae (pl)**: the explosive organelle found within cnidocytes, which protective or predatory purposes. Often uncritically referred to as a nematocyst.
- **Envenomation**: the process of being stung. A jellyfish can stings you causing an envenomation.
- **Ephyra (s), ephyrae (pl)**: the freeswimming product of asexual reproduction that will develop into a medusa. Ephyrae are typically released following the strobilation of polyps, but may be released by viviparous medusae or through changes from the planula larva.
- **Exumbrella**: upper surface of bell, often strongly pigmented and eventually with warts.
- **Gastric filaments**: fine, thread-like filaments of endodermal tissue responsible for the secretion of digestive enzymes into the gastric cavity. May occur in clusters interradially, or on gastric septa. Usually lost on collection and ironically most conspicuous on ephyrae.
- **Gastric ostia**: subgenital ostia
- **Gastric pouch**: in Coronamedusae/Pelagiidae the peripheral parts of the gastrovascular system divided by the radial septa forming a series of relative discrete areas or pouches.
- **Interradius, interradial**: two body axes, at 45° to the perradius, again running through opposite rhopalia.
- **Lappets**: scalloped flaps of ectodermal tissue at bell margin. The number of lappets per octant, their relative size and shape, pigmentation and internal canal extensions can provide useful information for separating taxa at the species level. Those lappets that flank the rhopalia tend to have a different character to the balance and are referred to as rhopalial lappets, as opposed to velar lappets. All are regarded as marginal lappets.
- **Manubrium**: mouth tube; frequently with a thick mesoglea; of variable length and supporting oral arms distally
- **Medusa**: free swimming cnidarian – classical jellyfish
- **Oral arms**: extensions of the mouth tube or manubrium; effectively long, thin and often coiled-lips bearing cnidae in the case of Semaestomeae that surround an open mouth centrally; or, in the case of Cepheida and Rhizostomida, much thickened and supporting numerous mouthlets externally, and with a branching gastrovascular network internally.
- **Pedaliu**: interradial extensions of the bell margin in which tentacles are attached. It has an internal pedalial canal which is connected to the

gastrovascular cavity. In its upper part some species present a knee-bend which has taxonomic value.

- **Polyp:** the generally sessile phase in the life cycle of cnidarians, resembling a sea-anemone, typically with tentacles around its mouth. In hydrozoans, polyps may occur in colonies of clones that display polymorphism. The polyp may be protected by a chitinous tube (some Hydrozoa and Coronamedusae), or be naked. Also known as a scyphistoma in Scyphozoa.
- **Rhopalium:** collection of sense organs (ocelli, light; statocysts, “balance”) into a single body, generally at or close to the bell margin.
- **Ring canal:** see gastrovascular system.
- **Scapulets:** eight short, rigid, pairs of mouthlet-bearing outgrowths at the base of manubrium in some Rhizostomeae.
- **Strobilation:** the process of asexual reproduction by a polyp that gives rise to ephyrae (through transversal fissions of the body).
- **Subumbrella:** lower surface of bell.
- **Tentacles:** threads (hollow or solid) of ectodermal tissue arising from the bell margin/subumbrella surface (Hydrozoa, Scyphozoa), or from pedalia (Cubozoa), which are laden with nematocysts and used for prey capture. Generally retractile; of variable length. The number and arrangement of tentacles are useful characters in taxon identification, though it should be remembered that they are frequently lost on rough collection. The designation primary, secondary, etc. refers to the order in which tentacles develop in some Semaestomeae, with the primary tentacles forming first from between velar lappets at the centre of each octant.

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AN INTRODUCTION TO THE IDENTIFICATION OF SEAHORSES

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Introduction

The seahorses have increasing demand in the international market as they are highly sought after for use in traditional Chinese Medicines (TCM), marine aquarium trade and as curios. Globally, studies have indicated depletion of seahorse population in the wild, due to their heavy demand in the international export market and the consequent over-harvest from the wild. The last global assessment of seahorses conducted in 2016 by Project Seahorse with the IUCN SSC Seahorse, Pipefish and Seadragon Specialist Group established that at least one-third of the 41 species then recognised were threatened (2 are Endangered, 12 are Vulnerable, 17 are Data Deficient, 10 are Least Concern). In India, a total of seven species have been reported viz., *Hippocampus kuda*, *H. trimaculatus*, *H. spinosissimus*, *H. histrix*, *H. kelloggi*, *H. mohnikei* and *H. camelopardalis* and of these, except for one species (*H. camelopardalis*), all the other species are listed as Vulnerable in the IUCN Red List of Threatened Species (Table 1).

Table 1. List of seahorse species reported from India

Sl. No.	Species	Common Name	IUCN Red List Status	Status in the Indian Wildlife (Protection) Act, 1972	CITES
1.	<i>Hippocampus kuda</i> Bleeker, 1852	Spotted seahorse	VU	Schedule I	Appendix II
2.	<i>Hippocampus trimaculatus</i> Leach, 1814	Longnose seahorse	VU	Schedule I	Appendix II
3.	<i>Hippocampus spinosissimus</i> Weber, 1913	Hedgehog seahorse	VU	Schedule I	Appendix II
4.	<i>Hippocampus histrix</i> Kaup, 1856	Thorny seahorse	VU	Schedule I	Appendix II
5.	<i>Hippocampus kelloggi</i> Jordan & Snyder, 1901	Great seahorse	VU	Schedule I	Appendix II
6.	<i>Hippocampus mohnikei</i> Bleeker, 1853	Japanese seahorse	VU	Schedule I	Appendix II
7.	<i>Hippocampus camelopardalis</i> Bianconi, 1854	Giraffe seahorse	DD	Schedule I	Appendix II

Habitat

The seahorses belong to the family Syngnathidae, which also encompasses pipefishes and seadragons. The members of Syngnathidae are generally found distributed from 50° North to 50° South latitude, with most species occurring in Western Atlantic Ocean and Indo-Pacific region. Seahorses are generally marine, except for some, which are found in estuaries. The seagrasses, seaweeds and coral reefs are the preferred habitats of seahorses, while some species are also found in the mangroves. Some of them are found to be associated with soft bottom communities such as sponges, sea squirts and gorgonids.

Feeding in seahorses

The seahorses are slow moving and hold on to the hold-fast using their prehensile tail. Most seahorses are active during day and feed on tiny organisms that come on their way. They feed on small crustaceans, fish fry and invertebrates (Tipton and Bell, 1988; Vincent, 1996; Do et al., 1998; Teixeira and Musick, 2001). They also have the ability to camouflage and change their colour in minutes to match their surroundings.

Reproduction

The seahorses show peculiar breeding behaviour in that the males becomes pregnant and give birth to young ones. They show highly structured social behaviour and male and female seahorses form faithful bonds. Most species of seahorses are monogamous (Vincent, 1994; Vincent and Sadler, 1995; Masonjones and Lewis, 2000); after pairing, the adult male and female remain as partners and mate successive times during the entire breeding season and sometimes even during successive breeding seasons. If one of the pair dies, the remaining partner will take many weeks to find a replacement (Vincent and Sadler, 1995).

The seahorses attain its first maturity and starts breeding at an age of six months to one year (Jiixin, 1990; Lourie et al., 1999). Sexual maturity in male can be recognised by the appearance of brood pouch. The fecundity is low and the eggs are large, pear-shaped, orange and semi-transparent. Mating occurs after an elaborate courtship, and the female deposits her entire egg clutch into the male's brood pouch where it gets fertilized. The embryonic development takes place inside the male's brood pouch. The gestation period ranges from 12 to 15 days at a temperature of 28 to 20°C. At the end of pregnancy, the males expel the young ones from the brood pouch through muscular contractions, during the late night or early morning hours. The young ones look like miniature adult seahorses, 6 to 12 mm long. Most of the seahorse species produce about 100 to 300 young ones per pregnancy.

Commercial uses of seahorse

The seahorses form the major constituents in the Traditional Chinese Medicines (TCM). TCM is practised in China, Hong Kong, Taiwan, Singapore and ethnic communities worldwide. In the Central Philippines, seahorses are used to treat

asthma, gas pains and hyperactivity (Alino et al., 1990). The seahorses are also one of the most popular fishes in the marine aquarium trade. Their peculiar body features like the horse-like head, tubular snout, prehensile tail and camouflaging behaviour make them a favourable choice of marine aquarium hobbyists. The dried seahorses are also used as curios like key chains, paper weights and jewellery and are kept as souvenirs in beach side shops and resorts in many countries.

Taxonomy of seahorses

Identification of species of seahorse is very important for the sustainable fisheries management and to achieve long-term conservation goals. The habitat requirements, reproductive behaviour etc. may differ from one species to the other, and hence the right species identity is a pre-requisite.

Morphological characteristics

The seahorse has peculiar body characteristics with a horse-like head, tubular snout, bony plates and a prehensile tail. Hence, unlike other teleost fishes, the morphological characteristics which are considered for the identification of seahorses are slightly different. The spines, rings, coronet and tubercles are some of the key characteristics which are used in the identification of species. The important morphological characteristics are given in figure 1 and table 2.

Table 2. Morphological characteristics of seahorse

Characteristics	Description
Height	Distance from the tip of the coronet to the tip of the uncurled tail
Operculum	Flap that covers the gill slits
Keel	Sharp median ridge running down the ventral side of the trunk (in some species)
Tubercles	Raised rounded nodules located at the intersections of rings and ridges (in some species)
Dorsal fin rays	Bones supporting the dorsal fin
Pectoral fin rays	Bones supporting the pectoral fin
Coronet	Large crown-like structure found on top of the head (in some species)
Eye spines	Spines found directly above the eye
Nose spine	Single spine located in front of the eyes on the upper side of the snout (in some species)
Cheek spines	Spines located at the bottom of the operculum on each side of the head
Cleithral ring	Bony ring just behind the operculum

Trunk rings	Raised bony ridges that encircle the body
Tail rings	Raised bony ridges encircling the tail of the seahorse
Snout length	Distance between the bump immediately in front of the eye (not the nose spine) to the tip of the snout
Head length	Distance from the mid-point of the cleithral ring to the tip of the snout
Trunk length	Distance from the mid-point of the cleithral ring to the lateral mid-point of the last trunk ring
Tail length	Distance between the lateral mid-point of the last trunk ring to the tip of the uncurled tail

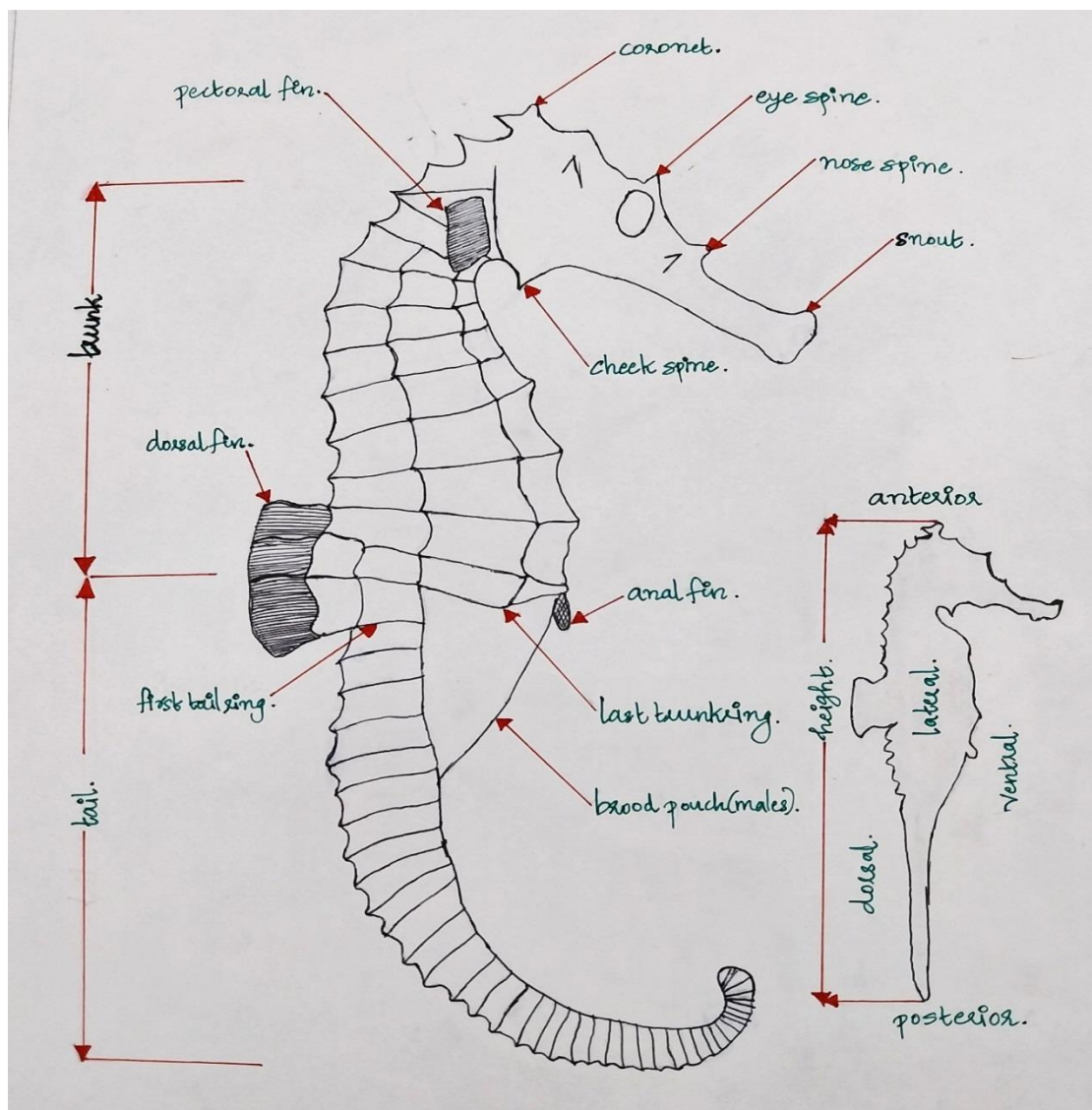


Fig. 1. Lateral view of seahorse

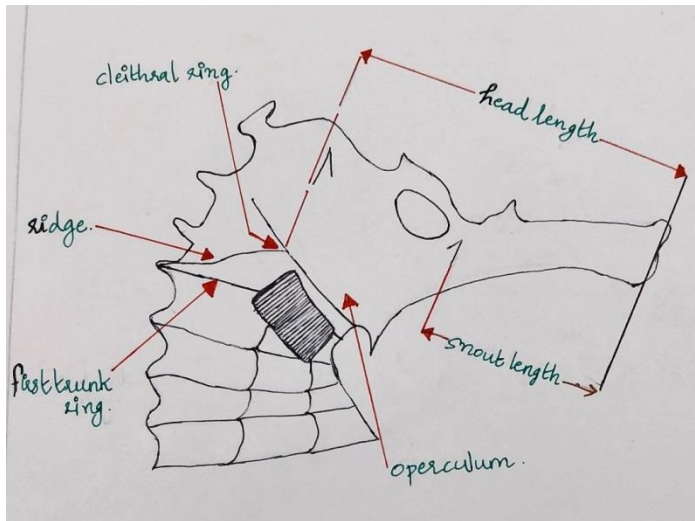


Fig. 2. Lateral view of seahorse head

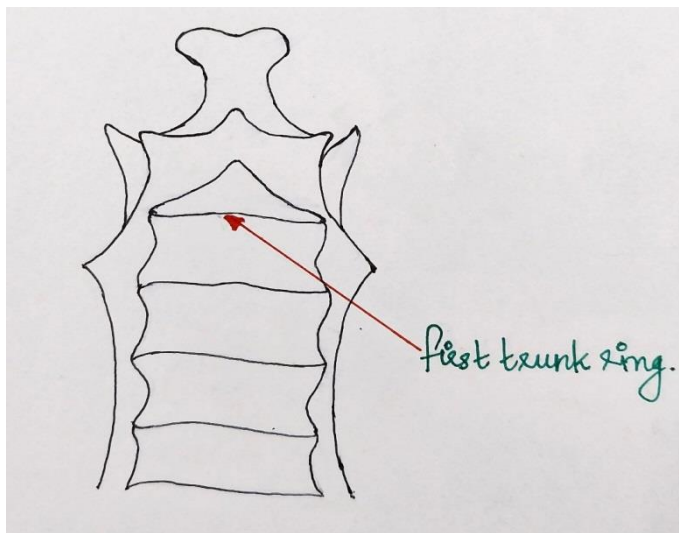


Fig. 3. Dorsal view of seahorse head

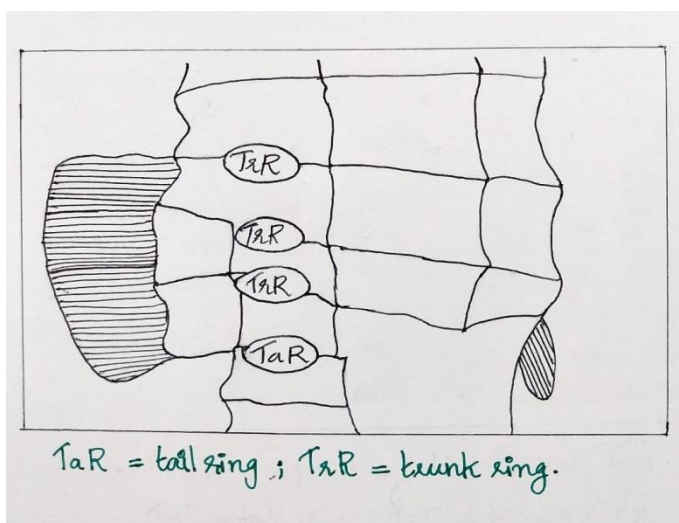


Fig. 4. Lateral view showing the rings supporting the dorsal fin

Steps in identification of seahorse specimen

A) Record the common characters used in seahorse species identification

1.	Record the height of the specimen (Ht): using a string/ wire
2.	Measure the head length (HL)
3.	Measure the snout length (SnL)
4.	Calculate the HL/SnL ratio of the specimen
5.	Count the number of tail rings (TaR)
6.	Count and record the number of trunk rings (TrR)
7.	Record the number of cheek spines (CS): counts range from 0 to 2.
8.	Record the number of eye spines (ES): counts range from 0 to 2.
9.	Record the number of trunk rings (TrR) that support the dorsal fin
10.	Record the number of tail rings (TaR) that support the dorsal fin
11.	Record the number of dorsal fin rays
12.	Record the number of pectoral fin rays

B) Verify the recorded characteristics with the tables provided in the seahorse identification data sheet (Tables 3 to 7; not an exhaustive table, given as examples only)

1. Compare the height of the unidentified specimen with information of species in table.
2. Compare the HL/SnL value.
3. Compare the number of tail rings recorded for the unidentified specimen.
4. Compare the number of dorsal fin rays.
5. Compare the number of pectoral fin rays.
5. Compare the trunk rings, rings supporting the dorsal fin, cheek spines and eye spines.

