

Coastal and marine biodiversity of India

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This paper summarizes what is known of the coastal and marine biodiversity of the Indian seas and their various ecosystems, from past literature, museum records and other lesser-known sources of information. The synthesis suggests that the number of species known could be of the order 13,000 or higher. However, the inventory is very detailed only in the case of commercially important groups such as fishes or molluscs and is very weak with respect to minor phyla or microbial organisms. In terms of spatial coverage, probably only two-thirds of the total marine habitat has been covered till today and the remote islands and other minor estuaries still virtually remain untouched. It is, therefore, likely that true inventory of coastal and marine biodiversity could be several times higher than what is known today. Lack of trained taxonomists, however, is a serious constraint to achieve this. Conserving what we have today is hampered by lack of management measures including outreach and our ability to predict what would live in Indian seas, by lack of data relating changes in biodiversity to those of environment.

[Key words: Biodiversity, flora, fauna, Indian coast, threats, natural threats]

Introduction

Accelerated loss of coastal and marine biodiversity components over the last few decades has been of great concern. Environmental changes, over-exploitation and habitat loss are among the major causes of species loss that, according to certain estimates, is of the order of a species per day. It is not known what fraction of this loss is from marine environment, a situation owing to a lack of systematic coverage of all faunal and floral classes with the prominence placed often on economically important groups, or on habitats of deep-sea where one out of two species collected could be new to science.

Probable estimates of species diversity have been variously arrived at, by extrapolation of known number of species from a section of the habitat to others. With microbes, such estimates are even less certain. It is likely that more than 99% of the potentially existing microbes are not amenable for detection with the conventional methods and even the number of the known ones has been on the increase. In all probability, the number of species from all groups and all habitats of seas could be of the order of several million but we know only a fraction of that for certain. Even the most recent and most global

inventory, the Ocean Biogeographical Information System (OBIS), has no more than 40,000 species listed. What is unknown of the diversity, thus, far exceeds what is known. A fraction of the former, from extreme habitats like polar seas, hydrothermal vents and deep-sea mounts, thanks to logistic and technical constraints, would remain unknowable for quite sometime to come.

Equally important as knowledge of what lives in the seas, is a prediction of what would live there in the future. This is especially true of regions where rapid loss of habitats and decline in water quality could be drastically altering the species diversity. Sea regions with developing nations around them are particularly vulnerable to this, a situation the gravity of which is compounded by the fact that even census of marine life there is relatively less documented. This paper addresses, therefore, the issue of what is known (and how much in depth) of coastal and marine biodiversity from India by reviewing the literature and examines the constraints to its sustainability.

India is one among 12 mega-biodiversity countries and 25 hotspots of the richest and highly endangered eco-regions of the world¹. Among the Asian countries, India is perhaps the only one that has a long

record of inventories of coastal and marine biodiversity dating back to at least two centuries. However, these are so diverse in space, time and taxon that it is almost impossible to review all records and reports. The synthesis of what is known of coastal and marine biodiversity in India attempted in this paper relies mainly on systematic accounts, records and reports of two major institutions concerned with surveys and inventories of fauna and flora – the Zoological Survey of India and the Botanical Survey of India as well as other research organizations such as Central Marine Fisheries Research Institute and National Institute of Oceanography.

In terms of marine environment, India has a coastline of about 8000 km, an Exclusive Economic Zone of 2.02 million km² adjoining the continental regions and the offshore islands and a very wide range of coastal ecosystems such as estuaries, lagoons,

mangroves, backwaters, salt marshes, rocky coasts, sandy stretches and coral reefs, which are characterized by unique biotic and abiotic properties and processes. A network of 14 major, 44 medium and numerous minor rivers together with their tributaries cover practically the entire country except for the western arid region of Rajasthan Desert. The total length of the rivers is estimated at over 40,000 km.

The dissimilarities between the west and east coasts are remarkable. The west coast is generally exposed with heavy surf and rocky shores and headlands whereas the east coast is generally shelving with beaches, lagoons, deltas and marshes (Fig. 1). The west coast is a region of intense upwelling associated with southwest monsoon (May-Sep) whereas the east coast experiences only a weak upwelling associated with the northeast monsoon

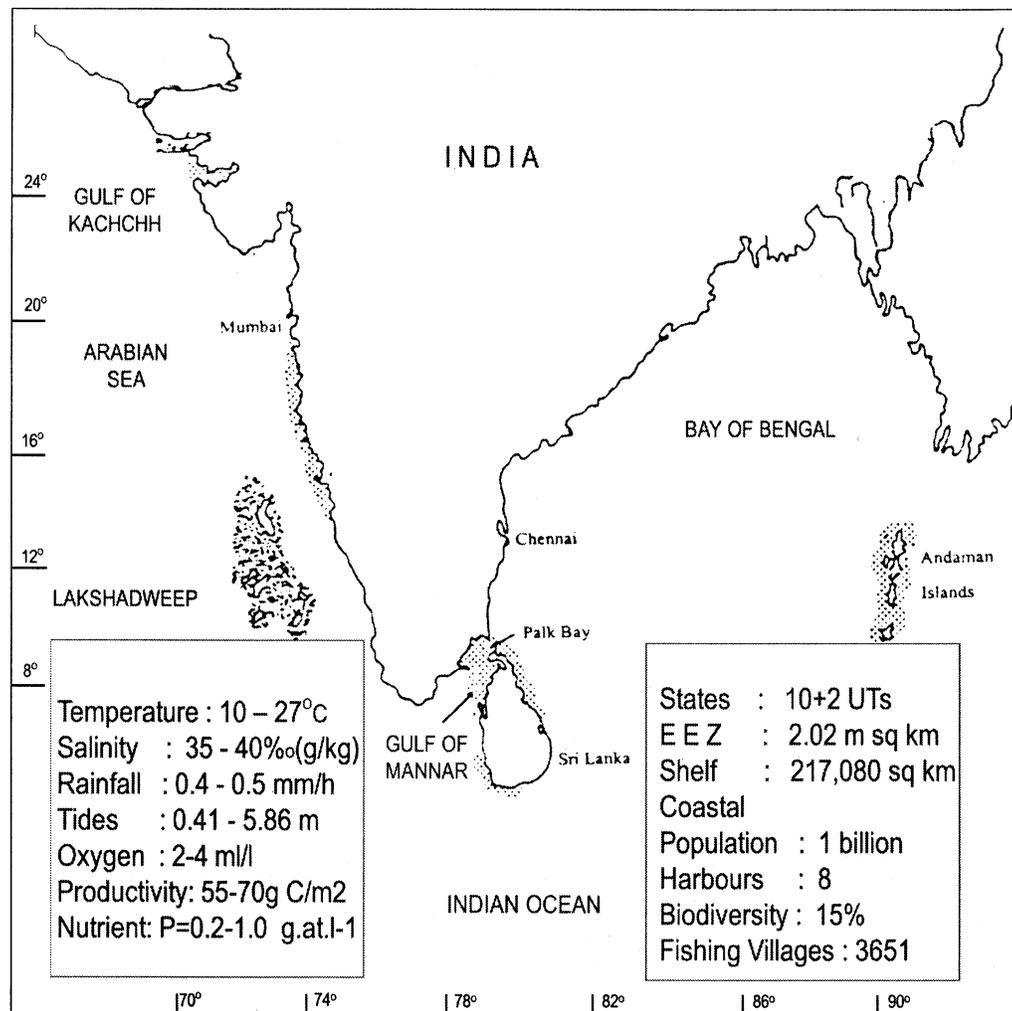


Fig. 1—Map of India showing information on the coastal and marine ecosystem.

(Oct-Jan), resulting in marked differences in hydrographic regimes, productivity patterns and qualitative and quantitative composition of fisheries. All islands on the east coast are continental islands whereas the major island formations in the west coast are oceanic atolls.

