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Taxonomy of Marine Molluscs of India: Status and Challenges Ahead

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Systematics

Mollusca represents the second largest animal phylum on our planet and recent estimates show that the extant species diversity is around 45,000 to 50,000 marine 25,000 terrestrial and 5,000 freshwater (Appeltans *et al.*, 2012; Rosenberg, 2014; MolluscaBase, 2016). Originated in the early Cambrian period almost 550 million years ago, molluscs entered almost every ecosystem in the world, though their diversity is enormous in the marine realm, occupying all habitats from the pelagic areas to the ocean trenches and representing roughly one-quarter of the marine species described (MolluscaBase, 2016). They are the morphologically megadiverse faunal group in the marine ecosystem, exhibiting enormous diversifications in body plan and habitat preferences and playing critical ecosystem roles, besides forming a noticeable element in marine fisheries.

The ten classes recognised under phylum Mollusca are Caudofoveata, Solenogastres (worm-like organisms in sea bed, 200-3000 meters), Polyplacophora (chitons, rocky tidal and sea bed), Monoplacophora (cap-like single shell, living forms discovered in 1952, generally deep sea form 1,800-7,000 meters), Gastropoda (snails and slugs, in sea, land and freshwater), Cephalopoda (marine), Bivalvia (marine and freshwater), Scaphopoda (tusk shells, marine), Rostroconchia (marine), and Helcionelloida (marine); the latter two classes are extinct and known only from their fossil records (Haszprunar, 2001). Caudofoveata and solenogastres were also put into one class, the Aplacophora (vermiform molluscs) by earlier workers (Healy, 2001). Aplacophorans and polyplacophorans may represent the early evolved living groups of molluscs (Sigwart and Sutton, 2007).

Of late, good quality molecular phylogenetic analyses support the polyphyletic origin of Mollusca and place the molluscs in the Lophotrochozoa, along with annelids, brachiopods, bryozoans and several

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other phyla (Halanych *et al.*, 1995; Sigwart and Sutton, 2007). The existing ‘aculiferan’ model of molluscan phylogeny considers two subphyla, Conchifera, the ‘shell-bearing’ molluscs, and Aculifera, ‘spiny’ molluscs (Aplacophora and Polyplacophora), while ‘testarian’ model group polyplacophorans together with conchiferans under Testaria (Sigwart and Sutton, 2007). The consensus model considers the traditional concepts of Aculifera and Conchifera, while Scaphopoda was considered in the clade along with Gastropoda and Bivalvia and the details are given in Fig. 1 (Stöger *et al.*, 2013).



Fig.1. Schematic representation of phylogenetic relationship of various classes of Mollusca (modified from Stöger *et al.*, 2013)

The total diversity of molluscs recorded from India is 5,169 species (MoEF, 2014), representing around seven percent of the total global molluscan diversity. With an extensive coastline of 8,129 kilometres, 0.5 million square kilometres of continental shelf and 2.02 million square kilometres of EEZ, marine biodiversity of India is impressive. Marine molluscan diversity of India include 3,400 species (Rao, 1991, 1998; Venkataraman and Raghunathan, 2015). According to Rao (1991, 1998) 5,100 species of molluscs have been recorded from freshwater (22 families, 53 genera 183 species), land (26 families, 140 genera and 1,487 species) and marine habitats (242 families 591 genera, 3,400 species) of India. There is no consensus among various authors on the total number of marine molluscs from India. In a report on coastal marine biodiversity of India, Venkataraman and Wafar (2005) considers 3,370 marine molluscs in India, while Tripathy and Mukhopadhyay (2015) report 2,300 species. As such there is no well-defined and updated checklist on



marine molluscs of India. The hotspots of marine molluscan biodiversity in India are Andaman and Nicobar islands (more than 1,000 species), Gulf of Mannar (around 428 species) and Lakshadweep (around 424 species) (Venkataraman and Wafar, 2005), all representing important coral reef ecosystems of India.

Molluscan taxonomy research in India

A comprehensive review of molluscan taxonomy research is not attempted in this note and the important studies are grouped into three phases, with Phase 1 listing major studies conducted before independence of India, Phase 2 compiling studies done after independence and Phase 3 documenting studies after the year 2000 (excluding all single species records and publications in predatory journals).

Phase 1: Taxonomic studies on molluscs of India were initiated by the Asiatic Society of Bengal (1784) and the Indian Museum, Kolkata (1814). The first scientific paper on Indian marine Mollusca was perhaps that of Benson (1830). HMS Challenger put into sea by England in 1872 for oceanographic research surveyed Indian Ocean and collected information on various groups of organisms including molluscs. Collection of faunal samples by a series of cruises by the Royal Indian Marine Ships (RIMS) since 1881 collected and described marine molluscs from seas around India. Gardiner and Sewell (1899-1900) carried out studies along Lakshadweep (Minicoy). Sewell carried out investigations in seas around Andaman and Nicobar islands and led the John Murray expedition (1933-34); primary objective of this expedition was the study of the biology of the Arabian Sea, especially the benthic organisms such as molluscs. Smith (1894) published notes on Mollusca dredged from Bay of Bengal and Arabian Sea during the expedition of the H.M Indian Marine Survey Steamer 'Investigator'.

During the latter half of the 19th century Abercrombie (1893a,b), Adam (1939), Alder and Hancock (1864), Comber (1906), Crichton (1940, 1941), Eliot (1903), Hornell (1921, 1949), Hoyle (1905), Melvill (1892, 1893, 1893-1894, 1898, 1909), Melvill and Ponsoney (1898), Melvill and Standen (1898), Prashad (1930, 1932), Preston (1910, 1911), Robson (1926), Smith (1878, 1894, 1895, 1896, 1899, 1903, 1904, 1906), Thurston (1890) and Winckworth (1927a,b, 1928, 1929, 1936, 1940) contributed knowledge to malacological studies. This was



the initial phase of explorations and expeditions to record marine biodiversity of seas around India.

