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9 Sponges - systematics, as pests of molluscs, agents of bioerosion and a source of bioactive compounds

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ABSTRACT

This paper on sponges deals mainly with 1) systematics, 2) as pests of molluscs and agents of bioerosion and 3) as a source of bioactive compounds. Sponges have many physical and physiological peculiarities not seen in other animal groups, and hence they can be used in the study of cellular biology, evolution of nervous system, reproduction, bioerosion, bioactivity, symbiosis, etc. Many of the lower invertebrates are considered to possess chemical compounds with proven biodynamic potentials. But, in India, such studies, except in a few groups, have not progressed satisfactorily for want of sufficient expertise on the 'source material', their availability and taxonomic position. Hence, basic taxonomic studies will have to be initiated on all lower invertebrate groups as priority areas for a better management of any project aimed at synthesising 'wonder drugs' from marine animals and also to meet the biodiversity - linked mandate endorsed by the recent GATT Agreement.

Introduction

Sponges constitute a group of primitive, diploblastic animals with several physical and physiological peculiarities not seen in any other animal groups. The history of spongology of the Indian Ocean is rather a short one. The area which received some attention in the 19th Century was Ceylon (= Sri Lanka) as works on sponges made by pioneers like Ehlers, Gray, Bowerbank, Haeckel, Carter, Sollas, etc. made either direct or indirect reference to the sponge fauna of Sri Lanka and/or of the Gulf of Mannar.

Comparatively very little work has been carried out on the sponge fauna of peninsular India during the earlier decades of the present Century by workers like Burton, Dendy, and Rao. Considering the dearth of knowledge on the sponge fauna of the Indian seas, Dr. S. Jones, the former Director of C.M.F.R.Institute entrusted the study on the systematics of Indian sponges with the present author, in 1964. Detailed studies on the systematics of sponges belonging to 135 species of the class demospongiae (siliceous sponges) referable to its 8 families collected from 15 sites (7 along the west coast, 6 along the east coast and one each from the Lakshadweep and Andaman group of islands) during 1964-'67 were carries out. Incidentally, the class Demospongiae Sollas forms the dominant class among 4 classes of the Phylum Porifera comprising about 88.8% of the total extant species.

Systematics of sponges

In this section sponges collected from the following areas are considered: (a) Indian coasts, (b) the oceanic islands, (c) southeast coast of Africa, (d) Papua and New Guinea and (e) the Antarctic.

Sponges of the Indian coasts

Taxonomy of 135 species with 8 new species and 20 new records from 15 centres along the Indian coasts were classified under 84 genera and 33 families of the Class Demospongiae (Thomas, 1968). Various new species and new records, thus collected, were subsequently published in a series entitled "Studies on Indian sponges" by Thomas

The Indo-Norwegian Fishing Vessel '*Klaus Sunnana*' made a collection of deep water sponges from the Gulf of Mannar and out of 9 species collected three were new to science (Thomas, 1970). The presence of the 'Bath-sponge' *Spongia officinalis* Lin. var. *ceylonensis*, in fishable magnitude in and around Rameswaram was highlighted during the 'Symposium on the living resource of the seas around India' (Thomas, 1973 b). Thus, the sponge, which were hitherto a neglected group, got a position in the resource map of India. While analysing more samples from the Gulf of Mannar and Palk Bay some more new species and new records could be obtained. Of these special mention may be made to an Ophlitaspongiid species, *Qasimella indica* (Thomas, 1974) and a Raspailiid, *Endectyon lamellosa* (Thomas, 1976 c). There were two general papers, one on 'The history of spongology of the Indian Ocean (Thomas,

1976) and the other on 'Distribution and affinities of the sponge fauna of the Indian region'. Affinity-wise the Indian sponge fauna comprising of 481 species, is closely related to that of Australia, Pacific Ocean and the Red Sea.

Extensive survey along the southeast coast at a depth of 50 m, using the C.M.F.R.I. owned Research Vessel *'Skipjack'*, revealed the presence of 8 species of sponges, including three new to science (Thomas, 1984).

Considering the richness of sponge species in the Gulf of Manner, a monograph was prepared. This work enumerated about 275 species under 38 families and 136 genera. The total number of species collected from the Palk Bay was 94 and since no documentation of the sponge fauna of this Bay has taken place in the past the scope of the above monograph was enlarged to include the Palk Bay species also (Thomas, 1986).

