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# Marine molluscs of India-a review on their diversity and distribution

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**Abstract**
This article establishes the significance of marine molluscs of India, existing and potential threats are discussed, and molluscan distribution in Indian states based on current information is examined. About 3370 molluscan species are known from marine habitats of India and the highest number of species from the east coast of India. Marine molluscs of India are facing threats because of various causes. The greatest threat to marine molluscs has been the loss and reduced quality of habitat caused by human-induced modifications and the capture of molluscs for the fishery. Species and habitat-based approaches to molluscan conservation are evaluated. The conservation measures taken by the Indian government are discussed.

**Keywords** Coasts · Bivalves · Gastropods · Threat · Conservation

## Introduction

Phylum Mollusca comprises up to 60% of global biodiversity (Gosliner et al. 1996). The world comprises about 1.75 million species which includes 46,000 valid species of marine molluscs (Bouchet et al. 2016). India is enriched with various marine habitats such as tidal flats, lagoons, coral reefs, deep sea and islands. Marine biodiversity in India was unexplored till the eighteenth century. With an extensive coastline of 8,129 kms, and 0.5 million square kilometres of continental shelf India is home to 3370 species of marine molluscs (Ramakrishna and Dey 2010). However, the status of various species of molluscs in India in the marine ecosystems remains unknown and threat status is not known.

Although the research on intertidal macrofauna has gained importance from the twentieth century onwards, marine molluscs of India are not studied comprehensively. Detailed descriptions of 470 species of molluscs belonging to families Testacellidae and Zonitidae and 485 species belonging to 11 families are found in different volumes of Fauna of British India, including Ceylon and Burma (Blandford and Godwin-Austen 1908; Gude 1914). Of the seven classes of molluscs represented in the world, five classes are found in India (Tripathy and Mukhopadhyay 2015).

There has been a substantial increase in studies documenting molluscan diversity from Indian coasts (Venkataraman and Sivaperuman 2015, Ravinesh et al. 2015; Biju Kumar et al. 2015) coupled with reports on new species (Ravinesh et al. 2017). These have improved our knowledge of the distribution of molluscs, along with concerns over threats and the need for their conservation (Paul et al. 2014; Joshi et al. 2015), making it timely to review what is known about the status of molluscs in marine habitats of India. In this paper, we review the diversity and regional patterns in the distribution of marine molluscs in India and existing threats to molluscs, species, and habitat-based approaches to the conservation of marine molluscs in India.

Pioneer in the study of Indian marine molluscs is Satyamurthy (1952, 1956) (Table 1). Later studies on molluscs of Indian coast gained the importance (Philip 1972; Nagabhushanam and Rao 1972; Apte (2004, 2009, 2012, 2014), Subba Rao and Dey (2000), Ramakrishna and Dey (2003, 2010), Subba Rao (2003), Dey (2006), Dey and Ramakrishna (2007), Ramakrishna et al. (2007, 2010), Raghunathan et al. (2010), Apte et al. (2010, 2012), Bhave and Apte (2011), Mukhopadhyay et al. (2012), Pati and Sharma (2012), Apte and Bhave (2014) and Bijukumar et al. (2015).

Dey (2016) prepared a catalogue of marine molluscs of India reporting 2300 species. It gives a systematic account on the molluscan diversity of India. After that Subba Rao (2017) gave a detailed account of 532 bivalve species

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belonging to 71 families and 260 genera. Of the marine molluscs reported from India, gastropods are highly diverse followed by bivalves, cephalopods, polyplacophores and scaphopods (Venkitesan et al. 2019). Class Gastropoda comprises 59% of the known marine molluscan families and class Scaphopoda is the least (Fig. 1). Venkitesan et al. (2019) stated that about 93 species of cone shells are known from India and the highest number (37) of species are distributed in Andaman and the least species (1) from Odisha and Karnataka. Molluscan diversity from the east coast of India has been explored quite well. In the mid- twentieth century, molluscan inventories were mostly confined to the east coast of India and the number of reported species are presented in Fig. 2. The remarkable studies are from Chennai (Gravely 1942; Venkataraman and Venkataraman 2012), Krusadai Islands (Satyamurthy 1952; 1956); Palk Bay (Ramesh et al. 1996); Parangipettai (Babu et al. 2011) and Tanjavur (Anandaraj et al. 2012) and Mudassal Odai

