MARINE MOLLUSCAN DIVERSITY IN INDIA - EXPLOITATION, CONSERVATION

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Introduction

The molluscs (soft bodied animals) belong to the large and diverse phylum Mollusca, which includes a variety of familiar animals well-known as decorative shells or as seafood. These range from tiny snails, clams, and abalone to larger organisms such as squid, cuttlefish and the octopus. These molluscs occupy a variety of habitats ranging from mountain forests, freshwater to more than 10 km depth in the sea. They range in size from less than 1 mm to more than 15 m (for example the giant squid) and their population density may exceed 40,000/m^2 in some areas. In the tropical marine environment, molluscs occupy every trophic level, from primary producers to top carnivores. India has extensive molluscan resources along her coasts. In the numerous bays, brackish waters and estuaries and in the seas around the subcontinent; molluscs belonging to different taxonomic groups, such as, mussels, oysters, clams, pearl-oysters, window-pane oysters, ark-shells, whelks, chanks, cowries, squids and cuttlefish have been exploited since time immemorial for food, pearls and shells.

About 3270 species have been reported from India belonging to 220 families and 591 genera. Among these the bivalves are the most diverse (1100 species), followed by cephalopods (210 species), gastropods (190 species), polyplacophores (41 species) and scaphopods (20 species). The first three orders are exploited by Indian fishermen from time immemorial. Presently over 150,000 tonnes of cephalopods, over 100,000 t of bivalves and nearly 20,000 t of gastropods are exploited from Indian waters. The importance of molluscs in the coastal economy of India is often overlooked. For example, the cephalopod fishery is now a US$ 250 million industry and is one of the mainstays of the Indian trawl fleet in terms of revenue. The bivalve exports amount to US$ 1.2 million and gastropod exports amount to US$ 1.8 million per annum.

The importance of gastropods, clams, oysters and mussels in maintaining both the economic base and the ambiance of our coastal communities is also frequently overlooked. Details on specific aspects of bivalve and gastropod management, biology, aquaculture and their relations to economic, public and ecosystem health are of paramount importance, but are at present lacking. An endangered species is an animal or plant that is in danger of becoming extinct. In most cases species that are listed as endangered will become extinct in the very near future unless some positive action is taken. The fact that a large number of gastropods have been placed in the endangered list is a cause for major concern. The importance of maintaining healthy molluscan populations and the type of information needed to sustain these structural and functional resources cannot be over emphasized.

General Characteristics of Molluscs

Three classes of the phylum Mollusca namely, Gastropoda, Bivalvia and Cephalopoda are of fisheries interest and their general characters as given by (Narasimham, 2005) are briefly given below.

Gastropoda: Gastropoda is the largest molluscan class with about 35,000 extant species. The gastropods are torted asymmetrical molluscs and usually possess a coiled shell. The soft body normally consists of head, foot, visceral mass and the mantle. Among the marine gastropods, the members belonging to the subclass Prosobranchia, are of major fishery importance (Poutiers, 1998). The shell in this subclass is typically coiled with an opening at the ventral end known as aperture. The aperture is covered by operculum which closes the opening of the shell. The head normally protrudes anteriorly from the shell and bears mouth, eyes and tentacles. The foot is muscular, ventrally located with a flattened base and is used for creeping or burrowing. The visceral mass fills dorsally the spire of the shell and contains most of the organs. The mantle forms mantle cavity which lines and secrets the shell. Asymmetry of the internal anatomy of the gastropods is due to twisting through 180° called the 'torsion' which takes place during the first few hours of larval development.

Bivalvia: There are about 10,000 living bivalve species. The bivalve as the name implies, possesses two valves (shells) lying on the right and left sides of the body. Bilateral symmetry is a characteristic feature. The shell is mostly composed of calcium carbonate. Umbo is the first formed part of the valve and is above the hinge. The soft body of the bivalve is covered by the mantle comprising two lobes. The foot is muscular and is ventral. Byssus is a clump

of horny thread spun in the foot and helps the sedentary bivalve to attach to hard substrates. In bivalves head is absent. Many bivalves possess a pair of gills, which are respiratory in function and produce water currents from which food is collected (Poutiers, 1998).

Cephalopoda: Cephalopods are purely marine in habit, and there are about 600 living species. They are considered as the fastest marine invertebrates. Head is highly developed.

The cuttlefishes come under the order Sepioidea and are characterised by the presence of a shell (chitinous or calcareous), 10 circum oral appendages and the tentacles are retractile into pockets. Suckers have chitinous rings. Posterior fin lobes are free and not connected at midline. The cuttlebone is internal and located dorsally underneath the skin.

The squids come under the order Teuthoidea. The shell is internal and is known as gladius or pen. It is chitinous and feather or rod shaped. There are 8 sessile arms and 2 tentacular arms which are contractile but not retractile. Suckers are stalked, and with or without hooks. Fin lobes are fused posteriorly. Eyes are without lids and either (1) covered with a transparent membrane, with a minute pore (Myopsida) or (2) completely open to the sea, without a pore (Oegopsida).

Octopuses are members of the order Octopoda. There are 8 circumoral arms and tentacles are absent. Fins are sub-terminal (on sides of mantle), widely separated or absent. Shell is reduced, vestigial, "cartilaginous", or absent. Suckers are without chitinous rings and are set directly on the arms without stalks.