Phase 2: The beginning of the 20th century was the most productive and significant period in the history of Indian malacology, with the lead role taken up by Zoological Survey of India (ZSI), along with contributions from Central Marine Fisheries Research Institute (CMFRI) and several maritime universities of India. This helped consolidating information on marine molluscs of India. Few general surveys on the taxonomy of the molluscan fauna of Indian coasts are those of Appukuttan (1983), Appukuttan *et al.* (1989), Apte (1993), Apte (1998), Bertsch and Attilio (1980), Hornell (1951), Hornell and Tomlin (1951), Kohn (1978), Kundu (1965), Kurian (1948), Menon *et al.* (1961 and 1967), Mookherjee (1985), Nagabhushanam and Rao (1972), Narayanan (1968), Panicker (1977, 1978), Pinn (1990), Rajagopal and Mookherjee (1978, 1982), Ramakrishna and Dey (2000), Rao (1970, 1977), Rao (1980), Rao and Dey (1984, 1986), Rao and Rao (1981, 1991, 1993), Ray (1949 a, b; 1951, 1956), Rockel *et al.* (1995), Santhakumaran (1973), Satyamurti (1952, 1956), Silas *et al.* (1985), Rao *et al.* (1991, 1992), Subrahmaniyan *et al.* (1952) and Tikader *et al.* (1986). This phase witness good quality publications, especially from Dr NV Rao and his team from ZSI based on exploratory studies on various ecosystems of India.

Phase 3: Recent studies on marine molluscan studies remain centred primarily around certain charismatic groups such as opisthobranchs (Apte, 2009; Apte and Bhave, 2014; Apte *et al.*, 2010; Apte *et al.*, 2012; Bhave and Apte, 2011, 2013; Carmona *et al.*, 2014; Raghunathan *et al.*, 2010; Ramakrishna *et al.*, 2010; Sreeraj *et al.*, 2012). There was no systematic all taxa studies in any of the specific ecosystems of India.

Major publications during the phase include those of Apte (2004, 2009, 2012), Apte and Bhave (2014), Apte *et al.* (2010, 2012), Bhave and Apte (2011, 2013), Bijukumar *et al.* (2015), Carmona *et al.* (2014), Dey (2006), Dey and Ramakrishna (2007), Franklin *et al.* (2009), Hylleberg and Kilburn (2002), Lutaenko (2006), Modayil (2007), Mukhopadhyay *et al.* (2012), Pati and Sharma (2012 a, b), Raghunathan *et al.* (2010), Ramakrishna and Dey (2000, 2003, 2010), Ramakrishna *et al.* (2007, 2010), Rao and Sastry (2005), Sreeja *et al.* (2012, 2016), and Venkataraman *et al.* (2004, 2012).



Gap Areas

Taxonomic impediment

The taxonomic impediment prevailing in other parts of the world is effervescent in India as well and many institutions working on faunal surveys and documentation lack the globally competent malacologists to carry out extensive surveys and identification, not to speak of infrastructure facilities to support such exploratory research. As revealed by the analysis of publications on taxonomy from the country in the last two decades and analysing the vision documents of marine research institutions, especially in the public sector, taxonomy is not projected as a priority item. If at all proposals are placed in paper, no strategies and action plans were suggested to overcome the taxonomic impediment. Further, human resources in taxonomy for satisfying the ever growing demands from various sectors, including marine bioprospecting and biotechnology, is abysmally poor even in institutions dedicated to biodiversity documentation.

One of the ways to circumvent the taxonomic impediment is to promote co-ordinated taxonomic research involving practicing taxonomists. Further, international collaboration in taxonomy should be promoted to document the diversity of all marine taxa in seas around India, as comprehensive data bases provide platform for advanced research and policy making towards conservation and sustainable utilisation of resources. Developing trained manpower in taxonomy is yet another priority to promote taxonomy, besides reserving positions for taxonomists in all the marine research institutions and universities to develop globally competent taxonomists from the country. Further, the curricula should be framed in schools and colleges involving taxonomy as a 'joyful' activity rather than a 'cumbersome' task, with more field oriented activities.

Database

While analysing the recent works on molluscan taxonomy in India, the major lacuna is the lack of a good quality updated data base on molluscs of India in the public domain. For example, the available checklists including that of the scheduled species in India document the synonyms and are not taxonomically validated, further contributing to the chaos in taxonomy. As a foundation element of biology, it is imperative that taxonomy is practised in a highly professional manner, as dubious taxonomy destabilizes the foundation of



science, with potentially serious setback in basic and applied research, and therefore publications in predatory journals hamper development of taxonomy in India ([Rajeev et al., 2014](#)). Therefore, publications that appear in predatory journals, without even mentioning anything on voucher specimens and accession numbers would not support taxonomic research. The existing databases have to be strengthened by validating species identity of all the collections by the research vessels of various organisations in India. Good quality handbooks and field guides of various classes of Mollusca form another requirement for strengthening taxonomic research in India.

Ecosystem/taxon based studies

In India majority of the molluscan studies were conducted in coral reef ecosystems. Majority of the surveys were conducted as part of compilation of data for general biodiversity data bases or all-phyla studies. Extensive surveys are required along continental shelves, sea mounts and deep seas along Indian coast. Ecosystem-based in-depth surveys are required to document species diversity of coral reefs, lagoons, mud flats, sandy beaches, estuaries and backwaters, intertidal and subtidal ecosystems.

Specific taxon based studies are also required to prepare comprehensive data bases on molluscs. In a biodiverse group such as Mollusca, developing taxonomic expertise in each family is a difficult task to attain and in such cases services of 'specialists' should be sought in collaboration with leading international museums and malacologists. Studies on molluscs involved in various kinds of associations, invasive species and planktonic molluscs are other areas that demand attention of malacologists in India. Micro molluscs from India also did not receive much attention by taxonomists.