Diatoms

Diatoms (Table 1) are the dominant component of phytoplankton in all the Indian estuaries and the coastal waters from where detailed inventories of floristic composition and seasonal changes are available. Among the estuaries of the east coast, phytoplankton composition has been studied in detail only from Hooghly, Rushikulya, Godavari, Couum, Ennore, Adyar and Vellar estuaries. A total of 102 species of diatoms belonging to 17 families are known from the east coast, with the largest diversity pertaining to Naviculaceae (21 spp) and Chaetoceraceae and Coscinodiscaceae (11 species each). Several other families like Biddulphiaceae, Lithodesmiaceae, Nitzchiaceae, Thalassionemataceae and Thalassiosiraceae are represented by fewer species. The diatom diversity along the west coast is relatively higher, with 148 species under 22 families. Naviculaceae among them is the dominant with 22 species, followed by Biddulphiaceae (16 spp), Lithodesmiaceae (15 spp) and Thalassiosiraceae (12 spp). Five families – Hemidiscaceae, Stellarimaceae, Stephanodisceae, Streptothecaceae and Helio-peltaceae – with one to three species are known so far only from the west coast. The families Bacillariaceae, Biddulphiaceae, Chaetoceraceae, Naviculaceae, Thalassiosiraceae, Thalassionemataceae and Rhizosoleniaceae are the most cosmopolitan in distribution. Of the few groups of marine organisms, planktonic algae appear to have been more completely catalogued^{2,3}. Their compilation suggests that the number of pennate diatoms in the world oceans could range from 500 to 784 and that of centric diatoms, from 865 to 999. Compared with these, not more than 25% of diatoms species are recorded in Indian waters.

Dinoflagellates

The dinoflagellate species diversity in the east coast estuaries is relatively small (15 species in 7 families) compared to the west coast estuaries (76 species from 10 families). The family Dinophyceae is the dominant with 18 species followed by Peridiniaceae and Ceratiaceae with 13 and 10 species each, respectively. Unlike the diatoms, the number of

Table 1—The diversity of marine flora and fauna of India
(+ estimated to be more)

Taxa	No. of Species
PLANTAE	
Diatoms	200+
Dinoflagellates	90+
Algae	844
Rhodophyta	434
Phaeophyta	191
Xanthophyta	3
Chlorophyta	216
Sea grasses	14
Mangroves	39
PROTISTA	
Protozoa	532+
Foraminifera	500+
Tintinids	32+
ANIMALIA	
Porifera	486+
Cnidaria	842+
Hydrozoa	212+
Scyphozoa	25+
Cubozoa	5+
Anthozoa	600+
Ctenophora	12
Annelida	
Achianeellida	20
Polychaeta	250+
Sipuncula	35
Echiura	33
Chaetognatha	30+
Tardigrada	10+
Arthropoda	
Crustacea	
Copepoda	1925+
Ostocoda	120+
Branchiura	5+
Cirripedes	104
Malacostraca	
Mysidacea	75
Cumacea	30
Tanidacea	1+
Isopoda	33+
Amphipoda	139+
Euphasacea	23+
Stomatopoda	121
Decapoda	
Macrura	55+
Brachyura	705+
Anomura	162
Mollusca	3370
Bryozoans	200+
Echindodermata	765
CHORDATA	
Hemichordata	12
Protochordata	119+
Fishes	2546
Reptiles	35
Mammals	25

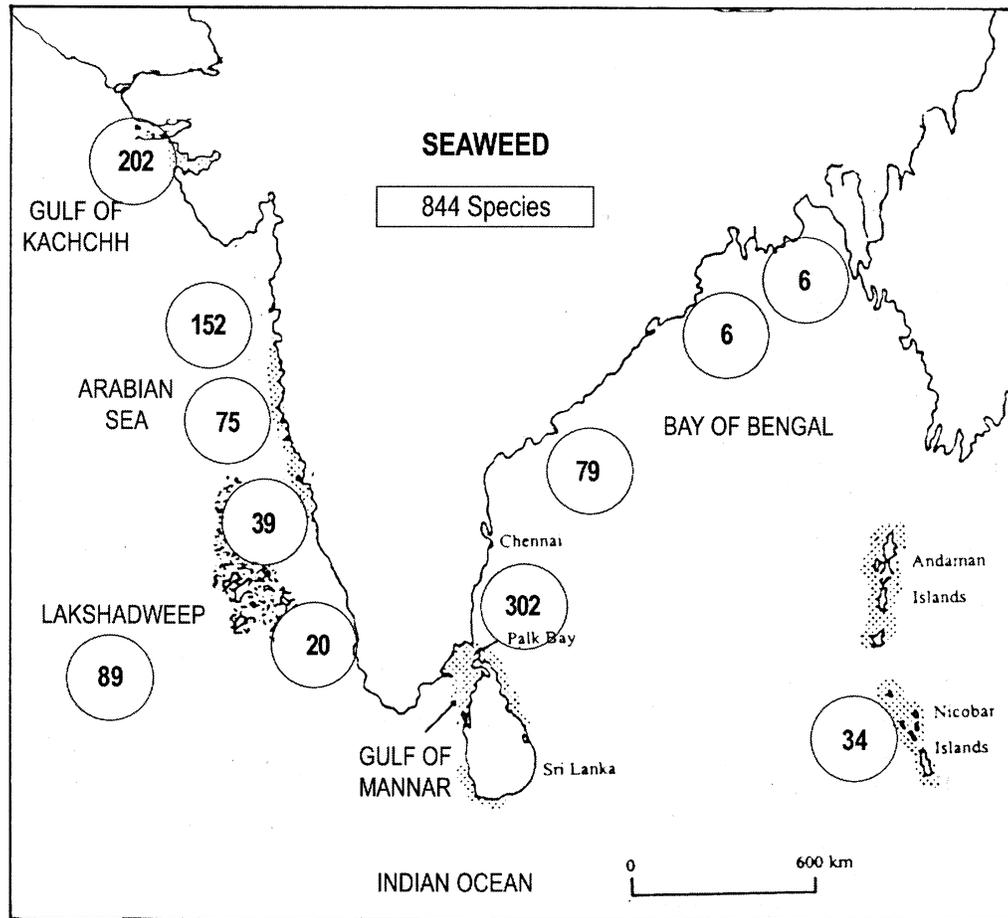


Fig. 2—Seaweed diversity of India

estimated dinoflagellate species in the marine environment varies from 1000 to 2000 (Table 1). Compared to these, the current inventory of dinoflagellates in the Indian waters appears too small. Such inventories, however, do not distinguish between truly tropical species and others that are cosmopolitan.

Marine algae

Marine algae from Indian coasts have been fairly well surveyed since several decades. The latest systematic account⁴ lists 844 species (including forma and varieties) distributed among 217 genera (Table 1). The most abundant among them are Rhodophyta (434 species), followed by Chlorophyta (216 species), Phaeophyta (191 species) and Xanthophyta (3 species). Among these, the maximum number of species has been recorded from Tamil Nadu (302), followed by Gujarat (202), Maharashtra (159), Lakshadweep (89), Andhra Pradesh (79) and Goa (75) (Fig. 2). The scanty records in other maritime states,

especially the Andaman and Nicobar Islands, may not necessarily mean a paucity of algal species but may rather reflect a lack of intensive surveys.

The seaweeds are harvested mainly for use as raw materials for the production of agar, alginates and seaweed liquid fertilizer. The red algae (*Gelidiella acerosa*, *Gracilaria edulis*, *G. crassa*, *G. foliifera* and *G. verrucosa*) are used for manufacture of agar and the brown algae (*Sargassum* spp., *Turbinaria* spp. and *Cystoseira trinodis*), for alginates and seaweed liquid fertilizers. Bulk of the harvest is from the natural seaweed beds of Gulf of Mannar Islands. Recently, *Euchema cottonii* has been introduced in the Gulf of Mannar for commercial farming. Its effect on native species, not known so far, remains a matter of great concern.

Seagrasses

Fourteen species of seagrasses under 6 genera are known from Indian seas (Table 1). They are often found in association with coral reef areas. Eleven