Magnitude of Molluscan Fisheries in India

Cephalopods are by far the most important group with decadal average annual production of about 1, 70,000 tonnes and in 2016, the production has touched an all-time high of 2, 31,276 t. They are landed as by-catch and as a targeted fishery mostly in mechanized trawlers operating up to 200 m depth, and beyond in some areas. Next in importance are the bivalves and fishing is pursued as a small-scale activity, mostly at subsistence level in various estuaries and inshore seas. The annual average clam production is about 57,000 t, oysters about 18,800 t, and marine mussels about 14,900 t. There was no fishery for marine pearl oysters since 1962 in the Gulf of Mannar area, which earlier supported major fisheries.

Scallops occur in stray numbers and do not form a fishery, while the windowpane oyster was of considerable fishery value till a few years back. Among gastropods, the chank is most important with annual production of over 1,000 t till a few years back. The fishing for top shell (*Trochus* sp) has been banned as they have been declared as endangered. Abalones occur in stray numbers and are not fished. Mining for subsoil shell deposits for industrial purposes is a major activity in the Ashtamudi and Pulicat Lakes.

A brief description of gastropod, bivalve and cephalopod fisheries of India is given below. Material from recent reviews by Mohamed (2006), Narasimham (2005) on molluscan fisheries; Ramadoss (2003) on gastropod fisheries; Kripa and Appukuttan (2003) on bivalve fisheries and Meiyappan and Mohamed (2003) on cephalopod fisheries have been principally used in this paper.

Bivalve Fishery

A variety of clams, oysters, mussels and the windowpane oysters are distributed along the Indian coastline where they are fished by the local people (Table 1). Clams and cockles form 73.8%, followed by oysters (12.5%), mussels (7.5%) and windowpane oysters (6.2%). The major bivalve resources and their total landing are given in Table 2. The production levels in other states are meagre. Information on the bivalve production from the NE and NW states are scanty.

Table 1. Commercially important bivalves of India

Resource	Common English name	Local name
Clams and Cockles		
Villorita cyprinoides	Black clam	Karutha kakka,(Ma)
Paphia malabarica, Paphia sp.	Short neck clam, textile clam	Manja kakka (Ma), Chippi kallu (Ka), Tisre (Ko)
Meretrix casta, Meretrix meretrix	Yellow clam	Matti (Ta)
Mercia opima	Baby clam	Njavala kakka (Ma), Vazhukku matti (Ta)
Mesodesma glabaratum		Kakkamatti (Ta)

Resource	Common English name	Local name
Clams and Cockles		
Sunetta scripta	Marine clam	Kadal kakka (Ma)
Donax sp.	Surf clam	Mural,Vazhi matti (Ta)
Geloina bengalensis	Big black clam	Kandan kakka (Ma)
Anadara granosa	Cockle	Aarippan kakka (Ma)
Placenta placenta	Window pane oyster	
Tridacna sp., *Hippopus hippopus*	Giant clam	Kakka (Ma)
Mussel		
Perna viridis	Green mussel	Kallumakkai, Kadukka (Ma) Alichippalu (Te)
Perna indica	Brown mussel	Kallumakkai, Chippi (Ma)
Pearl oyster		
Pinctada fucata	Indian pearl oyster	Muthu chippi, (Ma, Ta)
Pinctada margaritifera	Blacklip pearl oyster	Muthu chippi (Ma, Ta)
Edible oysters		
Crassostrea madrasensis	Indian backwater oyster	Kadal muringa (Ma); Ali, Kalungu (Te) Patti (Ta)
Saccostrea cucullata	Rock oyster	Kadal muringa (Ma); Ali,Kalungu, Patti (Ta)

Ka – Kannada, Ko – Konkani, Ma- Malayalam, Mr – Marati, Ta- Tamil, Te- Telugu

Table 2. Bivalve fishery details in different maritime states

State	Commercially important bivalve resources	Average Total landing (t)	Prospects
Kerala	Vc, Pm, Mc, Mo, Cm, Sc, Pv, Pi	58763	Clams and mussels are optimally exploited. Fishing effort for oysters can be increased. As management measures for Vc and Pm which are intensely fished semiculture is recommended
Karnataka	Mc, Vc, Pm, Cm, Sc, Pv	12750	Clams are optimally fished. Effort can be increased for oysters and mussels. Establishment of Clam fishermen Cooperative societies for marketing is suggested.
Goa	Mc, Vc, Pm, Cm, Sc, Pv	1637	Effort can be increased for all resources.
Maharashtra	Pm, Mc, Gb, Cg, Cr, Sc	2035	Effort can be increased for all resources.
Gujarat	Cg, Cr, Sc, Pp, Pf	4202	Utilization of pearls from windowpane oysters, Repopulating of pearl oyster beds in Gulf of Kutch will be beneficial
Tamil Nadu & Pondicherry	Mc, Mm, Pm, Cm, Sc, Pv, Pi, Pf	2098	Resources are fished only for shell; meat can be used instead of being discarded. Establishment of Clam fishermen Cooperative societies for marketing is suggested. Repopulating of pearl oyster beds of Gulf of Mannar and PalkBay will help to revive the pearl industry
Andhra Pradesh	Ag, Gb, Mc, Mm, Pm, Cm, Pv, Pp,	1278	Resources are fished only for shell; meat can be used instead of being discarded. Establishment of Clam fishermen Cooperative societies for marketing is suggested.
Andaman & Nicobar Islands	Tc, Tm, Pmar, Pv, Pm	NA	Intense effort to be made to replenish and conserve the existing stock
Lakshadweep	Tc, Tm	NA	Estimation of standing stock of these endangered resources, Effort to repopulate the coral reef with giant clams and pearl oysters