The Zoological Survey of India, Calcutta, while celebrating its Platinum Jubilee, released a State of the Art Report entitled 'Animal Resources of India-Protozoa to Mammalia' in 1991. The present author was invited to contribute an article on'Marine Porifera' (Thomas, 1991). The Government of India initiated some steps to assess the existing biological assets of India under GATT Agreement through the help of active workers in the respective fields, and accordingly an account on the sponge fauna of India was prepared and forwarded to the Ministry of Environment and Forests, New Delhi.

The extensive collection of sponges made by the author from different parts of the Indian coasts as also those sent to him by various expedition teams from the Seychelles Bank, Mozambique Channel etc. led to a considerable increase in the number of species, including types, in the Reference Collection of C.M.F.R.I. , Mandapam Camp, and this, in turn, resulted in the establishment of a separate section for Porifera in the Reference Collection Museum. A total of 152 species referable to 34 families and 90 genera was deposited and a Catalogue was published in 1969 (Thomas, 1969a). Some types were later transferred to the Indian Museum, Calcutta, on request.

During a reconnaissance survey carried out in the Gulf of Kutch (1978) a total of 25 species of sponges (22 genera; 15 families) could be collected. Of these 20 species were new to the Gulf of Kutch. Ecologically speaking, out of these 25 species 36% preferred lower silt-free surfaces of rocks/ corals; 32% showed the tendency to bore into calcarious objects; 24% showed the tendency to incorporate silt / sand into their body and 4% exhibited various kinds of malformations to their spicules / fibres. All these indicate that the Gulf of Kutch sponges live under severe 'stress' conditions.

Sponges of the oceanic islands

Lakshadweep Archipelago: An extensive collection of sponges from Minicoy, the southernmost island of the Archipelago, was made during 1964-69 period by the scientists of C.M.F.R.I., who were posted to or visited Minicoy from time to time. An analysis of specimens, thus obtained, revealed the presence of 11 species (Thomas, 1968). This was followed by a thorough sampling of sponges by Shri. M. Alimanikfan, a native of Minicoy Island, who was with C.M.F.R.I., Mandapam Camp. This collection was quite extensive when compared to any other collection made in the past and contained 41 species referable to 23 families and 32 genera. All species were new records to Minicoy Island and as no information on sponge fauna was available detailed systematic accounts were published (Thomas, 1973, 1979c, 1980, 1980a).

C.M.F.R.I. had undertaken an indicative survey of the Lakshadweep Archipelago in 1987 to assess the fishery resources and their potential, the impact of environmental damages of the endangered ecosystems and to evaluate the auxiliary resources such as seacucumbers, sponges, ornamental fishes, etc. Ten islands were covered, 5 of them intensively by the author himself, and sponges were collected on a transect-morphozone basis. Sponges, thus collected, together with those already recorded from Minicoy Island accounted for a total of 91 species referable to 33 families and 66 genera from this Archipelago (Thomas, 1989). Since the classical treatise on the fauna of Laccadives and Maldive Archipelagoes edited by Gardiner (1903 to 1909, *The fauna and geography of Maldive and Laccadive Archipelagoes*, Cambridge University Press, Cambridge, 1- 1979) did not record any sponge from lakshadweep, the works of the present author may serve as a useful compendium on the sponge fauna of Lakshadweep group of islands.

Mahe Island in the Seychelles Bank: While there are many references in literature on the sponge fauna of the Seychelles Bank in general, there are no works dealing directly with the sponge fauna of any particular island of this vast bank. As such all species from Mahe Island, the capital, are new records to this Bank. Thomas (1973a, 1981) in collaboration with the Brussels University, Belgium, could record a total of 104 species under 32 families and 71 genera. Of these, 7 species were new to science.

Maldive: Two collections were made in the past from Maldives by the University of Southern California, U.S.A., under the leadership of Prof. G.J. Bakus, for the study of antifouling compounds from marine organisms. The first collection, made in 1989, contained 17 species and a 'form' referable to 16 genera under 7 orders of the Class Demospongiae. Of these 3 species were new to science.

The second collection made in 1990 from the same area included 25 species falling under 17 families and 22 genera . This collection added one species new to science. Two boring species belonging to the family Adociidae have also been added to the list of boring species of the Indian Ocean (*Siphonodictyon mucosum* Bergquist and *S. coralliophagum* 'forma' *tubulosa* Rutzler). With these two species the total number of boring sponges of the Indian Ocean rises to 34(For earlier species see Thomas, 1979).