**Table 1** Major contributions by researchers towards Indian marine molluscan inventories

| Coast | Number of reported species of molluscs | Reference |
|---|---|---|
| Krusadai Island | 500 | Satyamurthy (1952, 1956) |
| Laccadive Archipelago | 71 | Nagabhushanam and Rao 1972 |
| East and West coasts | 488 (Gastropods) | Apte 2014 |
| | 530 (Polyplacophora and gastropods) | Subba Rao 2003 |
| Andhra Pradesh | 151 (Bivalvia, Scaphopoda and Cephalopoda) | Dey and Ramakrishna 2007 |
| Lakshadweep | 19 (Opisthobranchs) | Biju Kumar et al. 2015 |
| Gulf of Mannar | 866 | Hylleberg and Kilburn 2002 |

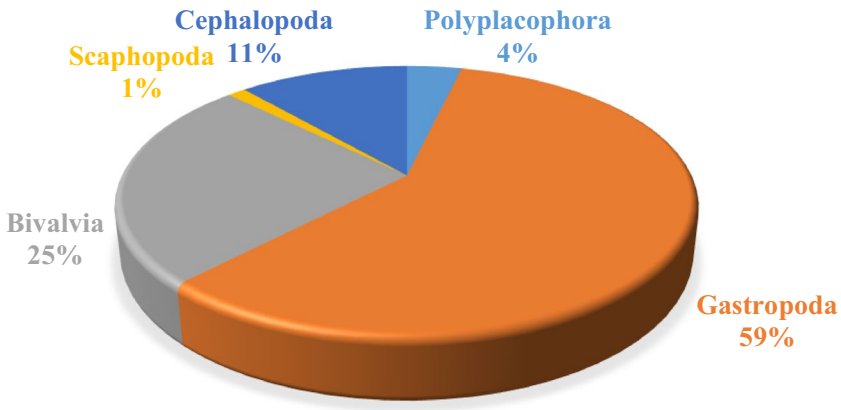


**Fig. 1** Number of molluscan families reported from the Indian coast (Source: Venkataraman 2018)

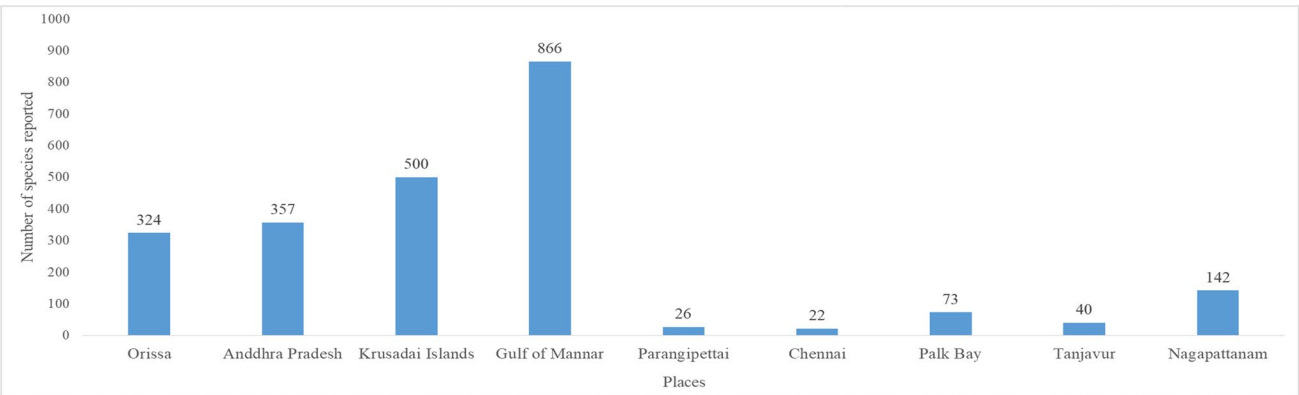


**Fig. 2** Molluscan inventories from East Coast of India. (Source: Published articles)

and Nagapattanam districts of Tamil Nadu (Saktiveil and Fernando 2014) . Samuel and Patterson (2001) showed the presence of 110 gastropod species and 35 species of bivalves from Koswari Island of the Gulf of Mannar. *Turbinella pyrum, Lambis lambis, Pleuroploca trapezium, Cymatium perryii, Harpulina lapponica,* and *Conus zeylanicrs* are commercially important molluscs. Thereafter Hylleberg and Kilburn (2002) recorded 866 species of molluscs from the Gulf of Mannar. The Tuticorn coast of Gulf of Mannar comprises 428 species of molluscs (Karthick et al. 2020). It includes 67% of gastropods and 33% of bivalves. Mohanraj et al. (2010) recorded 40 species of coral- associated molluscs from the Gulf of Mannar.