Table 3. Maximum height of selected species (Step B1)

Species	Maximum height (cm)
<i>Hippocampus trimaculatus</i>	17.0
<i>Hippocampus kuda</i>	17.0
<i>Hippocampus histrix</i>	17.0
<i>Hippocampus spinosissimus</i>	17.2
<i>Hippocampus kelloggi</i>	28.0

<i>Hippocampus mohnikei</i>	8.0
<i>Hippocampus camelopardalis</i>	10.0

Table 4. Ratio of Head Length to Snout Length (HL/SnL) of selected species (Step B2)

Species	Possible range of HL/SnL	Most common value
<i>Hippocampus trimaculatus</i>	1.9 - 2.4	2.2
<i>Hippocampus kuda</i>	2.0 - 2.6	2.3
<i>Hippocampus histrix</i>	1.7 - 2.0	1.8
<i>Hippocampus spinosissimus</i>	2.0 - 2.4	2.2
<i>Hippocampus kelloggi</i>	2.0 - 2.3	2.1
<i>Hippocampus mohnikei</i>	2.8 - 3.9	3.0
<i>Hippocampus camelopardalis</i>	2.7 - 2.9	2.8

Table 5. Number of tail rings in selected species (Step B3)

Species	Range of number of tail rings	Most common value
<i>Hippocampus trimaculatus</i>	38 - 43	40, 41
<i>Hippocampus kuda</i>	34 - 38	36
<i>Hippocampus histrix</i>	34 - 37	35
<i>Hippocampus spinosissimus</i>	33 - 39	36
<i>Hippocampus kelloggi</i>	39 - 41	40
<i>Hippocampus mohnikei</i>	37 - 40	38
<i>Hippocampus camelopardalis</i>	38	38

Table 6. Number of dorsal fin rays in selected species (Step B4)

Species	Range of numbers of dorsal fin rays	Most common numbers
<i>Hippocampus trimaculatus</i>	18 - 22	20
<i>Hippocampus kuda</i>	17 - 18	17
<i>Hippocampus histrix</i>	15 - 18	17

<i>Hippocampus spinosissimus</i>	16 - 20	17, 18
<i>Hippocampus kelloggi</i>	17 - 19	18
<i>Hippocampus mohnikei</i>	15 - 16	15, 16
<i>Hippocampus camelopardalis</i>	19 - 22	-

Table 7. Number of pectoral fin rays in selected species (Step B5)

Species	Range of numbers of pectoral fin rays	Most common numbers
<i>Hippocampus trimaculatus</i>	16 - 19	17, 18
<i>Hippocampus kuda</i>	15 - 18	16
<i>Hippocampus histrix</i>	17 - 20	18
<i>Hippocampus spinosissimus</i>	16 - 19	17
<i>Hippocampus kelloggi</i>	17 - 19	18
<i>Hippocampus mohnikei</i>	12 - 14	13
<i>Hippocampus camelopardalis</i>	17 - 18	17, 18

C) After elimination of the above 5 steps, the following characters need to be considered

1. Height and shape of the coronet
2. Number, distribution and size of spines on the body
3. Patterns or markings such as stripes or spots.

Table 8. Number of trunk rings, trunk & tail rings supporting the dorsal fin, cheek spines and eye spines

Species	Trunk Rings	Rings supporting Dorsal Fin		Cheek Spines	Eye Spines
		Trunk Rings	Tail Rings		
<i>H. trimaculatus</i>	11	2	1	1	1
<i>H. kuda</i>	11	2	1	1 or 2	0 or 1
<i>H. histrix</i>	11	2	1	1	1
<i>H. spinosissimus</i>	11	2	1	1 or 2	1
<i>H. kelloggi</i>	11	2	1	1	1
<i>H. mohnikei</i>	11	2	1	2	0
<i>H. camelopardalis</i>	11	2	1	0	1

Thus, careful examination of the collected specimens, and proper recording of data is essential to arrive at the correct species identification. 'A Guide to the Identification of Seahorses' by Lourie et al. (2004) gives an insight to the step-by-step identification of seahorses, which can be referred in addition to the other standard literature that are available for species identification.

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TAXONOMY OF SEA CUCUMBERS

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Introduction

Sea cucumbers are popularly called holothurians, belong to the phylum Echinodermata, which is a distinct phylum in the animal kingdom and are significant members of benthic invertebrate communities occurring in all of the major oceans and seas of the world. Echinoderms possess radial symmetry (generally pentamerous), an intradermic skeleton consisting of closely fitted plates, articulated plates, or ossicles, and a peculiar water vascular system of fluid-filled tubes. The phylum is divided into five classes of very different appearance :

- The crinoids (or feather stars)
- Holothuroids (or sea cucumbers)
- Echinoids (or sea urchins)
- Asteroids (or sea stars)
- Ophiuroids (or brittle stars)

As a significant benthic invertebrate community, sea cucumbers have more critical effects on the physicochemical processes of soft-bottom and reef ecosystems. Commercially exploited sea cucumbers provide income to millions of coastal fishers worldwide and nutrition to Asian consumers (Purcell et al., 2013). The processed product from sea cucumber is called 'beche-de-mer' in French, 'iriko' in Japanese, 'haisom' in Chinese and 'trepang' in Indonesian. It has a very high export value to Southeast Asian countries because of its higher protein and nutrients such as vitamins, amino acids, trace metals and minerals (Bordbar et al., 2011). Sea cucumbers are an integral part of traditional Chinese medicine, in addition to that recent research indicated their essential source of several bioactive compounds of anti-angiogenic, anticancer, anticoagulant, anti-hypertension, anti-inflammatory, antimicrobial, antioxidant, antithrombotic, antitumor and wound healing properties. Sea cucumbers have a more significant role in ecosystem functioning by contributing to sediment health via bioturbation, recycling of nutrients, and influencing seawater chemistry. Sea cucumbers host many parasitic and commensal symbionts from several phyla, thereby enhancing ecosystem biodiversity. Many taxa prey on them, thereby transferring animal tissue and nutrients (derived from detritus and microalgae) to higher trophic levels forming energy transfer pathways in food chains, etc (Purcell et al, 2016).

Morphology of sea cucumbers

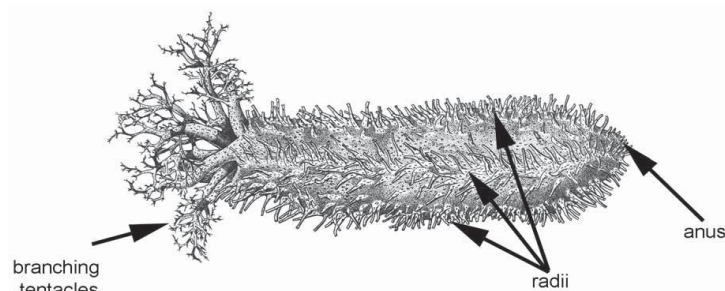


Fig1. A holothurian (adapted from Pawson, et al., 2010)

Holothurians have an orally-aborally elongated body (Fig.1) formed like a short or long cylinder, with the mouth at the anterior end encircled by tentacles and the anus at the posterior end often edged by papillae. Holothurians usually lay on the substrate with their ventral surface or trivium, formed by the radii. This creeping sole bears the locomotory podia, while on the dorsal surface, or bivium, the podia are often represented by sensory papillae (Conand, 1998). The mouth is terminal or displaced dorsally, surrounded by a thin buccal membrane, and generally bordered by a circle of tentacles (Fig. 1). Tentacles are buccal podia containing extensions from the water vascular system serve various functions related to feeding, sensory perception, and manipulation of food particles. The types of oral tentacles found in sea cucumbers can vary depending on the species and ecological adaptations.

Tentacles are significant in identifying sea cucumbers due to their diverse morphology, arrangement, and specialized functions. The morphology of tentacles can vary widely among different species of sea cucumbers. Characteristics such as tentacles' shape, size, length, and surface texture can be diagnostic features used to differentiate between species. The number and arrangement of tentacles around the mouth are often species-specific traits. Some sea cucumbers have a single ring of tentacles, while others may have multiple rows or clusters. Oral tentacles' presence, absence, or arrangement can aid species identification.

Types of tentacles

- i. Peltate tentacles: Peltate tentacles are characterized by a broad, flattened disc-shaped structure at the distal end, resembling a small paddle or leaf (Fig.2). These tentacles are often found in species that are specialized filter feeders, as the broad surface area aids in capturing suspended food particles from the water column.
- ii. Digitate tentacles: Digitate tentacles are slender and elongated, resembling fingers or digits. They may have a tapered or rounded tip. These tentacles are versatile and can be used for feeding and sensory perception. They are commonly found in generalist feeders that consume various food types.
- iii. Papillate tentacles: Papillate tentacles are covered with small, finger-like projections or papillae along their surface. These tentacles are often associated with species that feed on organic detritus or fine particulate matter. The papillae increase the surface area for efficient absorption of nutrients.

iv. Fusiform tentacles: Fusiform tentacles are cylindrical or spindle-shaped, with a uniform diameter along their length. They may be found in species that feed by selective deposit feeding, targeting specific types of organic matter or microorganisms in sediments.

v. Branched tentacles: Some sea cucumbers have oral tentacles that are branched or subdivided into smaller segments, resembling a tree-like structure (Fig.2). Branched tentacles may increase the surface area available for feeding or sensory perception, allowing sea cucumbers to efficiently capture food particles or detect chemical cues in the environment.

vi. Tentacular bulb: In certain sea cucumber species, particularly those in the family Synaptidae, the oral tentacles may be modified into a bulbous structure called a tentacular bulb. The tentacular bulb is used for burrowing into sediments and capturing prey buried within the substrate. It may also aid in respiration and gas exchange in some species.

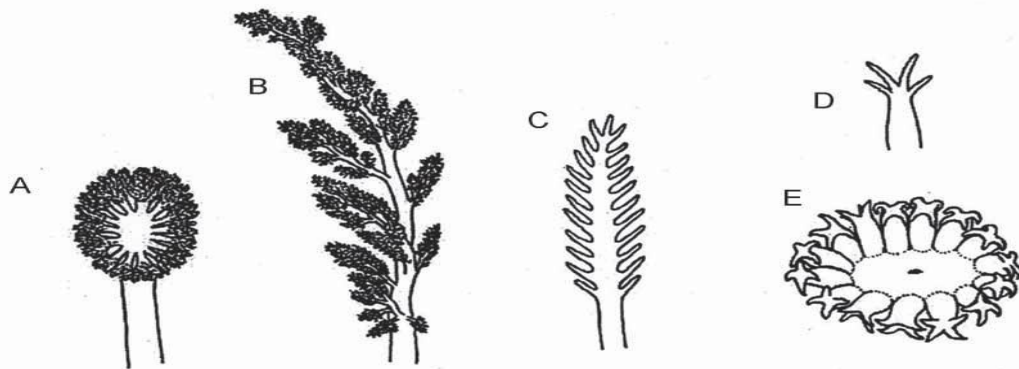


Fig.2. Holothurian tentacles. A, shield-shaped (Order Aspidochirotida); B, branching (O. Dendrochirotida); C, pinnate (O. Apodida); D, digitate (O. Apodida, O. Molpadiida); E, digitate (O. Molpadiida) (adapted from Pawson, et al., 2010).

Calcareous rings

The calcareous rings are skeletal structures found within the body wall of sea cucumbers, serving as a support framework for the internal organs and muscles. These rings comprise calcareous ossicles, small calcareous plates or pieces arranged in a circular or ring-like fashion around the oesophagus, forming a rigid structure. Calcareous rings play vital roles in the taxonomy and classification of sea cucumbers. They provide valuable insights into their taxonomy, phylogeny, species diversity, and functional ecology. By examining the morphology and characteristics of calcareous rings, researchers can enhance our understanding of these fascinating marine organisms' evolutionary history and ecological diversity.

The morphology and arrangement of calcareous rings are highly variable among different species of sea cucumbers. Taxonomists use the characteristics of

calcareous rings, such as the number, shape, size, and arrangement of ossicles, as diagnostic features for species identification and classification.

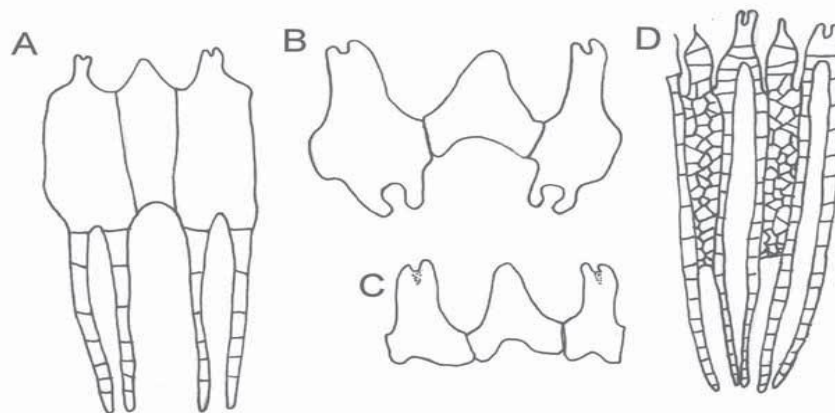


Fig.3. Calcareous rings; A, B, C with two radial pieces and one interradial piece, D with two interradial pieces and two notched radial pieces. A, ring with medium posterior projections; B, ring with short posterior projections; C, ring with no posterior projections; D, tubular ring with long, complex, posterior projections (adapted from Hyman, 1955).

Body wall and Spicules

The body wall is a thick layer of collagenous connective tissue dermis with a thin epidermis outside the dermis. The sea cucumber skeleton lies in the dermis, taking the form of vast microscopic ossicles called spicules. They display a profusion of beautiful geometric shapes that vary with species and age and are essential in taxonomy (Slater and Chen, 2015).

Spicules are composed primarily of calcium carbonate, which provides structural support and reinforcement to the soft tissues of these organisms. The exact composition of spicules may vary, with some sea cucumbers incorporating magnesium or other trace elements into their skeletal structures. Spicules may vary in shape, size, and surface ornamentation, ranging from simple rod-like structures to elaborate forms with branching or ornamented surfaces. Common types of spicules found in sea cucumbers include:

1. **Table Spicules:** Table spicules are flat, disc-shaped structures with a central perforation. These spicules support the body wall and contribute to the overall rigidity of the sea cucumber's skeleton.
2. **Anchor Spicules:** Anchor spicules are elongated structures with one or more pointed ends resembling miniature anchors. These spicules anchor the body wall to surrounding tissues and substrates, enhancing stability and preventing collapse.
3. **Wheel Spicules:** Wheel spicules are wheel-shaped structures with radiating spokes or arms. These spicules are thought to play a role in reinforcing specific regions of the body wall and may contribute to locomotion and burrowing behaviour in some species.

4. Cylinder Spicules: Cylinder spicules are elongated, cylindrical structures with smooth or ornamented surfaces. These spicules provide structural support and flexibility to the body wall, allowing sea cucumbers to withstand mechanical stresses and deformations.

Spicules serve multiple ecological functions in sea cucumbers. They can act as physical deterrents against predators by making the body wall of sea cucumbers more rigid and resistant to deformation or compression, and also help sea cucumbers to burrow into sediments.

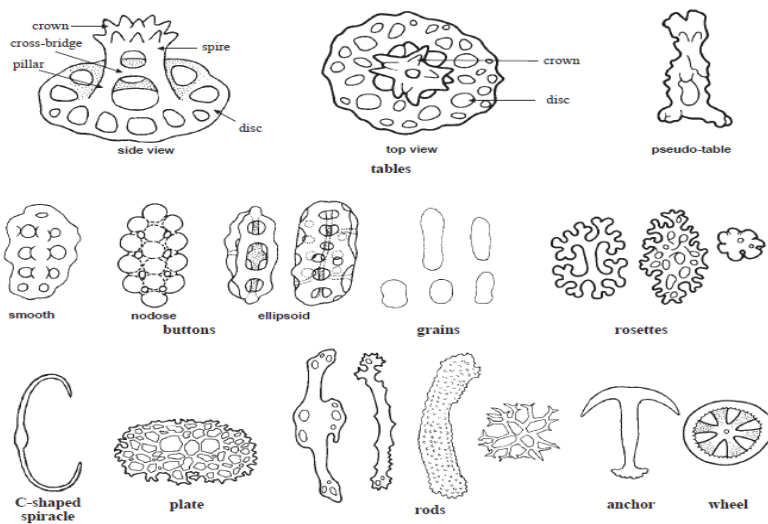


Fig.4. Basic types of spicules (adapted from Conand,1998)

Species identification of sea cucumbers

The sea cucumber species can be identified through the examination of the skeletal elements (ossicles) found in various parts of the body, especially those embedded in the body wall, papillae, podia and tentacles of live, dried or preserved animals and can be isolated by the following method (adapted from Purcell et al, 2023).

1. Small pieces (e.g. a few square mm) of tissue removed from different body parts and can be placed into separate small labelled vials.
2. Add the required volume (e.g. 0.5 ml) of sodium hypochlorite (concentrated household bleach) or sodium hydroxide to each vial to dissolve the organic tissue. The soft tissue will be dissolved in 20–30 minutes, leaving the hard ossicles in the bottom of the vial.
3. The spicules settled can be separated after decanting, or pipetting, out the bleach and are washed five times in distilled water and carefully sucking the liquid out of the vial with a pipette. Rinse the pipette in fresh water each time to not contaminate a sample with the ossicles from another.
4. The isolated ossicles can then be rinsed in alcohol and placed onto a microscope slide with a drop of a mountant (e.g. Euparal medium) for microscopic observation (scanning electron microscope (SEM) stub).

Characteristics of orders under the class - Holothuroidea

There are five orders in the class Holothuroidea (Dendrochirotida, Aspidochirotida, Molpadiida, Apodida and Elaspodida). The description is given below (adapted from Pinn, 2013).

Order	Description
Dendrochirotida	There were 10-30 tentacles highly branched or shaped in the form of dendritic, occasionally digitate. Ten calcareous plates form a simple or complex posterior process calcareous ring. They are usually sedentary, attached or burrowing. Introvert and retractor muscles are present.
Aspidochirotida	Very large group with very diverse and abundant in shallow tropical habitats. Tentacles always in the shape of peltate. Respiratory trees present. Introvert and retractor muscles absent.
Elaspodida	Lack of respiratory tree in body cavity. Strongly bilaterally symmetrical with commonly complicated and elaborate projections like frills, veils and sails on their gelatinous body. Only found in deep sea at abyssal depths.
Apodida	One of the simplest forms of sea cucumber. It has a very long and worm-like cylindrical body. .Body wall without any tube feet, except for the tentacles, hence have soft smooth and soft body. Respiratory trees and anal papillae absent. Ossicles often include wheels, or anchors....
Molpadiida	Tentacles are digitate. Stouted fusiform body with some slightly curved body to some curved liken a ball with tapering to a more or less conspicuous tail. No tube feet are present in the body wall and are mostly find in soft muddy substrates. Respiratory trees present; anal papillae may be present. Ossicles not wheel-shaped

Key to the shallow-water families of Aspidochirotida (adapted from James and James 1994).

1a. Body with trivium (sole) usually flattened and dorsal bivium convex; gonads forming a single tuft appended to the left dorsal mesentery; Cuvierian organs present or absent; dominant spicules of form of tables, buttons (simple or modified), and rods (excluding C- and S-shaped rods) **Holothuriidae.**

1b. Body square-shaped or trapezoidal in cross-section; Cuvierian organs always absent; gonads forming two tufts appended on each side of the dorsal mesentery; dominant spicules in form of branched rods and C-and S-shaped rods

Stichopodidae

Field keys to the commercially important genera of holothurians

1. Anal opening surrounded by five teeth-like structure *Actinopyga*

- 1'. Anal opening not surrounded by teeth-like structure ...2
2. Anal opening surrounded by five groups of papillae....*Bohadschia*
- 2'. Anal opening not surrounded by five groups of papillae 3
3. Body more or less quadrangular with distinct papillae....*Stichopus*
- 3'. Body not quadrangular, but tubular, sometimes loaf-shaped 4
4. Body massive up to 800 mm in length, dorsal papillae resembling leaf-like structure
Thelenota
- 4'. Body moderate in length up to 600 mm; papillae not expanded into leaf-like structures
Holothuria

Genus *Actinopyga* Bronn, 1861

Species belonging to this genus are either of medium value or low value.

Field key to the species of *actinopyga*

1. Colour completely black *A. miliaris*
- 1'. Colour brown or brown and white
2. Colour brown on the upper side and white on the lower side; often found near low water mark *A. mauritiana*
- 2'. Colour completely brown with often sand deposits on the upper side of body; mostly found in deeper waters ... *A. echinites*

Genus *Bohadschia* Jaeger, 1833

Massive forms with distinct anal papillae, often buried or covered with a fine coat of mud. Because of the Cuvierian tubules (sticky threads) processing is difficult. Species belonging to this genus have moderate commercial value.

Field key to the species of *Bohadschia*

1. Colour black or brown with distinct 'eye' like spots all over the body *B. argus*
- 1'. Colour variable, usually light brown with black spots *B. marmorata*

Genus *Stichopus* Brandt, 1835

Some species belonging to this genus reach a massive length of 900 mm. Body will disintegrate and becomes gelatinous when taken out of water.