Though marine molluscs consisting 242 families were recorded from India, only few families such as Conidae, Cypraeidae, Muricidae, Strombidae and Mitridae (Gastropoda), Donacidae, Tellinidae and Arcidae (Bivalvia) received special attention of taxonomists of India. Further studies are required in lesser known molluscan families from India, including Chilodontidae, Cerithiidae, Naticidae, Ranellidae, Columbellidae, Velutinidae, Trividae, Triphoridae, Volvatellidae, Vermetidae, Acteonidae, Buccinidae, Calyptraeidae, Cerithidae, Columbellidae, Haminoeidae, Philinidae, etc. (Gastropoda) and Galeommatidae, Nuculanidae, Yoldiidae, Spondylidae, Limidae (Bivalvia). Family-wise revisions are also required in other



biodiverse groups collected from Indian waters. Deep sea molluscs off Indian coast is yet another priority area for consideration.

Species categorised as “taxon inquirendum” (name which is listed from a literature source, but has not been recently re-evaluated for taxonomic validity and/or generic or familial placement) and “nomen dubium” (name which resists revision because the description and other supporting data are deficient) also require priority attention by malacologists. Further, stock assessments and ecosystem based studies are required for species included in Redlist of IUCN and in various schedules of Wildlife (Protection) Act of India.

In the era where consumptive and non-consumptive values of molluscs are held with much esteems, the services of taxonomists are all the more important not only to confirm identification of species involved in various economic benefits but also for preparing policy documents for conservation and sustainable use of molluscan resources.

Integrative taxonomy

‘Integrative taxonomy’ is defined as the science that aims to delimit the units of life's diversity from multiple and complementary perspectives (phylogeography, comparative morphology, population genetics, ecology, development, behaviour, etc.) ([Dayrat, 2005](#)). Molecular analyses play a very important role in elucidating extent, origin and history of marine biodiversity, and molecular techniques provide adequate information regarding the phylogenetic relationships and divergence times of evolutionary lineages and clades. Understanding the distribution and origin of diversity in the larger marine, especially Indo-Pacific is a fundamental problem in biogeography. Further, molecular studies would also facilitate identification of cryptic species and speed up the process of biodiversity documentation. Integrative taxonomic studies involving molluscan species should also be promoted to fully realise the diversity of marine molluscs of India. There is a need to develop specific course content focusing on ‘integrative taxonomy’ that needs to be taught first before training in systematics ([Pisupati, 2015](#)).

Involving Citizen Scientists and Civil Society

“Making taxonomy a combined study and science that brings on board non-experts and non-biologists to support identification of species as a hobby, passion and love for nature with support coming from trained scientists”



(Pisupati, 2015). In India the possibility of involving citizen scientists and civil society in biodiversity documentation were not fully explored, though opportunities for such an exercise are awesome. Long term biodiversity monitoring studies and preparation of inventories can be tried by expanding the network of local communities and civil societies.

Repositories

The depositions in the natural history museums and repositories reveal the great natural history and biodiversity of the nation and a source material for the taxonomists and biotechnologists to pursue their research. It also provides identification services on natural objects and rich fauna, flora and minerals resources to user groups. The priority therefore should be to prepare a database of type materials available in each of the repository and to simplify the procedure for sharing the data to practicing malacologists.

All the repositories should go for rampant modernisation, with the help of latest science and technology inputs. For examples, leading museums all over the world are in the process of digitalisation of collections, which has not been initiated by national repositories in India. The digitalisation include taking photographs of the type specimens and preparing 3 D images of the specimens using modern software, preparing DNA fingerprints of type specimens (as technology is now available for preparing DNA barcodes from formalin-preserved specimens) and preparing collections details and maps in GIS platform. The preparation of DNA barcodes has implications for “upstream sample collection and preservation methods, as well as downstream implications for highlighting biorepository specimens available for genetic and genomic research” (Hanner and Gregory, 2007).

Conclusions

Despite their high diversity and importance for humankind marine molluscs are not given due priority by researchers in India, as reflected in the lesser number of practicing taxonomists involved in the process. This situation can be improved only by taking concerted efforts in the following key areas: (i) molluscs and their critical ecosystem roles should be brought to the attention of general public in order to remove the public dilemma in this subject; (ii) policymakers and stakeholders are mostly unaware of conservation problems involving marine organisms and betterment of this political dilemma can be done only by involving them in conservation thinking through practical



examples of social and economic benefits arising out of marine biodiversity; (iii) biodiversity studies, especially those involving economically 'insignificant' invertebrate taxa such as Mollusca are underfunded and better funding options should be provided to the taxonomists to complete the inventory of each taxa in every coastal and marine ecosystem of the country. As suggested by [Cardoso *et al.* \(2011\)](#) this is all the more important since most species are undescribed (the Linnean shortfall), the distribution of described species is mostly unknown (the Wallacean shortfall), the abundance of species and their changes in space and time are unknown (the Prestonian shortfall) and species ways of life and sensitivities to habitat change are largely unknown (the Hutchinsonian shortfall); and (iv) thinking beyond achieving biodiversity targets fixed by the United Nations Convention on Biological Diversity through Aichi Targets 2020, government should plan urgent strategies and action plans to prepare a marine biodiversity data portal in the public domain, public high quality field guides and monographs on marine taxa, train a set of internationally competent taxonomists to cater to the future demands in biodiversity science, ensuring positions for taxonomists in each research institution involved in marine biology studies, nurturing young generation of taxonomists through appropriate revisions in curricula, and involving citizen scientists and local communities in biodiversity documentation process.

