# Biogeography of Indian Marine Molluscs

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Kilburn. R.N. 2002. Biogeography of Indian Marine Molluscs. - Phuket Marine Biological Center Special Publication 26: 5-17

Analysis of provisional lists shows the marine molluscan fauna of the Indian region to be predominantly Indo-Polynesian, with perhaps 4-7% endemism (the exact figure partly depending on whether fresh- and brackish water vicariates of marine groups are included). Significant differences in oceanographic conditions between the Bay of Bengal and Arabian Sea are summarized, and attention is drawn to factors that have created potential barriers or filter-routes. Based on these factors and on the limited faunal inventories available, four subregions are tentatively recognised as the basis for a working hypothesis.
There appear to be two centres of endemism: (1) south-eastern India (i.e the Gulf of Mannar/Chennai area): it is suggested that the key elements may have vicariated in Palk Bay during periods of emersion of the Mannar shelf, and (2) the estuaries and backwaters of Orissa, West Bengal and Bangladesh, which serve as refugia for various euryhaline marine taxa that may have evolved under hyposaline conditions in the northern Bay of Bengal. Conservation prospects for these two centres are discussed.

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## INTRODUCTION

The marine Mollusca of India are arguably among the most extensively sampled of Indo-Pacific invertebrate groups, yet are among the most poorly analysed. Historically, many of the earliest described Indo-Pacific molluscs were first collected in south-eastern India, the source being the Danish trading station established at Tranquebar (now Tarangambodi) between 1620 and 1845. Most of these species were illustrated in the works of Martini (1769-1777) and Chemnitz (1780-1795), and cited as type figures by generations of binomial workers. Indeed many of the species earlier described by Linnaeus (1758) from "in Indiis" certainly came from the same source. Yet subsequent research has been patchy, and identifications suffered from lack of access to types and other primary sources. As a consequence modern publications reveal little understanding of distribution patterns within the Indian region.

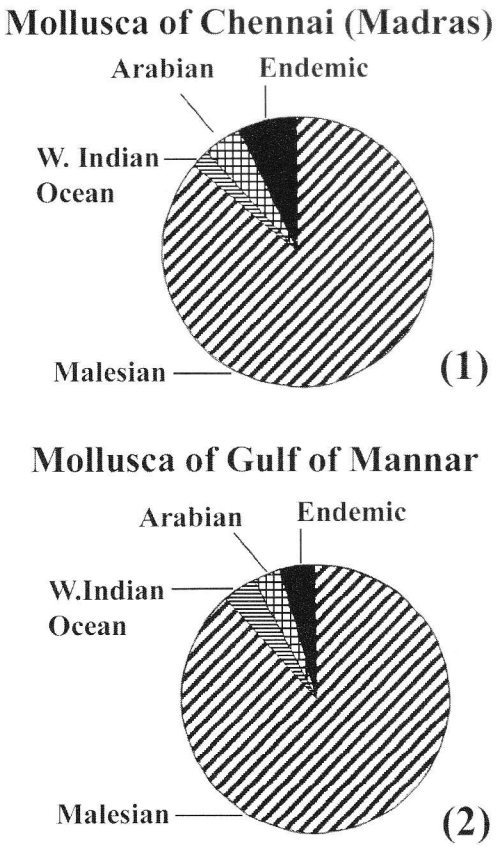
Before discussing its biogeography, it is first necessary to redefine "India". The modern state of India is not a biogeographic entity, excluding as it does the closely adjacent areas of Sri Lanka and Bangladesh, which share much the same fauna. On the other hand it includes the Andaman Islands, whose molluscan fauna clearly has strong Malesian ("Indo-Malaysian") affinities, with few if any true Indian elements (although a certain amount of subspeciation and vicariance of sister groups demonstrates the absence of permanent barriers). Presumably Pakistan and Burma (Myanmar) should be included, but these countries are not considered here, in the absence of even basic faunal inventories for these regions. For similar reasons the east and south coasts of Sri Lanka are excluded.

To sum up, in this paper "India" or "the Indian region", should be taken to cover the immediate coastal zones of India, adjacent Sri Lanka and Bangladesh to a depth of 200 m, but to exclude the Andaman and Nicobar Archipelagoes.

## BIOGEOGRAPHIC RELATIONSHIPS OF THE INDIAN MARINE REALM

Although they did not consider the molluscan fauna, Briggs (1974, 1995) and Hayden *et al.* (1984) included India in a wide Indo-Polynesian Marine Province, as distinct from a Western Indian Ocean one, the two provinces overlapping at the entrance to the Arabian Gulf.