Field key to the species of *stichopus*

1. Body quadrangular with four rows of large finger-like processes. Colour dark green, appearing almost black in some shades of light *S. chloronotus*
2. Body massive and loaf-like with irregular brown patches on yellow grey background *S. variegatus*

Genus *Thelenota* Brandt, 1833

Very massive forms with numerous large pointed teats in groups of two or three all over the upper surface.

Genus *Holothuria* Linnaeus, 1764

This is by far the most important genus for processing. Over one hundred species are known under this genus.

Key to the species of *Holothuria*

1. Body like a loaf with very thick body wall. In the living condition about six pairs of lateral teat-like projections are seen; body with black and white patches *Holothuria nobilis*
- 1'. Body tubular, body wall not very thick. No lateral projections in the living condition 2
2. Body completely black in colour; red colour comes off when live specimens are handled *Holothuria atra*
- 2'. The colour not completely black and no red colour comes off when live specimens are handled 3
3. Yellow transverse bands on the upper side of the body, lower side white with a number of black dots *Holothuria scabra*
- 3'. Body uniformly brown in colour; small stiff projections all over the body; highly burrowing form *H. spinifera*

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PLANKTON TAXONOMY

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Plankton includes all those organisms that live suspended in the water column of aquatic ecosystems. Unlike nektons, which swim actively against water currents, plankton are characterized by feeble power of locomotion and drift in the water column at the mercy of currents, winds, and tides. The term “plankton” was coined by Victor Hensen from the Greek word "plankton" meaning drifter or wanderer.

Plankton comprises diverse organisms ranging in size from microscopic viruses to macroscopic forms such as large colonial jellyfishes. Plankton are fundamental in maintaining the intricate balance of marine ecosystems, as both primary producers and as a crucial food source, channeling energy produced through photosynthesis to higher orders in the trophic levels that are exploitable by man. Besides their contribution to global primary production, they are also responsible for 50% of global oxygen production synthesised as by-product of photosynthesis. Their photosynthetic activity not only sustains marine life but also plays a critical role in the ocean's biological pump and carbon cycle, sequestering carbon from the surface to the deeper ocean in turn aiding in regulating earth's climate. They also play a vital role in the nutrient cycling and biogeochemical cycling of elements through their process of respiration, moulting, defecation, death and decomposition. Furthermore, plankton are often considered as sensitive indicators of perturbations associated with climate change and anthropogenic interventions in the aquatic ecosystems. The characteristics of plankton such as short life cycle, ectothermic nature, high sensitivity of their physiological and metabolic processes to subtle changes in habitat makes them an ideal indicator while evaluating ecosystem changes. Thus understanding and conserving these tiny wanderers are essential for maintaining the intricate health and sustainable productivity of our oceans. The training notes below will provide detailed insight on the significance of both phytoplankton and zooplankton community in aquatic ecosystems, their sampling and enumeration methodologies, and taxonomic identification.

Phytoplankton

Phytoplankton are microscopic autotrophs capable of synthesizing organic carbon from dissolved inorganic nutrients in the ocean using the sun as the source of energy. Through the process of primary production, they are responsible for generating 50% of global productivity and forms the base of ocean food web. Besides their role in organic carbon synthesis, they are also vital in generating 2/3rd of the atmospheric oxygen levels. They also have a crucial role in mitigating impacts of global warming occurring in conjunction with excessive CO₂ release to the atmosphere, through their process of primary production and subsequent carbon sequestration to deeper ocean.

Phytoplankton encompasses a diverse community consisting of both eukaryotic and prokaryotic organisms spanning wide size ranges and taxonomic diversity. The size of phytoplankton usually range between $\leq 2\mu\text{m}$ to $200\ \mu\text{m}$. The predominant phytoplankton representatives of aquatic ecosystems are diatoms, dinoflagellates, cyanobacteria, green algae, chrysophytes and coccolithophorids.

Classification of phytoplankton based on size

As the size of the phytoplankton community has an upper hand in determining the pathways of carbon cycling, type of food web active in the ecosystem, nutrient uptake and biological pump, they are often classified as,

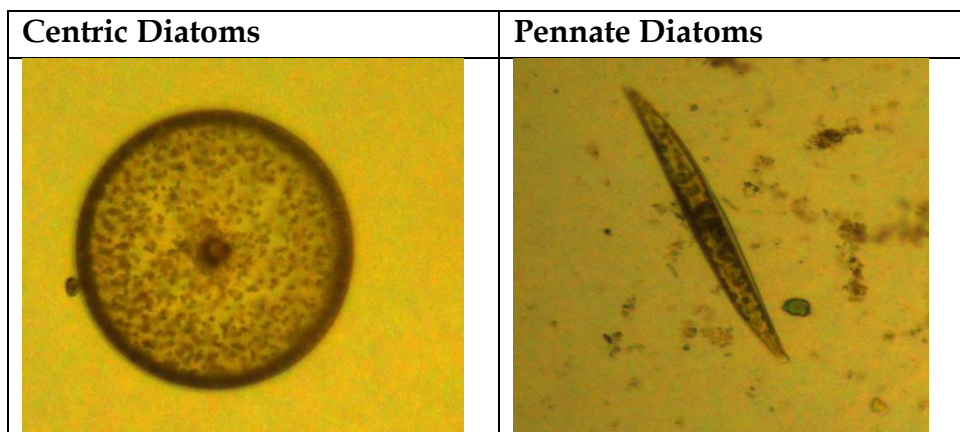
- **Picoplankton** - Phytoplankton having size $\leq 2\mu\text{m}$. Mostly include autotrophic bacterioplankton and smaller phytoplankton
- **Nanoplankton** - Phytoplankton having size in between $2 - 20\mu\text{m}$. Include the majority of the autotrophic diatoms, dinoflagellates, and coccolithophores.
- **Microphytoplankton** - Phytoplankton having size between $20-200\ \mu\text{m}$. Include larger chain forming diatoms and flagellates.

Major phytoplankton groups

Phytoplankton comprises a diverse community of photosynthetic organisms classified according to their morphological, physiological and genetic characteristics. The predominant members of phytoplankton are representatives of classes, Bacillariophyceae, Dinophyceae, Cyanophyceae, Chlorophyceae, and Prymnesiophyceae. Members from Raphidophyceae and Cryptomonads also contribute significantly to the phytoplankton community of freshwater and brackish water ecosystems.

1. Diatoms (Bacillariophyceae)

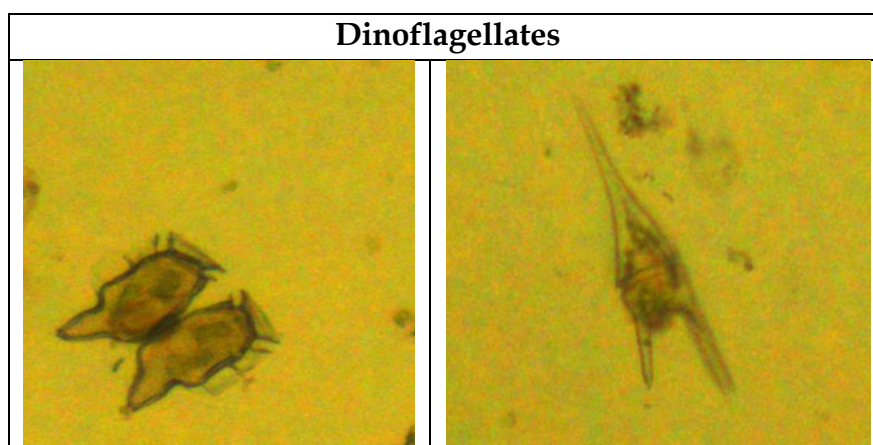
Diatoms, often referred as the "jewels of the sea," come under a diverse phytoplankton class bacillariophyceae ranging from unicellular, multicellular to colonial forms. They are distinguished by their intricate siliceous outer wall (frustule), which gives them a distinctive appearance under the microscope. These microorganisms are remarkable for their stunning diversity in shape and structure. They possess pigments such as chlorophyll *a*, chlorophyll *c*, and fucoxanthin, which enable them to carry out photosynthesis efficiently. Diatoms comprise two major forms distinguished by their shape i.e., **Centric diatoms** the discoidal forms and dominant members of the pelagic phytoplankton community, and the **Pennate diatoms**, the elongate/ bilaterally symmetrical forms and the dominant members of the benthic phytoplankton community. They are commonly found in cold, nutrient-rich waters worldwide, and have a crucial role in sustaining oceanic production and in regulation of global biogeochemical cycles. Some common centric diatoms are *Coscinodiscus*, *Thalassiosira*, *Cyclotella* while the pennate forms include *Navicula*, *Fragillaria*, *Diploneis* etc.



2. Dinoflagellates (Dinophyceae)

Dinoflagellates are unicellular flagellated protists that possess an organic cell wall and contain photosynthetic pigments such as chlorophyll *a*, chlorophyll *c*, and peridinin. They are characterised by two flagella, the *longitudinal flagella* lying in surface groove called *sulcus* and the *transverse flagella* lying in surface groove called *cingulum*. Dinoflagellates are often called as fire plants as they are bioluminescent and emit light upon disturbance. Some members of dinoflagellates are known for forming toxic algal blooms and discoloration of waters (Red tides). Dinoflagellates are often identified based on the shape of their cell (round, oval or elongated), flagella arrangement, ornamentation of their cellulose armor called thecal plates and chloroplasts, cell extensions (horns, spines) etc.

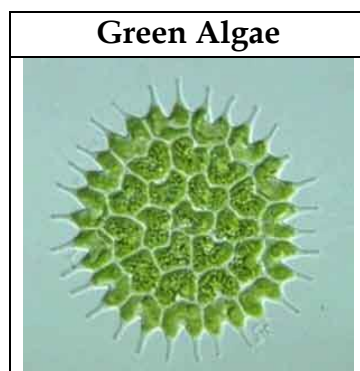
Common dinoflagellate representatives are *Gymnodinium*, *Prorocentrum*, *Dinophysis*, *Ceratium*, *Gonyaulax* etc.



3. Green Algae (Chlorophyceae)

Green algae, encompass a wide range of unicellular, colonial, and multicellular algae. They are distinguished by their green pigmentation, due to presence of photosynthetic pigments such as chlorophyll *a* and *b*, as well as various accessory pigments carotenoids and xanthophylls. Their cell walls are primarily composed of cellulose. Green algae display diverse forms, from simple unicellular species to complex multicellular filamentous or parenchymatous forms. They typically inhabit

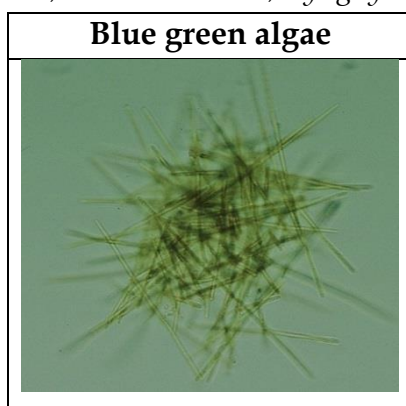
freshwater environments, although some species are found in marine habitats. Cell wall structure, color and shape of cell and chloroplasts aid in the identification of green algae. Common green algae found in our waters are *Spirogyra*, *Cladophora*, *Agmenellum*, *Pediastrum* etc



4. Cyanobacteria (Cyanophyceae or Blue-green algae)

Cyanobacteria, often referred to as blue-green algae, are a group of prokaryotic microorganisms commonly found in diverse habitats, including freshwater, marine, and terrestrial environments. Despite their name, they are not true algae but rather belong to the domain Bacteria. Cyanobacteria are characterized by their blue-green pigmentation, primarily due to the pigment phycocyanin and chlorophyll *a*. They possess cell walls made of peptidoglycan, similar to other bacteria. Cyanobacteria can be unicellular, colonial, or filamentous in structure, and they often form blooms in nutrient-rich waters. Some cyanobacteria are capable of fixing atmospheric nitrogen, and thus have crucial role in nitrogen cycling. Certain species are known to produce toxins posing risks to aquatic ecosystems and human health.

Eg. *Anabaena*, *Microcystis*, *Nostoc*, *Trichodesmium*, *Lyngbya* etc

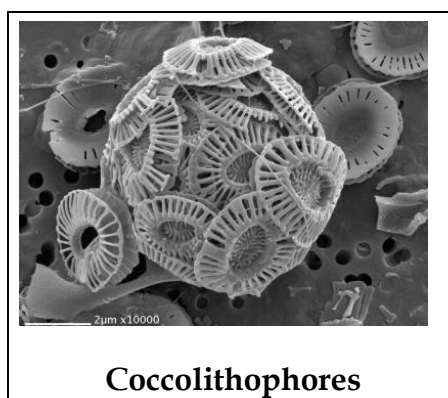


5. Coccolithophores (Prymnesiophyceae)

Coccolithophores are a unique group of marine phytoplankton belonging to the division Haptophyta. They are characterized by their distinctive calcium carbonate plates called coccoliths, surrounding their cells. These tiny, unicellular organisms are typically spherical in shape and range in size from few to several micrometers in diameter. Coccolithophores are photosynthetic, containing chlorophyll *a* and *c2* as well as other pigments like fucoxanthin and diadinoxanthin. They play a significant

role in the global carbon cycle, as their calcification process removes carbon dioxide from the ocean and contributes to the formation of carbonate sediments on the seafloor. Coccolithophores are abundant in nutrient-rich surface waters, particularly in temperate and subtropical regions, where they form blooms visible from space. Despite their small size, coccolithophores have a profound impact on marine ecosystems and biogeochemical processes, influencing the climate system through their role in carbon sequestration and albedo feedback mechanisms. They are often identified based on the intricate morphology of coccoliths as well as their cell structure.

Eg: *Emiliana*, *Coccolithus*, *Calcidiscus* etc.



Phytoplankton sampling

Phytoplankton sampling methodology is a crucial aspect of marine research, and various methods are employed to ensure accurate quantification and analysis of phytoplankton abundance and diversity. The choice of sampling method depends on factors such as the depth of water being sampled, the target size range of phytoplankton, and the specific objectives of the study. For surface water sampling in coastal waters, estuaries, or lagoons, the techniques commonly used include,

1. Water Samplers

Water samplers like Niskin bottles, Nansen bottles, and Van Dorn samplers are frequently utilized to collect phytoplankton samples. These samplers allow the collection of subsurface samples at various depths. They are typically made of flexible or rigid plastic tubes. They are immersed in water in open conditions and are closed at the top at specific depths via a messenger. The capacity of these samplers usually ranges from 5 to 20 liters. In oceanic regions, large-sized Niskin bottles are often used in conjunction with CTD (Conductivity, Temperature, and Depth) probes. The CTD probe provides data on the physical properties of seawater, such as temperature and salinity, while the Niskin bottles collect water samples at discrete depths simultaneously.

2. Towing Plankton Nets

Surface phytoplankton samples can also be collected by towing nets with mesh sizes ranging from 5 to 20 μm . Towing nets offer the advantage of filtering

larger volumes of water at a time, allowing the concentration of phytoplankton, including larger and rarer cells. Once the water samples are collected, phytoplankton are typically concentrated from the samples through settling or sieving using mesh sizes ranging from 20 to 200 μm , depending on the target size range of the organisms being studied.

3. Plankton pumps

Plankton pumps are an efficient method for collecting phytoplankton samples in shallow estuaries and coastal waters. These pumps facilitate continuous pumping and filtration of water, allowing for the integration of plankton samples from the surface down to a specified depth. The basic design of a plankton pump involves an inlet pipe that is lowered to the desired depth and an outlet pipe covered with a mesh of appropriate size, which is submerged in a tank of known volume. As water is pumped through the system, phytoplankton and other particles are captured by the mesh, allowing for the collection of a representative sample. A meter integrated into the pump records the volume of water filtered during the sampling process. While plankton pumps enable the filtration of large volumes of water, there are considerations regarding potential damage to phytoplankton cells due to frictional resistance within the pump mechanism. Care must be taken to minimize any adverse effects on the integrity of the collected samples.

Niskin sampler



Plankton pump



Image courtesy: serc.si.edu

Plankton nets



Fixing and Preservation

Phytoplankton samples collected are immediately preserved in acidified Lugol's iodine solution added in the ratio of 1: 100 volumes of water. Lugol's iodine solution helps in the discharging gas enclosed in vacuoles of cells and also kills, stains and weighs the algae. 4-5% formaldehyde solution is also added as a phytoplankton

preservative. Phytoplankton samples should be stored in iodine-proof glass bottles appropriately labeled with the date, time and area of collection. Samples should be stored in dark and cool conditions and cells should be counted as soon as possible as long-term storage leads to distortion and damage of cells. After fixation, phytoplankton are concentrated for enumeration by the settling and sedimentation process. In this method, the fixed phytoplankton samples are settled in Utermöhl sedimentation chambers of 5-100 ml capacity for 24 hours after which the cells concentrated at the settling plate of the Utermöhl chamber is separated and examined under an inverted microscope.

Enumeration and Estimation

Identification and enumeration of the phytoplankton samples are carried out either using a standard compound microscope or an inverted microscope of suitable magnification. The preferred magnification for observing picoplankton is 1000x; for nanoplankton is 200 – 630x and for microplankton is 100-200x. After concentrating the phytoplankton cells through the settling and sedimentation procedure, the cells are enumerated under microscope following the Sedgwick rafter cell counting method. In this method, 1 ml of concentrated phytoplankton sample is poured into the Sedgewick rafter counting chamber having 1 ml sample holding capacity using a micropipette. Later a cover glass is placed over the chamber and is kept idle for 5 minutes to allow the phytoplankton cells to get settled. Once the cells get settled at the base of the counting chamber it is enumerated under the microscope with suitable magnification.

Phytoplankton species in 1 litre of the sample is estimated by,

$$N = n * v/V,$$

where, N = Number of planktonic algae per litre of water filtered, n = Average number of planktonic algae in 1ml, v = Volume of plankton concentrate in ml, and V = Total volume of water filtered in litre

Phytoplankton biomass estimation

Phytoplankton biomass estimation usually involves the measurement of chlorophyll *a*, the universal photosynthetic pigment in autotrophic organisms. As estimation of photosynthetic pigments provides a quantitative measure of taxonomy, biomass and physiological state of the phytoplankton it is often taken as the proxy of phytoplankton biomass in the aquatic ecosystems Chlorophyll *a* estimation involves the following steps,

1. **Filtration of water samples** - For chlorophyll *a* estimation, about 500ml - 2litre of water samples (depending on the area sampled) are filtered using a 47 mm Whatman GF/F filter paper of pore size 0.7µm using a suction pump.
2. **Extraction of pigments** - After filtration, the filter papers are immersed in 10 ml of 90% acetone and kept overnight at 4°C under dark for the pigment extraction.

3. **Concentration of pigments** -The extracted pigment is concentrated by centrifugation at 3000 rpm for 10 minutes.
4. **Estimation** -The extracted pigment is estimated either using spectrophotometer, fluorometer or HPLC.

In Spectrophotometer, the concentration of chlorophyll corresponds to the absorbance of light by the sample. In spectrophotometric estimation of chlorophyll-*a*, after the centrifugation process, the clear supernatant obtained is transferred to a 10 mm path length cuvette and extinction at 750, 665, 645 and 630 nm is measured against a blank solution of 90% acetone. The amount of pigment in the sample is calculated following Strickland and Parsons (1972) as,

$$C \text{ (Chlorophyll } a) = 11.6 E_{665} - 1.31E_{645} - 0.14E_{630}$$

$$C \text{ (Chlorophyll } b) = 20.7 E_{645} - 4.34E_{665} - 4.42E_{630}$$

$$C \text{ (Chlorophyll } c) = 55 E_{630} - 4.64E_{665} - 16.3 E_{645}$$

Where, **E** = Absorbance at different wave length obtained and corrected by the 750nm reading

The Concentration of pigments in the sample,

$$\text{mg/pigment/m}^3 = C * 10/V$$

Where, **C** is the value obtained from the Strickland and Parsons equation and **V** is the volume of water filtered.