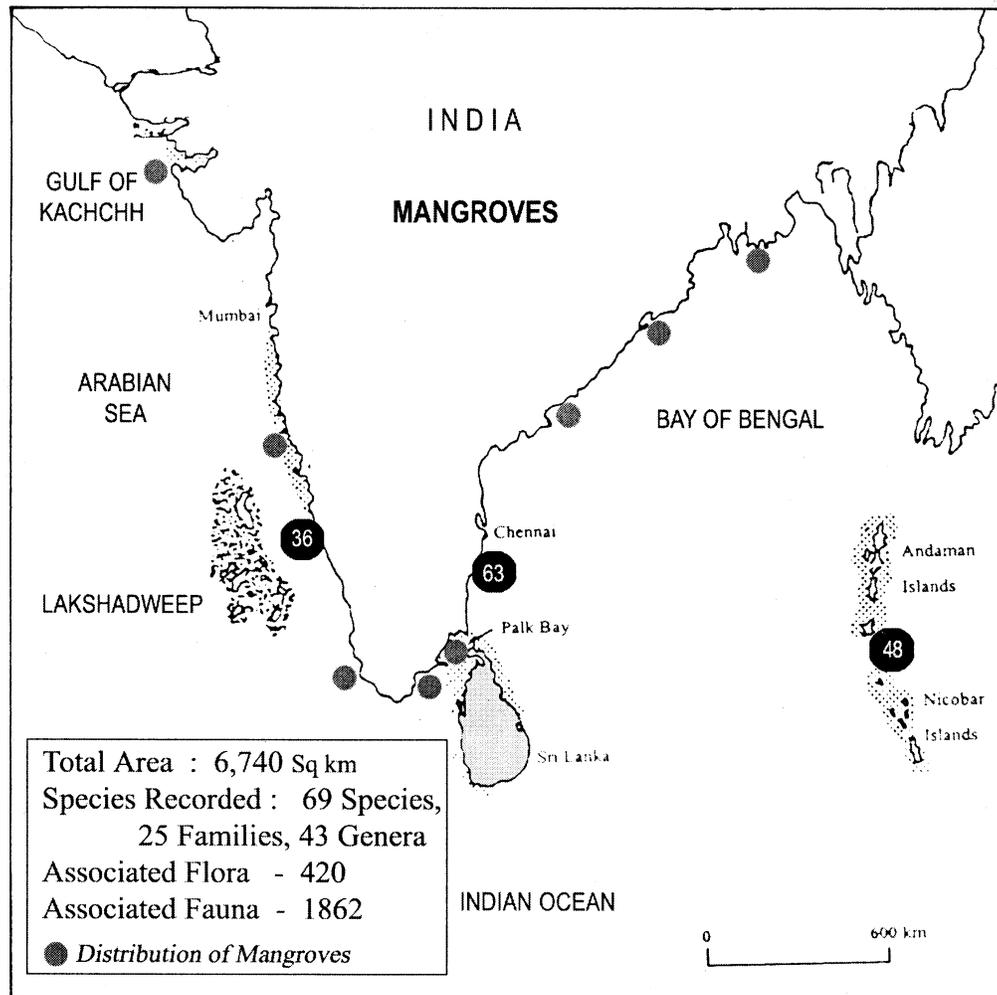


Fig. 3—Diversity of mangroves in India

species are known from the Palk Bay, which include *Cymodocea serrulata*, *Halophila ovalis* sub sp. *ovalis*, *Halodule pinifolia* and *Syringodium isoetifolium*. Thirteen species occur in the Gulf of Mannar Biosphere Reserve, with *Halophila*, *Halodule*, *Enhalus* and *Cymodocea* being common among them⁵. *Thalassia* and *Syringodium* are dominant in coral reef areas and coral rubbles whereas others are distributed in muddy and fine sandy soils. Along the west coast, only *Halophila* and *Halodule* species are cosmopolitan in distribution and *Cymodocea* sp. and *Syringodium isoetifolium* occur as very small patches at the southern most end of Thiruvananthapuram. Nine species, among which *Thalassia hemprichii* and *Cymodocea rotundata* are dominant are found in the Andaman and Nicobar Islands. From Lakshadweep Islands, 7 species are known, among which *Thalassia hemprichi* is dominant.

Mangroves

The Indian mangroves cover about 4827 km², with about 57% of them along the east coast, 23% along the west coast and the remaining 20% in Andaman and Nicobar Islands. The mangrove formations are of three types—deltaic, backwater-estuarine and insular. The deltaic mangroves occur mainly along the east coast, the backwater-estuarine type along the west coast and the insular in Andaman and Nicobar Islands. A total of 39 mangrove species are known from India (Fig. 3). While several of them are cosmopolitan in distribution, five of them - *Aegialitis rotundifolia*, *Heritiera fomes*, *H. kanikensis*, *Rhizophora annamalayana* and *R. stylosa*—are restricted to the east coast and one, *Lumnitzera littorea*, is present only in the Andaman and Nicobar Islands⁶.

Protozoa

The known number of protozoan species from Indian seas is 2577, equivalent to about 8% of the total world protozoan fauna. Among them, 52% are free-living and the remaining, parasitic species. Out of seven protozoan phyla only one viz., Labyrinthomorpha has not yet been reported from India.

Foraminifera

The most important phase of documentation of foraminiferan fauna began with the Challenger Expedition (1873-1876), giving rise to detailed descriptions of deep and shallow water Foraminifera⁷⁻⁹. Contemporary studies began with International Geophysical Year in 1958 and the International Indian Ocean Expedition (1962-1965). The major part of the work on this group was along the east coast of India. These are by Bhatia & Bhalla¹⁰ (14 benthic species from Puri Beach), Satyavathy¹¹ (Waltair Coast), Sarojini¹² (Waltair Coast), Subba Rao & Vedantam¹³ (distribution of 32 species on the continental shelf off Visakhapatnam at depths of 20–200 m), Bhalla¹⁴ (16 species from beach sand of Visakhapatnam), Bhatt¹⁵ (1969) (15 planktonic species off Visakhapatnam), Bhalla¹⁶ (15 species from Madras Marina Beach), Gnanamuthu¹⁷ (47 littoral benthic species from Krusadai Island, Gulf of Mannar) and Ameer Hamsa¹⁸ (description of four new records from the Palk Bay). Comparatively less work has been done on the west coast of India and the Arabian Sea. Mention may be made on the work of Antony¹⁹ (description and distribution of 164 species from Kerala coast), Siebold²⁰ (12 species of benthic foraminifera from Kochi backwaters), Chapman⁸ (description of 277 species from bottom samples near Lakshadweep Islands), Chatterjee & Gururaja²¹ (unidentified species from 16-20 m depth off Mangalore coast), Chaudhuri and Biswas²² (12 species from Juhu Beach, Bombay) and Rao²³⁻²⁵ (a series of papers describing 84 species from shallow waters of Gulf of Cambay). The study of Frerichs²⁶ on the distribution and ecology of benthonic and planktonic forms in the sediments of the Andaman Sea appears to be the only one from the Andaman and Nicobar Islands.

Tintinnid

The order Tintinnida comprises of more than 1000 species of marine ciliates that form an important component of the microzooplankton. A total of 32 species belonging to 12 genera are known from Indian

waters²⁷. The degree of abundance of tintinnid populations seems to coincide with diatom and dinoflagellate blooms, however, the persistence of such “swarms” appear to be controlled by the larger zooplankton grazers, such as copepods, chaetognaths, bivalve and gastropod veligers. More studies on diversity, biology and other ecological aspects of the tintinnids are needed.

Sponges

This group has an evolutionary history of about 570 million years and so far, 486 species have been described in India²⁸. The sponge fauna of India is dominated by species of Desmospongia followed by those of Hyalospongiae and Calciospongiae. Also 34 species of coral boring sponges (20 from Gulf of Mannar and Palk Bay, 5 from Andaman and Nicobar Islands and 18 from Lakshadweep reefs) have been recorded. The Gulf of Mannar and Palk Bay region has the highest diversity (319 species) followed by Andaman and Nicobar Islands (95 species), Lakshadweep (82 species) and Gulf of Kachchh (25 species) (Fig. 4).

Cnidaria

The global estimates of cnidarian diversity vary between 9000 and 12,000 species. In India 212 species of Hydrozoa, 25 species of Scyphozoa, 5 species of Cubozoa and 600 species of Anthozoa have been reported till now. Since all groups of Cnidarians have not received adequate attention of Indian taxonomists, the above figures cannot be taken as final. Except the pioneering works of Annandale²⁹⁻³¹, Leloup³² and Menon³³ other studies are few and scattered. Comprehensive accounts are available only for siphonophores by Daniel³⁴, scyphomedusae by Chakrapany³⁵ and scleratinian corals by Pillai³⁶.

Hydrozoa

The first description of hydrozoans in India was by Annandale³⁷ from Chilka Lagoon and subsequently by Menon³⁸ reporting 35 species under 28 genera and of Mammen^{39,40} who has recorded 116 species belonging to 13 families. Among these forms, species of the orders Milliporina, Stylasterina and Trachylina have received only scanty attention so far.

