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Status and importance of research on marine sponges in India with special reference to sponges on coral reefs

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Marine sponges are integral parts of the marine environment and play key ecological roles, especially in coral reef ecosystems. Though research on marine sponges started in the 1800s, most of the works to date have focussed their attention on taxonomy and marine natural products from sponges in India. The lack of ecological studies on sponges is attributed to the requirement of scuba diving skills and hectic field work. Major Indian coral reef regions are undergoing severe decline due to climate change and other factors. The interaction between corals and sponges has become essential in the context of global climate change. More studies are warranted for the better management of coral reefs in India. This paper reviews the studies carried out on sponges thus far and explores the critical areas where more research is desired.

[**Keywords**: Climate change, Coral reefs, Ecology, India, Sponges**]**

Introduction

Sponges are sessile organisms that are placed under the phylum Porifera. They are one of the most primitive multicellular organisms. Predominantly marine, sponges are found from the intertidal to the abyssal zone (6000 m)[1]. A small group of sponges is also known from freshwater habitats throughout the world. Occupying the temperate, tropical and polar habitats, marine sponges enjoy an almost universal distribution. They are important members of the benthic fauna. They serve as an essential food resource for many other organisms, besides acting as hosts to a wide array of organisms. The pioneer studies on the nature of sponges in 1765 by Ellis[2] demonstrated the movement of water currents through the oscula distributed on the surface of the body. Based on this finding, researchers like Linnaeus, Lamarck and Cuvier grouped sponges with Coelenterates. In 1816, Blainville placed them in a special group called Spongiaria. Further extensive studies on their morphology and physiology in 1836 by Grant gave them the name Porifera[3]. Many years later, researchers like Huxley in 1875 and Sollas in 1884 argued for the separation of sponges from other multicellular forms[3].

Sponges are grouped into four classes *viz*. Calcarea, Hexactinellida, Demospongiae and Homoscleromorpha. According to the World Register of Marine Species[4], there are an estimated 9,063 species of sponges worldwide. Demospongiae is the most abundant class followed by Calcarea and Hexactinellida. Class Homoscleromorpha has the least number of species. The number of marine sponge species in India is estimated to be 584, comprising 288 genera placed under 81 families of 21 orders[5]. Calcareous sponges are protected in India under Schedule III of the Wildlife Protection Act 1972. Of late, sponges have been the focus of research interest worldwide. One of the reasons for the new enthusiasm is that sponges are rich sources of active secondary metabolites, which offer great scope for drug research. According to some reports, a few sponge species can tolerate temperature fluctuations while other organisms are severely affected by the climate change effects[6,7]. It indicates that sponges can flourish in the predicted future climatic scenarios. Thus, studies on sponges are of critical importance under changing climatic conditions.

The coral reef is probably the most dynamic marine ecosystem that offers a wide range of ecological and economic benefits, and sponges constitute an inalienable part of any coral reef ecosystem. Sponges perform several ecologically significant roles in reefs: they contribute by promoting the aggregation of loose debris and stabilising it until carbonate-secreting organisms can bind to it permanently, facilitate coral

regeneration and coral recruitment, host many reef organisms while providing food sources, perform nutrient cycling and primary production, and harbour the microbial symbionts. Major coral reef areas in India include the Gulf of Mannar and Palk Bay in Tamil Nadu, the Gulf of Kutch in Gujarat, the Lakshadweep archipelago, and the Andaman and Nicobar Islands. Several reef formations have also been reported along the west coast of India along Kerala, Karnataka, Goa and Maharashtra. Despite the extensive research on sponges in the reef areas in India, the knowledge about sponges, their biology, and ecology are far from complete. The decline of coral reefs has been severe during the past few decades, especially due to climate change effects. Coral reefs in India provide a direct and indirect livelihood to thousands of people and hence, the decline of coral reefs due to changing climatic conditions is bound to cause much harm. As sponges have been portrayed as potential winners in these changing climatic conditions, studies on the ecology of sponges assume more significance, especially in India. The current study examines not only the in-depth research on sponges in reefs that have been done in India but also the knowledge gaps that must be addressed to understand crucial facts about sponges.