In fluorometer, concentration of chlorophyll corresponds to the emission of light by the sample. Chlorophyll *a* absorbs the blue light and fluoresce in the red region of the electromagnetic spectrum. In HPLC phytoplankton biomass estimated through the quantification of specific marker pigments of each taxa.

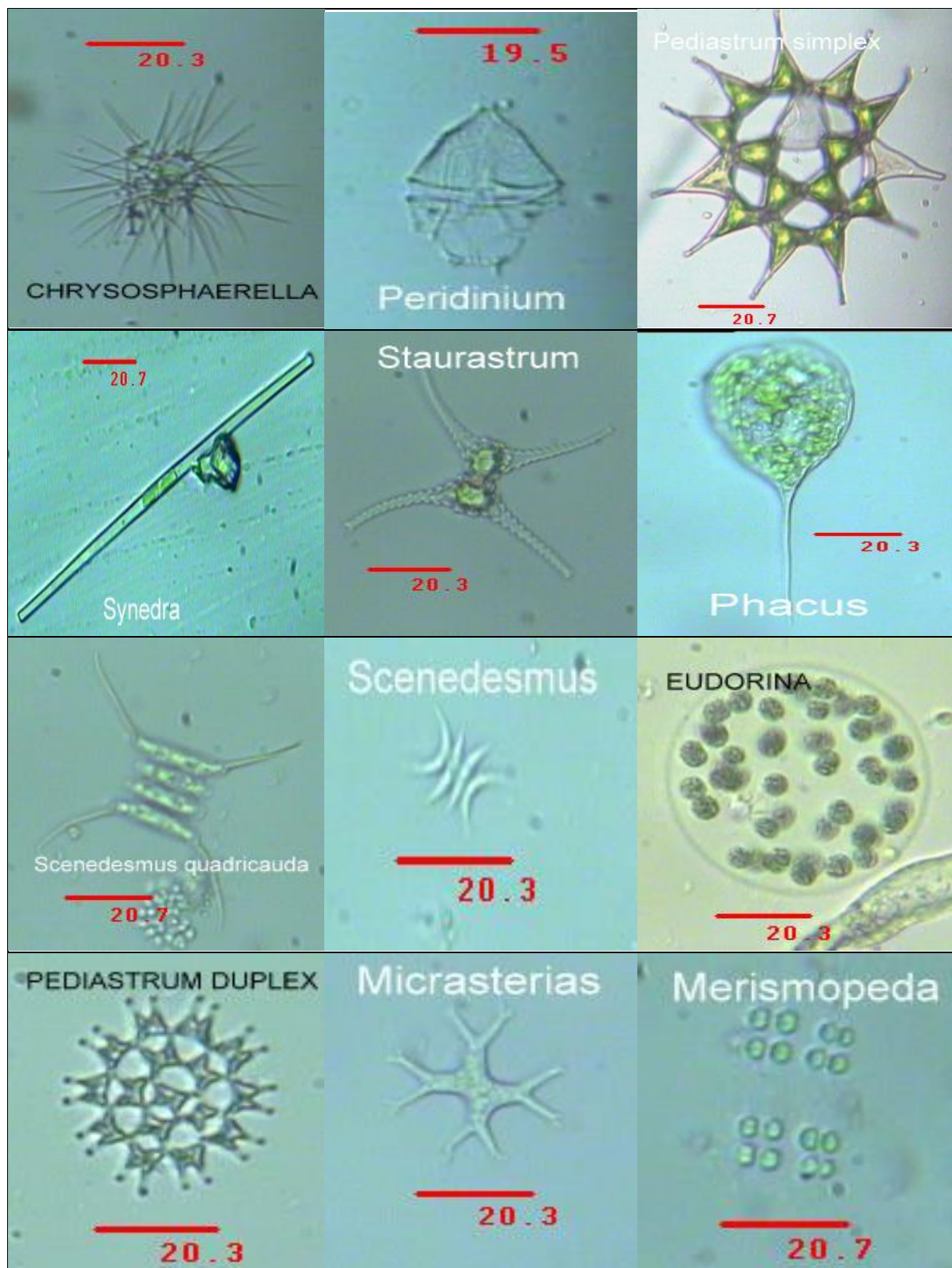
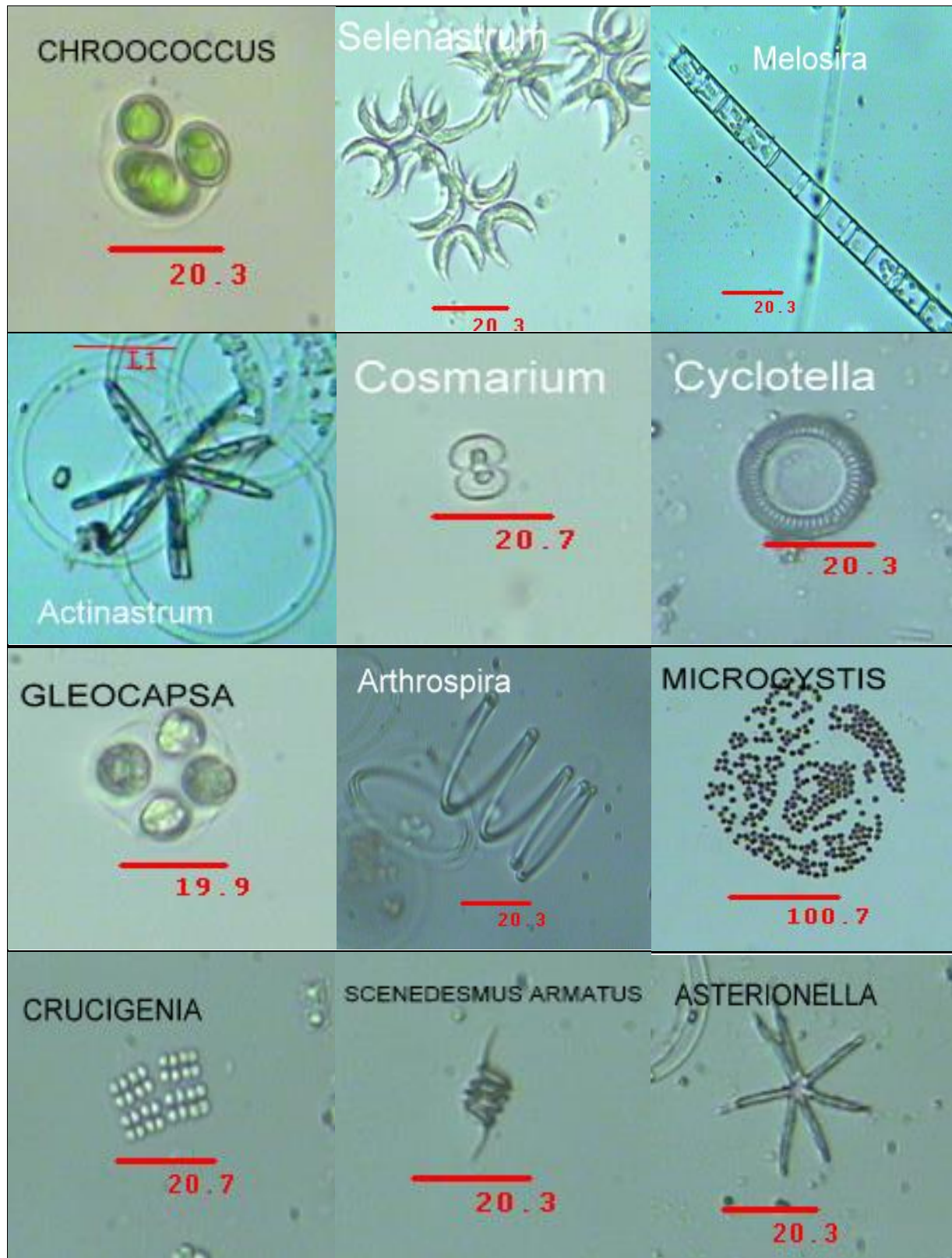
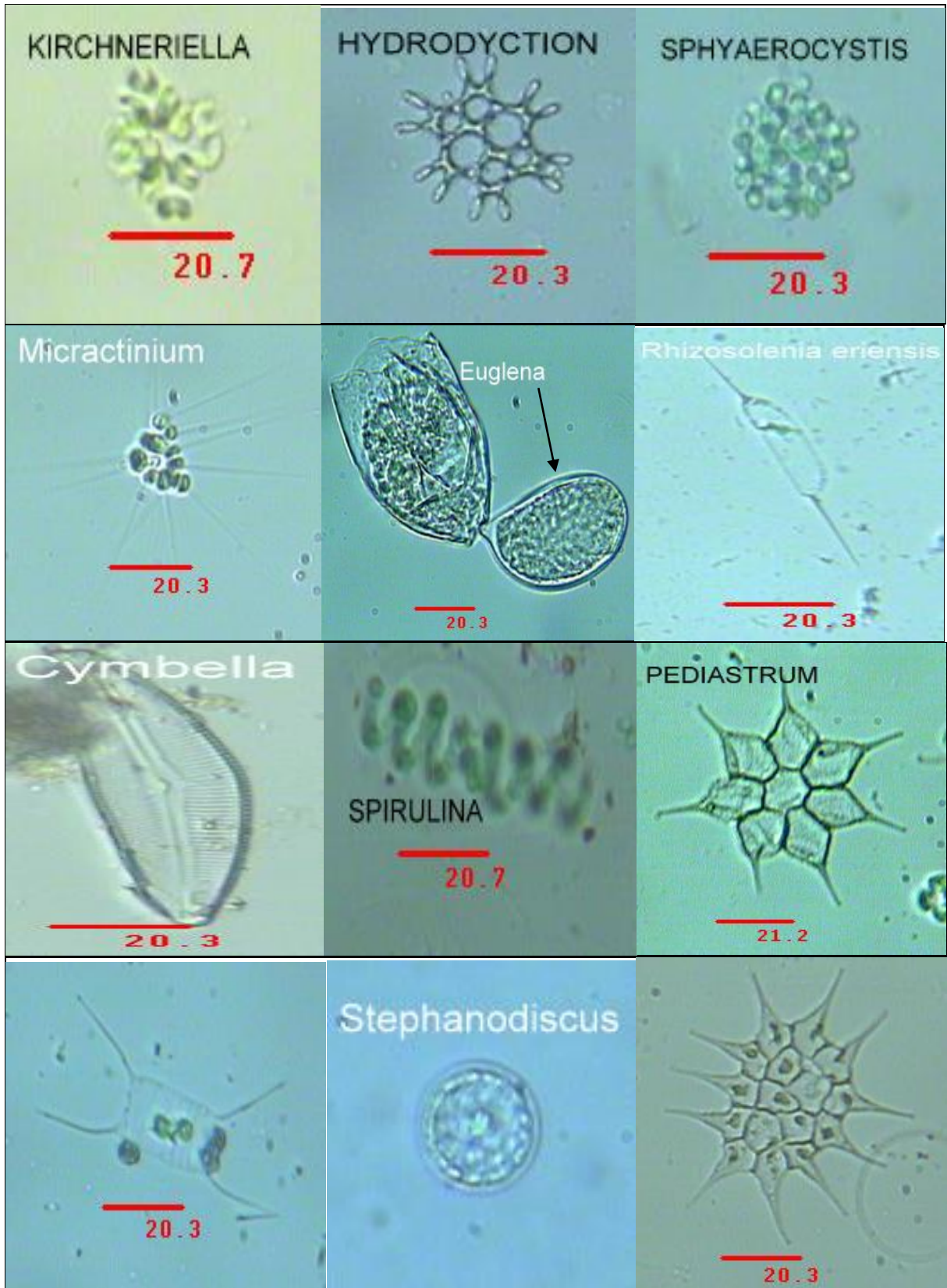
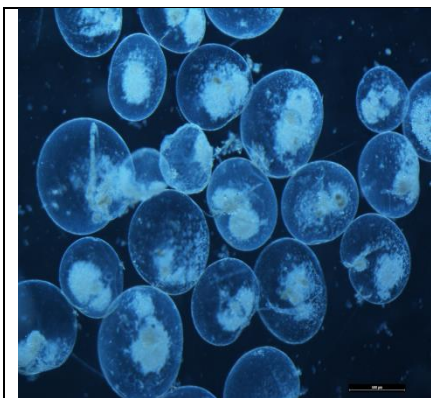
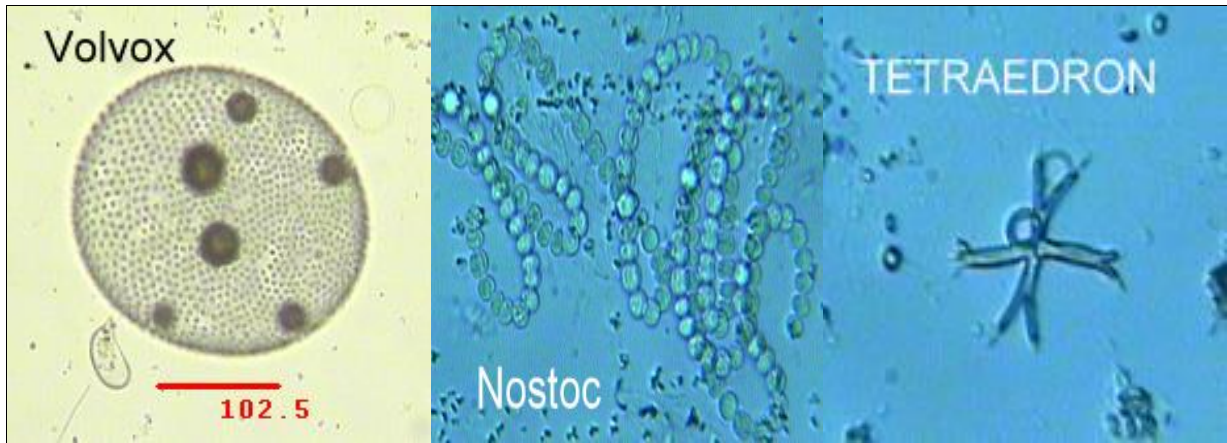


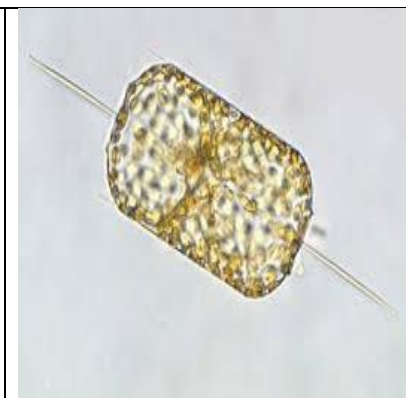
Fig. Common phytoplankters seen in aquatic systems (including fresh water and marine)







Noctiluca



Ditylum



Ornithocercus



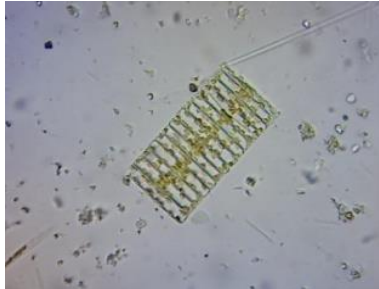
Surirella sp.



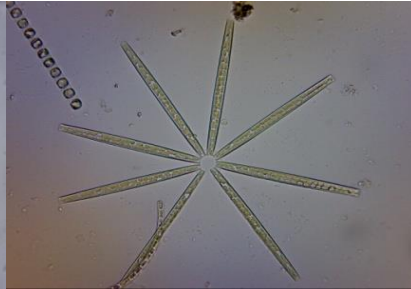
Ceratium sp.



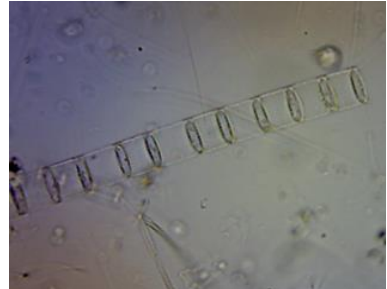
Planktoniella sol



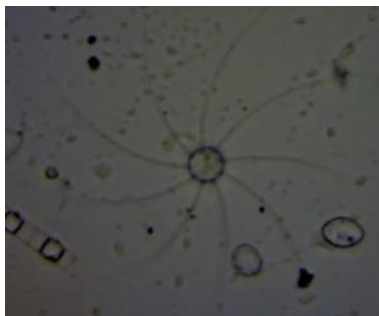
Fragilaria sp.



Thalassiothrix sp..



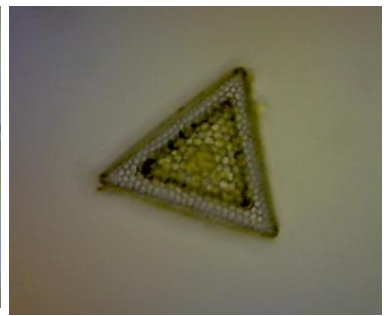
Skeletonema costatum



Bacteriastrum sp.



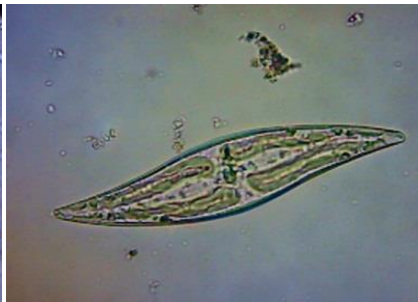
Navicula sp.



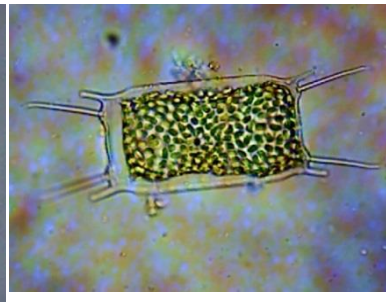
Triceratium sp.



Protoperidinium sp.



Pleurosigma sp.



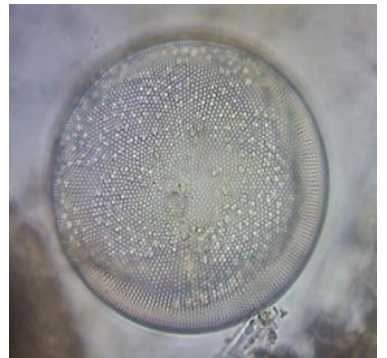
Biddulphia sp.



Rhizosolenia sp.



Chaetoceros sp



Coscinodiscus sp.

Mesozooplankton

Mesozooplankton comprises of a taxonomically diverse array of heterotrophic organisms spanning size range of 0.2 -20 mm. They form a vital intermediary link in the pelagic food web transferring carbon produced by primary producers (Phytoplankton) to higher trophic levels exploitable by man. Their wide distribution patterns, diversity and their crucial role in the trophodynamics of the aquatic ecosystem make them the chief index of the utilization of aquatic biotopes at the secondary level. Moreover, their significance in the nutrient regeneration and biogeochemical cycling of aquatic ecosystems further makes planktonology an inevitable part of ecological monitoring programmes.

Classification of mesozooplankton based on duration of planktic stage

1. *Holoplankton* are those organisms that spend their entire life drifting in the water column. They include representatives of nearly every phylum of the animal kingdom.
Eg: Copepoda, Ostracoda, Appendicularia
2. *Meroplankton* - Almost all aquatic organisms, be they are nekton or benthos are known to have a planktic stage in their life cycle and based on the duration they spend as plankton in the pelagic realm before getting transformed either as nekton or benthos are categorized as meroplankton.
Eg: Trochophore and veliger larvae of benthic worms and molluscs; nauplii and zoea of bottom and surface living crustaceans and also eggs and larvae of fin fishes.

Classification of mesozooplankton based on body composition

Zooplankton, based on their external body composition are categorised as

1. *Crustacean zooplankton*, are mainly the arthropodan representatives armed with chitinous exoskeleton. Predominant crustacean representatives include taxa like Copepoda, Ostracoda, Mysidacea, Amphipoda and Isopoda.
2. *Gelatinous zooplankton*, are mesozooplankton having more than 90% of water content in their body. Common gelatinous zooplankton representatives are Hydrozoa, Ctenophora and the appendicularian representatives like Salps and Doliolids.
3. *Gastropod zooplankton*
Pteropod and Heteropod molluscs often constitute the major *gastropod* members among the mesozooplankton community.