Paul et al. (2014) documented 63 species of molluscs from the North-East coast of India. A total of 324 species are known from Orissa state which includes 170 species of gastropods, 147 species of bivalves, six species of Cephalopods and one species of Scaphopoda. Of these nine species (three of gastropods and six of bivalves) are first records from India (Subba Rao et al. 1991). Subba Rao and Dey (2000) conducted an extensive survey of marine molluscs of Andaman and Nicobar Islands and recorded 1100 species that are placed in 143 families representing five classes of molluscs. About 19% of the species were endemic to these islands and 66 are the type species. About 45 molluscan species are reported from the Neil Islands of Andaman (Priyankadevi et al. 2017), 71 species of molluscs from this area (Jeeva et al. 2018), *49 species of Cone snails from Andaman (*Ravinesh et al. 2018).

Altogether a total of 357 species of molluscs are recorded from Andhra Pradesh coast of which 2 belong to Polyplacophora, 200 to Gastropoda, 6 to Cephalopoda, 146 to Bivalvia and 3 to Scaphopoda. Among these 6 cephalopod species represent 6 genera and 4 families. Bivalves (146 species) belong to 77 genera and 39 families whereas 3 species of scaphopods are assigned under a single genus and family. Six species of Cephalopods are under 6 genera of which one species *Sepiella inernlis Ferrussac* is the first record from the state (Ramakrishna et al. 2007). Monolisha and Edward (2015) recorded 70 species of molluscs from Andhra Pradesh coast, of which gastropod species like *Umbonium vestiarium, Cerithidea cingulata* and the bivalves like *Perna viridis* and *Donax faba* were abundant. The Pulicat lake of Andhra Pradesh is known to have 34 gastropod species and 17 bivalve species (Ramani Bai and Govindan 2018). Among bivalves, *Crassostrea madrasensis* was the dominant species.

The studies on molluscan diversity from the west coast of India are mainly confined to the states of Gujarat, Maharashtra and Kerala (Fig. 3). Molluscan species of the Sourashtra coast have been surveyed quite well (Surya Rao et al. 2004;Vaghela et al. 2013; Vadher et al. 2014; Bhajda et al. 2015; Baxi et al. 2017). Surya Rao et al. (2004) gave a comprehensive report on marine molluscs of Gujarat which includes 243 species of molluscs. Of these 37 species are endemic to the west coast of India, of which 25 species are confined only to Gujarat. The genus *Thalotia* was the new record from the Indian coast. About 82 species of molluscs are documented from Gujarat (Soni and Thakur 2015). This coast comprises of major proportion of molluscs belonging to class Gastropoda with dominating species like *Cellana radiata, Nerita albicella, Turbo coronetus, Turbo intercostalis, Trochus radiates* and *Rhinoclavis sinensis*. Gastropod*Turbo coronetus* is known to be abundant in the upper and mid littoral zones of the Sourashtra coast in post-monsoon whereas *Turbo intercostalis* is known to be present throughout the year (Vaghela et al. 2013). Molluscs like *Babylonia spirata, Bulla ampulla, Chiton peregrines, Chiton* spp., *Conus cumnigii, Mitra ambigua, Mitra guttata, Mitra scutulata, Murex brunneus, Purpura panama, Tibia curta, Turbo brunneus* were common in Gujarath coast (Vadher et al. 2014).

*Tectus, Trochus, Umbonium, Calliostoma, Clypeomorus* were dominant genera present during all the seasons in