Is this supported by existing molluscan inventories or can an Indian subregion be distinguished? Such inventories are few, largely far from comprehensive and the older ones based on obsolete taxonomy. However, an analysis of two published taxonomic lists is here offered, namely one for Chennai (Madras) given by Gravely (1941 and 1942), and a manuscript collation of molluscan records from the Gulf of Mannar (based mainly on those published by Satyamurti (1952, 1956) and Standen & Leicester (1906)). For these highly provisional lists, I have updated nomenclature and deleted synonyms; obvious misidentifications are excluded, as are brackish/fresh-water species, pelagic molluscs (including cephalopods), families of micromolluscs (for which identifications are sparse and unreliable), and nudibranchs. The results for the two areas are presented in charts 1 and 2.




Charts 1 & 2. The relative distribution (%) of 4 types of faunal elements along the east coast of India. Area 1: the coast around Chennai (Coromandel coast). Area 2: the Gulf of Mannar from Adam's Bridge towards Cape Comorin, *i.e.* the southern tip of India.

### (1) Chennai

At least 85% of the modified list of approximately 500 species are true Indo-Polynesian elements, occurring also in the Malesian region (Thailand, Malaysia, Indonesia, Philippines and vicinity). Evident Western Indian Ocean incursives (here restrictively defined as species known at least from East Africa and the Mascarenes, but apparently not reaching Malesia) comprise perhaps 2 %. This increases to 7 % if Arabian elements are included. Endemicity is a maximum of 7 %.

### (2) Gulf of Mannar

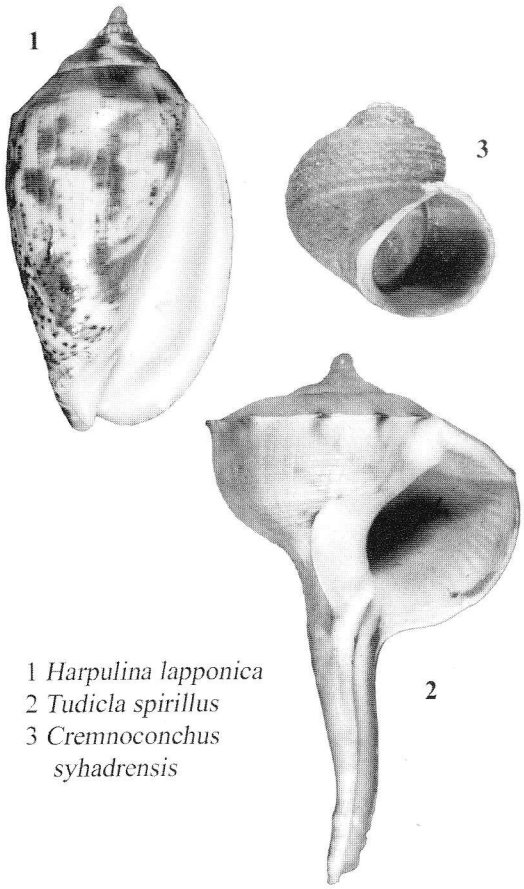
Here the identifications of the source lists are probably less accurate, and duplication of records under different names is to be expected

(in fact Winckworth (1928) observed of Standen & Leicester's list, "their identifications seem to me far from reliable").

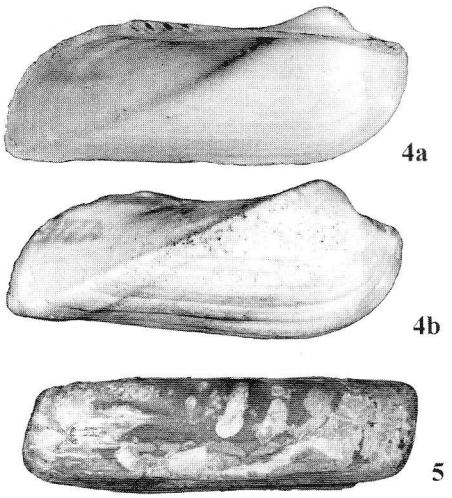
Nevertheless, overall results are comparable. Of the approximately 620 species, about 88% are Indo-Polynesian elements, *ca* 4 % are Western Indian Ocean (8% if Arabian elements are added), and endemicity is only 4 %.

Endemicity percentages for south-east Indian molluscs thus appear to be in the order of 4-7 %, which is not indicative of high local vicariance, and falls well short of the highly conservative 10 % accepted by Briggs (1974) as sufficient to qualify recognition of a marine province. Analysis of the molluscan fauna confirms Briggs later conclusion (1995: 231) that "India and Sri Lanka .... are populated by wide-ranging species and possess few local endemics". Nevertheless, there is sufficient endemism to justify treating the molluscan biota of the Indian region as a minor "faunal subset" of the Indo-Polynesian region. This is supported by the occurrence of several endemic marine genera, such as three species of the volute genus *Harpulina* (Fig. 1) and the monotypic turbinellid genus *Tudicla* (Fig. 2), plus a number of unique brackish to freshwater descendents of otherwise marine groups, such as the genera *Cremnoconchus* (Littorinidae) (Fig. 3), *Chilkaia* (Fossaridae), *Scaphula* (Arcidae) (Fig. 4) and *Neosolen* (Solenidae or Cultellidae) (Fig. 5).