References

- Abercrombie, A. (1893a). The common marine shells of the Bombay shore. Part I. *J. Bombay Nat. Hist. Soc.*, 8: 212-222.
- Abercrombie, A. (1893b). The common marine shells of the Bombay shore. Part II. *J. Bombay Nat. Hist. Soc.*, 8: 335-345.
- Adam, W. (1939). The Cephalopoda in the Indian Museum, Calcutta, *Rec. Indian Mus.*, 41(1): 61-110.
- [Alder, J. and A. Hancock \(1864\). Notice on the collection of Nudibranchiate Mollusca made in India by Walter Eliot Esq. with descriptions of several new genera and species. *Trans. Zool. Soc. Lond.* 5: 117-147.](#)
- Appeltans, W. et al. (2012). The magnitude of global marine species diversity. *Current Biology*, 22: 1-14.



- Appukuttan, K.K. (1983). Distribution of coral boring bivalves along the Indian coasts. *J.Mar. Biol. Ass. India*, 15 (1): 429-432.
- Appukuttan, K.K., A. Chellam., K. Ramdoss., A.C.C. Victor and M.M. Meiyappan (1989). Molluscan resources; pp. 77-92. In: Suseelan; C. (Ed.). *Marine Living Resources of the Union Territory of Lakshadweep: An Indicative Survey with Suggestions for Development. Bulletin; 43; Central Marine Fisheries Research Institute; Kochi, India, 256pp.*
- Apte, D., V. Bhawe and D. Parasharya (2010). An annotated and illustrated checklist of the opisthobranch fauna of Gulf of Kutch, Gujarat, India, with 20 new records for Gujarat and 14 new records for India. Part 1. *J. Bombay Nat. Hist. Soc.*, 107: 14–23.
- Apte, D. (1993). Marine Gastropoda of Bombay - A recent survey. *J. Bombay Nat Hist. Soc.*, 90: 537-539.
- Apte, D., V. Bhawe, R. Pitale, P. Nagale, and A. Prasade (2012). A Preliminary Report on Diversity of Coastal Ecosystems of Maharashtra Part 3: Ecologically Sensitive Coastal Areas of Ratnagiri, Rajapur and Vijaydurga. Bombay Natural History Society, Mumbai. 173pp.
- Apte, D. (1998). *The Book of Indian Shells*. Oxford University Press, Mumbai, 115pp.
- Apte, D. (2004). Molluscan Fauna of Point Calimere Wildlife Sanctuary Part 1: Gastropoda, *J. Bombay Nat. Hist. Soc.*, 101: 201-210.
- Apte, D. (2012). *Field Guide to the Marine Life of India*. Stusa Mudra Private Limited, Mumbai, 503pp.
- Apte, D.A (2014) *Sea Shells of India, An Illustrated Guide to Common Gastropods*, Oxford University Press, New Delhi, 197pp.
- Apte, D.A. (2009). Opisthobranch fauna of Lakshadweep Islands; India with 52 new records to Lakshadweep and 40 new records to India. Part 1 *J. Bombay Nat. Hist.Soc.*, 106: 162-175.
- Apte, D. and Bhawe, V. (2014). New records of opisthobranchs from Lakshadweep, India (Mollusca: Heterobranchia). *Journal of Threatened Taxa* 6(3): 5562–5568.
- Bertsch, H. and D' Attilio, A. (1980). New species of Muricidae (Gastropoda) from the Indian Ocean, the Philippines and Brasil. *Venus*, 39 (3): 131-138, figs. 1-7.
- Bhawe, V. and D. Apte. (2011). Opisthobranch fauna of Ratnagiri, Maharashtra, India with 8 new records to India. *J. Bombay Nat. Hist. Soc.*, 108(3): 172-182.



- Bijukumar, A., R. Ravinesh., A.R. Arathi and K.K. Idreesbabu (2015). On the molluscan fauna of Lakshadweep included in various schedules of Wildlife (Protection) Act of India. *Journal of Threatened Taxa* 7(6): 7253–7268.
- Cardoso, P., Erwin, T.L., Borges, P.A.V. and New, T.R. (2011). The seven impediments in invertebrate conservation and how to overcome them. *Biological Conservation* 144: 2647–2655.
- Carmona, L., Bhawe, V., Salunkhe, R., Pola, M., Gosliner, T. M., Cervera, J. L. (2014). Systematic review of Antaeolidiella (Mollusca, Nudibranchia, Aeolidiidae) based on morphological and molecular data, with a description of three new species. *Zoological Journal of the Linnean Society*, 171(1): 108-132
- Comber, E. (1906). A list of marine mollusca in the in the Bombay Natural History Society Collection. *J. Bombay nat Hist. Soc.*, 17: 207-215.
- Crichton, M.D. (1940). Marine shells of Madras. *J. Conch., Lond.*, 21 : 193-212.
- Crichton, M.D. (1941). Marine shells of Madras. *J. Bombay nat. Hist. Soc.*, 42: 323-341.
- Dayrat, B. (2005). Towards integrative taxonomy. *Biological Journal of the Linnean Society*, 85: 407–415.
- Dey, A. (2006) Contribution to the knowledge of Indian Marine Molluscs (Part - IV) Family Tellinidae; Rec of Zool Surv India, Occ. Paper No. 249 : 1-124.
- Dey, A. and Ramakrishna, (2007). Marine molluscs of Andhra Pradesh: Bivalvia, Scaphopoda and Cephalopoda. *Zool. Surv. India: Fauna of Andhra Pradesh, State Fauna series*, 5(7): 149-260.
- Dey, A. and Ramakrishna, (2007). Marine molluscs of Andhra Pradesh: Bivalvia, Scaphopoda and Cephalopoda, Fauna of Andhra Pradesh, State Fauna series, Zoological Survey of India, 5 (Part 7): 149-260.
- Eliot, C. (1903). Nudibranchiata; with some remarks on the families and genera and description of a new genus *Doriclomorpha*. Pp 540-573 In: Gardiner; S.J. (ed.). Fauna and Geography of the Maldivian and Laccadive Archipelagos 2(1): 473 588.
- Franklin, B.F., Subramanian, K. A., Fernando, S.A and K. S. Krishnan (2009). Diversity and Distribution of Conidae from the Tamil Nadu Coast of India (Mollusca: Caenogastropoda: Conidae), *Zootaxa*, 2250: 1–63.