Southeast coast of Africa

Sponges from 4 widely separated areas along the southeast African Coast were studied in detail. The areas were (a) Zanzibar Island, (b) Ras Iwatine (Kenya), (c) Inhaca Island and (d) Mambone and Paradise Islands.

Of these, the material from the first two areas were collected by Dr. A.J. Bruce of the East African Marine Fisheries Research Organisation, Kenya, as hosts of shrimps while those from other areas by Prof. J. Bouillon, Brussels University, Belgium, as 'source material' for the study of bioactive substances from marine animals by the Brussels University.

Sponges collected from Zanzibar Island composed of 14 species belonging to 10 families and 13 genera. While most of the species were found new record to the island, the distribution of *Megaciella tibiellifer* (Ridley) is extended to the Indian Ocean (Thomas, 1976a). Sponges from Ras Iwatine (Kenya) accounted for a total of 10 species falling under 9 genera and 9 families (Thomas, 1976b).

The collection of sponges from Inhaca Island requires special mention in this context, because it was a group left out by Macnae and Kalk (1958) while dealing with different animal groups of this island. The collection included a total of 42 species under 21 families and 36 genera. Two species and a subspecies were new to science. Since no information was available on the sponge fauna of Inhaca Island the work of Thomas (1979a) forms the first report on sponges of this island.

Geographically the Mambone and Paradise Islands are located close together and hence the sponge fauna of these two areas were clubbed together into a single communication (Thomas, 1979b). A total of 26 species under 15 families and 22 genera were recorded and from the point of affinity it may be stated that the sponge fauna of the southeast African coast showed more relationship with that of the Red Sea unlike in any collection from the Indian Ocean where the affinity with the Pacific used to be more pronounced than with the Red Sea.

Papua and New Guinea

An exhaustive collection of sponges made by Prof. J.Bouillon from Papua and New Guinea included a total of 44 species belonging to 34 genera under 20 families (Thomas, 1987 and 1991a for its first two parts).

Antarctica

Sponges collected during the Third Indian Antarctic Research Expedition (Dec.1983 to March 1984) were worked out (Thomas and Mathew, 1986). A total of 6 species, 3 belonging to Class Demospongiae and 3 to Class Hexactinellida were described with suitable illustrations. Of these *Isodictya echinata* was new to science.

Sponges as pests of molluscs and agents of bioerosion

Sponges constitute a major group among 12 different taxa of marine animals and plants which can cause considerable damage to the calcium carbonate secreting animals such as molluscs, corals, barnacles, etc. The biological, chemical and geological changes that these organisms would bring about in the marine and estuarine environments are by no way insignificant as they cause bioerosion, influence calcium balance in the sea and control the structure of calcium carbonate secreting animals.

A systematic account on the coral boring sponges infecting the fringing reefs of the Gulf of Mannar and Palk Bay revealed the presence of 20 species belonging to 3 orders, 4 families and 9 genera (Thomas, 1972). Of the various genera, species belonging to the genus *Cliona* were found wide spread in the reef system of the area. This was followed by a detailed study on the boring sponges infecting the economically important molluscs of the Indian seas, and 32 species belonging to 3 orders, 4 families and 13 genera were recorded

(Thomas, 1979). This number is very high (32) when compared to any other part of world oceans, and this indicates that the Indian seas are worst affected by boring sponges.

The Zuari and Mandovi estuaries are very rich in rock-oyster populations. An examination of boring sponges infecting them revealed the presence of only *Cliona vastifica* whereas the adjoining marine environment harboured as many as 4 species of boring sponges. Such a wide difference in their number is due to the fact that only *C. vastifica* is capable of surviving in lower salinities. The gradation in the differentiation of the brackishwater populations of *C. vastifica* throughout the world is a matter of great interest. It is true that *C. celata* colonises the higher salinity zones of both estuaries of Goa in every summer, but the excessive freshwater flow during monsoon wipes out *C. celata* populations (Thomas, 1975). In future any attempt to check the freshwater flow by way of constructing dams across the river would naturally result in an estuary which is more saline than at present and this, in turn, would provide congenial conditions for *C. celata* to invade and flourish. Those who are interested in initiating molluscan culture in these estuaries should take the above risk-factor also into consideration.