The apparently small proportion of true western Indian Ocean elements is unexpected, but may be correlated with the reduction in species diversity across the Indian Ocean reported (Kilburn 1977) for bivalves, and presumably applicable to molluscs in general. Of course, it must be stressed that the percentage of pan-Indo-Pacific elements whose origin could be either Indian Ocean or Malesian is indeterminate in the absence of genetic evidence. Future studies will presumably demonstrate the Arabian element




1 *Harpulina lapponica*
2 *Tudicla spirillus*
3 *Cremnoconchus syhadrensis*




4a *Scaphula celox* (inner surface)
4b *Scaphula celox* (outer surface)
5 *Neosolen aquaedulcioris*

to be better represented on the west coast than on the east. It would appear that the Indian marine fauna is derived largely from the Malesian area, which is widely acknowledged as a centre of taxonomic diversification and accumulation (Paulay 1997).

## THE INDIAN MARINE ENVIRONMENT

Before discussing regional variation within the Indian region, the overall oceanographic environment will be briefly reviewed. To generalise, the main environmental factors influencing the Indian molluscan biota are:

(1) a unique system of seasonally-reversing monsoon currents;

(2) differing oceanographic regimes on either side of the Indian peninsula;

(3) presence or absence of filter routes (or barriers).

### (1) Monsoon currents

Oceanographers have charted these currents in considerable detail (see for example Sewell (1938), Fairbridge *et al.* (1966), Wyrtki (1973), Longhurst (1998), etc.) but they need be treated only superficially here, as most of their effects on faunal composition are not yet clear.

The influence of seasonally-reversing monsoon gyres helps to explain the low endemicity and high percentage of pan-Indo-West Pacific elements, as this would facilitate incursion from both Malesia and the western Indian Ocean. For example, the offshore islands of the Lakshadweep (Laccadive) and Maldive Archipelagoes - which are under the more direct influence of the monsoon currents - have a typical core Indo-Pacific molluscan fauna (Surya Rao & Subba Rao (1991), and Smith (1903)), with extremely few if any endemics. However, as already discussed, the discernible Western Indian Ocean influence appears minor; a specific example is the mangrove genus *Cerithidea*, potentially easily dispersed by rafting, but represented in India by the Malesian *C. obtusa* (Lamarck, 1822) and *C. cingulata* (Gmelin, 1791), but not by the sole East African representative, *C. decollata* (Linnaeus, 1767).

Nevertheless, fluctuations in current intensity and pattern over geological time have obviously varied greatly. For example, plankton deposition in sediments has shown that pre-Holocene monsoons and associated upwelling were stronger than at present (Sheppard *et al.* 1992). A reduced current would facilitate isolation of populations and resultant vicariance, whereas intensified flow would increase the influx of incursives and mixing of gene pools (but would conversely also strengthen upwelling, which could accentuate temperature barriers).

### (2) Contrasts: the Arabian Sea and the Bay of Bengal

Major differences occur between the surface water masses on opposite sides of the Indian peninsula, and one may seek correlated differences in faunas. The most striking differences between these two bodies, namely salinity and upwelling, will be briefly considered.

#### *Salinity*

The Bay of Bengal receives freshwater runoff (heaviest in autumn) from major river deltas situated in the northern part of the Bay, particularly the Ganges and Brahmaputra, and in Myanmar (Burma), the Irrawaddy. Surface salinity is thus lower than in the rest of the northern Indian Ocean, mean salinity being in the order of 33-34 ‰, although southward flow along the east coast India may reduce nearshore salinity to as low as 18 ‰ (La Fond 1966), at least as far south as the Andhra coast. Furthermore, even off the Tamil Nadu coast,

which lacks major river systems, heavy winter rainfall may lower surface salinity to 25‰ (Pillai 1971).

An indirect result of the reduced salinity of surface waters is greatly impoverished plankton. As a consequence, the shelf benthos of the Bay of Bengal appears also to be generally much poorer than in the Arabian Sea. In fact, in places a mean benthic biomass of only 5.32 g/m$^2$ is recorded (Dwivedi 1993), against an average of up to 35 g/m$^2$ for the northern Arabian Sea (Neyman *et al.* 1973). (Of course, near the main deltas biomass may be locally very high as a result of direct organic enrichment from rivers and mangrove swamps.)