History of sponge research in India

Sponge research has a long history dating back to 1765(ref. 3), but it didn't take off until the late 1800s in India. The investigation on sponges in the Indian subcontinent has been reported in a plethora of publications by earlier researchers like Carter[8], Dendy[9], Burton[10], Thomas[11] and Pattanayak[12,13]. Dendy[14] initiated the study of sponges along India's east coast in 1887 and Ali[15] further extended it by describing the Madras sponges, while Annandale[16] investigated the sponges in the Orissa region in 1915. The Marine Survey of India undertook hydrographic surveys in the Andaman and Nicobar Islands from 1889 to 1907, in 1926 and 1956(ref. 17).

Studies on sponge diversity

In-depth research on the diversity of sponges has consistently been pursued in India. Schulze[18] began taxonomic work on sponges in India in 1895, and Carter[19] discovered new species of sponges in the Gulf of Mannar in 1880. More species from this area were reported by Dendy[20], Kumar[21] and Rao[22]. Dendy[14] and Ali[23] examined some early work along the east coast, including Madras in Tamil Nadu and Chilika Lake in Odisha. Ali[15,24] described the ecology of the sponge fauna of Madras[25].

Thomas[26] explored the boring sponges in the Zuari and Mandovi estuaries off the west coast and also talked about a range of other locations, including Mumbai, Mangalore, Minicoy Island, Cochin, Quilon, Kovalam and Kanyakumari[11]. The Gulf of Kutch's sponge fauna was recorded by Hornell[27]. Dendy[9,28] conducted and published the majority of the reports and descriptions of the sponge species of the Gulf of Kutch. Annandale[29] observed parasitic sponges belonging to the Clionidae family in the Andaman and Nicobar Islands' shallow waters. Dendy & Burton[30,31] provided reports on deep-sea sponges from the R.I.M.S. "Investigator" collections. Burton & Rao[32] then researched shallow-water sponges from the Indian Museum's collections.

One of the regions with the greatest distribution of sponges is the Gulf of Mannar[10,33], where Thomas[34-36] collected and identified various sponge species. Thomas[37] also gave a detailed description of the main boring sponges and the way they erode corals in the Gulf of Mannar. Sivaleela[38] collected and categorised 30 species of marine sponges belonging to 11 families and 19 genera. The reef areas of the Gulf of Mannar and Palk Bay have numerous sponge species, according to publications[39-43]. Thomas[44] also conducted a thorough investigation of the diversity of sponges in the Lakshadweep islands, recording 91 species over 10 islands. Between 1964 and 1970, he worked on the sponges he had continued to acquire from Minicoy and published his findings[45,46]. There are 22 species of sponges associated with the seagrass meadows, according to a study on the seagrass ecology in the Minicoy lagoon[47]. Mohan's investigations[48] on the diversity of sponges from the Agatti Islands identified 21 species. Lengthy gaps in taxonomical and ecological research on sponges in the Gulf of Kutch were filled by the initial reconnaissance survey conducted by CMFRI in 1978. A total of 25 species from 22 genera and 15 families were reported based on the CMFRI's collections[49]. Numerous species of sponge from this area have been reported by Subba Rao & Sastry[50].

Pattanayak[12] described 75 species of marine sponges found in the Andaman and Nicobar Islands using preserved museum specimens from the R.I.M.S. "Investigator" collections kept at the Zoological Survey of India, Kolkata. After Thomas[51] and Sara[52], there is a

hiatus in the literature about new records on sponges that lasts until Pattanayak[13]. The novel sponge species discovered by several researchers in recent years have generated a great deal of interest in sponge taxonomy. A lot of them[53-56] inspected the sponge taxonomy in the Andaman and Nicobar Islands. Dam Roy *et al.*[57] conducted a rigorous investigation of collecting and cataloguing sponges using DNA barcoding. The majority of current research on sponges in the Andaman and Nicobar Islands is confined to the island's more accessible regions. There is a lack of information on sponges in those isolated islands owing to the difficulty of doing relevant studies there.