Collection and Preservation of mesozooplankton

In shallow estuaries and coastal waters, mesozooplankton are collected by towing a Working Party 2 (WP-2) net, of mesh size ranging from 70 to 200 μm and mouth area 0.28 m^2 . The net is towed horizontally just below the surface (speed ~ 1 knot) for 10

minutes. A digital flow meter (Hydro Bios, Model- 438110) attached across the mouth of the net estimates the volume of water filtered through the net. For obtaining vertically stratified plankton samples from oceanic regions, a Multiple Plankton Net comprising of an assemblage of five nets are often used. Each net is used to collect samples of a particular depth zone and are controlled by ship board electronic sensors. The zooplankton samples collected are preserved immediately in 4% formaldehyde solution.



Working party net

Biomass (ml. m⁻³) and abundance (ind. m⁻³) estimation

Biomass of zooplankton is generally measured following the displacement volume method, after removing the large detrital particles and gelatinous organisms and is expressed as ml. m⁻³. Later, the mixed zooplankton samples are manually sorted in the laboratory into their respective taxa. The abundance of each taxa can be estimated by counting all the individuals present in the sample or in aliquots depending on the biovolume. Samples having a displacement volume greater than 5 ml biovolume can be subdivided into aliquots of adequate measure, either using a Folsom splitter or a Stempel pipette.



Fig: Folsom Splitter



Bogorov's counting chamber

Image courtesy: Hydrobios

Enumeration of mesozooplankton

The segregated zooplankton taxa from the sample are enumerated using a Bogorov's counting chamber under a stereo zoom microscope.

The abundance of each taxonomic group can be calculated as,

$$\text{Abundance}(\text{ind. m}^{-3}) = \frac{\text{Number of organisms}}{\text{Volume of water filtered}(\text{m}^3)}$$

The relative contribution of particular taxon towards the total zooplankton population can be calculated as,

$$\text{Relative abundance} = \frac{\text{Number of individuals of a particular taxon}}{\text{Total number of organisms}} \times 100$$

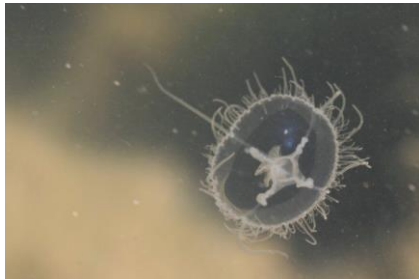
Taxonomic Identification of mesozooplankton

Zooplankton, collected by employing various methods such as vertical and horizontal towing of plankton nets of different mesh sizes, light traps to attract migrating organisms, plankton pumps for continuous water filtration, are preserved onboard using 4% formalin. Once collected, mesozooplankton samples undergo meticulous identification procedures. After biomass estimation, samples are sorted under a dissecting microscope to separate them into various taxonomic groups based on their morphology and size. Subsequently, detailed morphological analysis is conducted using compound microscopes, often aided by identification keys and atlases. Molecular techniques such as DNA barcoding and sequencing provide additional accuracy, particularly for cryptic or morphologically similar species. Staining methods highlight specific structures, while digital imaging systems and software assist in rapid identification and enumeration. Through these integrated approaches, researchers can accurately assess zooplankton species composition, abundance, and distribution, elucidating their vital role in aquatic ecosystems.

Major mesozooplankton groups

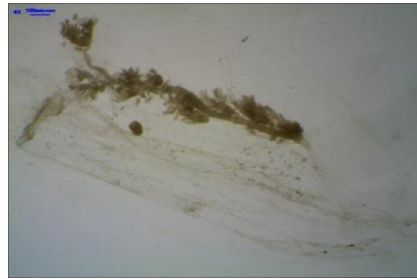
Phylum Cnidaria

- Class Scyphozoa
- Gelatinous organism
- ✓ Umbrella shaped body



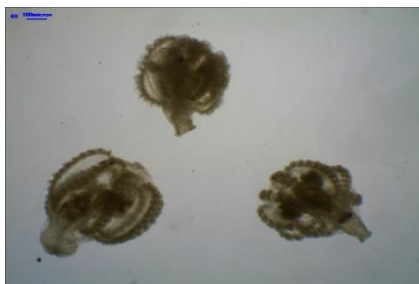
Phylum Cnidaria

- Class: Hydrozoa
- Order: Siphonophorae
- Bell shaped body



Phylum Ctenophora

- ✓ "Comb Jellies"
- ✓ Eight comb plates



Phylum: Chaetognatha

- "Arrow worms"
- Carnivorous organism
- Torpedo shaped body



Phylum: Annelida

- Class: Polychaeta
- Order: Tomopteridae
- Holoplanktonic



Phylum Arthropoda

- Sub phylum: Crustacea
- Subclass: Copepoda
- "Insects of the sea"
- Dominant zooplankton
- Largest biomass on earth

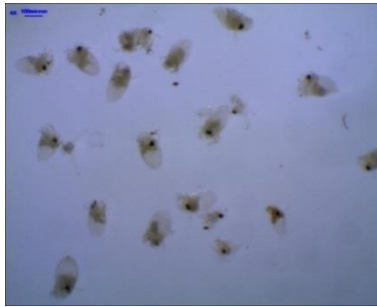


Phylum Arthropoda

- Order: Cladocera
- "Water fleas"
- 0.2-0.6mm
- Mostly freshwater or neritic

Phylum Arthropoda

- Order: Mysida
- Brood pouch in females
- Statocyst in uropods
- Pleopods absent or reduced



Phylum Arthropoda

- **Order: Euphausiacea**
- “Krill”
- Exposed gills
- Large brown eyes



Phylum Arthropoda

- **Family: Luciferidae**
- “Light bearer”
- Long rostrum
- Estuarine or Neritic



Phylum Arthropoda

- **Order: Amphipoda**
- “Different footed”
- Scavengers & detritivores
- Hyperiididae -planktonic



Phylum Arthropoda

- **Order: Isopoda**
- “Similar footed”
- Dorsoventrally flattened



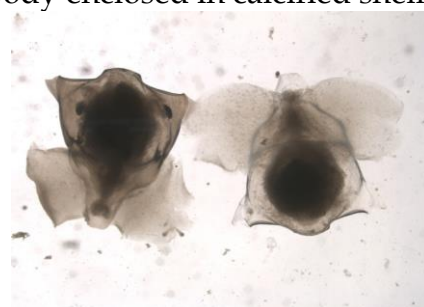
Phylum Arthropoda

- **Class: Ostracoda**
- 0.2 -30 mm in size
- Bioluminescent



Phylum Mollusca

- **Pteropoda**
- **Thecosomata -Sea butterflies**
- Holoplanktonic gastropods
- Body enclosed in calcified shell



Phylum Mollusca

- **Super family: Pterotracheoidea**
- Heteropods /Sea elephants
- Transparent body without shell



Phylum Chordata

- **Subphylum: Tunicata**
- **Class: Thaliacea**
- **Order: Doliolidae**
- Holoplanktonic
- Gelatinous
- Barrel shaped



Phylum Chordata

- **Class Appendicularia**
- **Order: Copelata**
- Gelatinous holoplankton
- Solitary tunicates
- Lives inside house/ test of protein
- Shape resembles tad pole larvae



Phylum Chordata

- **Subphylum: Tunicata**
- **Class: Thaliacea**
- **Order: Salpidae**



Meroplanktonic Crustaceans

Zoea



Megalopa



Mysis



Alima
Stomatopoda larvae



Phyllosoma
Lobster larvae



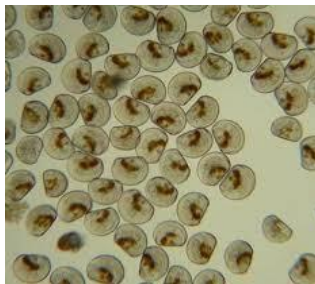
Cypris
Barnacle larvae



Pic courtesy: wikipedia

Meroplanktonic molluscs

Bivalve larvae



Gastropoda larvae

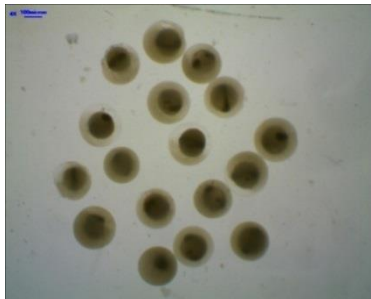


Cephalopod larvae

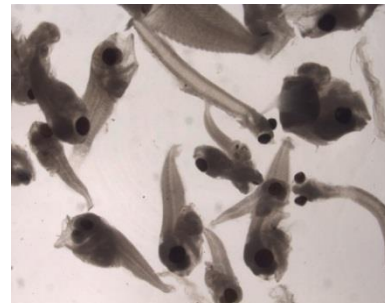


Meroplanktonic chordates

Fish eggs



Fish larvae



MAPPING FOR TAXONOMIC STUDIES

Dr. Shelton Padua

Senior Scientist, ICAR-CMFRI, Kochi

Introduction

Geographic Information Systems (GIS) play a crucial role in taxonomic studies and related research. One of the important applications is making location maps from where the samples have been collected. This helps visualize species distribution patterns, identify biodiversity hotspots, and track changes in distribution over time due to factors like climate change. By combining species occurrence data with environmental data (like water temperature, depth, salinity) in a GIS environment, researchers can create models that predict the suitability of habitats for specific species. This can guide targeted collection efforts and identify areas potentially harbouring different species. GIS also helps in designing marine protected areas (MPAs) by considering factors like species distribution, habitat types, and human activities. It can also be used to monitor the effectiveness of MPAs in protecting marine biodiversity. By overlaying species distribution data with geographic features like currents, oceanographic boundaries, and geological formations, GIS helps researchers understand the factors influencing biogeographic patterns in the marine environment. Moreover, GIS facilitates the integration of data from various sources, such as field surveys, remote sensing, and historical records. This promotes collaboration among researchers by allowing them to share and analyze data in a centralized platform. Thus, GIS plays a crucial role in advancing marine taxonomic studies by providing a powerful platform for data visualization, analysis, and modeling, leading to a better understanding of marine biodiversity and its distribution.

Basically, geographic information system (GIS) is a tool for making maps. GIS helps us in using spatial information and it is mainly concerned with the location of the features/individuals as well as properties/attributes of those features/individuals. 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 disciplines like geography, surveying, engineering, space science, computer science, cartography, statistics etc.

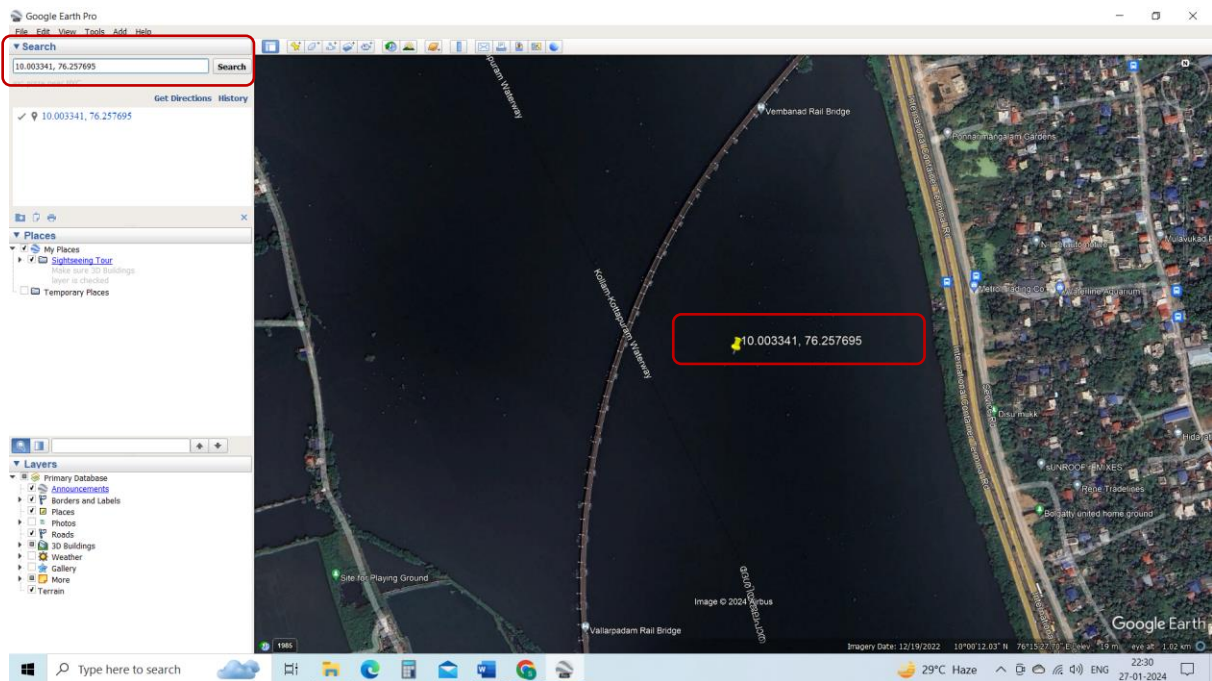
In GIS, we handle the spatial and attribute data sets. Spatial data describes the absolute and relative location of geographic features while attribute data describes characteristics of the spatial features. These characteristics can be quantitative and/or qualitative in nature. Attribute data is also 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.

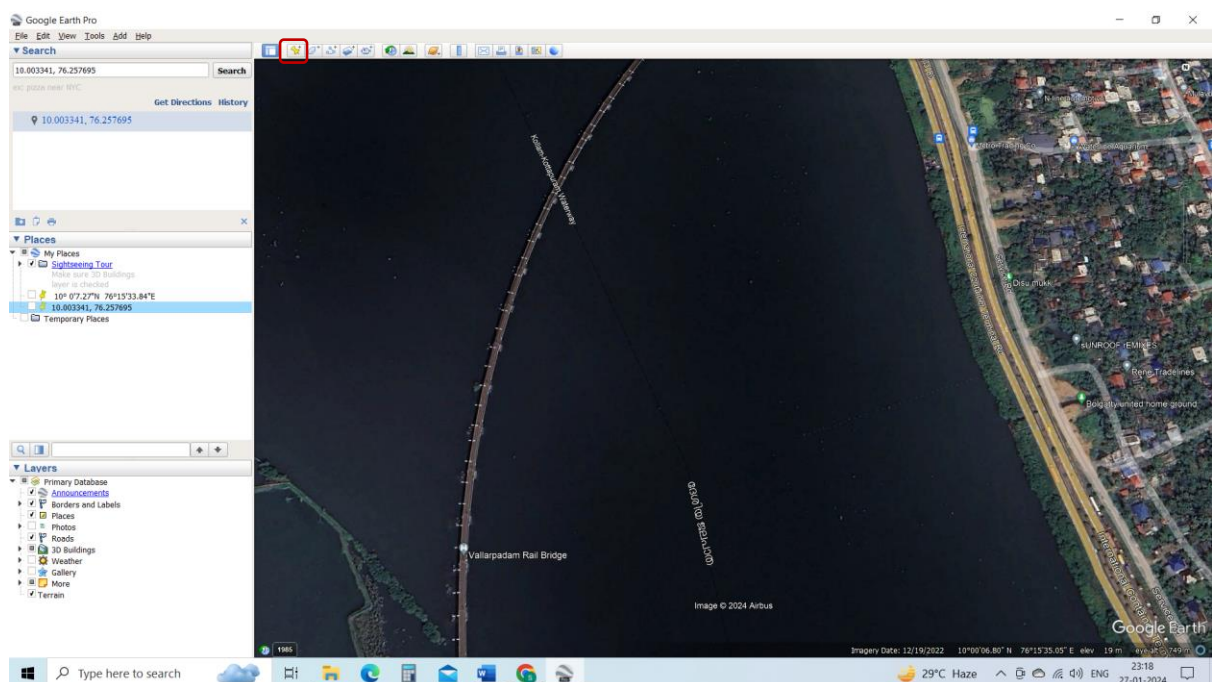
We will try to use two commonly available software (Google Earth and QGIS) for simple mapping.

Using Google Earth for Location Mapping

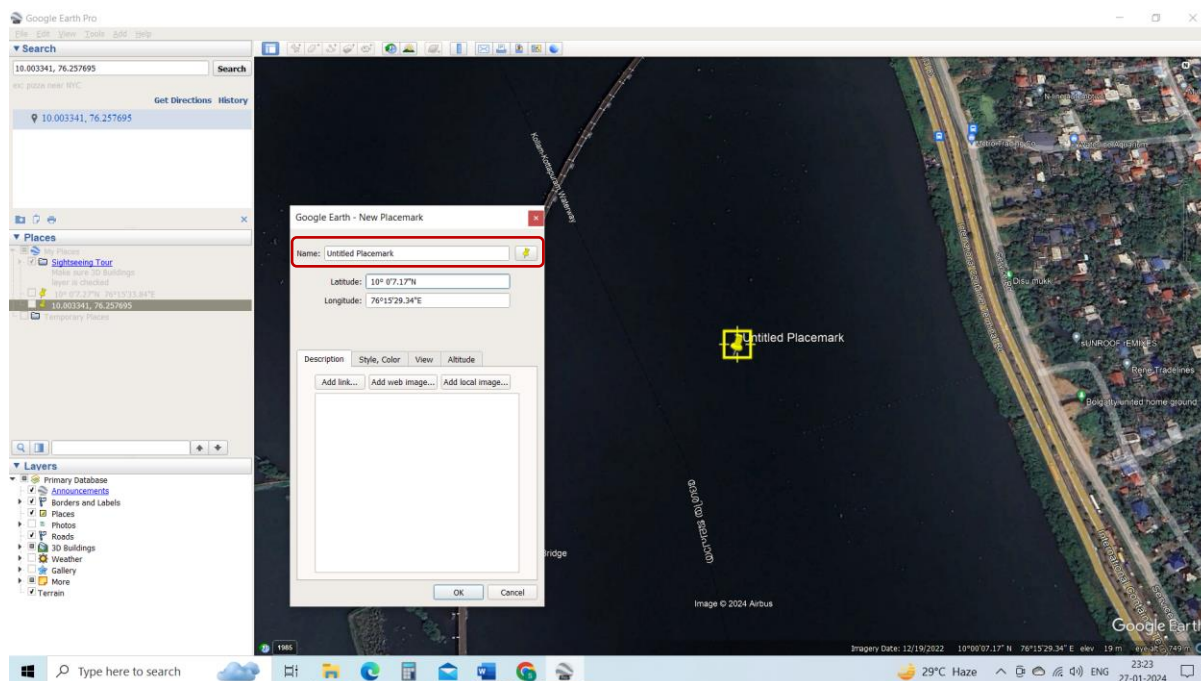
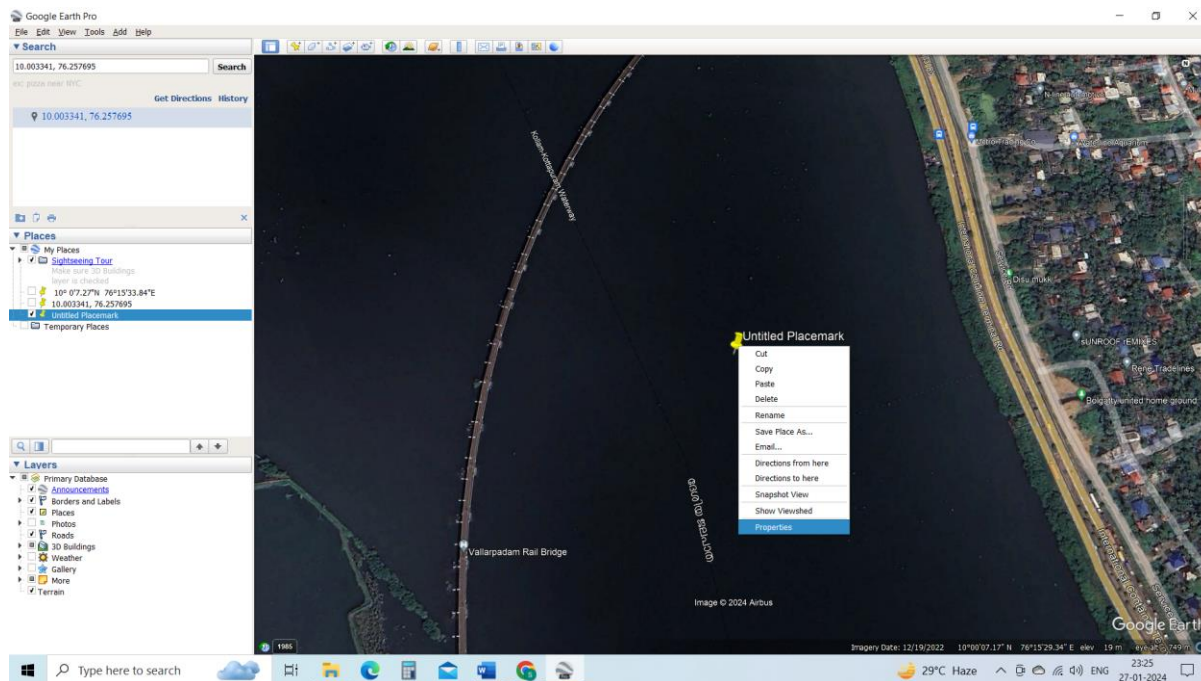
If you know the latitude and longitude of the location, type those coordinates in the search window and press the search button, a push button will be generated and it will be placed in the exact coordinates with the latitude and longitude visible.