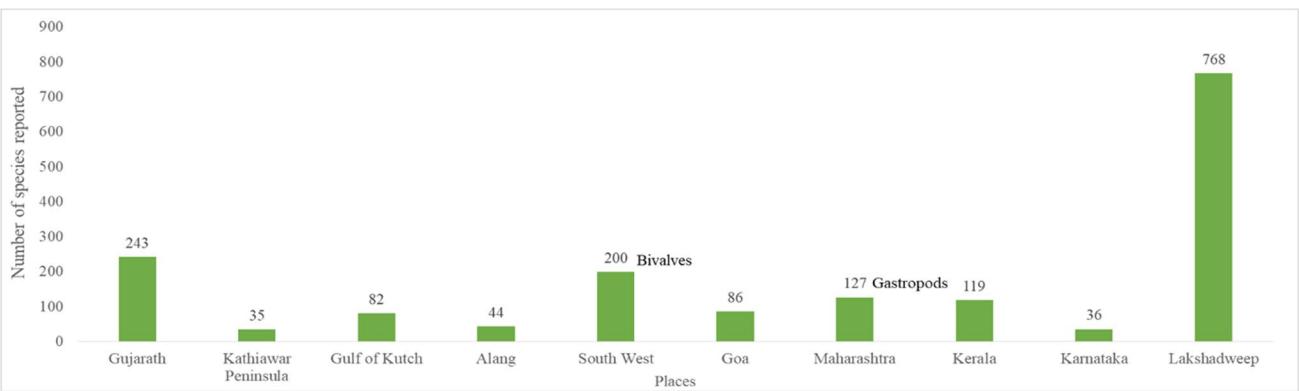


**Fig. 3** Marine molluscan inventories from the West coast of India. (Source: Published articles)

Alang coast of Gujarat. The highest density, abundance and frequency of *Clypeomorus batillariaeformis* was observed from Gujarath whereas *Umbonium vestiarium* showed density, abundance and frequency during summer and fewer individuals were observed during the monsoon (Baxi et al. 2017). *Calliostoma zizyphinum*, *Clypeomorus bifasciata* and *Clypeomorus batillariaeformis* were abundant in the middle intertidal zone of Gujarat coast. Species of families like Cerithiidae, Muricidae, Nassaridae, Onchididae and Trochidae were observed common during all the seasons (Baxi et al. 2017).

Diversity of molluscs is described from different coastal places of Maharashtra (Comber 1906; Parulekar 1980; Jaiswar and Kulkarni 2001; Datta et al. 2010; Bhave and Apte 2011; Khade and Mane 2012; Shaikh and Bhalerao 2012; Kurve et al. 2013; Balasaheb et al. 2017) and 127 species of gastropods are listed from this state (Kurhe et al. 2014). *Telescopium telescopium, Potamidus cingulatis, Hemifuscus pargytomus, Scrutus nongrlis, Pyrene atrata,* and *Bursa elegans* are reported only from the Gorai Creek of the Mumbai coast and were plentiful. *Trochus radiates, Cellana radiata, Saccostrea cucullata, Thias bufo* are the molluscs common to Mumbai coast. Gastropod, *Cyprea arabica* and bivalve, *Modiolus emerginatu*s were rare species to the Mumbai coast (Balasaheb et al. 2017). About 62 molluscan species have been identified from the Mumbai and the Palghar beaches of Maharashtra (Koliyar et al. 2020) . Vanamali and Jadhav (2015) recorded 30 species of molluscs belonging to 20 families Dativare coast of Maharashtra. Members of family Veneridae were abundant on this coast. Salvanker and Jadhav (2021) noted 80 species of molluscs belonging to 33 families from Palghar district of Maharashtra. Aitwar et al. (2023) studied monthly variation in molluscan diversity along the Sandkhol shore of Rathnagiri and showed the dominance of gastropod *Turritella duplicata*. They attributed variation in molluscan abundance to the fluctuation in environmental parameters.

David (2013) reported 86 species of molluscs from Goa coast and stressed the need to protect molluscan species. Pai and Kanekar (2016) recorded 47 species of mollusc under 23 different families from Miramar beach of Goa and attributed their maximum densities during monsoon to the availability of food and optimum temperature for breeding. Balakrishnan and Sivaleela (2022) studied the diversity and distribution of molluscs from the beaches of Goa and reported 40 species.

Studies on molluscs of Karnataka are scanty. Population dynamics of *D. faba* and *D. scortum* from Mangalore and Padukere coasts of Karnataka have been studied (Tenjing et al. 2011, 2016a). D'Souza et al. (2022) documented 36 species of molluscs from coastal Karnataka on the West coast of India. Molluscs belonging to family Muricidae were more in number and Veneridae members were least in number. *Bullia melanoides* was common on the beaches of Karnataka. *Clanculus scabrosus, Babylonia spirata, Mactrinula striatula* were the rare species found along the coast. Molluscs such as *Gyrenium natator, Saccostrea cucullata, Perna viridis, Cellana radiata, Semirincinula tissoti, Littoraria scabra* and *Echinolittorina leucostica* were confined to rocky shores.

The diversity of molluscs from Dharmadam Beach and Vijinjham Beach of Kerala has been studied (Pavitran and Nandan 2014; Anu et al. 2017). Molluscan diversity associated with mussel beds of Kerala and bivalve diversity from the west coast of India have been surveyed by Anu et al. (2017) and Arathi et al. (2017) respectively. Arathi et al. (2017) showed the commonness of 25 species of bivalves to the states of Kerala, Karnataka, Goa and Maharashtra. They also showed the existence of bivalves that are new to the west coast of India (Table 2). About 119 species of molluscs are known from the Asthamudi estuary of Kerala (Ravinesh et al. 2021). Ravinesh et al. (2022) documented 46 species of Conidae from the Kerala coast of which 15 species are new records to the coast, and one species is reported for the first time from the Indian coast. They also revalidated the status of *Conus ceylanensis* and *Conus bizona*.