Siphonophora

Siphonophora are abundant in the Indian seas and constitute an important part of the marine plankton. The siphonophores from the Indian Ocean have been studied by several workers and the reports for Indian

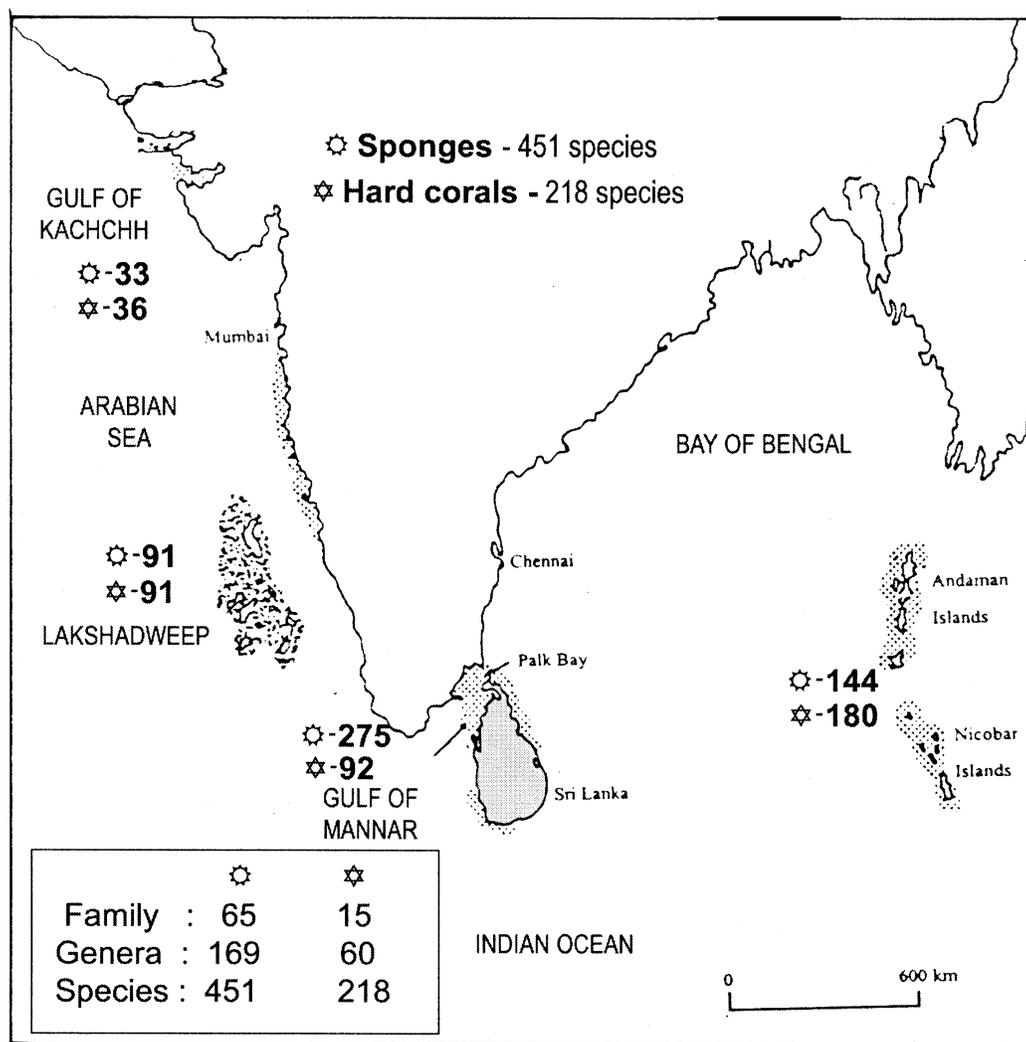


Fig. 4—Diversity of Sponges and hard corals in India.

waters were those by Sundara Raj⁴¹, Lelop⁴² and Daniel & Daniel⁴³ from the Madras Coast; Rengarajan⁴⁴ from the West Coast of India and Daniel^{45,46} from the West and East Coasts of India and those collected by R. V. 'Vityaz' along 90-110° E longitude down 35° S latitude. A comprehensive account of Siphonophora of India⁴⁷ shows 116 valid, one variety and 3 doubtful species known from the Indian Ocean, of which 89 occur in the Indian seas.

Anthozoa - Scleractinia

Studies on the taxonomy of Indian coral reefs started in India as early as 1847 by Rink in Nicobar Islands and later in 1988 by Thurston at Gulf of Mannar region. Brook⁴⁸ recognized 8 species of *Acropora* from Rameswaram (South East coast of India), out of which *A. multicaulia*, *A. thurstoni* and

A. indica were described as new. Subsequent contributions to inventory of coral species were made by Alcock^{49,50}, Gardiner⁵¹, Matthai⁵², Gravely⁵³ and Sewell⁵⁴. Contemporary studies on corals are those of Pillai⁵⁵ and Venkataraman *et al.*⁵⁶, which lists a total of 218 species under 60 genera and 15 families. Among the four major reef areas of India, Andaman and Nicobar Islands are rich in coral species diversity whereas those of Gulf of Kachchh is poorer. Lakshadweep Islands have more number of species than the Gulf of Mannar (Fig. 4). Among the deepwater (ahermatypic) corals, so far 686 species belonging to 110 genera and 12 families have been reported from the world of which 227 species belonging to 71 genera and 12 families have been reported from the Indian Ocean region. However, meager attention has been paid so far to inventorise

the deepwater corals and as a result, only 44 species are known until now from Indian seas⁵⁶.

Scyphozoa - Scyphomedusae

The earliest records of Scyphozoa in Indian seas were made by Browne⁵⁷⁻⁵⁹ from Lakshadweep, Maldives, Sri Lanka and Okhamandal Coast of Kattiawar, followed by Annandale⁶⁰, Menon^{61,62}, Panikkar⁶³, Nair^{64,65} and Chakrapany⁶⁶. In the Indian seas several cruises of the *R.I.M.S. 'Investigator'* and coastal surveys by the Officers of the Zoological Survey of India have yielded a collection of 24 species, which form the Indian National Collections in the Zoological Survey of India, Calcutta⁶⁶. In addition, several cruises of the *R. V. 'Chota Investigator'* along the Madras coast from 1972 to 1983 revealed the occurrence of 19 species of which 11 were already known from the Indian seas. Thus, out of the 200 species of Scyphomedusae known from the World Oceans, 34 are known from the Indian seas⁶⁶.

Ctenophora

Only 12 species of Ctenophores, among the 100-150 species known from the world ocean, occur in the Indian seas. This inventory is derived from sporadic studies carried out several decades ago by Annandale & Kemp⁶⁷, Varadarajan⁶⁸ and Devanesan & Varadarajan⁶⁹. Since then there has been no studies on Ctenophores in India so far.

Annelida - Archiannelida

Pioneering studies on archiannelids of India were made by Aiyar & Alikunhi⁷⁰ and Alikunhi^{71,72} along Madras coast from which 2 species of *Polygordius*, 2 species of *Protodrilus* and 4 species of *Saccocirrus* were described as new to science. Rao & Ganapati⁷³ recorded 15 species of archiannelids from the beach sands along Waltair coast. Thus, compared to the vast stretch of Indian coast, the investigations hitherto carried out on Archiannelida are quite limited and any further intensive surveys of the fauna in other areas are quite likely to yield interesting results. The world records of Archiannelida hitherto made fall under 5 families, 18 genera and over 90 species, of which about 20 species are reported from Indian coasts.

Polychaeta

In the phylum Annelida, the Polychaeta have received considerable attention from 1909. Survey of this group actually started with Southern's⁷⁴ work on "Polychaeta of Chilka Lake" followed by the littoral

fauna of Krusadai Island in the Gulf of Mannar by Gravely⁷⁵ (nearly 36 species under 11 families) and by Fauvel⁷⁶ (119 species under 22 families). Perusal of literature shows that most of the records pertaining to this group are either from the Madras coast or the Gulf of Mannar⁷⁷⁻⁸¹. Central Marine Fisheries Research Institute has listed 200 species under 46 families in the catalogue of types and reference collections. From the collections of Zoological Survey of India and the Indian Museum, Fauvel⁸² described 300 species under 30 families and in his later monograph⁸³ raised this to 450 species. Hartman⁸⁴ while dealing with polychaetes of Indian Ocean recorded 244 species of which 116 are considered new to the region. The catalogue of the polychaetous annelids from India lists 883 species.

Oligochaeta

Marine Oligochaete fauna is poorly known in India, and most of the species are recorded from littoral zones of small freshwater bodies like ponds, tanks, pools, ditches, etc., all over the country. The Enchytraeidae (pot-worms) occur in terrestrial, littoral and marine habitats, being abundant in acidic soils with high organic matter. As compared to the world fauna, only 3% of enchytraeid species have so far been reported from this region, mainly from Orissa.