A large quantity of semifossilised shells of window-pane oyster *Placenta placenta* accidentally unearthed from a paddy field near Panaji, the capital of Goa, led to the conclusion that there was a flourishing population of window-pane oyster in the estuaries of Goa in the past; but it got destroyed as a result of indiscriminate reclamation for agricultural purposes. Since 10.5% of the shells were bored by sponges a study was made to identify the boring sponge species from the pattern of their boring, which was in a linear and reticulate manner, as no spicules were preserved due to long subterranean existence.

Window-pane oyster shells collected from an extant bed in the Zuari Estuary (Jacinto Island) also indicated the presence of the boring sponge *C. vastifica*, boring into the shells in a linear and reticulate pattern as seen in the shells from the ancient bed. This indicates that the boring sponge *C. vastifica* was quite active in the estuaries of Goa in the past also. The infection rate in the Jacinto bed is found to be very high (63%) as compared to a 10.5% incidence noticed in the ancient bed (Thomas and Thanapathi, 1980).

In 1980 a study on the boring animals infecting various gregarious molluscs such as the pearl oysters, rock oysters, chanks, mussels, etc. was initiated at Vizhinjam. Apart from shells obtained from the wild those of the tended stocks of pearl oysters from Tuicorin and Vizhinjam, mussel (brown) from Vizhinjam were utilised for the study. This study revealed that the gregarious molluscs of this coast are infected with six species of sponges, six species of boring molluscs, and four species of polychaetes. The infection rate noted among tended stocks, as compared to that in the wild, was much higher. Of the 6 species of boring sponges, two species, *viz. Cliona margaritifera* Dendy and *C. lobata* Hancock require special mention in the context as the former, after its first appearance in Sri Lankan pearl banks in an epidemic level in 1902, disappeared totally from the beds. The reappearance of this highly dangerous species on raft cultured pearl oysters at Vizhinjam around 1980, hence, is very interesting as it forms a major invasion on pearl oysters of Indian seas after a lapse of about 80 years. Since 1980, the incidence of *C. margaritifera* in various natural molluscan beds along the southwest coast of India has generally been on the increase and by 1982 a sizeable fraction of the boring sponge population was constituted by this species. The other species, *C. lobata*, which is a wide spread oyster pest in the Atlantic, was first recorded from the Gulf of Mannar in 1937 by Burton. But all subsequent surveys failed to record the same from the Indian seas. As in the case of C. margaritifera, the impact of this species was also felt among all gregarious molluscs of the southwest coast of India (Thomas *et al.*, 1983).

The incidence of boring sponges (infection/100 shells) was very high (up to 75%) on raft-cultured pearl oysters both at Tuticorin and at Vizhinjam against a meagre rate of 3-7% noted in natural beds. When the above two new invaders spread to natural beds after 1980, there was an abrupt increase in the rate of incidence in various natural beds initially, but the percentage came down gradually to an equilibrium level within a few years due to the slakening in the activity of less competent conventional boring species of the various beds. The higher incidence of boring species noted on culture rafts for a prolonged period, on the contrary, is an indication that the ecological equilibrium which is at play in nature is no longer in operation in the man made system- the culture raft. Therefore any management system which gives more importance to ecological aspects would only help in cutting down the higher incidence of boring sponges seen on artificial systems to a lower level as noticed in the natural beds (Thomas *et.al.*, 1983).

Further studies up to 1986 to know how the two above mentioned new invaders compete among themselves and with various conventional boring species characteristic to various natural molluscan beds of the area. The conventional species severely competed with the two new invaders in all natural beds and culture systems. In this competition the new invaders proved to be more adaptable, but when conventional species and the two new invaders were considered individually it could be seen that *C. celata* from the conventional and *C. margarítifera* from new invaders were more adaptable in some beds, while in some other beds the adaptability shifted from *C. celata* to *C. vastifica* which is another co-existing boring species in the Indian molluscan beds. The probable reason to this might be the historical dominance of the respective boring species to the molluscan bed in question (Thomas *et. al.*, 1993).

When boring sponge spreads inside the shell of a live pearl oyster a lot of energy is being wasted by the oyster in secreting additional quantity of nacreous material for mending the holes made in the inner aspect of the shell to prevent the sponge from coming into contact with the soft tissue of the oyster. Since the nacreous matter secreted by the mollusc is diverted for "repair work" which is of top priority to the animal and not for pearl production, it is necessary to assess whether such a stress will adversely affect the pearl producing capacity of the oyster.