Ag- Anadaragranosa, Cg- Crassostreagryphoides, Cm - C.madrasensis, Cr- C. rivularis,
Mc – Meretrixcasta, Mo – Mercia opima, Mm – Meretrix meretrix, Pf – Pinctadafucata, Pi – Pernaindica, Pv – Pernaviridis, Pm – Paphiamalabarica, Pp – Placentaplacenta, Pmar- Pinctadamargaritifera, Sc- Saccostrea cucullata, Tc – Tridacnacrocea, Tm – T .maxima, Vc– Villorita cyprinoids, Gb – Geloinabengalensis

Stock Assessment of Bivalves

Only few studies have been made to assess the stock of bivalves. However, short term surveys have been conducted in the estuaries and coastal regions of maritime states to study the standing stock bivalve resource. Using the standing stock estimates by CMFRI the potential yield of bivalves has been estimated (Table 3).

The present status shows that the clam and oyster resources are underutilized in Gujarat and Maharashtra and effort to utilize these resources should be enhanced. However bivalves have varied reproductive potential hence these resource estimates have to be revalidated frequently. In other states like Kerala and Karnataka the resources are utilized and in some regions they require conservation.

Table 3. Standing stock and potential yield estimates of bivalves

Resource/ State	Estimated standing stock	Potential Yield Estimate
CLAMS AND COCKLES		
Maharashtra	4000	5000
Goa	1200	2000
Karnataka	8027	6823
Kerala	65000	55250
TN & PON	5770	4905
Andhra Pradesh	58000	49300
TOTAL	**141997**	**123278**
OYSTERS		
Gujarat	1500	1050
Maharashtra	335	235
Karnataka	450	315
Kerala	4200	2940
Tamil Nadu	19032	13322
Andhra Pradesh	23000	16100
TOTAL	**48517**	**33962**
MUSSEL		
Maharashtra	1800	1260
Goa	1120	784
Karnataka	9800	6860
Kerala	17473	12231
Tamil Nadu	350	245
Andhra Pradesh	1000	700
TOTAL	**31543**	**22080**
WINDOWPANE OYSTERS		
Gujarat	5000	3500
Goa	120	84
Andhra Pradesh	12420	8694
TOTAL	**17540**	**12278**
GRAND TOTAL	**239597**	**191598**

Management Strategies

Bivalves offer one of the important examples of marine resource management along the Indian coast. However, apart from the restriction on the pearl oyster

fishery by the Government of Tamil Nadu, and the management measures on the short-neck clam fishery of Ashtamudi Lake, Kerala, there are no regulations for effective utilization and conservation of these sedentary marine resources. One of the major bivalve resources, the short-neck clam (*P. malabarica*) is well protected by the following regulations formulated by the Government of Kerala based on recommendations made by CMFRI. a) Ban on fishing activity during breeding season (September to February), b) use of gears with 30 mm mesh size to avoid exploitation of smaller clam, c) Restrict the grade of export of frozen clams meat to 1400 nos/kg and above and d) Initiate semi-culture or relaying of small clams. The minimum legal size (MLS) for exploitation of *P. malabarica* and *Villorita cyprinoides* from Vembanad Lake has been set at 20 mm APM. After the creation of the fishery management plan (FMP) for Ashtamudi Lake short-neck clams and the Ashtamudi Lake Clam Fisheries Governance Council (ACFGC), the fishery became the first Marine Stewardship Council (MSC) certified fishery in the country in November 2014. This will help to boost sustainable fisheries and also protect the ecosystem. Benefits of certification include potential for premium prices, access to new markets, preferred supplier status, potential to attract ethical investment in the fishery, improvements in management of fisheries and public recognition of fishery conservation effort.

Ashtamudi Lake
A managed Clam Fishery

The short-neckclam fishers (numbering about 500 fulltime and part time fishers) of AshtamudiLake are perhaps one of the best examples of a well managed local fishery benefiting the fishers and maintaining sustainable harvests. The management practices are implemented by the cooperative societies with the active scientific support of CMFRI.

One of the major drawbacks in bivalve fishery management is that there is no proper data collection system on the fishery landings. A proper database on the resource availability and their utilization pattern is essential.

Cephalopod Fishery

Cephalopods are a marine fishery resource of increasing importance and many species are exploited as by-catch by trawlers from throughout the Indian coast. Although they form only 4-5% of the total marine fish landings, cephalopod stocks are under heavy fishing pressure because of their high value as an exportable commodity. So much so, of late, they are even targeted by the trawl fleet in certain seasons of the year along parts of the west coast of India. The CMFRI has initiated studies on cephalopod stock from Indian waters during the

seventies. The initial results of this programme on the taxonomy, biology, fishery and stock assessment of cephalopod stocks pertaining to the seventies were published as a bulletin (Silas, 1985). Subsequently a major exercise on the stock assessment of Indian cephalopod stocks with data of 1979-89 was made by CMFRI. These studies indicated that squids were exploited at optimum level on both coasts (Meiyappan et al, 1993) and cuttlefishes were optimally exploited along east coast and under exploited along west coast (Nair et al., 1993 and Rao et al., 1993). Besides, a number of authors (Kasim, 1985; Rao, 1988; Mohamed, 1996; Mohamed and Rao, 1997) have published information on specific aspects of cephalopod stocks. Other contributions from India on cephalopod resources, biology and population dynamics include that of Kore and Joshi (1975) on the food of squids, Oommen (1977) on the food, feeding and fishery of squids, Silas et al (1982) on the resources, Philip and Ali (1989) on cuttlefish population dynamics, Nair et al (1992a and b) on squids caught by jigging along SW coast and the monsoon fishery for cephalopods along west coast and Kripa and Mathew (1994) on the octopus resources of Cochin.