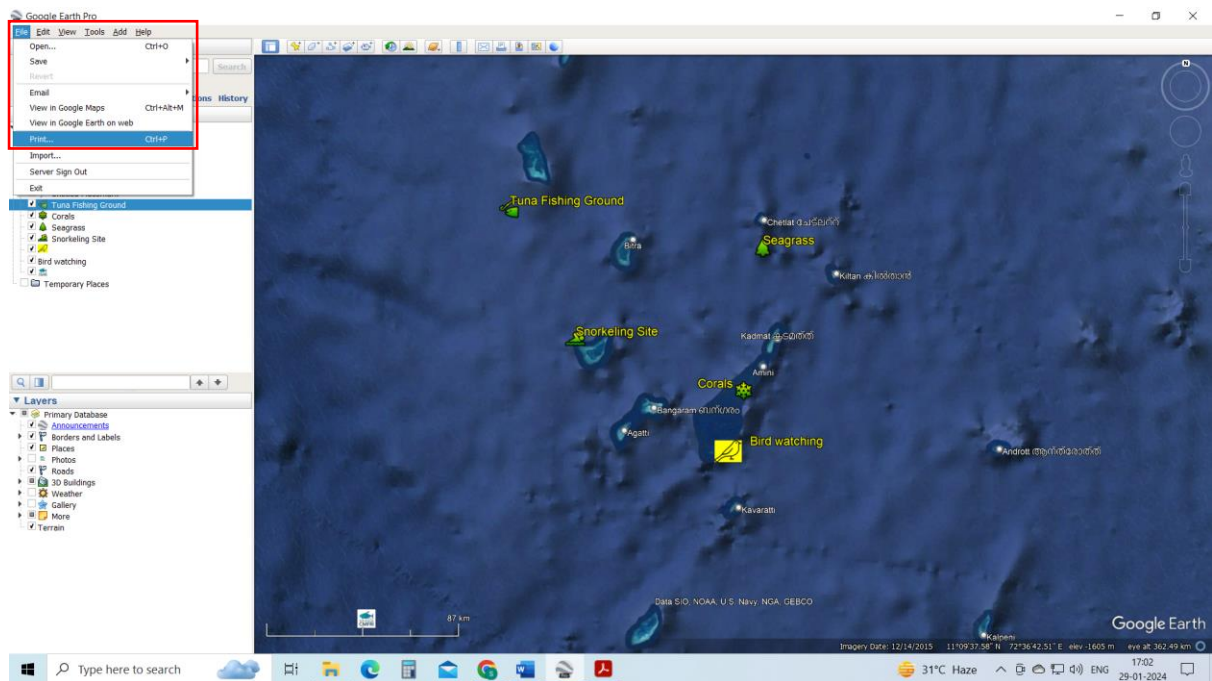
If you do not know the coordinates, but know the spot on the imagery, you can use the push button icon to add a place mark over the location. Using the properties menu of the place mark, one can do the required modifications like changing the place mark title, icon style etc.



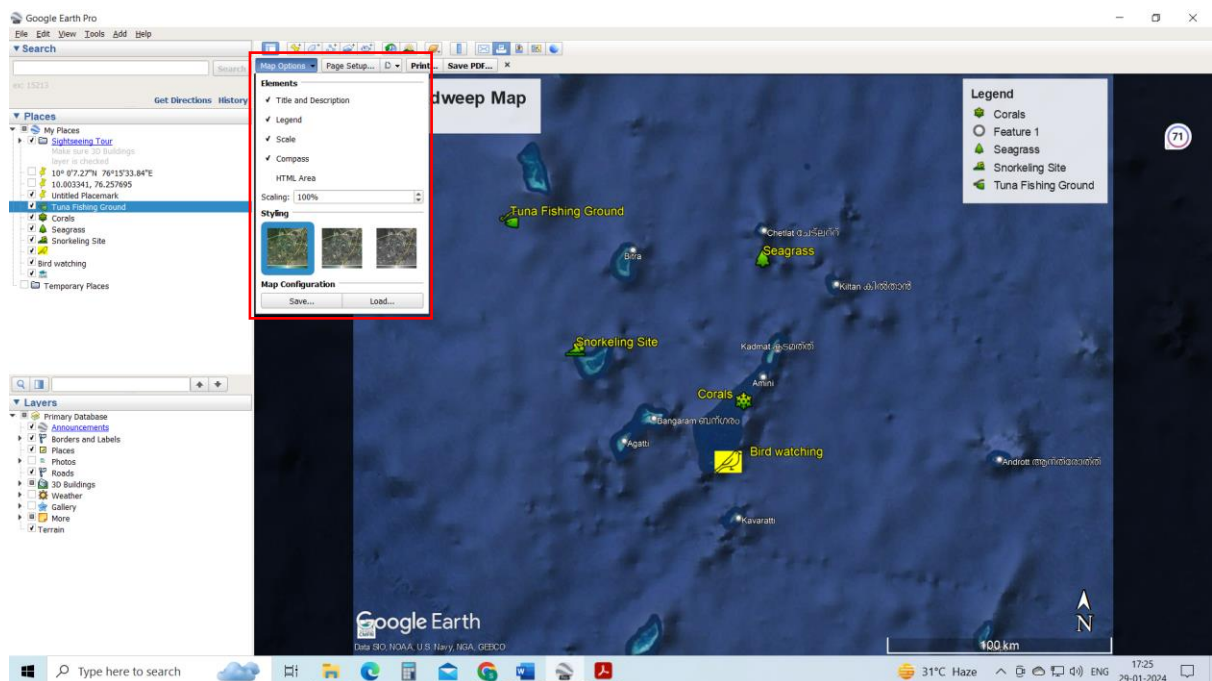
Right-clicking the placemark icon will open drop-down menu showing the properties button using which you can change the placemark icon properties and do the editing.



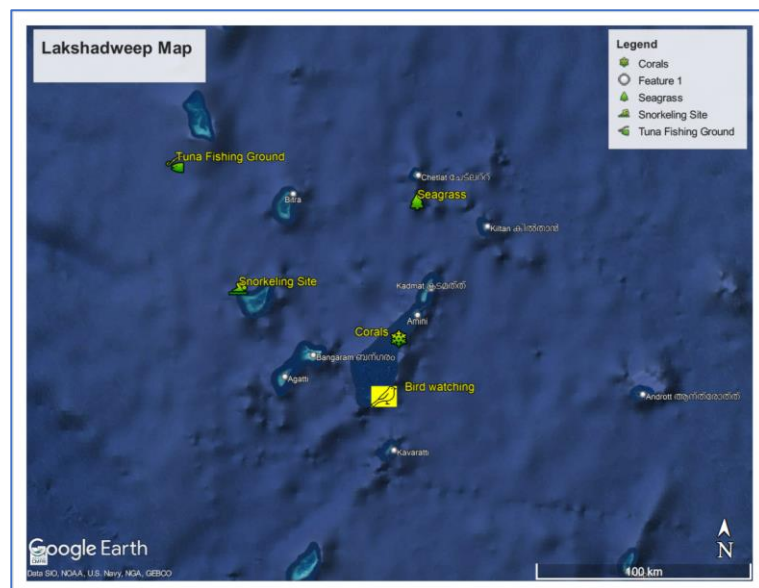
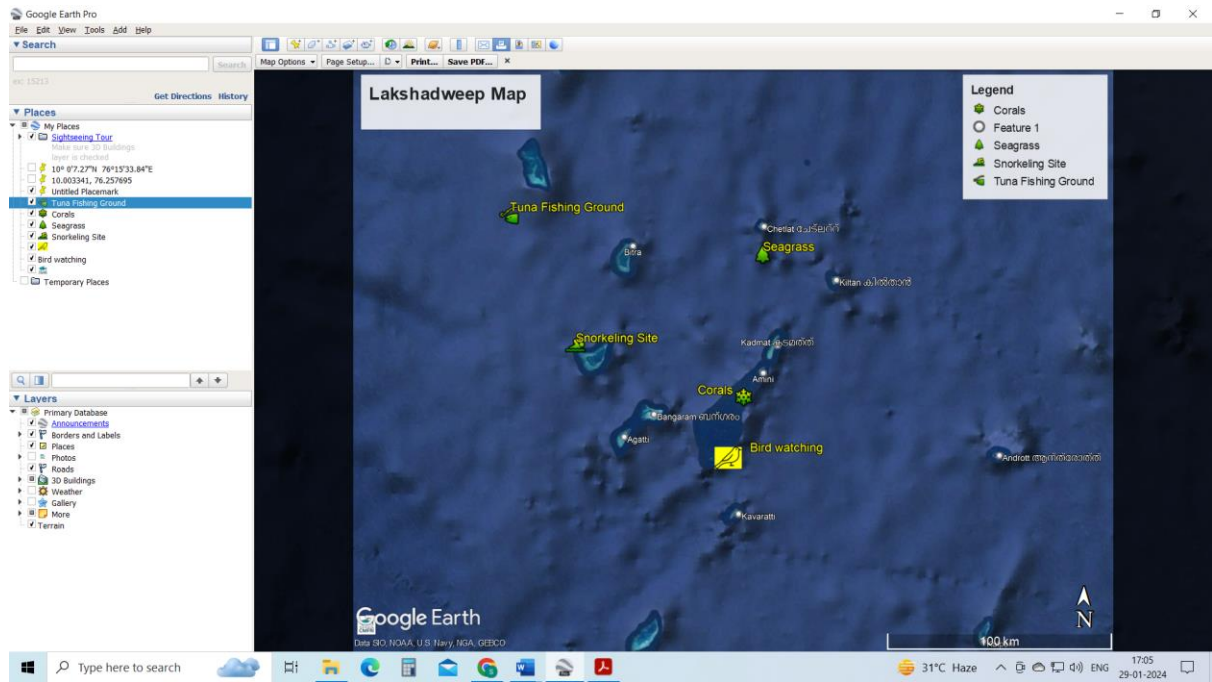
Once you are finished adding the placemarks, you can make the map composition from the print option of the File menu.



It will open up the print composition window using which you can add the map elements like Title, north arrow, legend and scale from the 'Map options' menu.



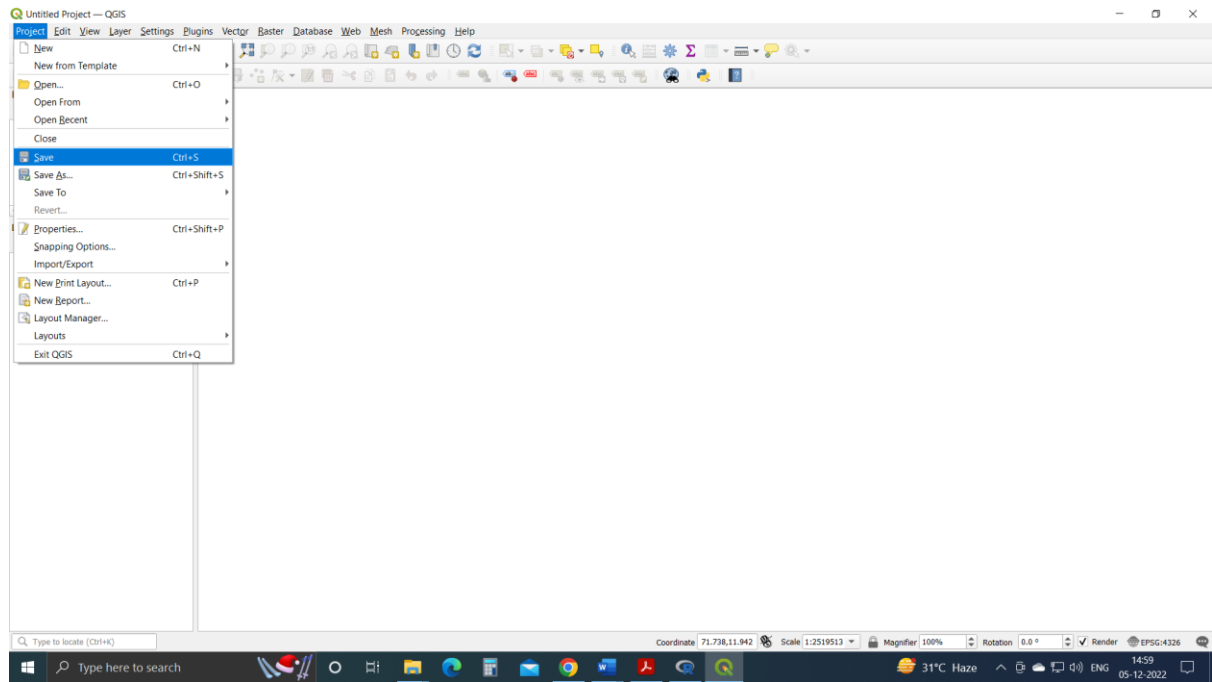
Make necessary editing in the map elements and save the map/print the map.



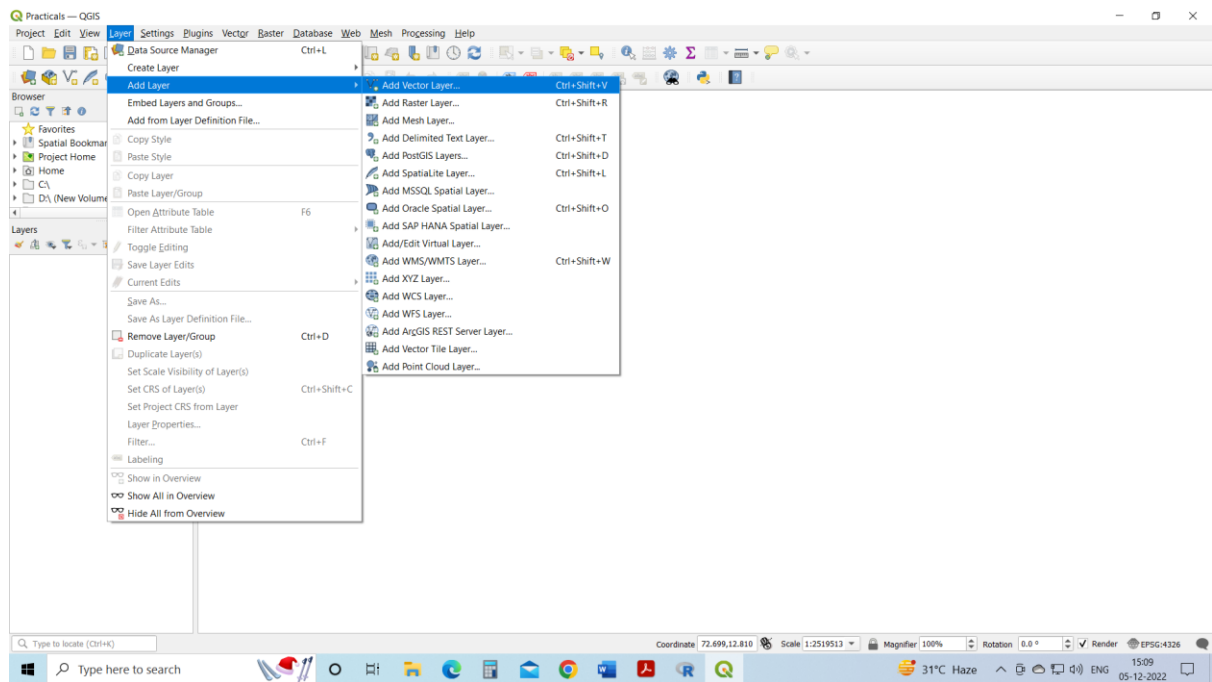
Making a Simple Location Map Using QGIS

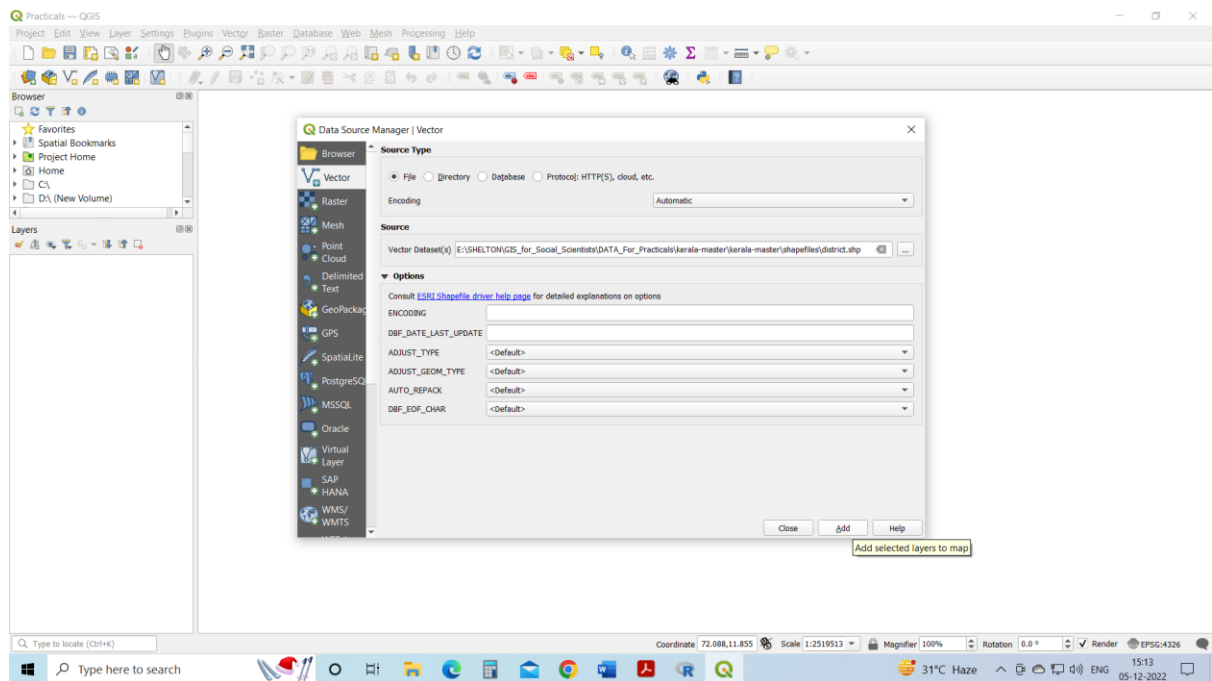
Here we learn to make a simple location map.