- Halanych, K.M., JD Bacheller, AM Aguinaldo, SM Liva, DM Hillis, JA Lake (1993). Evidence from 18S ribosomal DNA that the lophophorates are protostome animals. *Science*, 267: 1641-1643.
- Hanner, R.H. and Gregory, T.R. (2007). Genomic diversity research and the role of biorepositories. *Cell Preservation Technology*, 5: 93-103.
- Haszprunar, G. (2001). *Mollusca (Molluscs). Encyclopedia of Life Sciences. John Wiley & Sons, Ltd.*
- Healy, J.M. (2001). *The Mollusca. In: Anderson, D.T. (ed). Invertebrate Zoology (2 ed.). Oxford University Press. pp. 120–171.*
- Hornell, J. (1910). Report on the results of the fishery cruise along the Malabar coast and the Laccadive Islands in 1908. *Madras Fish. Bull*, 4: 71-126.
- Hornell, J. (1917). The edible Molluscs of the Madras Presidency. *Madras Fish. Bull.*, 11: 1-51.
- Hornell, J. (1921a). Common molluscs of South India. *Madras Fish Bull.*, 14 (6): 97-212.
- Hornell, J. (1921b). Common molluscs of South India; Appendix Molluscan fauna of the Laccadive Islands. *Madras Fish Bull.*, 14 (6): 213-215.
- Hornell, J. (1922). The common molluscs of south India. *Madras Fish. Bull.* 14 : 97-215.
- Hornell, J. (1949). The study of Indian molluscs. *J. Bombay nat. Hist. Soc.* 48 : 303-337, 543-569, 750-774.
- Hornell, J. (1951). Indian molluscs. Bombay Natural History Society. Bombay. 96 pp. Hornell, J. and Tomlin, J. R (1951). Check list of marine and fluviatile Mollusca of Bombay and neighbourhood. In: Hornell, 1951, 83-94.
- Hoyle, W. E. (1905). The Cephalopoda. In: Gardiner; S.J. (ed.). *Fauna and Geography of the Maldive and Laccadive Archipelagos 2; Suppl, 1, 575-988.*
- Hylleberg, J. and Kilburn, R.N. (2002). Annotated inventory of molluscs from the Gulf of Mannar and vicinity (Ed.) Nateewathana, A. *Tropical Marine Mollusc Program (TMMP): Zoogeography and inventory of marine molluscs encountered in southern India: Phuket Marine Biological Centre, Special Publication, 26. : 19-79.*
- Kohn, A.J. (1978). The Conidae (Mollusca: Gastropoda) of India. *Journal of Natural History*, 12, 295–335.



- Kundu, H.L. (1965). On the marine fauna of the Gulf of Kutch. Part III-pelecypods. *J. Bombay nat. Hist. Soc.*, 62(1): 84-103.
- Kurian, C.V. (1948). On a collection of scaphopods (Mollusca) from the Travancore coast. *Proc. Indian Sci Congr.*, 5: 197.
- Lutaenko, K.A. (2006). On the fauna of bivalves of the subfamily Anadarinae (Arcidae) from Southern India. *Bull. Russian Far East malac. Soc.*, 10: 102-121.
- Melvill J. C (1909). Report on the marine Mollusca obtained by Mr. J. Stanley Gardiner FRS among the islands of the Indian Ocean in 1905. *Trans. Linn. Soc. London*, (2) :65438.
- Melvill, J. C., and Abercromeie, A. (1893). The marine Mollusca of Bombay. *Mem. Proc. Manchr lit. phil. Soc.*, 7: 17-51.
- Melvill, J. C., and R. Standen, (1898). The marine Mollusca of Madras and the immediate Neighbourhood. *J. Conch.*, 9 : 30-48, 85.
- Melvill, J.C (1892). Descriptions of twenty five new species of marine shells from Bombay collected by Mr.Alexander Abercrombie, Esq. *Ibid.*, (4)7:52-67.
- Melvill, J.C (1893-94). Descriptions of twenty five new species of marine shells from Bombay collected by Mr.Alexander Abercrombie, *J. Bombay nat. Hist. Soc.*, 8: 234-245.
- Melvill, J.C (1898). Descriptions of new species of marine shells from Bombay, *J. Bombay nat. Hist. Soc.*, 11: 506-514.
- Melvill, J.C and J.H. Ponsoney (1898). Descriptions of new species of minute marine shells from Bombay, *proc malac soc London*, 2:108-116.
- Menon, P. K. B., Dattagupta, A. K., and Dasgupta, D. (1961). On the marine fauna of the Gulf of Kutch, Part 2-Gastropods. *J. Bombay nat. Hist. Soc.*, 58: 475-494.
- Menon, P. K. B., M. L. Sareen and Tandon. K. K. (1967). On the marine fauna of Goa. Apreliminary Survey. Part. I. Mollusca - Pelecypoda. *Res. Bull. (N.S) Punjab Univ.*,18(3-4): 315-320.
- Modayil, M.J. (2007). *A Field Guide to the Common Marine Molluscs of India*, CMFRI, Kochi, 80pp.
- MoEF (2014). India's fifth national report to the convention on biological diversity. Ministry of Environment and Forests, New Delhi, 100pp.
- MolluscaBase (2016). Accessed at <http://www.molluscabase.org> on 2016-05-03