Exploited Cephalopods

Cephalopods exploited from Indian seas can be broadly divided into three, viz., squids (order Teuthoidea), cuttlefishes (order Sepiiodea) and octopuses (order Octopodidea). A list of neretic species commercially exploited is given in Table 4.

Table 4. List of commercially exploited cephalopods from Indian Seas

Species	Common Name	Distribution
Squids		
Uroteuthis(P.) duvaucelii	Indian squid	All along Indian coast
Loliolus (N) uyii	Little squid	Madras & Visakhapatnam
U (P) edulis	Swordtip squid	SW coast
U (P) singhalensis	Long barrel squid	SW and SE coast
Loliolus (L) hardwickei	Little Indian squid	All along Indian coast
Sepioteuthis lessoniana	Palkbay squid	Palk bay & Gulf of Mannar
Sthenoteuthis oualaniensis	Oceanic squid	Oceanic Indian EEZ
Thysanoteuthis rhombus	Diamond squid	Oceanic Indian EEZ

Species	Common Name	Distribution
Cuttlefishes		
Sepia pharaonis	Pharaoh cuttlefish	All along Indian coast
S. aculeata	Needle cuttlefish	All along Indian coast
S. elliptica	Golden cuttlefish	Veraval & Cochin
S. prashadi	Hooded cuttlefish	SW & SE coast
S. brevimana	Shortclub cuttlefish	Madras & Visakhapatnam
Sepiella inermis	Spineless cuttlefish	All along Indian coast
Octopuses		
Amphioctopus neglectus	Webfoot octopus	SW & SE coast and islands
A. marginatus	Veined Octopus	SW & SE coast and islands
A.aegina	Marbled octopus	SW & SE coast and islands
O. lobensis	Lobed octopus	SW & SE coast and islands
O. vulgaris	Common octopus	SW & SE coast and islands
Cistopus indicus	Old woman octopus	SW & SE coast and islands

The dominant species occurring in commercial catches are *Uroteuthis (Photololigo) duvaucelii*, *Sepia pharaonis, S. aculeata* and *Amphioctopus neglectus*.

Methods of Exploitation

Although about 40% of the world's cephalopod catches are taken by squid jigging and 25% by trawling (Rathjen, 1991), in India, cephalopods are principally caught by bottom trawlers operating upto 200m depth zones. While most of the catch is brought in as by-catch from the shrimp and fish trawls employed by the trawlers, of late, there is a targeted fishery for cuttlefishes during the post monsoon period (Sep-Dec) using off bottom high opening trawls along the SW and NW coast. Prior to the seventies traditional gears like shore seines, boat seines, hooks and lines and spearing were the principal gear employed to

capture cephalopods. These traditional gears continue to be used especially for cuttlefishes at Vizhinjam, where there is no trawl fishery. Experimental squid jigging has been tried with Japanese expertise along the west coast by GOI vessels with considerable success (Nair et al., 1992a). However, commercial squid jigging is not practised in India.

Cephalopod Production

Cephalopod production, which remained at very low level upto the early seventies, has shown a remarkable increase crossing the 150,000 tonne mark in 2006. From 1973 onwards the commencement of export of frozen cephalopod products to several countries saw the transition of the resource from a discard to a quality resource fetching high foreign exchange (Silas, 1985). Thereafter its production showed a steep increase. The west coast maritime states, Gujarat (GUJ), Maharashtra (MAH), Goa (GOA), Karnataka (KAR) and Kerala (KER) contribute to the bulk (86%) of the production. While the production from the east coast amounts to only 14%, of which, Tamil Nadu (TN) contributes the maximum followed by Andhra Pradesh (AP). The states of West Bengal (WB), Orissa (OR) and Pondicherry (PON) contribute only a small percentage. Overall, KER ranks first contributing a third of the all India production followed by MAH, GUJ and KAR. The cephalopod production ($t.km^{-2}$) in different maritime states indirectly this indicates the relative abundance in the continental shelf and level of exploitation of cephalopods in the different maritime states. Maximum productivity (0.699 t/km^2) was observed in Kerala, followed by Tamil Nadu, Karnataka, Maharashtra and Goa.

At the national level, Jan-Mar and Oct-Dec were the most productive period. Along the upper east and west coast, the above months were the most productive, while in KAR, KER, TN and AP Jul-Sep was also equally productive.

Species-wise Production

The neretic squid *U. (P) duvaucelii* followed by the pharaoh cuttlefish *S. pharaonis* and the needle cuttlefish *S. aculeata* together contribute to 84% of the total cephalopod production from India. Along the west coast, *U. (P) duvaucelii* contributes to more than 50% of the landings, followed closely by *S. pharaonis* and *S. aculeata* (47%). Among squids, *Doryteuthis* sp. and among cuttlefishes, *S. elliptica* form significant part of the catch from Kerala and Gujarat respectively. A number of octopus species, chiefly, *O. membranaceous* forms 1% of the catch mainly from Kerala.