More than 768 species of molluscs have been identified from the Lakshadweep Islands including 78 species of cone snails (Dalia Susan et al. 2014; Ravinesh and Biju Kumar 2015; Sneha Chandran et al. 2017). The giant clam *Tridacna maxima* is found on the coral reefs of Lakshadweep whereas octopus spp. (*Octopus vulgaris, O. membranaceus and O. cyaneus*) were common to the lagoons. Cone shells (*Conus leopardus* and *C. litteratus*), and Cowries (*Cyprea caputserpentis* and *C. tigris*) were commonly seen in these islands. Among the 24 species of marine molluscs included in Schedule I and IV of the Wildlife (Protection) Act (WPA) of India, 14 scheduled molluscs are from Lakshadweep. Of these *Placuna placenta* and *Tudicla spirillus* are new records of scheduled species from Lakshadweep (Biju Kumar et al. 2015). Ravinesh et al. (2017) reported the occurrence of an alien sea slug (*Thecacera pennigera)* from south west coast of India. They recommended intensive surveys on south-west coast and Lakshadweep islands which can add more species to the currently known list of molluscs.

Number of molluscs varies concerning location, type of substratum and climatic conditions (Balasaheb et al. 2017). Seasonality in molluscan abundance has been observed from the east and west coasts of India and their abundance will be more in post-monsoon or in winter and least in monsoon (Paul et al. 2014; Vaghela et al. 2013; D'Souza et al. 2022). Winter or post-monsoon season was found to be suitable for the molluscs probably because of the availability of ample seaweeds to feed during winter. Moreover, the abundance of molluscs in post-monsoon is also related

**Table 2** New records of Bivalves from West Coast of India (Arathi et al. 2017)

| SI. No | Families | Species | SI. No | Families | Species |
|---|---|---|---|---|---|
| 1 | Arcidae | *Anadara consociata* | 10 | Mesodesmatidae | *Coecellahors fieldii Nemocardium fulvum* |
| 2 | Cardidae | *Freneixicardia victor* | 11 | Pinnidae | *Atrina exusta* |
| 3 | Chamidae | *Chama croceata* | 12 | | *Atrina rigida* |
| 4 | Galeommatidae | *Lepirodes ambiguous* | 13 | Pteriidae | *Pteria howensis* |
| | | | 14 | Pectinidae | *Mimachlamys townsendi* |
| 5 | Glycymerididae | *Tucetona sibogae* | 15 | Propeamussiidae | *Propeamussium arabicum* |
| 6 | Glossidae | *Meiocardia cumingi* | 16 | Psammobiidae | *Hiatula rosea* |
| 7 | Gryphaeidae | *Hyotissa numisma* | 17 | Veneridae | *Pelecyora ceylonica, Pelecyora excisa, Protapescor, Globivenus toreuma, Aphrodora sewelli, Venerupis bruguieri* |
| | | *Hyotissa sinensis* | 18 | Semelidae | *Leptomya bracheon* |
| 8 | Lucinidae | *Lamellolucina oliveri, Myrtea triclotae, Scabrilucina vitrea, Divalinga arabica* | 19 | Tellinidae | *Tellina albinella* |
| 9 | Mytilidae | *Leiosolenus tripartus* | 20 | Trapezidae | *Trapezium oblongum* |

to the breeding potential of molluscs in monsoon and the appearance of juveniles in post-monsoon (Tenjing 2016a; D'Souza et al. 2022).

## Threats:

The coasts of India are subjected to various anthropogenic stress which leads to variations in the intertidal faunal assemblages (Bhajda et al. 2015). Anthropogenic activities affect the physiological state of the molluscs, which alters growth rates and disturbs their survival.

- Over-exploitation and overfishing: Over-exploitation and overfishing some molluscan species for commercial purposes has led to the gradual decline of the species. Of the common species, some molluscan species like snails, clams, etc. are found to be commercially exploited and shipped as part of the international trade in shellfish; other species are harvested, sold, and consumed locally (Soni and Thakur 2015). Overexploitation of pearl oysters and the destruction of their habitats have led to the decline in their natural habitats. Demand for Sacred Chank has been increased in West Bengal and Odisha whereas windowpane oyster is exploited for livelihood by fisherman communities (Ravinesh et al. 2019). Deepak Samuel and Patterson (2001) also opined that the islands of the Gulf of Mannar are subjected to overfishing and illegal coral mining. These activities influence the diversity of the islands. In India, about 19 species of gastropods, 4 species of bivalves and cephalopod (1 species) are placed under the endangered category and known as scheduled species (Table 3). Their collection, possession and trading of these species or their parts are banned under Wildlife Protection Act 1972 (Joshi et al. 2015; Venkatesan et al. 2019).