- Mookherjee, H.P (1985) Contributions to the Molluscan fauna of India, Part III. Marine molluscs of the Coromandel Coast, Palk Bay and gulf of Mannar Gastropoda: Mesogastropoda: (Part - 2); Zoological Survey of India, Kolkata, 129pp.
- Mukhopadhyay, A.K., Sharma, A.K. and Ramakrishna (2012). Two new species of molluscs (Naticidae: Gastropoda) from India. *Rec. zool. Surv. India*, 112: 7-12.
- Nagabhushanam, A. K. and Rao, G. C (1972) An ecological survey of the marine fauna of Minicoy Atoll (Laccadive Archipelago, Arabian Sea). *Mitt Zool, Mus, Berlin*, 48 (2) 265-324.
- Nair, N. B and M. Salim (1994). Marine timber destroying organisms of the Andaman Nicobar islands and the Lakshadweep Archipelago. *Rec. Zool. Surv. India*, Occ. Paper No. 159.
- Nair, N. B. and K. Dharmaraj (1983). Marine wood boring molluscs of Lakshadweep Archipelago. *Ind. J. Mar. Sci.* 12 (2) : 96-99.
- Nair, N.B. (1962). Incidence of marine wood boring molluscs on the South-east coast of India. *Curr Sci.*, 31(7): 290 -291.
- Narayanan, K. R. 1968. On the opisthobranchs from the South-West Coast of India. 1 *Marine Biological Association of India*, 10(2): 377-380.
- Narayanan, K.R. (1968). On the opisthobranchiate fauna of the Gulf of Kutch. Proceedings of the Symposium on Mollusca, *Marine Biological Association of India* 3(1): 188-213.
- Panicker, K. C. S. 1977-78. Cowry shells of Lakshadweep. 1341. Cent. Inst. Fish. Education, Bombay 123; e144.
- Pati, S.K. Sharma, R.M. (2012) Marine gastropods (Mollusca: Gastropoda), Fauna of Maharashtra, State Fauna Series, Z.S.I., Kolkata 20 (2012) 291-302.
- Pinn, F. (1990). *Sea Snails of Pondichery*, Nehru Science Centre, Pondichery, 163pp.
- Pisupati, B. (2015). Taxonomy – the science and art of species. *Current Science*, 108: 2149 2150.
- Prashad, B. (1930). On two new species of the genus *Solemya* from Indian waters, *Proc Malac soc. Lond.*, 20: 178-180.
- Prashad, B. (1932). The lamellibranchia of the Siboga Expedition, Systematic Part-II, Pelecypoda. *Siboga Expedition*, 53C: 1-353.



- Preston, H.B. (1910). Description of five new species shells from the Bay of Bengal. *Ibid.*, 5:117-121.
- Preston, H.B. (1911). Description of five new species shells from the Bay of Bengal and Madras. *Ibid.*, 6:39-42.
- Raghunathan, C., C. Sivaperuman and Ramakrishna (2010). An account of newly recorded five species of nudibranchs (Opisthobranchia, Gastropoda) in Andaman and Nicobar Islands, pp. 283–288. In: Ramakrishna, C. Raghunathan& C. Sivaperuman (eds.). *Recent trends in biodiversity of Andaman and Nicobar Islands*. Zoological Survey of India, Kolkata, 542pp.
- Rajagopal, A. S. and H. P. Mookherjee (1978). Contributions to the Molluscan Fauna of India part I. Marine molluscs of the coromandel coast, Palks strait and Gulf of Mannar Gastropoda : Archaeogastropoda; Occasional Paper No. 12. Zoological Survey of India, 1-51.
- Rajagopal, A. S. and H. P. Mookherjee (1982) Contribution to the molluscan fauna of india part II. marine molluscs of the coromandel coast, palk bay and gulf of mannar gastropoda: 'mesogastropoda (partim) Zoological Survey of India, Calcutta; 57pp.
- Rajeev, R., Neelesh, D., Knight, M.J.D., Bijukumar, A., Unmesh, K., Krishnakumar, K., Ali, A. and Siby. P. (2014). Predatory journals and Indian ichthyology. *Current Science*, 107(5): 740-742.
- Ramakrishna and Dey A., Barua, S. and Mukhopadhyaya, A. (2007) Marine Molluscs. Polyplacophora and Gastropoda. In: Fauna of Andhra Pradesh, State Fauna Series, Zoological Survey of India. 5 (Part-7) : 149- 260.
- Ramakrishna, A and Dey, A. (2010). Annotated Checklist of Indian Marine Molluscs (Cephalopoda, Bivalvia and Scaphopoda) : Part-I. Rec. zool. Surv. India, Occ. Paper No, 320: 1-357.
- Ramakrishna, C.R Sreeraj, C. Raghunathan, C. Sivaperuman, J. S. Yogesh Kumar, R. Raghuraman, T. Immanuel & P.T. Rajan (2010). *Guide to Opisthobranchs of Andaman and Nicobar Islands*. Zoological Survey of India, Kolkata, 198pp.
- Ramakrisna, A and Dey, A. (2003) Manual on Identification of Scheduled Molluscs from India. Zoological Survey of India, Kolkata, 39 pp.
- Rao, K.V. and N.V. Rao (1991). Mollusca, pp. 273–362. In: Ghosh, A.K. and A. Kumar (eds.). State Fauna Series 2, Fauna of Lakshadweep. Zoological Survey of India, Kolkata, 413pp.
- Rao, N.V. (1970). On the collection of Strombidae (Mollusca : Gastropoda) from Bay of Bengal, Arabian sea and Western Indian Ocean with some