The dominant species in landings from the east coast is *S. pharaonis*, followed by *U. (P) duvaucelii* and *S. aculeata*. The diversity of squid and cuttlefish species exploited in commercial quantities is more along east coast as compared to west coast. *Doryteuthis* sp. and *S. lessoniana* are also caught in considerable quantities from TN and AP. Octopus species, which were formerly discarded, has gained importance in recent years. The major production is from Kerala State (Kripa and Mathew, 1994). Their proportions in the landings from both the coasts are increasing considering the export value of the same.

Stock Assessment and Management of Cephalopods

Ever since the CMFRI initiated a major research project on the biology and stock assessment of cephalopod resources of India, a number of research papers have been published on the subject (see Table 7 for complete list). Mostly F based models have applied to study cephalopod stocks. In the first study on Indian cephalopod stocks, Silas et al (1985) used length cohort analysis to estimate stock sizes. Later studies (Meiyappan et al., 1993; Nair et al., 1993 and Rao et al., 1993) also used cohort analysis to estimate mortality and stock and the yield and biomass estimates were obtained with length based Thomson and Bell analysis. Mohamed (1996) used the yield per recruit model to estimate MSY for Mangalore populations of *U.(P) duvaucelii*. Later Mohamed and Rao (1997) assessed the squid yield along Karnataka coast using the TB model to derive MSY and MSE. They also studied the relationship between spawning stock and recruitment of squids to assess the productivity of the population in terms of recruitment. They found that Ricker's stock recruitment curve could adequately explain the variation in recruitment with respect to spawning stock biomass (SSB).

Most of these studies indicated that cephalopods were either under exploited (e.g. *S. pharaonis* and *S. aculeata* along east coast) or optimally exploited (Table 7). While Mohamed (1996) and Mohamed and Rao (1997) found squid stock along Karnataka coast to be marginally over exploited.

Since trawl is the principal gear used for exploitation, and since the cod-end mesh used by these trawls are much below the notified mesh sizes, a large number of juveniles or young ones are caught. Thus there is need for curtailing this exploitation. It is quite clear that regulation of cod-end meshes by the state fisheries departments has not been effective. An alternate measure would be to regulate the trade in such a manner that young or juvenile

cephalopods are not traded or exported. Prescription of a minimum legal size (MLS) as a trade barrier is an accepted practice in such instances. The MLS and corresponding weights for 3 species of commercial cephalopods was determined as shown in Table 5 and recommended to the MPEDA (Mohamed et al. 2009) and the same is also prescribed by the Government of Kerala notification G.O.(P) No. 40/15/F&PD dated 24th July 2015.

Table 5. Recommended minimum legal sizes and weights for the 3 major commercial cephalopods exploited in India

Species	MLS(Mantle Length)	Corresponding Total Live Weight
U. (P) duvaucelii	80 mm	25 g
Sepia pharaonis	115 mm	150g
A. neglectus	45 mm	15 g

At present, the proportion of juveniles commercially exploited for *U.(P) duvaucelii* is 5.3%; *S. pharaonis*, 8.7% and *A. neglectus*, 5.9%. If the juveniles are permitted to grow to L_{mean} by implementing the MLS, the estimated economic gain is to the tune of Rs. 426 crores per annum. Mohamed et al. (2009) showed that harvest weights can be improved by up to 34 times and would result in higher incomes to trawl fishers.

Cephalopods are not a targeted fishery along the Indian coast (excepting seasonally along the SW coast) and therefore, it is difficult to set management targets and many of the models applied would have little relevance. Yet, Rosenberg et al (1990) suggests that the most effective means of managing cephalopod fisheries is by regulating fishing effort, which will reduce the risk of recruitment overfishing. The present ban on trawl fishing during the monsoon as variously practised by different maritime states is in effect a means of regulation of fishing effort and should be continued.

A policy guidance document on Fish Aggregating Devices (FAD) based cuttlefish fishery is prepared highlighting the negative impacts on the spawning stocks leading to recruitment overfishing in Karnataka (Sasikumar et al. 2015). They found that the average annual loss in cuttlefish eggs is very high (estimated as 927 million /Rs. 1130 crores). The annual Spawning stock Biomass (SSB) is reduced to one fifth of the mean value.

Utilization and Marketing

There is very little internal market demand for cephalopods and consequently almost all the catch is exported. While the export quantity peaked in 1995 the annual average is about 24%. However, the value of cephalopods in total marine exports has remained at 15% from 1992 onwards without much variation. In 2003 the value of cephalopods exported amounted to more than Rs 800 crores. Category-wise, squid products are the maximum in all years followed by cuttlefish products. The products include dried, frozen whole, filleted, tentacles, rings, roe, wings, IQF and bones and ink. Octopus products exported are meagre, but from 1994 onwards there is rising trend in its exports. The main markets for export of Indian cephalopods are Europe, Japan and China.

The emergence of cephalopods as an important marine fishery resource of the country with almost cent percent export potential warrants careful monitoring and appropriate management particularly because we are exploiting above the revalidated potential yield of 101,000 tonnes. Several gaps exist in our knowledge of these valuable resources, especially on the life histories of our species. For example, we still have not resolved the question of semelparity of most of our species. At present we know that most of the species lay their eggs in the shallow inshore waters. These grounds are subjected to sedimentation due to man-made causes such as dumping of sludge. This might degrade the benthic conditions with a negative impact on cephalopod egg laying and consequently on the recruitment.