The main target of the boring sponge is the calcareous matter and the same is removed in the form of minute chips, also called 'microchips', of uniform size and shape. 'Microchips', thus expelled, from hard calcareous matter, while increasing the sediment load of the adjoining areas, will weaken the substratum continuously.

When boring sponge attacks a live mollusc it may lead to malfunctioning of the shell in many ways; when hinge-teeth are damaged totally, it will affect the opening and closing of the valves at will. Twelve diseases have been documented in the past from different species of molluscs (Thomas, 1983).

In 1987 the C.M.F.R.I., made an indicative survey of the Lakshadweep Archipelago, and during the survey it was possible to make some direct observations on sponge-generated bioerosion in 5 atolls of this archipelago. The total number of boring sponge species recorded during the survey was 18, under 4 orders, 5 families and 9 genera. *C. celata* dominated in two atolls (Kavaratti and Suheli), *C. ensifera* in Kalpeni, and *C. mucronata* in Androth.

Both *C. celata* and *C. vastifica* were equally dominant in Minicoy Atoll.

Mortality caused to corals due to sponge infection was recorded on a transect - morphozone basis, and data on different groups of borers infecting both branching and massive corals were collected separately. For branching corals the infection on branches and on stalk proper were treated separately. It could be seen that *C. ensifera* formed the dominant species followed by *C. celata* and *C. mucronata* on branches; *C. ensifera* followed by *C. celata* and *C. vastifica* on stalk proper of branching corals. The infection on massive coral, however, was effected only by *C. celata*. From pooled data for both branching and massive corals it could be seen that sponge forms the major group among various groups of borers followed by others such as polychaetes, molluscs, sipunculids, crustaceans and algae (Thomas, 1988).

Sponges, as agents of bioerosion at microlevel, were surveyed during 1987. In the atolls of Lakshadweep sponges were found to play an important role in the destruction/ death of corals (James *et. al.*, 1989).

Pearl oysters (mainly *Pinctada margaritifera* and *P. fucata*) collected from the wild as well as from culture farms of the Persian Gulf were studied at the request of the Persian Gulf Shellfish Research Centre, Iran. Pearl oysters of the areas are infected with three species of boring sponges *viz. Cliona vastifica, C. carpenteri* and *C. margaritifera* (unpublished).

Marine fouling is economically a serious problem to all man-made structures since any structure installed in the sea is just another surface for the settlement and luxurient growth of marine organisms. For obtaining a first hand information on sponges which migrate to culture rafts, those moored at Vizhinjam, Tuticorin and Mandapam, for the cultivation of molluscs and sea weeds, were studied in detail for two years (1981-'82).

A total of 32 species (6 orders, 16 families and 23 genera) were found settling down on these culture rafts every year, and based on the period of their settlement they were classified into pre-monsoon, monsoon, post-monsoon and protracted settlers. Aspects like the distribution of fouling sponges, factors influencing fouling, faunal specificity, stress parameters, reproductive preference, etc. were also dealt with by Thomas (1990).

Sponges as a source of bioactive compounds

The discovery of arabinose nucleosides from the sponge *Tethya crypta* (de Laubenfels) with biomedical potentials has triggered off a world wide interest in the biochemistry of the group in general. Studies in this line were initiated in India as early as 1970s and Prof. Ch. Bheemasankara Rao of Andhra University was the first to approach the present author for the identification of sponges. This was followed by many other universities and research institutions and finally the efforts in this line got considerable momentum with the initiation of an ambitious programme by the Department of Ocean Development, New Delhi, entitled 'Drugs from the sea' with C.D.R.I., Lucknow, as the nodal institution.

During 1984 a project was initiated in C.M.F.R.I. Cochin, with a view to studying the toxicity and haemolytic activities of marine organisms. Under this project 118 marine animals and plants belonging to different taxa were screened to check the effects of their extracts on fish fingerlings and mice.

The study showed that all the echinoderms and 2 flagellates had strong toxic and haemolytic activities, but only haemolytic activity for 15 species of sponges, 8 corals and 7 other animals. No toxic or haemolytic activity could be seen in 15 species of sponges, 5 species of corals and 21 species of molluscs (Rao *et al.*, 1989).

Finding that the various 'Research Groups' on bioactivity in India, being composed only of chemists, were not well versed with collection of marine organisms and as this led to a lot of complication with regard to the final results, a paper highlighting the methods of specimen collection/preservation was presented at the 'Training Workshop' held at C.D.R.I., Lucknow in 1992 (Thomas, 1992). The need to train a few scientists in the field of taxonomy for a better assessment of Indian biodiversity and the utilisation of this knowledge for an effective planning of our future ventures in the field of 'wonder drug' were also discussed in the above paper.