Sipuncula

The pioneering work on the Indian Sipuncula dates back to Shipley⁸⁵, followed by a rather scattered series of taxonomic contributions made by Gravely⁸⁶, Prasad⁸⁷, Johnson⁸⁸⁻⁹⁰, Haldar^{91,92}, Cutler⁹³ and Cutler & Cutler⁹⁴. Of the 145 species under 17 genera known from the world oceans, 35 species under 10 genera and 5 families occur in the Indian coasts. So far as the distributional pattern of the sipunculan fauna is concerned the major areas of species concentration are Andaman and Nicobar Islands, Lakshadweep Islands, Gulf of Mannar and Gulf of Kachchh.

Echiura

The phylum Echiura comprises of 127 species under 32 genera and 5 families. Studies on Indian echiuran fauna began only in the early 20th Century when Annandale & Kemp⁹⁵ described two new species of the genus *Anelassorhynchus* from Chilka Lagoon. Subsequent studies^{96,97} had enriched knowledge on Indian echiuroids so much so that the current inventory of 33 species under 11 genera is fairly rich in comparison with what is known (43 species under 14 genera) from the Indian Ocean.

Maximum abundance of echinurans is in Gulf of Kachchh, Gulf of Kambath, Lakshadweep, Andaman and Nicobar Islands and Gulf of Mannar. Mud-dwelling forms are few in numbers and are found in Kerala, West Bengal and Orissa.

Chaetognatha

Chaetognaths (arrow worms or glass worms) rank second in terms of abundance after copepods in marine zooplankton and are cosmopolitan in distribution. They are mostly marine, but a few species are estuarine. Among the 120 species known from the world oceans, about 30 are reported from the Indian Seas. Chaetognaths have been extensively studied in Indian waters and from various coastal and oceanic sites: Bombay harbour⁹⁸; Madras coast⁹⁹; Kurusadai Island¹⁰⁰; Trivandrum coast^{101,102}; Malabar coast¹⁰³; Mandapam area^{104,105}; Lawson's Bay, Waltair^{106,107}; Ennore estuary^{108,109}; Andaman Sea¹¹⁰ and coastal and offshore waters¹¹¹⁻¹¹⁴. In contrast with this numerous studies, chaetognaths of the deeper waters of the seas around India and those of Andaman and Nicobar Islands and central and northern parts of the Bay of Bengal are not well known.

Tardigrada

Tardigrades occur as meiofauna in the sandy beaches up to 2 or 3 m from water's edge of seacoast. Among the three orders of the Phylum Tardigrada, the Heterotardigrada is found in marine, freshwater and high altitude mountains. So far 214 species are reported from the world under five families and 20 genera. However in India only 10 species under two families and three genera have been reported as meiofauna of marine region¹¹⁵.

Arthropoda: Crustacea

Global estimate of Crustacean species diversity is 150,000 of which 40,000 have been described so far. Of the 2934 species of Crustacea that have been reported¹¹⁶ so far, marine species (94.85%) contribute maximum to this diversity. In India as many as 139 species of stomatopods (4 families and 26 genera), 26 species of lobsters (4 families, 11 genera), 162 species of hermit crabs (3 families, 40 genera), 705 brachyuran crabs (28 families, 270 genera), 84 species of shrimps and prawns (7 families, 19 genera) and 159 species of Caridea (15 families, 56 genera) have been recorded so far. Other than these, 540 species of copepods, 104 species of cirripeds, 120 species of ostracods have also been recorded (Fig. 5).

Copepoda

Copepods are the most widely studied group among the marine zooplankton. There are approximately 210 described families, 2,280 genera and over 14,000 species in the world. Important contributions to systematics of copepods from Indian waters are those of Sewell¹¹⁷, Krishnaswamy¹¹⁸ and Pillay¹¹⁹. Largely as a result of these studies as well as several others since then (e.g. Madhupratap¹²⁰) it is now known that there are 540+ number of copepod species in Indian waters. Among these, the most dominant group is Calanoida, with the Cyclopoida and Harpacticoida being relatively less important. Major studies on Cyclopoids are again those of Krishnaswamy¹¹⁸. Only very few papers dealing with marine Harpacticoida of India and neighboring seas have been published so far¹²¹⁻¹²⁴. Studies on sand-dwelling forms are still less: only those of Krishnaswamy^{118,123,124} provide an account of 17 sand-dwelling harpacticoids under five families together with discussion on their adaptation as well as their ecology. A total of 106 species belonging to 23 families are known from the east coast estuaries. Among them the calanoids are the dominant, distributed in 16 families, followed by harpacticoids (5 families) and cyclopoids (2 families). The diversity in the west coast estuaries is relatively higher, with 179 species in 31 families. Calanoids are dominant with 20 families. Though the number of families of harpacticoids and cyclopoids are the same (6 families), the latter is more diverse, with 22 species compared with 7 species of harpacticoids.

Ostracoda

The Ostracoda are one of the most successful aquatic crustacean groups with approximately 8000 living species. The six extant and extinct orders are ubiquitous and diverse, with over 50,000 named species and genera and more awaiting study. Except for the studies of Poulsen¹²⁵ very little is known of Indian ostracods. Only 60+ species of ostracods are known from the Indian coast of which 38 species are known from the east coast and 28 species from the west coast¹²⁶.

Branchiura

Our knowledge of this group from the Indian region is rather scanty. It is not until 1951, when Ramakrishna contributed to our knowledge of the Indian species of arguulids found parasitic on fishes, that the group received adequate attention. He

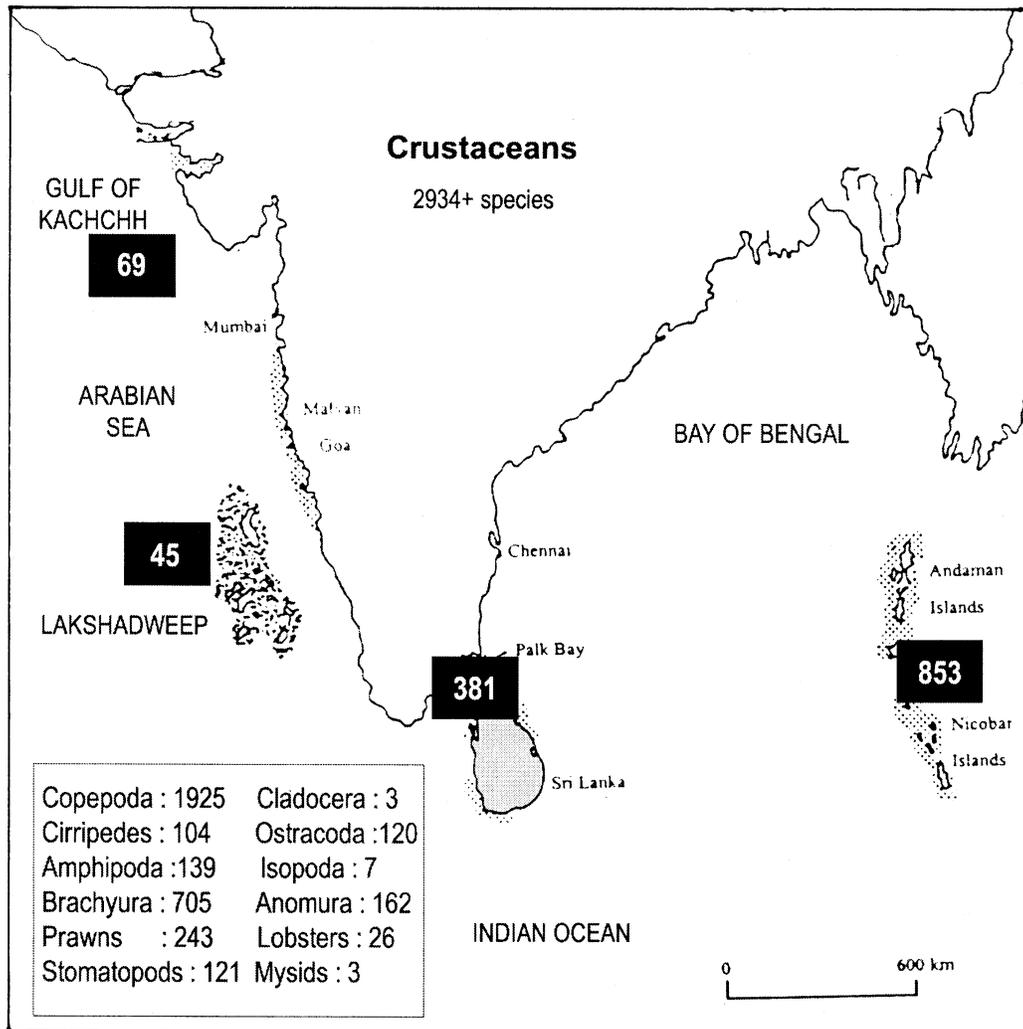


Fig. 5—Diversity of Crustacea in India

described five species of the genus *Argulus* of which three were described as new to science.