Oceanic Squids

The purpleback flying squid *Sthenoteuthis oualaniensis* (Lesson, 1830) is distributed in the tropical and sub-tropical areas of the Pacific and Indian Oceans. The Arabian Sea is considered as one of the richest regions for these oceanic squids in the Indian Ocean. These squids are pelagic animals living in the open ocean, usually absent over the continental shelves (<200 m), and first appear over continental slopes at depths above 250-300 m. The species has been called as the *master of the Arabian Sea* due to its high abundance, large size, short life-span, fast growth and near monopoly of the higher trophic niche. The estimated squid stock in the Arabian Sea varies in the range 0.9-1.6 million t. In recent years, the species has been found to occur in hook and line and gillnet catches in Cochin (Mohamed et al., 2006) and Veraval (Moorthy et al., 2009) and Mohamed et al. (2006) has worked out its population characteristics as $L\infty$ = 49.1 cm; K = 0.83 yr^{-1} and t_0 = -0.06 yr. Total biomass

and the annual fishable biomass (MSY) of this species is estimated (Mohamed et al. 2014). It is established that purse seining and gillnetting with light attraction from converted commercial fishing boats are the most efficient gears for exploiting oceanic squids in the Arabian Sea (Mohamed et al. 2014). A major programme is currently underway to exploit this resource using squid jigging.

Gastropod Fishery

The exploitation of gastropods in India is age-old for both as food and as curios. The famous money cowries used as currency and the religious sentiments attached to the sacred chank are well known. The gastropod biodiversity in Indian waters is very large (see Table 6) and no systematic effort has been made to document this qualitatively and quantitatively, apart from few works. Considering the intense exploitation of these shelled animals in certain areas of the country as a raw material for the shell-craft industry, a number (24) of these ornamental molluscs have been declared as endangered and are protected under the Indian Wildlife Protection Act.

Table 6. List of commercially exploited gastropods from Indian waters

Species	Common name	Utility		Availability
		Edible	Ornamental	
Turbinella pyrum	Sacred chank		O	SW, AN &Gulf of Mannar
Turritella attenuata	Screw shells		O	WC
Polystirasp	Screw shells		O	WC
Crassispirasp	Screw shells		O	WC
Architectonica perspectiva	Staircase shells		O	WC
Epitonium scalaris	Ladder shells		O	WC
Xenophorasp	Carrier shells		O	WC
Tibia curta	Wing shells		O	WC &EC
Naticaalbula	Moon snail		O	WC &EC
Naticalineata	Moon snail		O	WC & EC
Phalium glaucum	Ton shells		O	WC & EC
Ficus ficus	Fig shells		O	WC & EC
Rapana bulbosa	Purples		O	WC
Murex pecten	Venus comb		O	EC
Murex trapa	Rock shells		O	WC

Species	Common name	Utility		Availability
		Edible	Ornamental	
Murex virgineus	Rock shells		O	WC
Murex badius	Rock shells		O	WC & EC
Murex sp.	Rock shells		O	WC &EC
Babylonia spirata	Whelk	E	O	WC
Babylonia zeylanica	Whelk	E	O	WC
Hemifuses pugilinus	Spindle shells		O	WC
Fusinus toreuma	Spindle shells		O	WC
Oliva gibbossa	Olive shells		O	WC &EC
Oliva sp.	Olive shells		O	WC & EC
Harpa conoidalis	Harp shells		O	WC &EC
Conus glans	Cone shells		O	WC & EC
Conus sp.	Cone shells		O	WC & EC
Umbonium vestiarium	Button shells		O	EC
Cellana radiata	Limpet shell	E	O	EC
Turbo intercostalis	Turban shell	E	O	EC
Turbo sp.	Turban shell		O	Lakshadweep
Strombus sp.	Conch	E	O	EC & Lakshadweep
Thias sp.	Dog whelk	E	O	EC
Chicoreus ramosus	Ramose murex	E	O	EC
Plueroploca trapezium	Elephant shell	E	O	EC
Lambis lambis	Spider conch		O	EC
Melo indica	Begger's bowl		O	EC
Dentalium sp.	Tusk shell		O	WC & EC
Nassa sp.	Button shells		O	EC
Nerita sp.	Nerite shells		O	EC
Trochus niloticus	Top shell	E	O	AN
Turbo marmoratus	Turban shell	E	O	AN
Cypraea moneta	Money cowry		O	EC & Lakshadweep
Cypraea arabica	Cowry		O	EC & Lakshadweep
Cyprea tigris	Cowry		O	EC & Lakshadweep
Lambis truncata	Spider shell		O	Lakshadweep
Charonia tritonis	Trumpet triton		O	Lakshadweep

Chank Fishery

Chanks (*Turbinella pyrum*) are fished mainly for the shell and an organised fishery of considerable magnitude exists along the southeast coast of India. They are also collected at a few other places along the Indian coast.

Major chank resources occur in the Gulf of Mannar, particularly along the Ramanathapuram – Tirunelveli coast. Other areas are Tanjavur, South Arcot and Chingelpet in Tamil Nadu, Trivandrum coast in Kerala, the Gulf of Kutch in Gujarat and the Andamans. Nayar and Mahadevan (1973, 1974) dealt in detail the chank fisheries while Alagarswami and Meiyappan (1989) gave a general review. Appukuttan et al. (1980) described the long line fishing for chanks in Kerala and Pota and Patel (1988) reported on the Gulf of Kutch chank fisheries. Unlike pearl oysters, the chanks are regularly fished with few exceptions.