The Arabian Sea receives no major rivers other than the Indus, so that only during the rainy season does the salinity of the upper 50 m ever drop lower than 35 ‰, and at other times it may exceed 36 ‰. Contributory factors are high rates of evaporation in the central and northern Arabian Sea, plus inflow of hypersaline water from the Red Sea and Arabian Gulf.

In effect the Arabian Sea forms an evaporation basin, whereas the Bay of Bengal is a dilution basin – this will certainly have some effect on their respective biotic compositions. One would expect, for example, a higher proportion of stenohaline taxa in the former area. This, however, remains to be investigated.

*Upwelling*

Upwelling plays a positive role in bringing nutrients to the surface, but by suddenly lowering surface temperatures may disrupt development and reproductive cycles, and even cause mass mortality, particularly when the upwelled water is low in oxygen and high in sulphides. Indeed, eutrophication resulting from increased upwelling is believed to have been one factor in specific extinctions (Hallock 1987).

Bay of Bengal: Here, upwelling – and its effects - is not a major factor. Off the north coast, freshwater inflow from the major rivers is sufficient to inhibit upwelling locally. Elsewhere along the east coast of India, weak upwelling may follow favorable winds, particularly south of Visakhatapan (17.5°N). However, during the SW monsoon, upwelling is suppressed by warm, low salinity surface water (Johns *et al.* 1992)

Arabian Sea: During summer, the SW monsoons force strong wind-driven upwelling along the south Arabian coast; as a result, cold water (temperature as low as 16 °C) rises to the surface. At this time there is also wind-driven upwelling on the south-west coast of India (Backus 1994). The possible effects will be noted later. However, the organic enrichment resulting from upwelling may result in unusually high benthic biomass; off the northern coast of the Arabian Sea this may exceed 500 g/m$^2$, the highest recorded for the Indian Ocean during the International Indian Ocean Expedition (Neyman et al. 1973). Furthermore, high evaporation in the central part of the Arabian Sea results in denser surface water, which sinks, carrying oxygen down to moderate depths.

(3) Barriers and filter-routes

Biogeographic regions can only be differentiated where there exists some form of boundary to reduce incursion of adjacent faunas and facilitate vicariance. To quote Pielou (1979): "boundaries of biotic provinces are determined by modern abiotic factors". True barriers, such as land masses or permanently adverse currents do not presently exist within the Indian region, but there are many filter-routes, which would impede dispersal (but do not prevent it), at least over

the passage of geological time. These are first briefly outlined before possible effects are discussed.

## Bay of Bengal

The hyposaline and turbid conditions that seasonally exist in the northern part of the Bay, at least during wet phases, have presumably influenced incursion and vicariance, reducing the former and strengthening the latter, certainly in the case of stenohaline littoral and shelf species. Climatic oscillations throughout the Quaternary caused alternation of wet and dry phases; thus monsoon runoff was greater at the start of the Holocene than today (Cullen 1981).

Most Indian molluscs appear to have planktonic larvae, which would facilitate dispersal, except perhaps during wet phases when veligers must traverse surface waters that are low in salinity and sometimes poor in oxygen. However, for molluscs that hatch at the crawling stage, the Bay of Bengal could present a wide, deep-sea barrier, as the narrow shelf slopes steeply from the shelf-break (at 120-180 m) to a depth of 3,000 m in the middle of the Bay and 4,000 m at entrance. Thus there can be no question of ancient shoals or "stepping stones" (apart from the Tertiary Andaman Ridge of which the Andaman and Nicobar Islands are a remnant). Furthermore, even at moderate depths (100 m), temperatures drop to 12-18 °C, and below 300 m the water becomes oxygen-poor. Thus in effect the Bay of Bengal is rimmed by a curved linear shelf (*sensu* Valentine & Jablonski 1983) rather than a two-dimensional one; the exception is the Gulf of Mannar/Palk Strait area, which now (and during previous warm periods) is rendered two-dimensional by the proximity of Sri Lanka and many small islands.

However, even species with crawl-away young have traversed the Bay – or at least dispersed around its head. During glacial maxima some continental shelf would remain accessible (the shelf break lies mostly in 120-180 m, maximum lowstand was *ca* 120 m). During interglacials and other predominantly wet periods, flooding of low-lying coastal areas would have provided refugial lagoons and backwaters. However, even during the Eemian (or near its end) a cool, dry event has been reported (see Adams 2000). During such dry periods, reduction in inflow of freshwater and silt would have facilitated dispersal of sand-dwelling species across the head of the Bay.