Cirripedes

Information on the diversity of Cirripedia of Indian coast is far from complete, with only 36 species having been recorded so far. Even these records¹²⁷⁻¹³² are rather sketchy and have low geographical coverage.

Malacostraca - Mysidacea

Mysidaceans, with a total number of about 75 species, are known so far only from the works of Tattersall¹³³ and Pillai^{134,135}.

Cumacea

Cumacean species are also little known except for the studies of Calman¹³⁶ Kemp¹³⁷ and Kurian^{138,139}.

Altogether 23 species of Bodotriidae, 3 species of Disstylidae, 4 species of Nannastaeidae and one species of Camylaspidae are known from the Indian region.

Tanaiacea

Our knowledge of Tanaiacea is rather poor from the Indian region. Chilon¹⁴⁰ contributed a paper dealing with a species of the group from the Chilka Lake.

Isopoda

Very little is known about the marine isopods when compared to terrestrial isopods of India. Chopra¹⁴¹ contributed a monumental monograph on the Bopyrid isopods of Indian Macrura wherein 33 species pertaining to 13 genera were described from Andaman Islands, Delta of Ganges and Madras and

other areas. Chopra¹⁴² contributed another paper on the Bopyrid isopods on Indian Macrura. The collection included 12 species pertaining to 7 genera collected mostly from the Andaman and Nicobar Islands, Delta Ganges, Gulf of Mannar and Bombay. The contributions on the marine woodborers from 1963 to 1968 by various Indian authors revealed six species of the genus *Sphaeroma* and nine species of *Limnoria* from the Indian waters.

Amphipoda

Studies on the amphipods of the Indian and the neighboring waters received the attention of Zoologists only as late as 1885 when Giles¹⁴² reported on the occurrence of two species of amphipods from Bengal. His subsequent works raised the number to 27. Gravely¹⁴³ and Sundara Raj¹⁴⁴ reported sixteen species amphipods from Krusadai Island, Gulf of Mannar and the neighbouring waters. Bernard¹⁴⁵ reported amphipods from the collection made from Travancore, Cochin and Bengal coasts by the Zoological Survey of India, apart from the record of the three species of amphipods off the coast of Mahabalipuram by Giles¹⁴² and a brief note about the occurrence of three species of amphipods at Adyar in Madras, in the last half of the previous century, Sivaprakasam¹⁴⁶ in a series of contributions enriched our knowledge on the amphipods of east coast of India and listed 61 species. Nayar^{147,148} dealt with the amphipods of the Madras coast and Gulf of Mannar. In his monographs on the Gammaridean amphipods of the Gulf of Mannar he dealt with 78 species, of 26 families. Surya Rao¹⁴⁹ enumerated a detailed account of the intertidal Gammarid amphipods from the Indian coasts and listed 132 species pertaining to 54 genera.

Euphausiacea

The earliest account on Indian euphasids is known through the work of Wood-Mason & Alcock¹⁵⁰, Alcock & Anderson^{151,152}. Tattersall¹⁵³ gave an account of them from the Indian Ocean. Among the Indian coasts 23 species of euphasids from the Laccadive and Maldives as well as from adjoining regions and two species from south west coast of India have been recorded so far.

Stomatopoda

Kemp¹⁵⁴ published a monograph on Indo-Pacific stomatopods comprising of 139 species and varieties known till then. Kemp and Chopra published papers on the stomatopods form collection of the John Murray Expedition (1933-34) made by Sewell. Tiwari

& Biswas¹⁵⁵ published a paper based on material accumulated since Chopra's work. After a gap of two decades Ghosh^{156,157} and Tiwari & Ghosh¹⁵⁸ have contributed a series of papers highlighting the present knowledge of Stomatopoda in the Indian waters. The study of Stomatopoda of India is, however, far from complete.

Decapoda - Macrura

Decapoda as a whole has received a good attention from scientific workers compared to other groups. The earliest to contribute was de Man¹⁵⁹ who, in a series of papers, referred to the Decapod collection from the brackish water ponds of West Bengal. The contributions of Kemp to the study of Indian Crustacea are among the most noteworthy of the group. His contributions on decapod crustaceans of the Indian Museum published in 24 parts in the *Records of the Indian Museum* contains systematic account of various marine and brackish water forms belonging to the families Hippolytidae, Carangonidae, Disciadidae, Palaemonidae, Pasiphasidae, Stylodactylidae, Rhynchocinetidae, Pacdalidae and Anchistodidae in which, species from most varied habitats have been reported. Alcock¹⁶⁰ contributed a comprehensive catalogue on the penaeid prawns of India. Since then several Indian researchers have contributed to inventories of this group. Although large number of species of prawns and lobsters are known to occur in and along the Indian coast, work on this group of species is very limited. World over 17 families, 67 genera and 383 species have been recorded as commercially important. A total of 55 species of commercial shrimps and prawns have been recorded in India. The east coast of India contributes to about 24.5% and the west coast contributes to 75.3% of country's shrimp production.

Brachyura

The earliest works on the crabs of Indian seas were those of Milne Edwards¹⁶¹, Henderson¹⁶² and de Man¹⁶³. The first comprehensive study of the crabs of west coast was that of Borradaile¹⁶⁴. Alcock^{49,50,160} gave a detailed account of marine and brackish water crabs. Kemp¹⁶⁵ dealt with 38 species under six families collected from the Chilka Lake and in 1923 accounted for crabs collected from the mouth of Hooghly River. Chopra^{166,167} in a series of contributions entitled "Further Notes on Crustacea Decapoda in the Indian Museum" published in seven parts dealt with Hymenosomatid, Dromiacea,

Oxystomata, Oxyrhyncha, Brachyrhyncha and Potamonid crabs. These series were in continuation of Kemp's series entitled "Noters on Crustacea Decapoda in the Indian Museum". Many other Indian authors added to the earlier works raising the total carcinological fauna to above 250 species. There are about 254 species of crabs belonging to 120 genera under 24 families recorded along the west coast of India. Among these, the names of 100 species have been revised. 22 families and 37 subfamilies represents brachyuran crabs. Family Leucosiidae represented the higher number with 20 species followed by subfamily Thalamitae of family Portunidae (19 species). Family Xanthidae alone is represented by 10 subfamilies of which the subfamily Zosiminae is represented by 14 species.

Anomura

Sarojini & Nagabhushanam¹⁶⁸ gave a detailed account on the Porcellanids from the Waltair coast. Reddy & Ramakrishna¹⁶⁹ listed twenty species pertaining to the families Paguridae and Coenobitidae. The study on the Anomuran crabs is far from complete and more studies are needed in this group.

Mollusca

The history of malacological study in India is immense and interesting. Studies on Indian molluscs were initiated by the Asiatic Society of Bengal (1784) and the Indian Museum, Calcutta (1814). Benson in 1830 was perhaps the first author to publish a scientific paper on Mollusca. Between the years 1830 and 1865 he published a total of about 90 papers dealing with the land and freshwater molluscs of the Indian subcontinent. The beginning of the 20th century is the most productive and significant period in the history of Indian Malacology, with the Zoological Survey of India, Central Marine Fisheries Research Institute and several maritime universities contributing immensely to the knowledge of the molluscan fauna. In India, till today, 5070 species of Mollusca have been recorded of which, 3370 species are from marine habitats^{170,171}. From the available data, it is possible to identify certain areas having rich molluscan diversity. Andaman and Nicobar Islands have a rich molluscan diversity, which includes over 1000 species from the marine region¹⁷². Gulf of Mannar and Lakshadweep have 428 and 424 species respectively¹⁷³ (Fig. 6). Eight species of oysters, two species of mussels, 17 species of clams, six species of pearl oysters, four species of giant clams, one species

of window-pane oyster and other gastropods such as Sacred chank, *Trochus*, *Turbo* as well as 15 species of cephalopods are exploited from the Indian marine region.

Bryozoans

Although regarded traditionally as a minor phylum, the group contains as many as 20,000 described species actually occupying an intermediate position in the hierarchy of animal phylum in respect of species representation. Of these, approximately 4,000 species are living. At least 200 valid species occur in India¹⁷⁴. The bryozoa are grouped under three classes i.e. Phylactolaemata (freshwater species), Stenolaemata and Gynolaemata. A total of 126 families are recognized – 100 from Gymnolaemata (15 from the order Ctenostomata and 85 from Cheilostomata), 21 from Stenolaemata and five from Phylactolaemata. In India, as in other parts of the world, only a few species of bryozoans inhabit freshwater lakes and rivers (Phylactolaemata) and most others are marine or estuarine. It is however to be noted that vast stretches of the long Indian coastline still remain unexplored and biology and ecology of several species still remain uninvestigated.