Whelk Fishery

The whelks come under the order Neogastropoda and family Buccinidae. They are mostly carnivorous and scavengers. The meat is edible and the shell is used in the shell craft industries. In India, two species namely, *Babylonia spirata*, and *B. zeylanica* are landed as by-catch, mostly in the bottom trawls. The former species is more abundant and most of the production is exported. Except for some fishery data in the by-catch of shrimp trawls, no information seems to be available on *B. zeylanica*.

Till early 1990s, *Babylonia* spp. were incidentally caught, mainly in shrimp trawls, and were not considered as of much fishery value. In July 1993, their meat was exported to Japan for the first time (Philip and Appukuttan, 1995). Since then the by-catch landed by shrimp trawlers, particularly off Kollam, is being sorted and the whelks collected. Total whelk meat export amounted to an average 247 tonnes valued at Rs. 528 lakhs during 1999-2003 period. The meat of *B. spirata* fetches US $ 6.9/kg and the operculum US $ 17/kg (Shanmugaraj and Ayyakkannu, 1997).

Philip and Appukuttan (1997) described on the heavy landings of *Babylonia* spp. off Kollam. During January-May 1996 as the whelk price shot up to Rs.35-70/kg from an earlier price of Rs.20-30/kg coupled with relatively poor shrimp landings, the shrimp trawl owners modified the net by adding 20-28 kg of lead rings to the trawl nets and increased the cod end filament thickness to 1.5 mm. As a result, the trawl net operated much closer to the bottom and

the thick cod end filament helped to withstand the weight of shells. This was reflected in higher by-catch and the whelk catch was estimated at 390 t in May 1996, compared to an average monthly catch of <50 t during the preceding four months. *B. spirata* formed 60% of whelk catch and the length ranged from 19-51 mm (average length 33.7 mm and average weight 12.7 g). *B. zeylanica* accounted for 40% of the production and the length ranged from 21-67 mm (average length 48.1 mm and average weight 17.87 g). The value of the whelks fished in May 1996 was estimated at Rs.1.75 crores. It was observed that 390 t of whelk would yield 3.9 t of operculum valued at Rs.15.5 lakhs (Philip and Appukuttan, 1997).

The population characteristics of *B. spirata* and *B. zeylanica* have been studied by Anjana (2007). The estimates (Table 7) indicate that both *B. spirata* and *B. zeylanica* are overfished at Kollam following the $E_{0.1}$ management strategy.

Table 7. Population parameters of whelk fishery at Kollam, Kerala (from Anjana, 2008)

Parameters	*B. spirata*	*B. zeylanica*
L_∞ (mm)	*68.7*	*76.0*
K (y^{-1})	*1.08*	*1.15*
Z (y^{-1})	6.05	5.02
M (y^{-1})	1.61	1.65
F (y^{-1})	4.4	3.6
E	0.73	0.71
Emax	0.73	0.77
$E_{0.1}$	0.66	0.72
Spawning stock biomass (t)	92.9	267.7
Standing stock biomass (t)	216.2	404.1
Recruitment numbers	84,565	92,782

Since 1995, the fishermen began to exploit *Babylonia* spp. off Pondicherry in 5-25 m depth with slightly modified ring net, normally used for crab fishing. The average daily catch for ring net/catamaran unit varied from 14 kg in March 1996 to 42 kg in February 1996

(Chidambaram, 1997). Ayyakkanuu (1994) reported that at Annappanpettai landing centre along the Porto Novo coast, fishing for *B. spirata* was carried by special traps with dried octopus or eel as bait and operated from catamarans in 5-20 m depth. Fishing is throughout the year except during October-December. There are 7 mechanised and 6 non-mechanised catamaran trap units and the former unit carries 60-70 traps and the latter 25-40 traps. During March-August 1993, the production of *B. spirata* was estimated at 211 t. Boiled meat from 211 t of the whelk was estimated at 54 t (Rs.40/kg) and operculum 11 t (Rs.400/kg).

At Tuticorin, both the whelk species occur in 100-150 m depth at a distance of 50-60 km from the coast. During January-February the whelk catch was 1.5 t/trawler/month and in July it was 1.7 t/trawler/month. In other months the whelk catches were poor (Selvarani, 2001).

Along southern Karnataka whelk (*B. spirata*) fishing is practiced using traps normally used for crabs and ladyfish (Sasikumar et al. 2006). Annual yields are around 175 t and maximum abundance is seen in January-February and November. The major market for Indian whelk (as chilled whelk, shell-on) is Hong Kong (90%) followed by Thailand, UAE and Maldives.

Fishery for ornamental gastropods

There are several economically important species of gastropods which are regularly collected for meat / and or shell. They come under many families, extensively used in shell craft industry and are popularly called as ornamental gastropods. Many of them live in coral reef habitat in regions such as the Gulf of Kutch, Gulf of Mannar, Palk Bay, Andaman and Nicobar Islands and the Lakshadweep group of Islands.

Philip and Appukuttan (1995) reported on the occurrence of 29 species of gastropods in the by-catch of shrimp trawls, operated off Kollam. In addition to *Babylonia* spp. and chank, important ornamental gastropods landed are *Tibia curta* (wing shell), *Bursa spinosa* (purse shell), *Turritella attenuata* (screw shell), *Rapana bulbosa* (purple shell) and *Conus glans* (cone shell). They accounted for 80% of total gastropod landings.