An example of a mollusc with intracapsular (crawl-away) development that has crossed the Bay of Bengal and vicariated (see Kilburn 1981) is the common Indian *Ancilla ampla* (Gmelin, 1791) (Fig. 6). The nominate subspecies is somewhat euryhaline (mean salinity within range 25-36.5 ‰) and is distributed from Aden to Burma. However, it is represented from the Andaman Sea eastwards into Malesia by a distinct subspecies, *Ancilla ampla cylindrica* (Sowerby, 1859). Since its original dispersal, the Bay has evidently been restored as a barrier, leading to vicariance.

An even more striking case is the genus *Turbinella,* to which belongs India's characteristic "sacred chank", *Turbinella pyrum* (Linnaeus, 1758) (Fig. 7). Its ancestry has been traced to the widespread Tethyan *T. episoma* (Michelotti, 1861), whose presence in western India dates from the Oligocene, and which evolved into a sequence of species which culminated during the Pliocene in the surviving *Turbinella pyrum*. [Although Vredenberg (1916 and 1923) was convinced that *pyrum* was not part of the *episoma* lineage but an incursive from elsewhere, he did not take into consideration possible character reversals, nor the extreme genetic diversity and phenotypic plasticity of *T. pyrum* (Hornell

(1916) documented a wide array of local races and ecomorphs, several of which are sometimes considered full species).] However, in the Andaman Islands and western Indonesia occurs a second species, *T. fusus* Sowerby, 1825, which according to Vredenberg appears to be morphologically indistinguishable from the ancestral *T. episoma* and can probably be assumed to be a relict population, isolated by the Bay of Bengal perhaps since the Oligocene.

The possible function of the Gulf of Manaar as a barrier during periods of low sea level is touched on below.

### Arabian Sea

Three potential dispersal filters characterize the west coast of India. Firstly, as has been noted, seasonal upwelling of cold or oxygen-poor water is a characteristic of different parts of the Arabian Sea. Similar effects are produced by winter shoaling of the thermocline, when barometric events on the west coast India and off Pakistan may cause the 20°C isotherm, low in oxygen, to rise to less than 50 m (Wyrtki 1973). An oligotrophic area with a poor fauna of mainly suspension feeders, is reported in 75-150 m; this partly results from the frequent inflow of such oxygen-poor water (Neyman *et al.* 1973).

Secondly, the presence of a mobile mud bottom along parts of the Mumbai Shelf does not support a rich shelf biomass, which decreases to 5 gm/m$^2$ down the west coast (Neyman *et al.* 1973). An associated phenomenon is the movement of inshore mudbanks ("chankara") on the inner shelf off Kerala (Longhurst 1998).

Finally, off the Gulf of Kutch is a "dynamic barrier", discussed by Nair (1984), which deprives the shelf of sediment, and will certainly negatively affect larval dispersal across the Indus region.

## REGIONAL VARIATION WITHIN INDIA

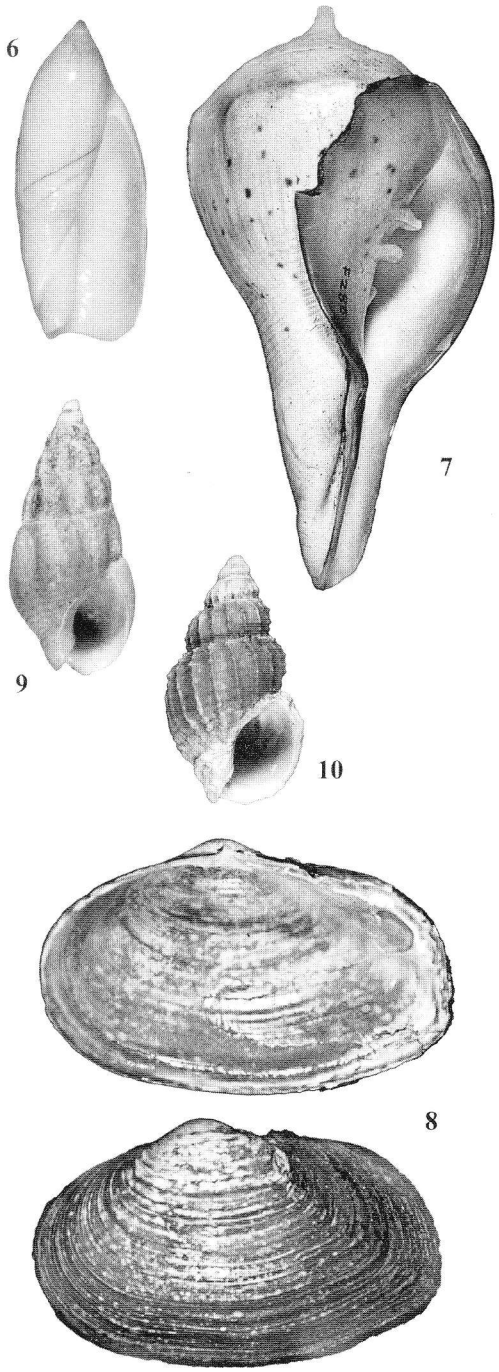
In view of the oceanographic contrasts between the two coasts of India we would expect some differences in faunal composition. To determine whether the region can be subdivided faunistically one should ideally start with exhaustive molluscan inventories, which can be analyzed for patterns such as main centres of endemicity and position of subtraction margins. Unfortunately, faunal lists for India are mostly inadequate or have been compiled by so many different authorities that they cannot be directly compared with any confidence. The following thoughts are thus only tentative:

### (1) The Delta Coast

Much of Orissa, West Bengal and Bangladesh comprise an estuarine coast, rich in mangroves, with a high outflow of freshwater and silt. Off the Ganges delta, the continental shelf is *ca* 160 km wide, narrowing further south off the predominantly sandy coast of Orissa to only 40-120 km wide. Off Bangladesh salinities of 30-31 ‰ occur even during the dry season, dropping to 17-18 ‰ during the rainy season (Dwividi 1993). The delta coast is naturally characterised by many estuarine/backwater elements, including endemic bivalves such as the pharids *Tanysiphon rivalis* Benson, 1858 (Fig. 8), and *Novaculina gangetica* Benson, 1830 (Subba Rao *et al.* 1992).

Slightly further south, on the Orissa coast, about 11% of the modified total of 293 species given by Subba Rao *et al.* (1991) are endemic, although if backwater (brackish to freshwater) species are omitted, this would fall to 7 %.

The low salinity that has prevailed in the northern Bay of Bengal, at least during wet phases, has apparently facilitated the adaptation of a number of species of normally marine groups to the brackish and freshwater




6 *Ancilla ampla*
7 *Turbinella pyrum*
8 *Tanysiphon rivalis*
9 *Nassarius subconstrictus*
10 *Nassarius orissaensis*

refugia provided by the extensive estuaries and backwaters, the latter usually originating from the deposition of sand spits across the mouth of inlets. Examples include 3-4 species of Arcidae (genus *Scaphula* (Fig. 4)), 2-3 of Nassariidae (subgenus *Pygmaeonassa* of *Nassarius* (Figs. 9, 10)), and at least two Solenidae (*Neosolen aquaedulcioris* Ghosh, 1916 (Fig. 5), and *Solen annandalei* Preston, 1915). The Orissa coast is particularly rich in endemic backwater molluscs – over 20 such species inhabit the Chilka Lake system and other backwaters (Subba Rao *et al.* 1991, 1995). In the Chilka Lake salinity originally fluctuated from 0.1 to 36 ‰, being largely flushed out by freshwater during the rainy season except in the southern part (Annandale & Kemp (1915, 1916), Annandale (1924), Directorate of Fisheries (1970)). However, conditions have deteriorated considerably in recent years (see Conservation section).

(2) South-East India

*(the Mannar-Palk Bay-Sri Lanka area)*

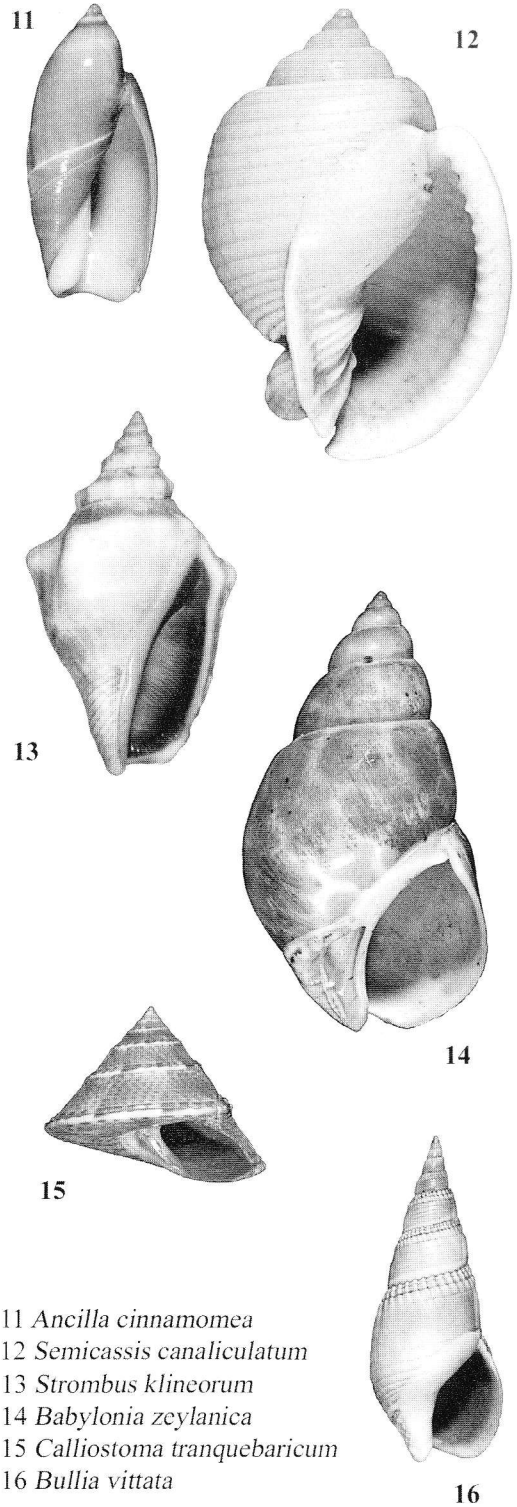
This area is inhabited by India's best-known endemic molluscs, such as the *Turbinella pyrum*-species complex, *Tudicla spirillus* (Linnaeus, 1758) (Fig. 1), *Ancilla cinnamomea* Lamarck, 1801 (Fig. 11), *Semicassis canaliculatum* (Bruguiere, 1792) (Fig. 12), *Strombus klineorum* Abbott, 1960 (Fig. 13), *Babylonia zeylanica* (Bruguiere, 1789) (Fig. 14), *Harpulina lapponica* (Linnaeus, 1758) (Fig. 1), *Calliostoma tranquebaricum* (Röding, 1798) (Fig. 15), *Turris variegata* (Kiener, 1840, *non* Philippi, 1836), and *Bullia vittata* (Linnaeus, 1767) (Fig. 16). The range of many of these elements extends north at least to Chennai (Madras) and eastward along the Sri Lankan coast.