The molluscan species like *Cassis cornuta, Charonia tritonis, Conus milneedwardsi, Cypraecassis rufa, Nautilus pompilius, Hippopus hippopus, Tridacna maxima, Tridacna squamosa* etc. are protected under the Wildlife Protection Act, 1972 Schedule I.

- Tourism: They concluded that the less molluscan diversity in these beaches is due to continuous tourism and the dumping of garbage in these sites. Destruction of shells by tourists is also evident from Digha coast (Mitra and Misra 2006). Trampling of the beach sand, shells and litter has changed the look of the many beaches along the Indian coast. The beaches along the Indian coast have been attracting more and more tourists and many beaches are being used for recreation, which includes some amusement parks and resorts.
- Pollution: Indian coasts are threatened by pollution from domestic sewage and runoff from agricultural land (D'Souza et al. 2022; Lonkar et al. 2022; Venkataraman and Venkataraman 2012). Balasaheb et al. (2017) noted the decline in species diversity of molluscs on the Mumbai coast in comparison with earlier studies from this area. They observed the existence of sources of pollution indicates the effect of human pressures onshore in

**Table 3** Scheduled marine molluscs of India

| | | | |
|---|---|---|---|
| Gastropods | | | |
| 1 | *Cassis cornuta* (Linnaeus, 1758) | 11 | *Tudicla spirillus* (Linnaeus, 1767) |
| 2 | *Charonia tritonis* (Linnaeus, 1758) | 12 | *Staphylaea limacina* (Lamarck, 1810) |
| 3 | *Conus milneedwardsi* (Jousseaume,1894) | 13 | *Leporicypraea mappa* (Linnaeus, 1758) |
| 4 | *Cypraecassis rufa* (Linnaeus, 1758) | 14 | *Talparia talpa* (Linnaeus, 1758) |
| 5 | *Ophioglossolambis digitata* (Perry, 1811) | 15 | *Pleuroploca trapezium* (Linnaeus, 1758) |
| 6 | *Lambis millepeda* (Linnaeus, 1758) | 16 | *Harpulina arausiaca* (Lightfoot, 1786) |
| 7 | *Lambis scorpius* (Linnaeus, 1758) | 17 | *Dolomena plicata sibbaldi* (G.B. Sowerby II, 1842) |
| 8 | *Harpago chiragra* (Linnaeus, 1758) | 18 | *Lambis truncata* ([Lightfoot],1786) |
| 9 | *Harpago arthriticus* (Roding 1798) | 19 | *Rochia nilotica* (Linnaeus,1767) |
| 10 | *Turbo marmoratus* Linnaeus, 1758 | | |
| Bivalves | | | |
| 1 | *Hippopus hippopus* (Linnaeus, 1758) | 3 | *Tridacna squamosa* (Lamarck, 1819) |
| 2 | *Tridacna maxima* (Roding, 1798) | 4 | *Placuna placenta* (Linnaeus, 1758) |
| Cephalopods | | | |
| 1 | *Nautilus pompilius* (Linnaeus, 1758) | | |

the Mumbai city area. Pollution affeted the clams of the Girgaon coast, where shells such as *Paphia textile* were filled with mud and coated with black colour. It indicates that intertidal macrobenthic species are declining, and threatened by increasing human pressures on this habitat. Das and Dalvi (2020) fund that the Aksa and Madh Island beaches of Mumbai comprised of less molluscs than the other beaches of Mumbai. Besides, Paul et al. (2014) showed that pollution and other environmental disturbances also cause the loss of molluscan species. They also suggested the need for molluscan exploration from highly disturbed shores to implement the ecosystem conservation action plans.