The origin and biological pathways of many of the bioactive compounds elaborated by sponges are not well documented. Many of the chemicals isolated till date have definite ecological bearing and hence such studies, in future, may be oriented in such a way to link with ecology on one hand and with drug industry on the other. A multi-disciplinary approach in this line is the only answer (Thomas, 1994, 1996).

Conclusion

Biochemistry of marine invertebrates is now a field of topical importance to scientists all over the world. Many novel chemical compounds isolated from marine organisms are of considerable pharmaceutical potentials. This shows that both chemists and pharmacologists should work hand in hand for a better utilization of these rare resources in our seas.

The studies made by the present author during the period 1964 to 1996 have made a strong taxonomic foundation to this group in India. But still it may be admitted that the sponge fauna of the Indian seas, as per latest estimates, is known only to a 60% level, and it is our duty to document the remaining 40%. Situation in other lower invertebrate groups is also quite unimpressive, and the man-power to take up this herculian task is also lacking very much at present.

The solid foundation of taxonomy now available in India is somewhat properly utilised only by those interested in the biochemistry / bioactivity. Institutions with mandate on cellular/immunological/geological/ecological/ biological studies should rise to the occasion and try to build up a sound data base in their respective areas utilising the foundation work now available on the taxonomy of sponges in India.

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References

James, P.S.B.R., C.S. Gopinadha Pillai, P.A.Thomas, D.B.James, and Said Koya, 1989. Environmental damage and consequences. *Bull. Cent.Mar.Fish.Res. Inst.*, 43: 212- 227

Rao D. Sadananda, D.B.James., P.A.Thomas., K.K.Appukuttan, C.P.Gopinadhan, K.G.Girijavallabhan., S.Muthuswamy and M.Najumuddin, 1989. Biotoxicity in marine organisms. In: *Bioactive compounds from marine organisms with emphasis on the Indian Ocean.* Indo-United States Symposium (Eds) M.F.Thomson, R.Sarojini and R.Nagabhushanam, Oxford & IBH Publishing Co. New Delhi, 367-371

Thomas, P.A. 1968. *Studies on sponges*, Ph.D. Thesis, Submitted to the Kerala University. Degree awarded in 1969 (unpublished)

.... 1969a. Catalogue of sponges in the Reference Collection of the Central Marine Fisheries Research Institute, Mandapam Camp. *Bull. Cent. Mar. Fish. Res. Inst.*, 7: 13-21

.... 1970. Some deep-sea sponges from the Gulf of Mannar with descriptions of three new species. *J.mar.biol.Ass.India*, *12*(1&2): 202-209

.... 1972. Boring sponges of the reefs of Gulf of Mannar and Palk Bay. *Proc. Symp. Coral and Coral reefs. Mar.Biol. Ass. India*, 333-362.

.... 1973. Two new record of Demospongiae from the Indian Ocean. *J. mar. biol. Ass. India*, *15*(1): 443-445

.... 1973a. Marine Demospongiae of Mahe Island in the Seychelles Bank (Indian Ocean). *Mus. Roy. L'Afr. Cent.*, 203: 1-98

.... 1973b. Sponge Resources of India. *Proc. Symp. Living Resources of India*, C.M.F.R.I., 693-699

.... 1974. A new genus and species (*Qasimella indica*) of Demospongiae from Indian sea. *J. Mar. biol. Ass. India*, *16*(1): 311-313

.... 1975. Boring sponges of the Zuari and Mandovi Estuaries. *Bull. Mar. Sci. Univ. Cochin*, 7(1): 117-126

.... 1976. The history of spongology of the Indian Ocean. *Proc. Symp. Indian Ocean and Adjacent seas. J. mar. biol. Ass. India*, *18*(3): 610-625

.... 1976a. Marine Demospongiae of Zanzibar Island. *Ibid.*, *18*(3): 448-460

.... 1976b. Marine Demospongiae of Ras Iwatine (Kenya). *Ibid.*, *18*(3): 642-649

.... 1976c. *Endectyon lamellosa* n.sp., (Demospongiae: Poecilosclerida) from the

Indian seas and a revised key to the Indian species of *Endectyon* Topsent. *Ibid.*, *18*(1): 169-172.