Entoprocta

The Entoprocta are predominantly marine having about 60 species known from the world with the exception of one genus in freshwater. Reports of Entoprocta from India are scanty except for the brackish and marine water species reported by Annandale^{175,176} and Harmer¹⁷⁷. The diversity in Entoprocta is limited and restricted basically to the following three families viz., Loxosomatidae, Pedicellinidae and Urnatellidae. Family Loxosomatidae is commonly represented in India by two genera (*Loxosoma* and *Loxocalyx*). The family Pedicellinidae is represented by the genera *Pedicellina*, *Myosoma*, *Chitaspis*, *Loxosomatoides*, *Pedicellinopsis*, *Barentsia*, *Gonypodaria* and *Arthropodaris*.

Echinodermata

Plancus and Gualtire made the first report on Indian echinoderms from Goa in 1743 and the next one in 1830 was by Collier¹⁷⁸ on the *beche-de-mer*. Subsequently, the accounts of Muller¹⁷⁹, Lutken^{180,181} and Marktanner-Turneretscher¹⁸² included a few new species from the Bay of Bengal. Most of what we know of the echinoderm fauna is from examination of

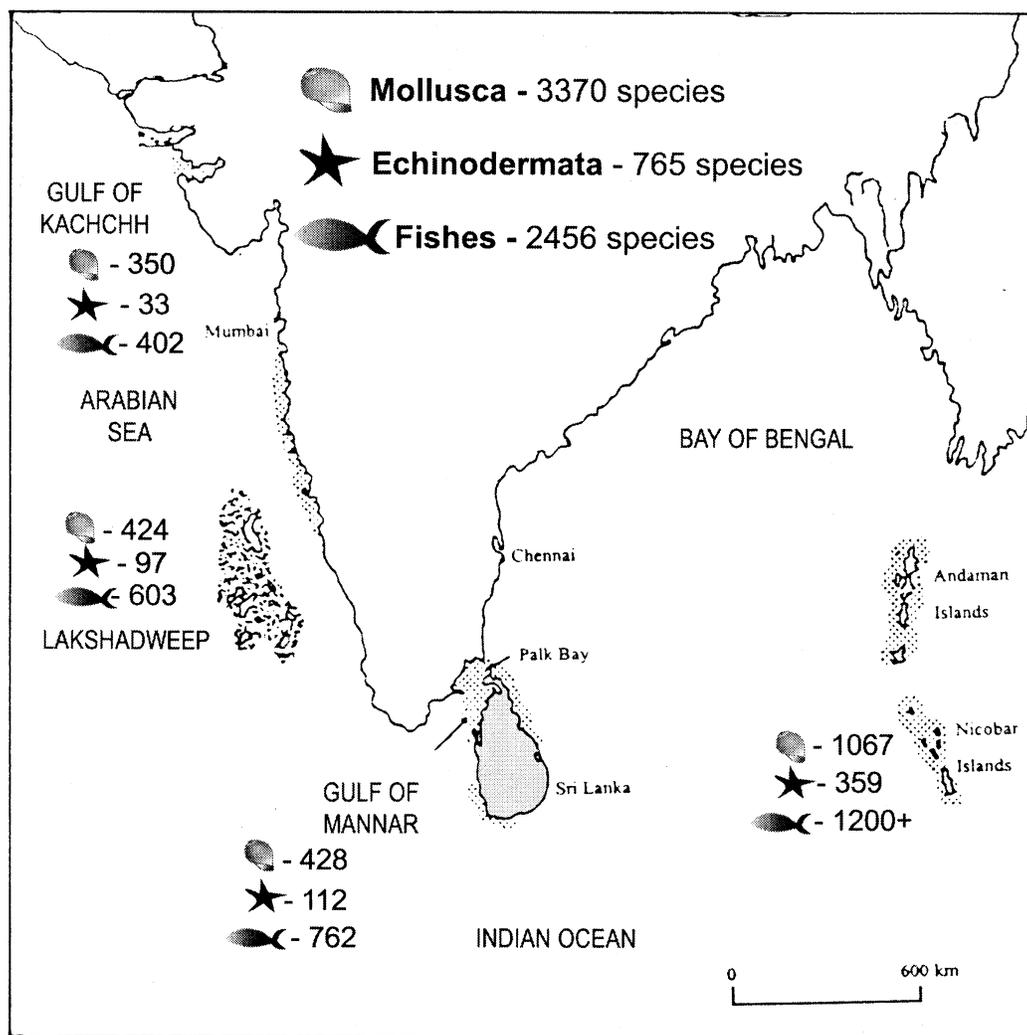


Fig. 6—Diversity of mollusca, echinoderms and marine Fishes of India.

the collections from expeditions such as *Investigator*, *Challenger*, *Valdivia* and *John Murray*. India has 765 species (Crinoidea: 13 families, 43 genera 95 species; Asterozoidea: 20 families, 81 genera and 180 species; Ophiurozoidea: 15 families, 67 genera 150 species; Echinozoidea: 28 families, 79 genera 150 species; Holothurozoidea 14 families, 62 genera 160 species) recorded until today and about 257 species are known from Andaman and Nicobar Islands¹⁸³. Lakshadweep has 77 species and the Gulf of Mannar, 112 species (Fig. 6). Economically, only Holothurozoidea are exploited on a commercial scale for export. Twelve species of Holothurozoidea belonging to the genera *Actinopyga*, *Bohadschia*, *Holothuria*, *Stichopus* and *Thelenota* are known to be of commercial importance in India. However, only three species *Bohadschia marmorata*, *Holothuria scabra* and *H. spinifera* are

being exploited to a large extent in the Gulf of Mannar. All holothurians are now included under Schedule 1 of the Wildlife Protection Act, 1972.

Hemichordata

Phylum Hemichordata is divided into three classes, *i.e.* Enteropneusta, Pterobranchia and Planctosphaerozoa. Of the four families known from the world only three families are recorded from India. So far, 102 species are recorded from the world of which 12 are known from India¹⁸⁴. Genera such as *Ptychodera*, *Balanoglossus*, *Glandiceps* have been collected from the Gulf of Mannar, Gulf of Kachchh, Andaman Islands, Lakshadweep and Maldive Seas, the Tamil Nadu coast up to Cape Comerin and the *Saccoglossus* has been recorded from the high saline marshy areas of Sunderbans in West Bengal. The only

commonly available enteropneust worm in India is *Ptychodera flauva*.

Protochordata

This phylum includes two subphylum Cephalochordata and Urochordata. Worldwide the diversity of cephalochordates includes 2 families, 2 genera and 24 species and in India 6 species are reported under 2 families and 2 genera. The subphylum Urochordata is divided into class Ascidiacea (sea squirts) that are sessile or benthos attached to substratum on the coral reef, Class Thaliacea (= salps) and Class Larvacea that are planktonic. About 2000 species of ascidians are reported from all over the world of which 47 are reported in India (9 families, 21 genera). Out of 57 species of Thaliacea reported from the world, 48 species (four families and 19 genera) occur in India and out of 25 species of Larvacea reported from the world 18 (two families 14 genera) are reported from India^{185,186}.

Fishes

The history of ichthyology in India is colossal and interesting. Brief histories of Indian Ichthyology may be found in Day^{187,188} and Whitehead & Talwar¹⁸⁹. Among the books published on Indian fishes, Francis Day's (1875-1878) treatise "*The fishes of India*" is of greatest importance. The publications on "*Commercial sea fishes of India*" by Talwar & Kacker¹⁹⁰ and "*Fishes of the Laccadive Archipelago*" by the Jones & Kumaran¹⁹¹ are noteworthy in our knowledge of fish faunal resources of India besides many other research publications by other scientists. Fishes comprise about half the total number of vertebrates. The number of estimated living fish species might be close to 28,000 in the world. Day¹⁹² has described 1418 species of fish under 342 genera from the British India. Talwar¹⁹³ has described 2546 species of fish belonging to 969 genera, 254 families and 40 orders (Fig. 6). The distribution of marine fishes is rather wide and some genera are common to the Indo-Pacific and the Atlantic regions. 57 percent of the Indian marine fish genera are common to the Indian Ocean and to the Atlantic and Mediterranean.