- Industrial and municipal wastes: Major fertilizer industries, petrochemical and agrochemical industries are located in Chennai, Gujarat, Mumbai and Mangalore (Venkataraman and Venkataraman 2012; Lonkar et al. 2022; D'Souza et al. 2022). Industries located in the vicinity of the beaches release pollutants into the sea causing adverse effects on the molluscan population (D'Souza et al. 2022).Wastes of aquaculture and agriculture farms are posing threats to the coastal water quality and to the diversity of molluscs. Untreated or partially treated domestic waste and industrial effluents when released into the sea reduce the growth rate and reproduction of molluscs (Venkataraman and Venkataraman 2012). Growing industries and thermal power plants on the Indian coasts are detrimental to the molluscan population. Tuticorn thermal power plant discharges heated water and dumps fly ash into the sea. This causes damage to chanks, corals, pearl oysters and all marine organisms. The fly ash affects the pelagic animals by clogging their gills, causing their death and malformation to the eggs and larvae of molluscs (Murugan and Patterson Edward 2000).
- Illegal shell trading: The population of protected marine molluscs of Indian coast has declined due to indiscriminate collection of shells for food, illegal shell trading, and poor enforcement of laws. The molluscs that are listed in the Wildlife Protection Act (1972) are commonly traded in shell markets (Ravinesh et al. 2019). Top Shell and Turban Shells are prized for their lustre, used to make buttons and other artefacts. Window Pane Oysters *Placuna placenta* are utilised in manufacturing lamps, articles for display, hair clips and other accessories. Further Triton (*Charonia tritonis),* Pineapple Shell (*Cassis conuta)* and Helmet Shell (*Cypraecassis rufa)* are sold as souvenirs. Horse Conch (*Pleuroploca trapezium*) is consumed by local fishermen and the processed meat is sold in local markets in the districts of Tuticorin and Ramanathapuram. Shells have great demand in the international market but imported shells by Indian dealers will be sold in the local market. For example, is the African Conch *Busycon contrarium* (rare sinistral shell with a left-hand rotation), which is imported and sold) as an alternative to the Indian Sacred Chank (dextral shell). However, the outer whorl can be cut to look like sinistral shells and sold to tourists for an exorbitant price.
- Ports and dredging: Construction of port and dredging operations on the Chennai coast deposit large quantities of silt, which increases the turbidity in the water causing damage to marine life (Venkataraman and Venkataraman 2012). In addition, the continuous movement of marine vessels and oil transport at Chennai and other parts of Indian coast are known to cause harm to the biodiversity.
- Bycatch: Mollusc species are being landed by bottom trawlers in large quantities which imposes a greater threat

to molluscs. Shells caught as bycatch are allowed to rot in the landing centres or on beaches (Ravinesh et al. 2019). Many tonnes of bycatch are discarded at fish landing centres of Mangalore, Kochi etc. Latest fishing operations and technologies lead to overfishing causing damage to marine biota (Venkataraman and Venkataraman 2012). In India, two species of Whelks namely, *Babylonia spirata*, and *B. zeylanica* are landed as by-catch, mostly in the bottom trawls. Their meat is edible and the shell is used in the shell craft industries. Whelks will be landed as bycatch by shrimp trawlers, particularly off Kollam, and exported to other countries for their good meat value. 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). These ornamental gastropods and used in shell craft industries and food (Sunil Mohamed and Venkatesan 2012).

The shores of the east and west coasts of India have dissimilar coast characteristics and climatic conditions, and they face different levels of human activities. Therefore, the variations in molluscan diversity in intertidal habitats are possibly caused by coastal geomorphology, environmental conditions anthropogenic stress (Bhajda et al. 2015; D'Souza et al. 2022). Studies from the Indian coast stressed the need to implement appropriate conservational strategies to minimize the anthropogenic pressure on the affected coastal areas and to conserve the molluscs in these regions (Bhajda et al. 2015).

Seasonal variations in the salinity and electrical conductivity of water influenced the molluscan diversity of the Indian coast, thus, these were the limiting factors for the distribution of living organisms in the intertidal region (Bhajda et al. 2015; D'Souza et al. 2022). Preference of different substratum, adaptive capabilities against changing environmental conditions and mobility to avoid harsh conditions have played possible roles in shaping the molluscan diversity of India (Bhajda et al. 2015).

## Conservation

Indian coasts are endowed with a rich diversity of marine molluscs. Conservation molluscan population would help in the restoration of species balance in nature, especially in the ecologically sensitive, fragile ecosystems such as intertidal, coral reef, mangrove and seagrasses. Several conservation action plans can be taken to control the shell trade and thus minimise over-exploitation and habitat damage.

### Conservation measures by the Government of India:

Altogether, 24 species of marine molluscs (0.7% of the total molluscs found in the country) are declared as Scheduled species of the Wildlife (Protection) Act, 1972 by the Ministry of Environment, Forest and Climate Change. The inclusion of nine molluscan species under Schedule I and 15 species under Schedule IV has helped to protect threatened molluscs.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) aims at controlling the international trade of highly threatened species. At present giant clams of Family Tridacnidae are listed in Appendix II of CITES. Shells, meat or live animals can be traded between other countries by procuring a valid export licence from the country of origin. This is one of the effective measures to monitor trade in molluscs. There is a lack of information on the current status of Indian protected species of shells, landing data, their life history and habitats. However, certain legislations are introduced by India to protect the molluscs. They are given in Table 4.