It is unlikely to be coincidence that such endemicity should be centered around an area bounded in the north by a hyposaline filter route, and in the south by the Gulf of Mannar

which for most of the Pleistocene (pers. comm. Dr P. Ramsay) would have formed at least a partial land bridge (the Palk Straits have a sill depth of only 10 m). In other words, it is not unreasonable to speculate that the origin of this fauna may be traced to periods of low sea level, when the molluscan fauna of what is now Palk Bay would have been largely isolated from the south coast fauna. Dispersal round the south coast of Sri Lanka would have been hindered by its narrow shelf and extremely steep continental slope, which descends at an angle of 45° (La Fond 1966).

To return to the Recent fauna, the presence of a relatively wide, two-dimensional shelf between India and Sri Lanka, with comparatively little fluctuation in salinity and temperature, now provides a refuge for a highly diverse fauna of over 600 species. The area is relatively sheltered, at least during the NE monsoon, when a surface current is forced south through Palk Strait. Temperatures are warm (28-30 °C) throughout the year in the shallows (UNEP/IUCN, 1988), although in the deeper channels these drop rapidly below 100 m, with temperatures as low as 13.5-18.0° C being recorded at 200 m (Sewell 1938). The Gulf of Mannar itself contains a chain of over 20 coral islands and many reefs, all shallower than 6 m. In the shallows are extensive grassbeds comprising some 13 species of marine angiosperms, which harbor Indian endemic molluscs such as *Turris amicta* (E. A. Smith, 1877) and *Fusinus laticostatus* (Deshayes, 1831) plus some local endemics such as *Colina selecta* (Melvill & Standen, 1898).

On water characteristics, Colborn (1974) included the Gulf of Mannar in his "Laccadive Sea", which extends up the west coast to south of Mumbai. It remains to demonstrated whether the core south-east Indian fauna extends far up the exposed Malabar coast.




11 *Ancilla cinnamomea*
12 *Semicassis canaliculatum*
13 *Strombus klineorum*
14 *Babylonia zeylanica*
15 *Calliostoma tranquebaricum*
16 *Bullia vittata*

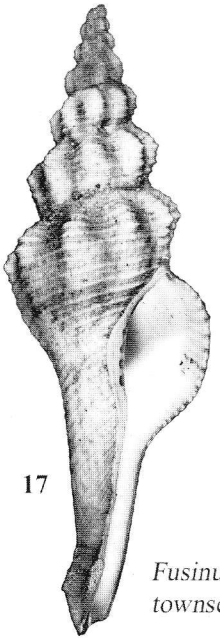
(3) North-West India.

This area has the widest shelf in India (reaching 400 km off the Gulf of Khambat, although extending only *ca* 70 km off the Indus), but narrows considerably to the south. The substratum consists mainly of sand, overlain by mud or clay, and turbidity is much higher than in the open Arabian Sea.