Open the QGIS software and give a name to the project. (Open QGIS>Project Menu>Save>give file name (Practicals.qgz))

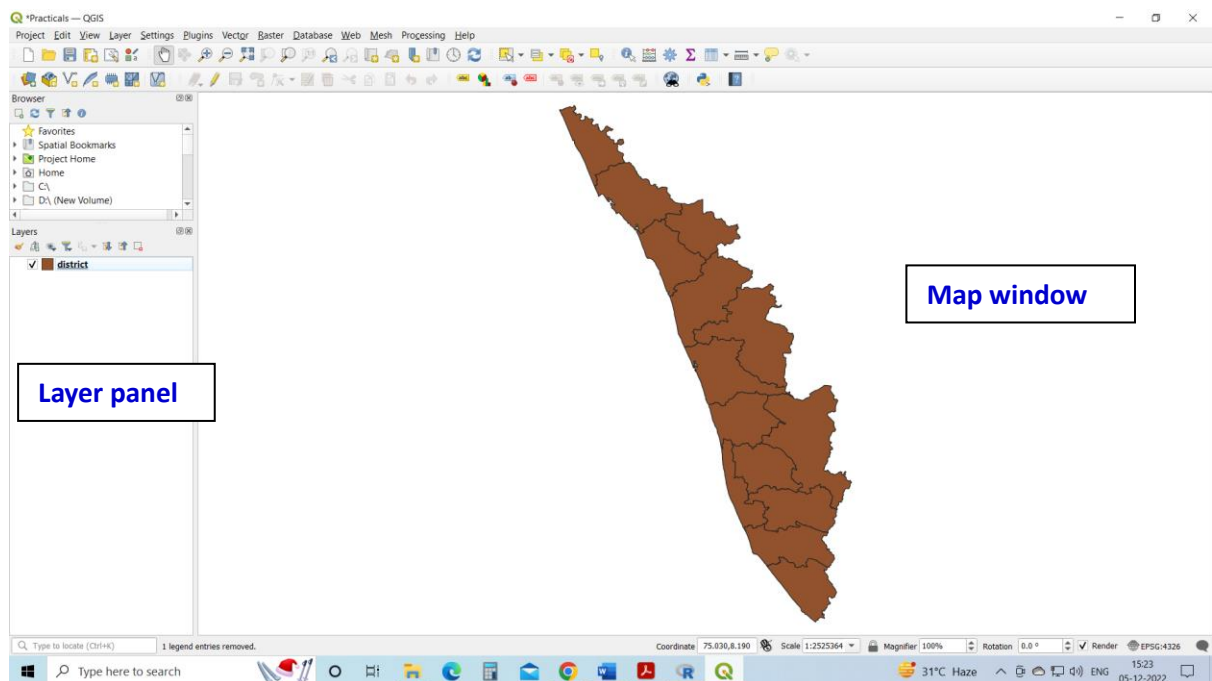


Now, load the shape file (District.shp). Layer Menu > Add Layer> Add Vector Layer> select the file name (District.shp)>Add.



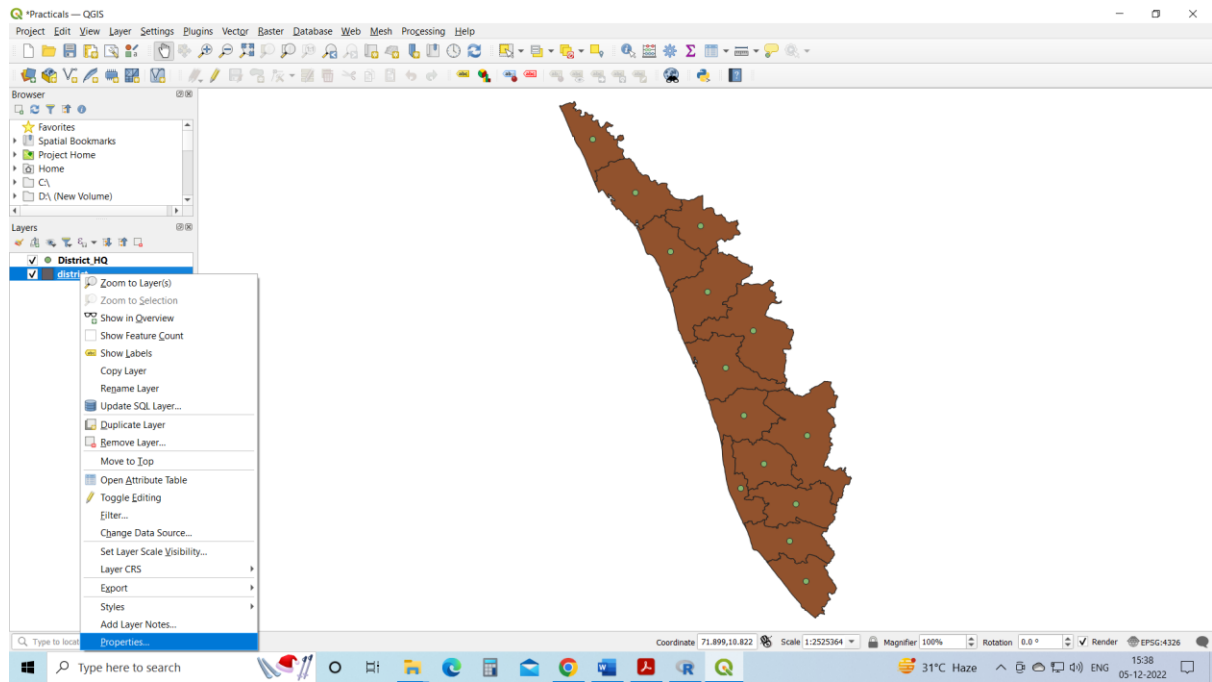


Now the Districts will appear in the map window and we can modify the appearance of the districts using the Layer panel.

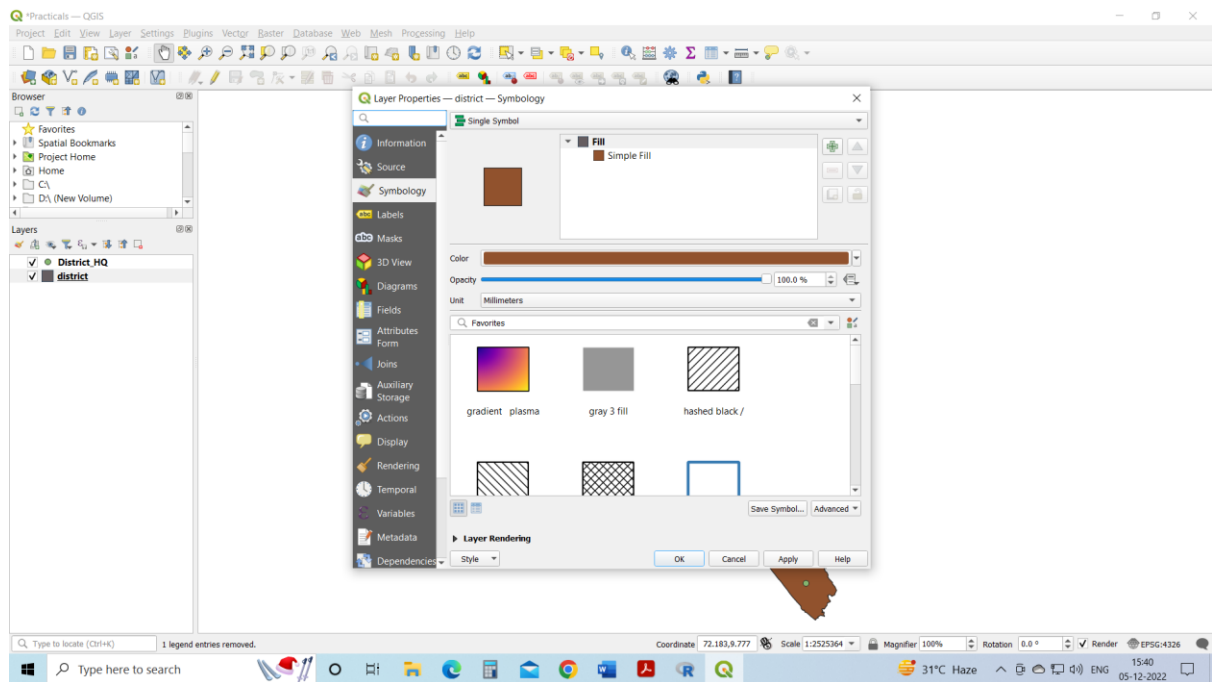


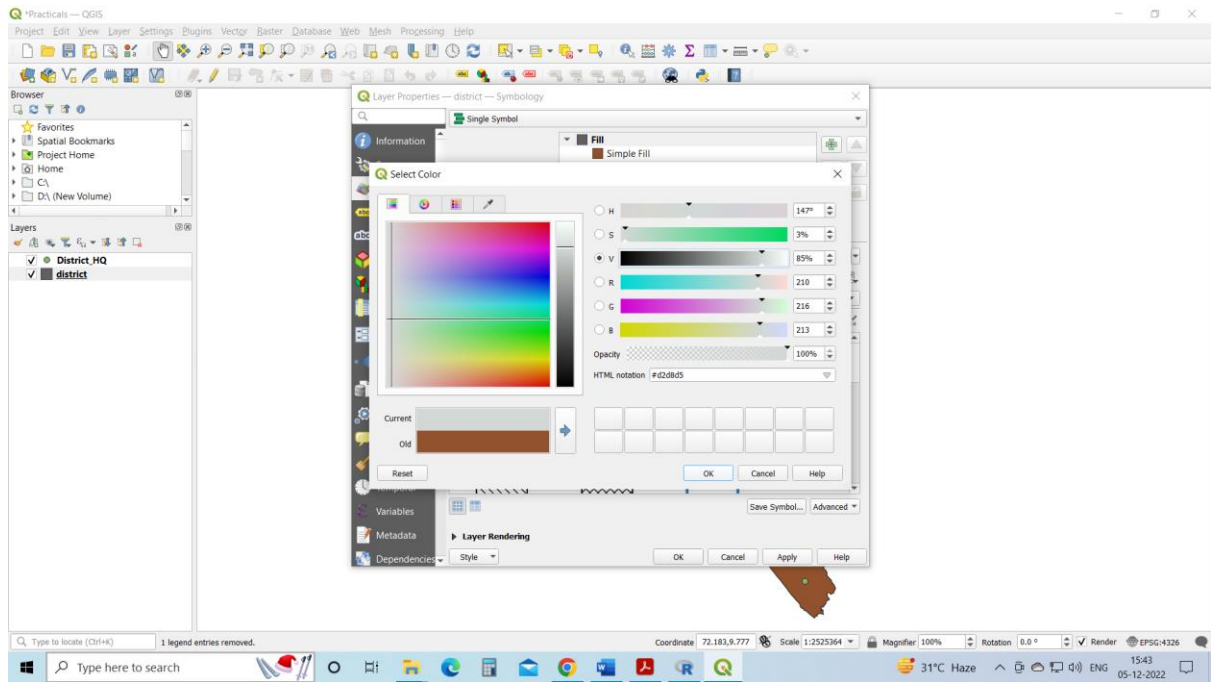
Likewise, add the file District_HQ.shp (Layer Menu > Add Layer> Add Vector Layer> select the file name (District_HQ.shp)>Add).

Now, we will change the appearance of the above vector files. Right-click the District.shp file in the layers menu to open its properties.



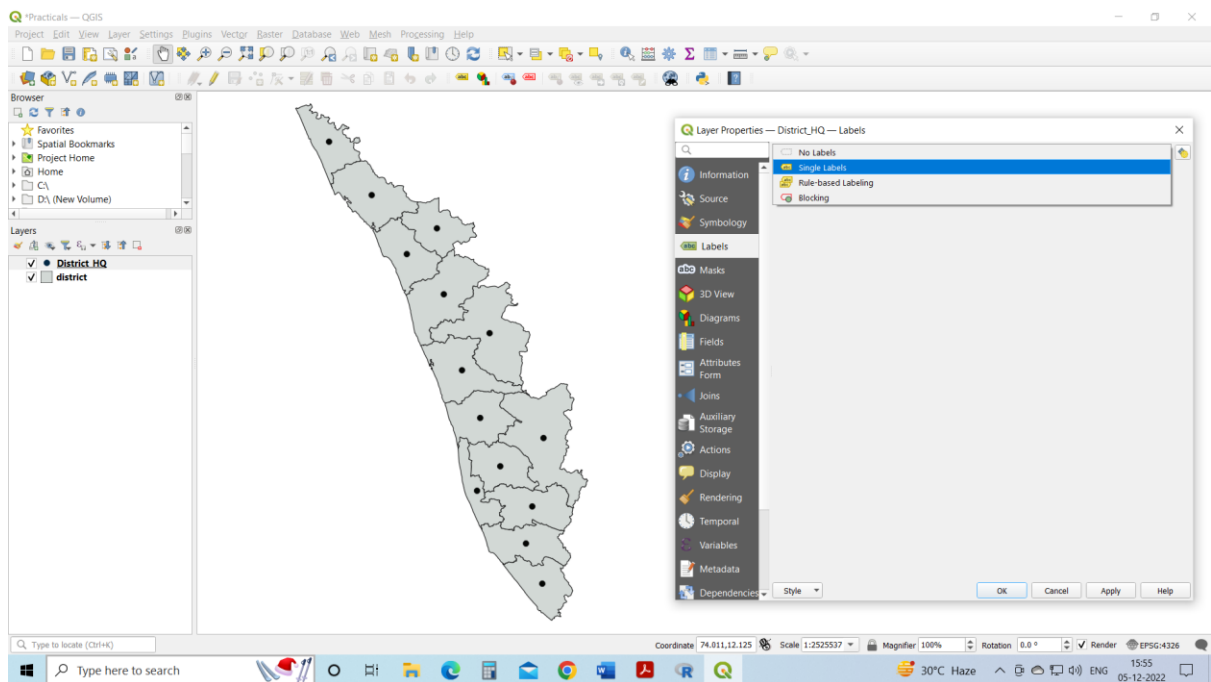
Then the Layer Properties window will appear. Then select the Symbology menu and change the colour of the polygon by clicking the colour bar in the window.



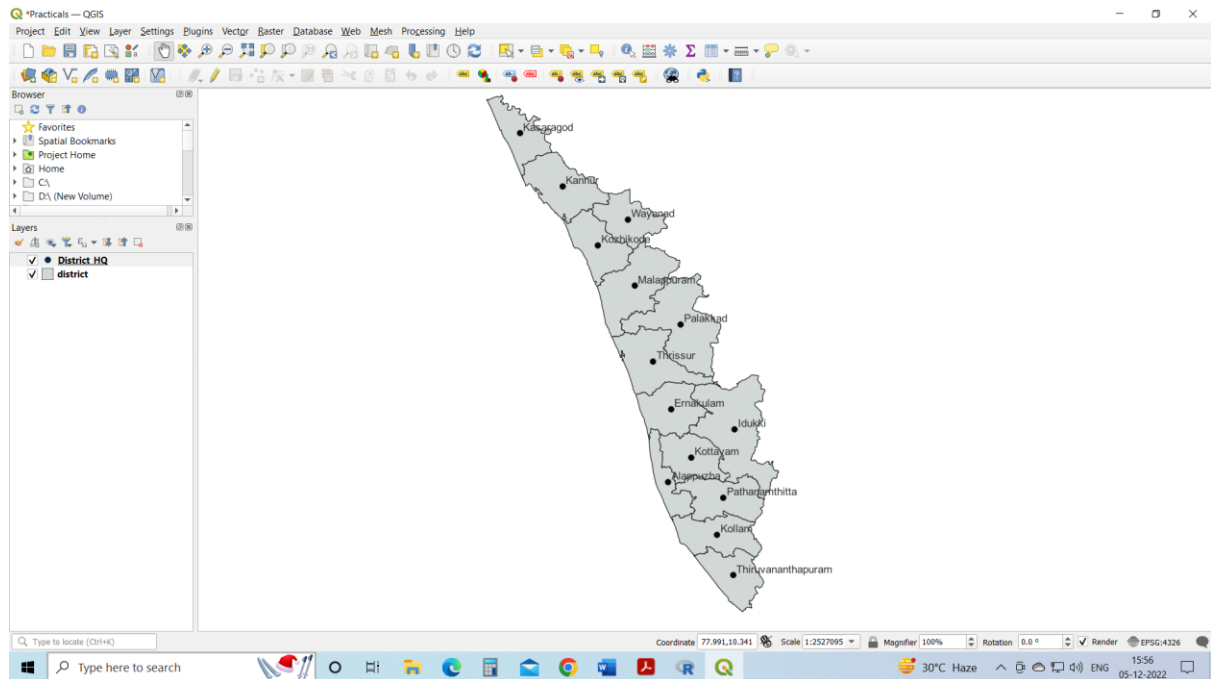


Likewise, change the colour of the District_HQ.shp file.

Now, we will add names to the points (District_HQ.shp). Right-click the District.shp file in the layers menu to open its properties. *Layer Properties* window will appear. Then select the Labels menu and change the selection from *No Labels* to *Single Labels*.