The exact number of species associated with coral reefs of India is still to be found, however the number of fishes in Indian Ocean is 1367 species. The Lakshadweep Islands have a total of 603 species of fishes¹⁹¹. Over 1000 species are found in the Andaman and Nicobar Islands and about 538 in the

Gulf of Mannar Biosphere Reserve. The categories of fishes occurring in coral reef ecosystem of India includes groups such as the damselfishes (52 species), butterfly fishes (32 species), sweet lips (16 species), angelfishes (16 species), parrot fishes (14 species), snappers (42 species) and most of the wrasses (53 species), groupers (43 species) and surgeonfish (18 species)¹⁹⁴. Another 20% are composed of cryptic and nocturnal species that are confined primarily to caverns and reef crevices during daylight periods.

Reptiles

About 26 species of sea snakes belonging to the family Hydrophiidae and five species of sea turtles have been reported from seas around India. All the sea snakes and four species of turtles in their marine environment are known from islands of Andaman and Nicobar. Studies on sea turtles occurring in the coastal waters of India and their nesting grounds were neglected till Smith¹⁹⁵ focused our attention on these giants among the sea reptiles. Seven species of sea turtles are found in the world's warm oceans of which five species are reported in India. Of these Leatherback sea turtle, *Dermochelys coriacea* is the sole representative of the family Dermochelyidae and is a rare species. The remaining four species namely the Green turtle (*Chelonia mydas*), the Olive Ridley (*Lepidochelys olivacea*), the Hawksbill (*Eretmochelys imbricata*), and the Loggerhead (*Caretta caretta*) are contained in a single family, Cheloniidae.

Marine mammals

Marine mammals belong to three orders Cetacea, Carnivora and Sirenia. A little over 120 species are estimated to occur world over and of these 40 are reported from Indian Ocean and 25 species of marine mammals belonging to the order Cetacea and Sirenia are reported from Indian waters¹⁹⁶. However, a majority of these are oceanic forms and occasionally a few individuals may get stranded on the shore. Sea cow, *Dugong dugong* occurs in near shore waters of Gulf of Mannar, Gulf of Kachchh and Andaman and Nicobar Islands. Dolphins and some of the whales that live or breed in tropical waters, such as humpbacks, are occasionally seen near shore areas. The Government of India has so far listed three species of cetaceans (Irrawady dolphin, Ganges River dolphin and sperm whale) and the dugong in Schedule I of Wildlife Act 1972 (amended in 1991).

The current inventory of coastal and marine biodiversity of India (Table 1) shows that many

groups that are commercially and trophically important are the ones that have been extensively inventorised, leaving several groups, notably the minor phyla grossly understudied.

Threats to coastal and marine biodiversity

Marine resources have traditionally been a major source of food for local inhabitants and of major economic value in terms of commercial exploitation. The human exploitation of marine resources has increased dramatically in the last few decades for reasons, both commerce and subsistence living. Marine ecosystems of India have been exploited since long time but it is only in the last century that the rate of exploitation has increased dramatically, due mostly to the increase in the human population. Except for some of the Andaman-Nicobar Islands, no pristine area exists today. Noticeable decline of marine resources of India go back at least as far as Gardiner who in 1936 expressed concern about the degree to which the degradation takes place where the habitation occurs near marine areas. At the end of the last century or in the beginning of this century, very few marine areas of India remained unaffected, whereas most were partially deteriorated and a few were severely affected.

Natural threats

The major stresses on marine ecosystems are storms and waves, particularly cyclones. Cyclonic disturbances develop during October-November along the coast. These cyclones have sustained winds with speed ranging from 65 to 120 km per hour. High-speed winds cause extreme wave action that kills many fauna and flora, also break coral into rubbles and sometimes large amounts of sand and other materials may be dumped onto the coral reef. Also freshwater runoff kills many fauna and flora in semi-enclosed bays and lagoons by lowering salinity and depositing large amounts of sediments and nutrients.

Human impacts

Varied human activities which are, a cause for concern over and above the natural disturbances, include runoff and sedimentation from development activities (projects), eutrophication from sewage and agriculture, physical impact of maritime activities, dredging, collecting, and destructive fishing practices, pollution from industrial sources and oil refineries and the synergistic impacts of anthropogenic disturbance. A general rule for coastal zone is: whatever is used on

land today ends up in the aquifer or coastal zone tomorrow. The amount of sediments and chemicals the runoff water carries to the sea have profound effects on fertilization of eggs of marine species. Likewise, the quality of runoff water can affect the metamorphosis of the larvae of many species. Oil pollution induces mortality, decrease fecundity and fail recruitment. India has three mega cities, many small, medium and major ports and industries around the 8000 km coast. The enactment of Water Pollution Act in 1974 and Environment Protection Act, 1986 have helped in regulating the disposal of wastes from the industries. These measures have resulted in reduction of pollution loads of the coastal waters to certain extent. Major industries like fertilizer, petro and agrochemical and chemicals are mainly located along the coasts. Besides industrial and municipal wastes, port related operations such as continuous movement of marine vessels in the major ports including oil transport as also the wastes of aquaculture and agriculture farms are increasingly posing threats to the coastal water quality and to the biodiversity.

Fishing is a major activity and at present in the 3651 fishing villages situated along the 8129 km coastline of India, about one million are occupied full time in marine capture fisheries. The value of the annual marine fish production was 4.6 million tons during the year 2002-2003 and the value of marine products export was Rs 6,881.31 crores (US \$ 152.92 m). This is mainly due to the introduction of bottom trawlers, which was introduced in the Indian waters in the early 1960s. Several types of net fishing have also been responsible for over-exploitation of marine resource. The use of fish traps made of long-lasting materials with small mesh sizes results in the capture of pre-reproductive juveniles affecting future populations and the death of fish when traps become dislodged during storms and continue to capture fish, which eventually starve. Fishing operations with latest technologies are causing damage to the marine living resources. Along with increase in the targeted catch, a number of untargeted fish and other biota are removed from their habitat and discarded as waste. Shrimp trawlers probably have the highest rate of by catch bringing in up to 90% or more of "trash fish". Random capture techniques destroy immature fish and other non-targeted marine species. Gill nets used to catch fish bring in a host of other animals such as dolphins, turtles *etc.* Because of the large size of the

areas concerned (Gulf of Mannar and Andaman and Nicobar Islands or other areas in India), and the general lack of resources for enforcement, awareness appears to be more successful than legislation in controlling these practices.

Conclusion

Study of marine fauna in India has drawn greater attention from the 18th century onwards. This was achieved due to many surveys and expeditions conducted in the country by westerners in particular by British. The introduction of Surgeon Naturalist in the expedition ships helped the marine research to flourish in varied fields of fauna and flora. Out of 34 phyla, 32 are reported in the marine ecosystems of the world. However, in India major studies have been conducted only on the commercially important organisms such as crustaceans, molluscs, holothurians and higher vertebrates. Focus of studies was not made on many minor phyla, which are not important for commercial purposes. For example species of different minor phyla living as the interstitial fauna are not reported till today due to lack of expertise in the field. Though taxonomy is being taught as a subject in the curricula of school and college level, there is no committed institution for the learning of taxonomy except survey departments under the placard Government of India. So far, surveys and inventorisation of fauna and flora have been conducted only in selected areas especially around the mainland coasts where some of the research institutions are based (for e.g. NIO, Goa; Andhra University, Visakapattinam; Gulf of Mannar, CMFRI, Chennai Coast, Zoological Survey of India). Probably more than 75% of the marine fauna of Andaman and Nicobar Islands and Lakshadweep Islands are not reported. This is mainly attributed not only to the decline in number of taxonomists but also due to want of facility. Taxonomists who contributed to the marine diversity studies during the 20th Century have retired from service and no substitution has been made until now. Moreover taxonomic studies in the universities are discouraged for various reasons. To culminate the present scenario in the taxonomic studies in India, capacity building on taxonomy at national, regional and sub-regional level with the preparation and publishing of faunal guides for identification both in the electronic as well as print media is essential. Government of India has established many marine protected areas for

conservation of fauna and flora, whereas, for better conservation of marine ecosystems of India the community involvement in the management programmes is highly essential. To involve public, better awareness programs are the need of the hour. The establishment of government museums (Natural History Museum, Zoological Survey of India, Forest Departments, Navy, CMFRI and in State Government and Union territories) and aquaria alone are not enough to create an awareness among the masses of the importance of the conservation and management of marine biodiversity for the future generation of this country.

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