.... 1979. Boring sponges destructive to economically important molluscan beds and coral reefs in Indian seas. *Indian J. Fish.*, *26* (1&2): 163-200

.... 1979a. Sponges of Inhaca Island (Indian Ocean). *Mus. Roy. L'Afr. Cent.*, *227*: 1-45

.... 1979b. Sponges of Mambone and Paradise Islands. *Ibid.*, 49- 73

.... 1979c. Demospongiae of Minicoy Island (Indian Ocean) Part I- Orders Keratosida and Haplosclerida. *J. mar. biol. Ass. India*, *21* (1&2): 10-16

.... 1980. Demospongiae of Minicoy Island (Indian Ocean) Part II- Order Poecilosclerida. *Ibid.*, *22* (1&2): 1-7

.... 1980a. Demospongiae of Minicoy Island (Indian Ocean) Part III- *Ibid.*, 22 (1&2): 8-20

.... 1981. A second collection of Marine Demospongiae from Mahe Island in the Seychelles Bank (Indian Ocean). *Mus. Roy. L'Afr. Cent.*, *233*: 1-54

.... 1983. Distribution and affinities of the sponge fauna of the Indian region. *J. mar. biol. Ass. India*, 25 (1&2): 7-16

.... 1983a. Some pathological aspects akin to sponge boring in molluscan shells. *Proc. Symp. Coastal Aquaculture*. 2: 671-676 .

.... 1984. Sponges collected aboard R. V. *'Skipjack'* from the southeast coast of India. *J. mar. biol. Ass. India*, 26 (1&2) : 95-102

.... 1986. Demospongiae of the Gulf of Mannar and Palk Bay. *Recent Advances in Marine Biology*. In: P.S.B.R. James(Ed) Today and Tomorrow's Printers and Publishers, New Delhi, 205-363

.... 1987. Sponges of Papua and New Guinea- Part I. Order Keratosida Grant. *J. mar. biol. Ass. India*, 24 (1&2): 15-22

.... 1988. Sponge generated bioerosion in Lakshadweep. *Mar. Fish. Infor. Serv.*, *T & E* Ser., No. 86: 20-26

.... 1989. Sponge fauna of Lakshadweep. *Bull. Cent. Mar. Fish. Res. Inst.*, 43: 150- 161

……….., 1990. Systematics and ecology of the fouling and boring sponges in the Indian coastal waters (in *Marine Fouling and Power Plants*. Proceedings of the Specialist's Meeting on Marine Biodeterioration with reference to Power Plants Cooling system, BARC, Kalpakkam, April 26- 28, 196-217

…………. 1991. Marine Porifera (in) Animal Resources of India, Protozoa to Mammalia. State of the Art Report, *Zool. Surv. India, Calcutta*, 19- 29.

…………. 1991 a.Sponges of Papua and New Guinea- Part II. Order Haplosclerida Topsent. *J. mar. Biol. Ass. India, 33* (1&2): 308-316

…………. 1992. Marine Products Chemistry and Sponges. Training Workshop on the use of Chemical Techniques for the study of marine products, C.D.R.I., Lucknow, 26- 36

………….., 1994. Studies on the systematics of sponges with particular reference to their role as pests of molluscs, agents of bioerosion and a source of bioactive compounds. D.Sc Thesis. Submitted to the University of Kerala. Degree awarded in 1995. (unpublished).

…………..,1996. An appraisal of the biological and biochemical diversity in sponges. *Mar. Fish. Infor. Serv., T & E Ser.*, 1-5

………….., K.K., Appukuttan, K. Ramadoss and S.G.Vincent, 1983. Calcibiocavitological Investigations. *Mar. Fish. Infor. Serv., T&E Ser.*, 49: 1-13

………….., and K.J. Mathew, 1986. Sponges collected during the Third Indian Antarctic Research Expedition with description of *Isodictya echinata* Sp. novo., *Third Indian Expedition to Antarctica* Scientific Reports, 1986. DOD Technical Publication. 3: 109-115

………….., K. Ramadoss and S.G. Vincent, 1993. Invasion of *Cliona margaritifera* Dendy and *C. lobata* Hancock on the molluscan beds of the Indian coast. *J. mar. biol. Ass. India*, 35 (1&2): 145- 156

………….., and V. Thanapathi, 1980. An ancient window pane oyster bed in Goa with comparative notes on the oysters in an extant bed. *Indian J. Fish.*, 27 (1&2) : 54- 60