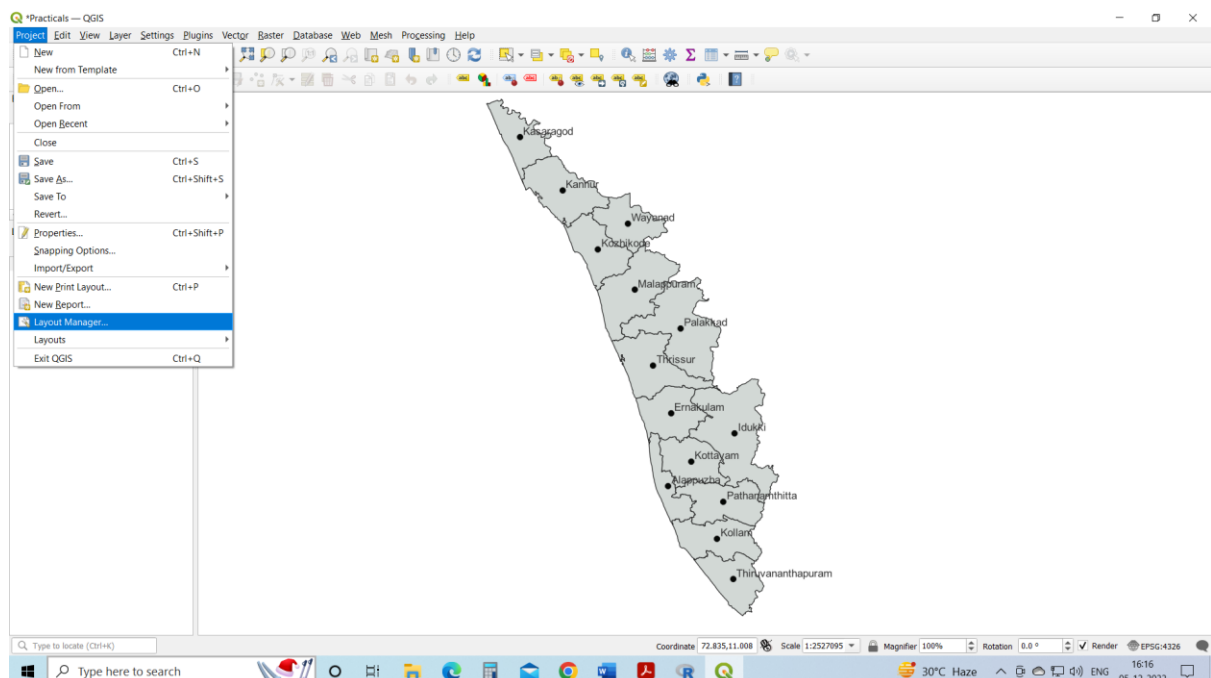


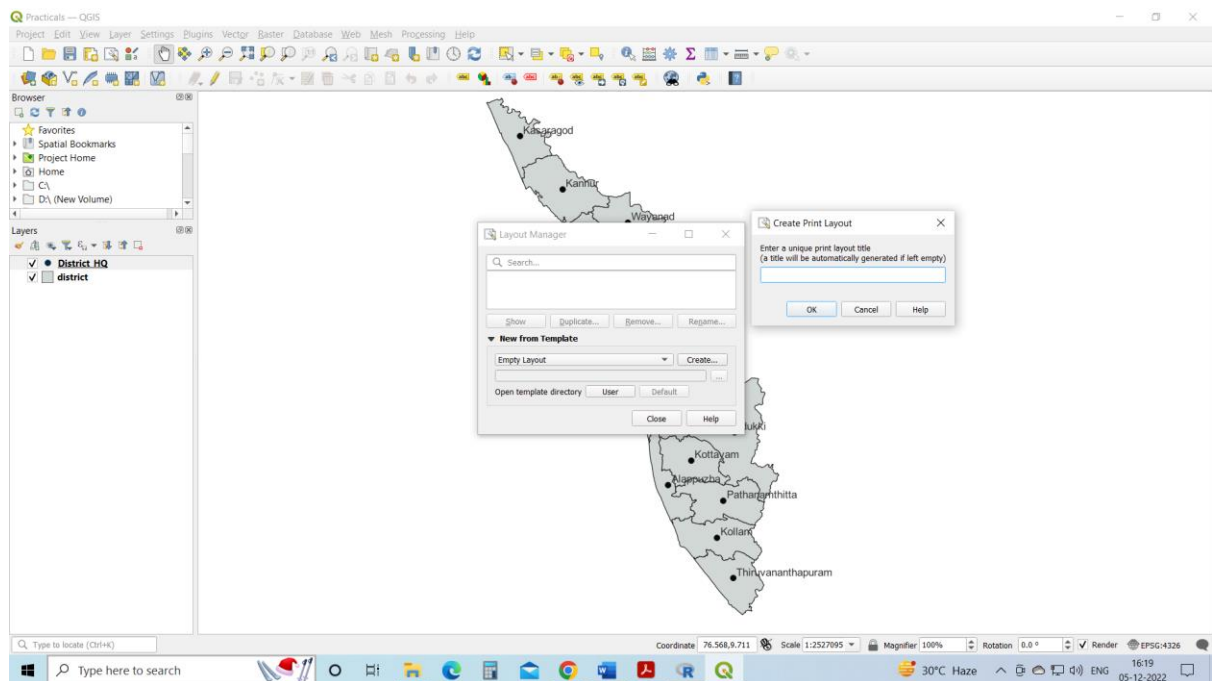
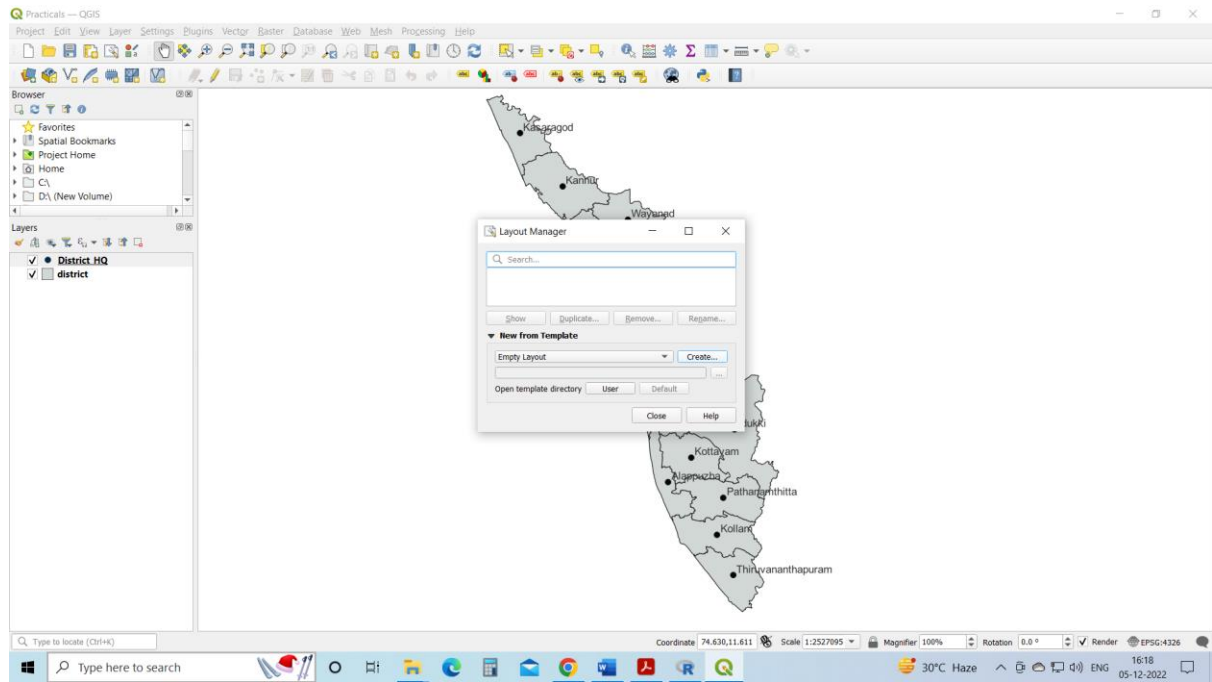
And click *Apply Button*. Now the District_HQ names will appear on the Map Window.



Now we will make a map layout from this data.

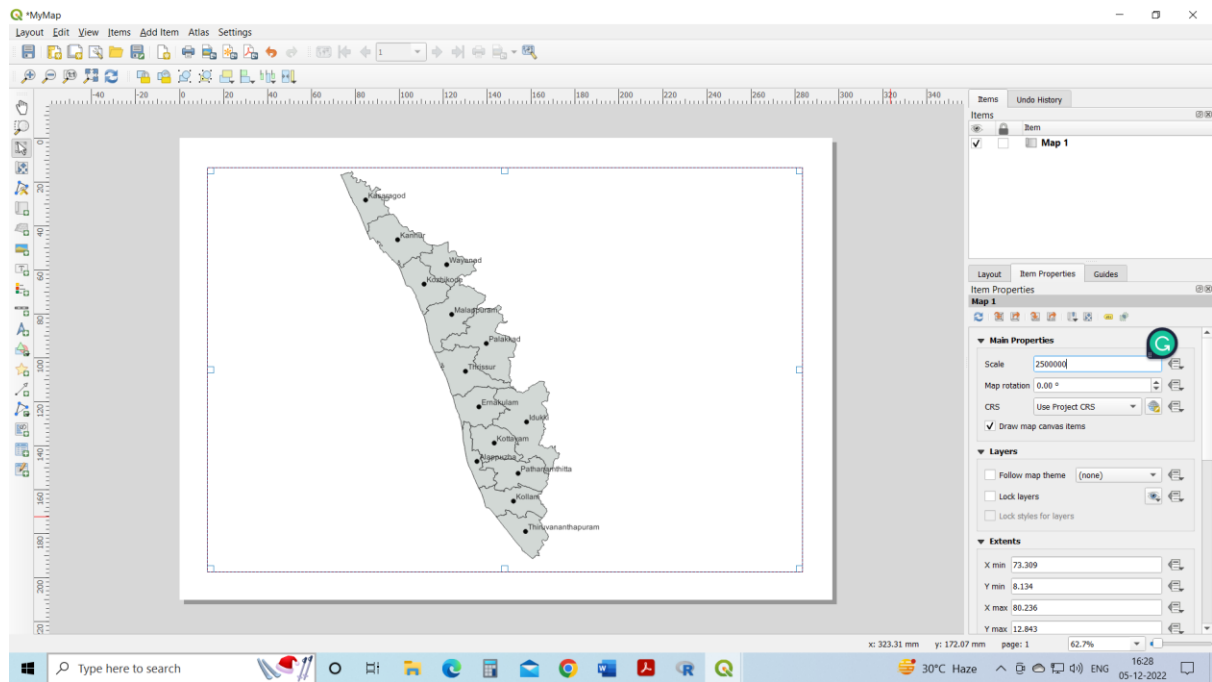
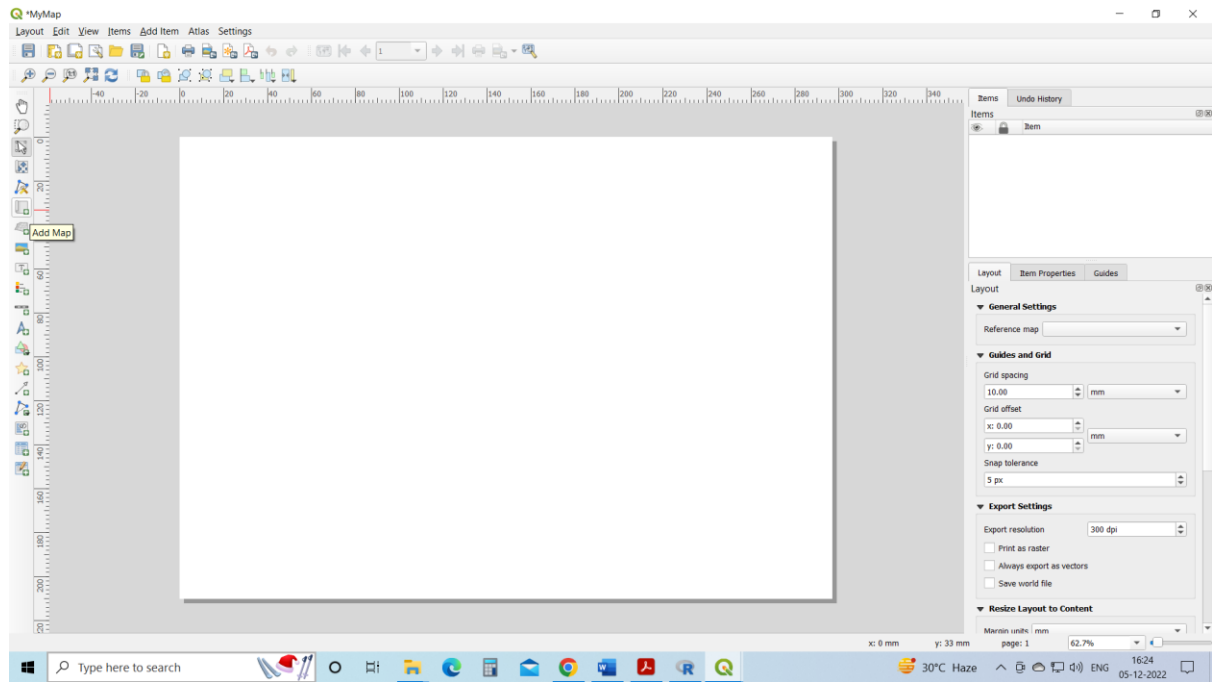
Go to the Layout Manager in the Project Menu (Project Menu>Layout Manager) and create an Empty Layout by clicking the create button in the Layer Manager, give a name for the Layout (*MyMap*) and press OK.



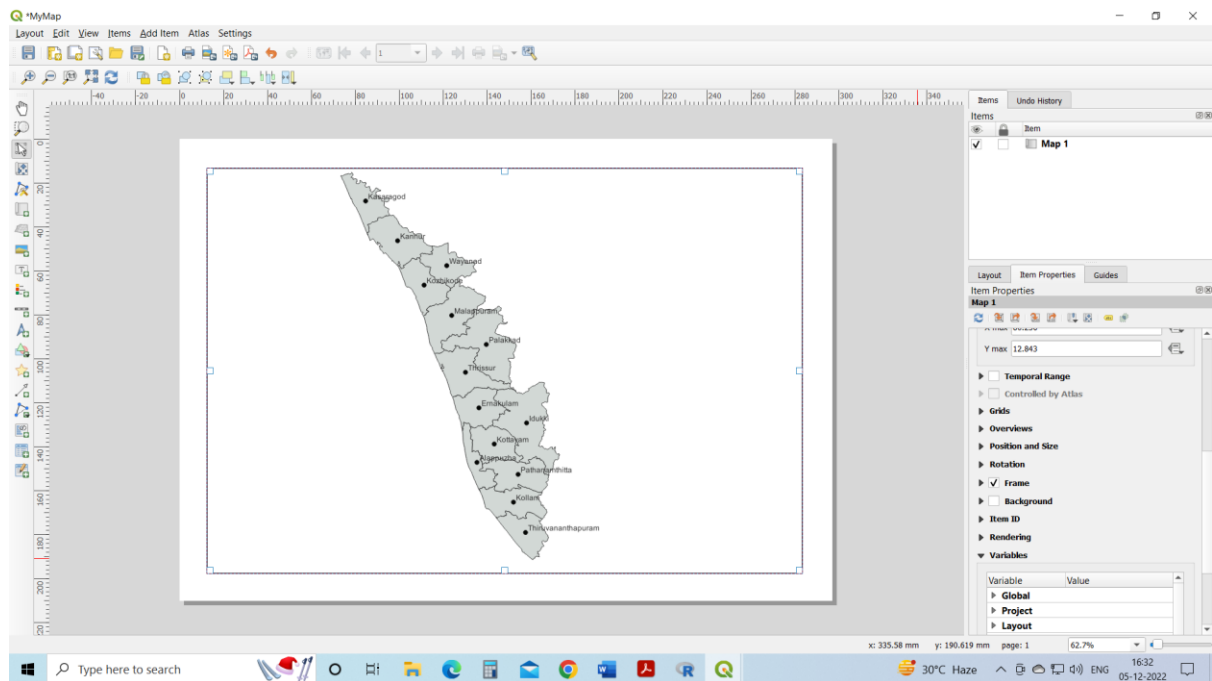


Now the MyMap layout will open up and one can make the necessary manipulations in it to make the map.

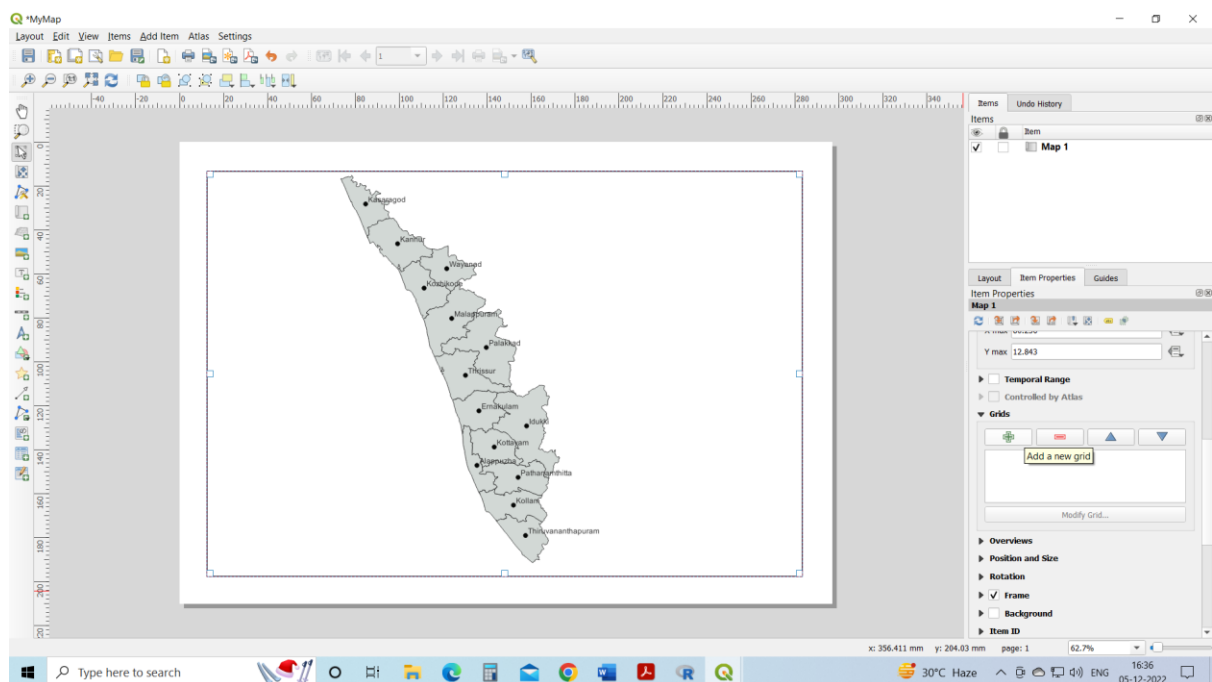
At first, we have to add the map to the *MyMap* layout by clicking the *Add Map* icon in the left panel of the map layout window and by clicking and dragging in the canvas.



You can give a frame to the map by ticking the *Frame* option in the *Item Properties Menu* in the panel on the right side.



Now, we can add the lat-long grids to the map by adding a new grid to the map layout and changing its properties to suit the requirements. We can also add other map elements like North Arrow, Title, Legend, Scale Bar etc., using the icons in the left side of the Map Layout Window. Once the map is ready, it can be exported as an image using the *Export As Image* icon at the top of the Map Layout Window.



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5. economics. Journal of regional science, 50 (1). pp. 165-180. ISSN 0022-4146;
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6. QGIS: A Free and Open Source Geographic Information System;
<http://www.qgis.org/en/site/>

MODEL DATA ENTRY SHEET (FISH)

Parameters	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
TL					
SL					
BDD					
BDA					
HBDD					
HBDA					
CPD					
CPW					
HD1					
HD2					
Sub Orbital D					
IO					
HL					
SNL					
POL					
ORL					
ORD					
UJL					
LJL					
SNW					
Bar L					
Bar W					
SD1					
SD2					
D1D2					
CPL					
Pre Anal Leng					
SPEL					
SPEC					
D2AnL					
D1Pelv					
D1Pec					
D1B					
D2B					
CL					
Anal Base					
Anal H					
Pelv L					

Pec L					
Pect W					
D1H					
D2H					
MERISTICS					
D1					
d2					
A					
c					
p					
v					
Lat Scales					
Ltr tr.					
wt					
Gr RU					
Gr DU					
Gr DL (corner)					
Gr RL					
Gr U (T)D					
Gr L(T)D					
Gr (D+R)					

About ICAR-CMFRI

ICAR-Central Marine Fisheries Research Institute (CMFRI) is the leading fisheries institute with vast expertise in marine fisheries and taxonomy. Over 224 species have been described by scientists at this institute. Its Marine Biodiversity and Environment Management Division focuses on building and maintaining a knowledge base for Indian marine biodiversity, monitoring coastal and marine habitats, and developing protocols for their conservation and restoration. This Division also evaluates the impacts of natural and human activities on marine life to create mitigation and adaptation strategies. Marine taxonomy, vital for identifying and classifying marine organisms, supports marine science, conservation, and management. It's crucial for the sustainable management and conservation of marine biodiversity, aiding in scientific research, and conservation projects, and raising public awareness about marine ecosystems.



Know your Marine Biodiversity & Environment (MarBiE 2)

Short-term training on the Taxonomy of selected marine organisms

May 13-17, 2024

Venue: ICAR-CMFRI, Kochi

Course Fee: Rs 3500 per candidate

Objective: To empower marine conservation students and professionals with the taxonomic skills necessary to effectively manage and protect marine biodiversity.

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

Topics to be covered

- The candidates will have theoretical and practical exposure to different groups of marine organisms
- Introduction to Taxonomy
- Sample collection, Preservation of samples
- Museum accessions
- Type examination and preparation of descriptions
- General Fish Taxonomy
- Marine Mammal Taxonomy
- Seaweed Taxonomy
- Coral Taxonomy
- Microbial Diversity
- Underwater sampling techniques

Hands-on practicals will be given importance

Who should attend?

Postgraduate students, researchers & and academicians. A maximum of 20 participants will be accommodated.

Course duration

The training will be held from May 13-17, 2024, for a period of 5 days. Local hospitality (lunch, tea, and snacks) will be provided to all participants. Outstation candidates will have to meet their stay and accommodation.

<https://forms.gle/KBEVTmfuBzDjC97f8>

Selection of participants

The applicants will be screened and selected based on the submitted application and will be duly informed.

Team:

Course Director

Dr Rekha J Nair, Principal Scientist, MBEMD


Course Co Director

Dr Grinson George, Head, MBEMD

Course coordinators

- Dr Miriam Paul Sreeram, Principal Scientist
- Dr K R Sreenath, Senior Scientist
- Dr Shelton Padua, Senior Scientist
- Dr Ratheesh Kumar R, Scientist
- Dr Divya Viswambharan, Scientist

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Contact:

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Course Director

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Email: cmfrimbemd@gmail.com



OUR TEAM

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