The Ramanathapuram coast in Tamil Nadu is famous for the production of several ornamental gastropods and 12 small scale shell-craft industries exist at Rameswaram and Keelakarai. Natarajan et al. (1988) reported that species of the following genera are collected and used by the industry: *Oliva, Cypraea, Natica, Cerithidea, Cymatium, Lambis, Xancus, Pyrena, Umbonium, Littorina, Tibia, Strombus, Conus, Murex, Babylonia, Fusinus, Cymbium, Faciolaria, Cassis, Bursa, Phalium, Tonna* and *Thais*. Among these, 1,75,000 *Lambis* spp. are fished

annually and each shell fetches Rs.1-3 for the fishermen. The methods of collection include hand-picking, skin diving, hand dredging and as by-catch from different fishing gears. On an average 4,00,000 shells, which also include those brought from the Andamans are used by the shell-craft industry. The shells are placed in bleaching powder solution for 24 h in cement tanks, followed by immersion in caustic soda solution for one hour. They are polished by keeping them in 5% Hydrochloric acid for 10 seconds to 4 minutes, depending on size, thickness and colour. The ornamental products made out of these shells include table lamps, lamp shades, necklaces, ear-drops, beads, hair pins, sculptures of Gods and Goddesses, agarbathi stands, bangles, flower vases, and shell screens for doors and window curtains. There are about 70 shell craft selling shops at Rameswaram and the annual turn over is about Rs.10 lakhs (Natarajan *et al*., 1988).

In the Andaman and Nicobar Islands, in addition to the use of topshell, green snail and chank, species of *Cypraea, Strombus, Lambis, Conus* and *Thais* are regularly used in shell craft industry (Appukuttan and Ramadoss, 2000). Appukuttan *et al*. (1989a) reported on the ornamental gastropods of the Lakshadweep. The cowries *Cypraea caputserpentis*, *C. moneta* and *C. tigris* are important and are exploited at a sustenance level by hand-picking during low tides. Other methods adopted are by diving and by collecting from the coconut leaves, placed in the lagoon water for a few days on which *C. moneta* congregate. The estimated production in numbers of *C. moneta* was 5-7 lakhs per year priced at Rs.25-30/ kg and *C. caputserpentis* 2-3 lakhs/year valued at Rs.30-35/100 cowries. Other ornamental gastropods collected include *Cypraea rufa, C. arabica, Conus leopardus, C. litteratus, Cassis cornuata* and the spider conchs*, Lambis truncata* and *L. chiragra*.

From the Kakinada Bay, Rao and Somayajulu (1996) estimated the average annual production of *Cerithidia* sp. at 990 t, *Telescopium* sp. 221 t, *Umbonium* sp. 292 t, *Thais* sp. 79 t and *Hemifusus* sp. 35 t. Some of these gastropods are also used in lime preparation.

Alagarswami and Meiyappan (1989) estimated the production of ornamental gastropods from the country at 600 t/year. Since then substantial increase in production is discernible. During 1991-2003, on an average 271 t/year of sea shells (average value Rs.7.20 crores) were exported from the country (MPEDA).

In a notification dated July 21, 2001 the Ministry of Environment and Forests, Government of India has included 44 gastropod species in Schedule I of the Wild Life Protection Act,

1972. The species include 11 under the genus *Cypraea*, 6 each under the genera *Conus* and *Lambis*, 3 under *Murex*, 2 each under *Harpulina, Strombus* and *Mitra* and one species each under 12 different genera. A vast majority of them are ornamental gastropods and are protected by the Act.

An estimated production of ornamental gastropods at Kollam during 2016 was 1676 tonnes forming 99% of entire Kerala's catch. *Babylonia spirata* and *B. zeylanica* are the dominant species in the catch forming 97.8%. Exports take place from mainly Rameswaram, Tuticorin and Chennai and a large number of species such as *Busycon, Haliotis, Cypraea* and *Mitrella* are imported for processing and re-export. The major regularly landed ornamental gastropods at Tuticorin by bottom set gill nets are *Turbinella pyrum* and *Chicoreus ramosus.* Apart from the stray number of other ornamental gastropods such as *Murex spp, Lambis lambis, Babilona spp, Cypraea sp* etc are also landed by the bottom set gill nets primarily set for lobster and crabs. Fossilised *Turbinella pyrum* is also exploited regularly from Kalavasal at Tuticorin. These fossilised *T. pyrum* is mostly exported to Kolkata (CMFRI, 2017-unpublished).

Future of Molluscan Exploitation

The following are areas of concern with regard to exploitation of molluscs in India:

- Exploitation of cephalopods above the potential yield estimate and localized over-exploitation of stocks
- Oceanic cephalopod potential to the tune of 20-50,000 t which are yet to be exploited
- Grossly under-reported catches of bivalves and gastropods
- No major studies in the country on bivalve and gastropod biology and no information on the magnitude and economics of the shell-craft industry
- Conservation and stock rebuilding strategies with respect to endangered molluscs are not in place

In the light of this, it is important to determine the science, management and institutional requirements needed to obtain the tremendous potential value from molluscan resources to the country and to make a path for sustaining molluscan fisheries and rebuilding protected species stocks to realize their long-term potential.

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