Little has been published on the molluscs of north-western India, although records from Mumbai (Bombay) were summarized by Subrahmanyam *et al.* (1949, 1951, 1952). These lists (obviously very incomplete and based mainly on early records by Melvill & Standen (1901)) indicate low diversity, totalling *ca* 310 species (excluding obvious misidentifications, freshwater and pelagic elements, etc.). Only a few typically Arabian Gulf elements are included, such as *Drupa* [= *Ocinebrina*] *xuthedra* (Melvill, 1893) and *Fusinus townsendi* (Melvill, 1899) (Fig. 17). However taken at face value the majority of shallow water molluscs are core Indo-Polynesian species, the few that are more characteristic of South-East India, such as *Conus monile* Linnaeus, 1758. and *Turbinella pyrum* (Linnaeus, 1758) (Fig. 7), being ornamental shells that are widely transported by human agency.

(4) South-West India

In one of the very few definite statements pertaining to the molluscan biogeography of India that have been published, Neyman *et al* (1973) claimed that Panjim (Nova Goa) was the boundary between eastern and western Indian molluscs, as this was "the northernmost limit of the penetration of equatorial waters onto the shelf of western India". However, the latter statement was evidently based solely on oceanographic sampling conducted during one month of one year, and no faunistic evidence is presented to justify their conclusion.



17 *Fusinus townsendi*

Consequently this claim is not here accepted.

Nevertheless, the scant evidence available indicates that most of the west coast is occupied by a wide, somewhat depauperate subtraction margin of the south-east Indian coast (overlapped to an unknown extent by elements of the Arabian fauna). This could be ascribed to a combination of unfavorable factors (discussed above) in various areas and different seasons, notably the upwelling or shoaling of cold, oxygen-poor water and an unstable mud bottom. To this may be added the sandy (and frequently high-energy shore) of much of southern Kerala, whose limited hard substrates appear to harbour few molluscs except for the littorinid *Nodilittorina leucosticta* (Philippi, 1847) and the mytilid *Perna indica* Kuriakose & Nair, 1970 (an apparent south-west Indian endemic, which is replaced in northern Tamil Nadu by the Malesian *P. viridis* (Linnaeus, 1758)).

The extent of endemicity amongst the molluscs of the west coast littoral and shelf is unknown. However the presence of one marine group that has here adapted to freshwater

should be noted; this is the endemic littorinid genus *Cremnoconchus* (Fig. 3), two species of which occur in the hill streams.

## CONSERVATION

As indicated above, within the Indian region there are two main areas of molluscan endemicity, namely the backwater and estuarine systems of Orissa and the northern coast of the Bay of Bengal, and the Gulf of Mannar to Chennai area. Clearly, conservation of these faunas is imperative, and on paper attempts have been made to address this need. Thus Chilka Lake was designated as a RAMSAR site in 1981, and much of the second region falls within the Gulf of Mannar Marine Biosphere Reserve, established in 1989.

Unfortunately, Chilka Lake is not only shrinking at an estimated rate of 1 sq. km per year as a result of progressive silting, but blocking of the outer channel has led to falling salinity, which threatens the survival of its brackish-water molluscs. Pollution from human habitations and prawn farms has contributed to its degradation (Siddiqui & Rama Rao 1995). Significantly, Subba Rao *et al.* (1995) reported collecting only 15 of the 60 molluscan species described from the Lake. It is to be hoped that the announcement of designs to open a new outlet plus a "comprehensive catchment treatment plan" (*The Times of India*, 19th June 2000) will lead to some reversal of this scenario.

The Gulf of Mannar remains among the most heavily exploited marine areas in India. From recent personal observations not only is the destruction of coral reefs ("coral mining") ubiquitous and blatant, but there is no control over the activities of the more than 50,000 fishermen exploiting the region. Large fishing fleets trawl the deeper grounds with fine-mesh nets, and the mainland is lined with fishing villages which daily drag nets over the neighbouring shallows. Fishing is not selective and the bycatch, rich in molluscs, unwanted crustaceans and other benthos, is either dumped on the shore to decompose or taken back to port and processed as "trashfish", apart from the more ornamental shells and starfish that are sold to dealers. The long-term prognosis for the Gulf of Mannar benthos is not good, unless conservation ethics are introduced to the fishing industry, and strictly enforced by regulation. It is to be hoped that Palk Bay will remain a reservoir for this fauna.

## ACKNOWLEDGEMENTS

This paper is based on a keynote address delivered by me at the 11th International Congress of the Tropical Marine Mollusc Programme in Kodaikanal India, in September 2000. I express my appreciation to Professor Jorgen Hylleberg, director of the programme, for the opportunity to participate in this and other congresses and workshops of the TMMP. I thank Dr J. K. Patterson Edward for his hospitality and for facilitating fieldwork. I would also like to thank Dr N. Subba Rao for his hospitality during an early (1994) visit to the Zoological Survey of India.

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