- new records 1. Genus *Strombus*. *Marine Biological Association of India*, 12(1and2): 109-124.
- Rao, N.V. (1977). On the collection of Strombidae (Mollusca : Gastropoda) from Bay of Bengal, Arabian sea and Western Indian Ocean with some new records 1. Genus *Lambis*, *Terebellum*, *Tibia* and *Rimella*. *J. Marine Biological Association of India*, 19: 21-34.
- Rao, N.V. (1980) On the Conidae of Andaman and Nicobar Islands. Records of the Zoological Survey of India 77, 39–50.
- Rao, N.V. (2003). Indian Sea Shells (Part I). Polyplacophora and Gastropoda. Zoological Survey of India, Kolkata, 416pp.
- Rao, N.V. and Dey A. (1984). Contribution to the knowledge of Indian marine molluscs.I. Family Mitridae. Records of the Zoological Survey of India, Occasional Publications, No. 61, 48 pp.
- Rao, N.V. and Dey A. (1986). Contributions to the knowledge of Indian marine molluscs 2. Family Donacidae. Records of the Zoological Survey of India, Occasional Publications, No. 91, 304 pp.
- Rao, N.V. and Dey A. (1991). Composition and distribution of marine molluscs of Andaman and Nicobar Islands. *Journal of the Andaman Science Association* 4, 61–66.
- Rao, N.V. and Dey, A. (2000). Catalogue of Marine molluscs of Andaman and Nicobar Islands. *Rec. zool. Surv. India*, 187 : 1-323.
- Rao, N.V. and Rao, K.V. (1993). Contribution to the Knowledge of Indian Marine Molluscs. 3. Family: Muricidae, Zoological Survey of India, Kolkata, 151pp.
- Rao, N.V., K.V. Surya Rao and Maitra, S. (1990). Marine molluscs of Orissa. *Zool Surv. India. Fauna of Orissa, State Fauna series*, 1(3) : 1-175.
- Ray, H.C. (1949). On a collection of Mollusca from the coramandel coast of India. *Rec Indian Mus.*, 46. 87-122.
- Ray, H.C. (1949). Revision of Cypraea in the collection of the Zoological survey of India. The families Trividae, Eratoidae and Pedicularidae. *Rec Indian Mus.*, 46: 183-213.
- Ray, H.C. (1951). On some deep water molluscs from the Indian Ocean, with descriptions of three new species (*Bivalvia*). *Rec Indian Mus.*, 49:185-190.
- Ray, H.C. (1956). Mitres of Indian waters (Mollusca: Gastropoda Family Mitridae). *Mem Indian mus.*, 14:1-72.



- Robson, G.C. (1926). Notes on the Cephalopoda. No.1. Descriptions of two new species of Octopus from Southern Indian and Ceylon. *Ann. Mag. Nat. Hist.*, (9)17: 159-167.
- Rockel, D., Korn, W. and Kohn, A.J. (1995). Manual of the Living Conidae. Volume 1 Indo-Pacific Region. Verlag Christa Hemmen: Wiesbaden, Germany 517pp.
- Rosenberg, G. (2014). A new critical estimate of named species-level diversity of the recent Mollusca. *American Malacological Bulletin*, 32(2), 308-322.
- Santhakumaran, L.N. (1973). Systematics of molluscan wood borers recorded from India. *J. Bombay nat. Hist. Soc.*, 70(2): 348-360.
- Satyamurti, S. T. (1956). The mollusca of the Krusadai Island (In the Gulf of Manaar II) Scaphopoda, Pelecypoda, Cephalopoda. *Bull. Madras Govt. Mus. New Serie (Nat. Hist.)*, 1(2). 7: 1-202.
- Satyamurti, S.T. (1952). The Molluscs of Krusadai Island (in the Gulf of Manaar. I. Amphineura and Gastropoda. *Bull. Madras Govt Mus., N.S.*, 1(2): 1-267.
- Sigwart, J.D., and M.D. Sutton. 2007. Deep molluscan phylogeny: synthesis of palaeontological and neontological data. *Proceedings of the Royal Society B* 274(1624):2413-2419
- Silas, E. G. (1968). Cephalopoda of the west coast of India collected during the cruises of the research vessel VARUNA, with a catalogue of the species known from the Indian Ocean. *Proc. Symp. Mollusca Mar. Biol. Ass. India*, Part 1: 277-359.
- Silas, E.G. (1968). Cephalopoda of Indian Ocean. *Proc Symp on Molluscs, Marine Biological Association of India*, 1: 277-359.
- Silas, E.G., Sarvesan, R., Rao, K.S., Nair, P.K. and Meiyappan, M.M. 1985. Identity of common species of cephalopods of India. *Cephalopod Bionomics, Fisheries and Resources of the Exclusive Economic Zone of India*, *Bull. Cent. Mar. Fish. Res. Inst.*, 37: 13-37.
- Smith, E. A. (1896). Descriptions of new deep sea Mollusca. *Ann. Mag. nat. Hist. Lond.*, (6) 18: 367-375.
- Smith, E. A. (1899). On Mollusca from the Bay of Bengal and the Arabian Sea. *Ann. Mag. nat. Hist. Lond.*, (7) 4 : 237-251.
- Smith, E. A. (1904). On Mollusca from the Bay of Bengal and the Arabian Sea. *Ann. Mag. nat. Hist. Lond.*, (7) 14 : 1-14.