Besides, environment departments and marine research institutions of Indian states help to limit the activities of shell collection and processing to a large extent. Gulf of Mannar Marine Biosphere Trust (GoMBRT), was started by the Government of Tamil Nadu and funded by United Nations Development Programme (UNDP) organised sensitisation programmes like mini-exhibits, village-level

**Table 4** Legislations for protection of molluscs of India

| | |
|---|---|
| 1 Forest Act | 1927 |
| 2 Wild life (Protection) Act | 1972 |
| 3 The Wildlife (Protection) Licensing (Additional Maters for consideration) Rules | 1983 |
| 4 The Wildlife (Specified Plants Conditions for Possession by License) Rules | 1993 |
| 5 The Wildlife (Protection) Rules | 1995 |
| 6 Chank Fisheries Act (The Indian Fisheries (Tamil Nadu Amendment) Act, 1927 Act 2 of 1929 Keyword(s): Central Act Amendment, Indian Fisheries Act 1897, Prohibition of Fishing Amendment appended: 12 of 1980) | 1980 |
| 7 Pearl Fisheries Ordinance (The Indian Fisheries Act, 1897 (ACT IV OF 1897) 4th February, 1897) | 1897 |

*Source: Venkataraman 2018

street plays, posters, flashcards on protected marine species under the WPA, 1972 (Ravinesh et al. 2018). Few fishermen residing in the villages near the Gulf of Mannar Biosphere Reserve serving as Anti-Poaching Watchers (APW), are actively involved in helping curb marine wildlife crime. The government of India created the Wildlife Crime Control Bureau (WCCB), a nodal agency at Ramanathapuram for curbing wildlife crime in India, and monitors the coastal biodiversity and illegal collection of shells (Ravinesh et al. 2018).

### Sea ranching of Molluscs:

Aquaculture is proven to be beneficial for the commercial production of Mollusca for food, and calcium production. It involves the rearing of larvae and juveniles in hatcheries, production of spawn and their harvesting. Aquaculture is useful for bulk production enhancing molluscan diversity, sustainable utilization and conservation (Ravinesh et al. 2018).

### Improved collection methods and awareness:

Shell collectors should employ methods that do not damage the habitat. In this regard, guidelines could be produced for both commercial collectors and tourists. Awareness programmes such as seminars, symposia, and training programmes can be conducted for common people, coastal inhabitants, and tourists about the role of molluscs in the ecosystems and their conservation (Ravinesh et al. 2018).

To conserve marine molluscs there is a need to implement site specific conservation and management strategies (Soni and Thakur 2015). Studies also insisted the necessity for a complete survey of all the shores to get more accurate knowledge of the biodiversity status of the various shores. Habitats of protected species should be identified and their zones need to be demarcated for conservation. Measures should be taken to avoid catching protected species in bycatch (Ravinesh et al. 2019). Besides, capacity building for fishing communities and enforcement officials needs to be conducted on a regular basis to enlighten the need for the conservation of molluscs. The main hurdle to implement enforcement actions to stop the illegal trade of marine species is their identification. The example is similarity between Spider Conch *Lambis lambis* (a non-protected species) and Giant Truncate Spider Conch *Lambis truncata* (a protected species) creates confusion. Often wrong shells will be collected by trawlers. Hence new identification tools should be generated and training needs to be given to coast guards, marine police and other stakeholders (Anti-Poaching Watchers (APW). Although scientific names are continuously being updated by taxonomists based on new findings, old names/synonyms for many species still remain the same in WPA, 1972 creating confusion for enforcement agencies (Ravinesh et al. 2019). Steps should be taken to address ongoing issues such as the release of untreated wastewater from domestic and industrial sources to the shores, then macrobenthic species and habitats could be recovered. The government should think of starting fishing zones and marine sanctuaries to avoid bycatch. Night trawling should be banned.

## Conclusion:

Of the total molluscan diversity of the world, 4% of them are known from India. Many studies have been carried out to document the molluscan diversity from east and west coasts of India and marine molluscs of different states have been recorded. Almost all the shores of India are threatened by human disturbances. Anthropogenic activities cause severe impacts on molluscs and lead to their loss of habitats. The need to monitor these ecosystems to record the decline in the number of molluscan species is suggested by the studies from Indian coasts. Overfishing of mollusc and aquatic pollution should be controlled and site-specific conservation action plans should be implemented. Conservation measures are undertaken by the Indian government such as the Wildlife (Protection) Act, 1972 under which Scheduled species are listed and their trade is prohibited. Sea ranching and implementing molluscan collection methods that do not destroy the habitats would help to protect the population of molluscs. Further, this review suggests that there is a need for intensive surveys to explore the new species of molluscs from Indian coasts which will add up to the existing molluscan species. Breeding biology and life cycle of protected marine species should be known to prepare conservation plans and implement region-specific activities. Research institutes need to be funded on projects related to status and recovery programmes for marine species to monitor wild populations and associated threats to their population.

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## Declarations

**Conflicts of interest/Competing interests.** The authors declare that they have no competing interests.

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