- Smith, E.A (1903). Marine Mollusca pp 589-630. In: Gardiner; S.J. (ed.). Fauna and Geography of the Maldive and Laccadive Archipelagos, 2(2): 119-222.
- Smith, E.A (1906). On Mollusca from the Bay of Bengal and the Arabian Sea. *Ann. Mag. nat. Hist. Lond.*, (7)18 : 157-175 and 245-264.
- Smith, E.A. (1894). Natural history notes from H. M. Indian Marine Survey Steamer 'Investigator', Commander C. F. Oldham, R.N. Ser. II, No. 10, Report upon some Mollusca Dredged in the Bay of Bengal and the Arabian Sea. *Ann. Mag. nat. Hist., Ser. 6*, 14:157-174.
- Smith, E.A. (1878). On the collection of marine shells of the Andaman Islands. *Proc. zool. Soc. London*, 1878 : 804-821.
- Smith, E.A. (1895). Report upon some Mollusca dredged in the Bay of Bengal and Arabian Sea. *Ann. Mag. Nat. Hist.*, (6) 15: 1-19 and 262-265.
- Smith, E.A. (1906). Gardiner's fauna and Geography Maldive and Laccadive Archipelagoes, pt. 2, Marine Mollusca., pp. 589-630.
- Sreeja V., Norman M.D. and Biju Kumar A. (2015). A new species of pouched octopus, *Cistopus* Gray, 1849 (Cephalopoda: Octopodidae) from the southwest coast of India. *Zootaxa*. 4058(2): 244-256.
- Sreeraj, C.R., C. Sivaperuman & C. Raghunathan (2012). An annotated checklist of opisthobranch fauna (Gastropoda: Opisthobranchia) of the Nicobar Islands, India. *Journal of Threatened Taxa* 4(4): 2499–2509.
- Stöger, I., Sigwart, J. D., Kano, Y., T. Knebelsberger, B. A. Marshall, E. Schwabe and M. Schrödl (2013). The Continuing Debate on Deep Molluscan Phylogeny: Evidence for Serialia (Mollusca, Monoplacophora + Polyplacophora). *BioMed Research International*, 2013, <http://dx.doi.org/10.1155/2013/407072>
- Subba Rao, N. V., Dey, A., and Barna, S., (1992). Estuarine and Marine Molluscs. State Fauna Series 3. Fauna of West Bengal. Zoological Survey of India pt. 9 : 129-268,
- Subba Rao, N.V., (1991). Mollusca. Animal Resources of India. Zoological Survey of India, Kolkata, pp. 125–147.
- Subba Rao, N.V., (1998). Mollusca. Faunal Diversity in India. Zoological Survey of India, Kolkata, pp. 104–117.
- Subba Rao, N.Y. and Sastry, D.R.K. (2005). Fauna of Marine National Park, Gulf of Kutch, (Gujarat): An Overview. Conservation Area Series 23: 1-79,



- Subrahmaniyan, T.V., K.R. Karandikar and N.N.Murti (1952). Marine gastropoda of Bombay II. General characters, habits and habitat of Bombay Gastropoda. *Ibid.*, (8) 20: 50-81.
- Subrahmaniyan, T.V., K.R. Karandikar and N.N.Murti (1951). Marine gastropoda of Bombay, I. *Ibid.*, (8) 20: 50-81.
- Subrahmaniyan, T.V., K.R. Karandikar and N.N.Murti (1949). Marine pelecypoda of Bombay, *J Univ Bombay (new Series.)*, (5) 25:50-81.
- Thurston, E. (1890). Notes on the pearl and chank fisheries and marine fauna of the Gulf of Mannar. *Madras: Government Central Museum*, 116 pp.
- Tikader, B.K., Daniel, A. and Subbarao N.V.(1986). Sea shore animals of Andaman and Nicobar Islands. Zoological survey of India, Calcutta, 188pp.
- Tripathy B, Mukhopadhyay A.K (2015) Marine Molluscan Diversity in India Venkataraman, K and , Sivaperuman, C., Ed.) Marine Faunal Diversity in India, Taxonomy, Ecology and Conservation, Academic Press is an imprint of Elsevier, 32 Jamestown Road, London NW1 7BY, UK pp 39-74.
- Venkataraman K Wafar M. (2005) Coastal and marine biodiversity of India. Indian journal of marine sciences, 57-75.
- Venkataraman, K and C. Raghunathan. (2015). Coastal and Marine Biodiversity of India pp303-372 In: Venkataraman, K. and C. Sivaperuman (Eds.). *Marine Faunal Diversity in India: Taxonomy, Ecology and Conservation*. Academic Press, London, 519pp.
- Venkataraman, K., Jeyabaskaran, R., Raghuram, K.P., Alfred, J.R.B., (2004). Bibliography and checklist of corals and coral reef associated organisms of India. Rec. Zool.Surv. India, Occ. Paper 226, 1-648.
- Venkataraman, K., R. Rajan., C.H. Satyanarayana., C. Raghunathan and C. Venkataraman (2012). *Marine Ecosystems and Marine Protected Areas of India*. Zoological Survey of India; Kolkata; 296pp.
- Vishal, B and D. Apte (2013). Current Status of Indian Opisthobranch Fauna, pp 63-79 In, Venkataraman, K., C. Sivaperuman & C. Raghunathan (eds.).*Ecology and Conservation of Tropical Marine Faunal Communities*. Springer, London, 481pp.
- Winckworth, R (1927a). New species of chitons from Aden and south India. *Proc malac soc Lond.*, 17: 206-208.
- Winckworth, R (1927b). Marine mollusca from India and Ceylon. I. Dentalium. *Ibid.*, 17: 167-169.



- Winckworth, R (1928). Marine mollusca from India and Ceylon. II. Limpets. *Ibid.*, 18: 133-136.
- Winckworth, R (1929). Marine mollusca from India and Ceylon. I. Pinna with an index to recent species of pinna. *Ibid.*, 18: 206-208.
- Winckworth, R (1929). New species of shell from Madras *Ibid.*, 24: 41-43.
- Winckworth, R. (1936). Marine Mollusca from South India and Ceylon. 4. A New Indian Sepia. *Proc. Molac. Soc. London*, 22: 16-23.
- Winckworth, R. (1940). New species of shells from Madras. *Proc. malac. Soc. London*, 24 : 19-29.

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- Yonow, N. (2012). Opisthobranchs from the western Indian Ocean, with descriptions of two new species and ten new records (Mollusca, Gastropoda). *ZooKeys*, 197: 1 129.
- Huber, M. 2015 Compendium of Bivalves 2. A Full-Color Guide to the Remaining Seven Families. A Systematic Listing of 8'500 Bivalve Species and 10'500 Synonyms 907 pp.
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Gosliner, T.M., Valdés, A. & Behrens, D.W. 2015. Nudibranch and Sea Slug Identification - Indo-Pacific. New World Publications, Jacksonville, Florida.

Gosliner, T. M., Behrens, D. W., & Valdés, A. 2008. Indo-Pacific Nudibranchs and Sea Slugs: A Field Guide to the World's Most Diverse Fauna. Sea Challengers, Gig Harbor, WA & California Academy of Sciences, San Francisco, CA, 426 pp.