The diversity and distribution of sponges have also been investigated in additional locations besides these significant reef areas. For instance, from the coast of Karnataka, Pattanayak & Mitra[58] identified 12 species of marine sponges. Kavungal *et al.*[59] investigated the diversity and distribution of 24 species of shallow-water sponges in an undiscovered patchy reef on the Kerala coast. While Varsha *et al.*[60] and George *et al.*[61] documented new species of sponges from the southern coast of India, and Mote *et al.*[62] reported a new sponge species from the west coast of India.

Studies on marine natural products from sponges

During the last few decades, sponges have been recognised as the most promising sources of new natural products for drug discovery. It has led to many works being carried out on marine natural products from sponges. For example, Rao *et al.*[63] studied the novel bioactive compounds present in marine sponges collected from the Gulf of Mannar. Studies on the antibacterial, antimicrobial and antifungal properties of these compounds were carried out by Boobathy *et al.*[64] from the Tuticorin coast. Several recent studies were based on the microbial and secondary metabolites of bacteria associated with sponges[65-67] in the Gulf of Mannar and Palk Bay. The works done by Baig *et al.*[68], Lekshmi *et al.*[69] and Mote *et al.*[70] was carried out on the west and east coast of India. Feby & Nair[71] collected and studied two demosponges from the Lakshadweep and screened them for commercially important enzymes. Phylogenetic studies on marine sponges were carried out by Mohan *et al.*[72], who isolated endo-symbiotic microorganisms from 21 species of sponges from the Lakshadweep archipelago as well.

Ecological studies on sponges in India

Sponge ecology has not been given the degree of priority it deserves despite its critical importance in the context of global climate change. The initial works on sponge ecology in India were primarily based on field collections instead of underwater surveys. Early ecological work on sponges was carried out by Annandale[73], who discussed in detail the association of some sponges with molluscs. The association of various taxa with sponges was reported by various authors[74]. The association of sponges with other organisms in the marine ecosystem is universal in space and time. The association of the brittle star *Ophiactis modesta* (Brock, 1888) with the sponge *Biemna fortis* (Topsent, 1897) was reported from Goa by Dahihande and Thakur[75]. Infestation of brown mussels by a bio-eroding sponge from the Kerala coast was reported by Kumar & Thomas[76]. Marine sponges, sensitive to any change in environmental conditions, are suggested as biological indicators by Kiruba-Sankar *et al.*[77] from the Andaman and Nicobar Islands.

Studies on the coral-sponge association

Though there are enormous works on the various aspects of sponges, *in-situ* studies on coral-sponge interaction are very few. There is a greater need for such studies in India for the health and well-being of corals as the latter provide a livelihood to thousands of Indian fishermen. The lack of studies in this area is due to the necessity for scuba diving skills and extensive fieldwork. Studies on coral-sponge interaction demand researchers to be long time under the water and require knowledge on the ecology of sponges and corals. Difficulties in securing entry permission to the Marine Protected Areas and permission to collect samples have also contributed to comparatively less works in this area. Reports of sponges taking over corals have become common worldwide in the past few decades, but there are very few reports on the Indian reefs. Corals in Indian reefs face the threat of competition for space with some sponge species (Fig. 1). Ten species of coral-boring sponges of the Great Nicobar Island were reported by Namboothri & Fernando[78]. The invasive coral-killing sponge species *Terpios hoshinota* (Rützler & Muzik, 1993) was reported in Palk Bay by Thinesh *et al.*[79] and subsequently in the Gulf of Mannar by Raj *et al.*[80]. The sponge has been reported to cause significant coral mortalities in many reef regions around the world. An *in-situ* experiment using artificial shading on *T. hoshinota* and *Favia abdita* (Ellis and Solander, 1786) colonies was carried out by Thinesh *et al.*[81] who found that the shading effectively controlled sponge growth on live corals without affecting coral homeostasis. Thinesh *et al.*[39] reported the impacts of *T. hoshinota* on

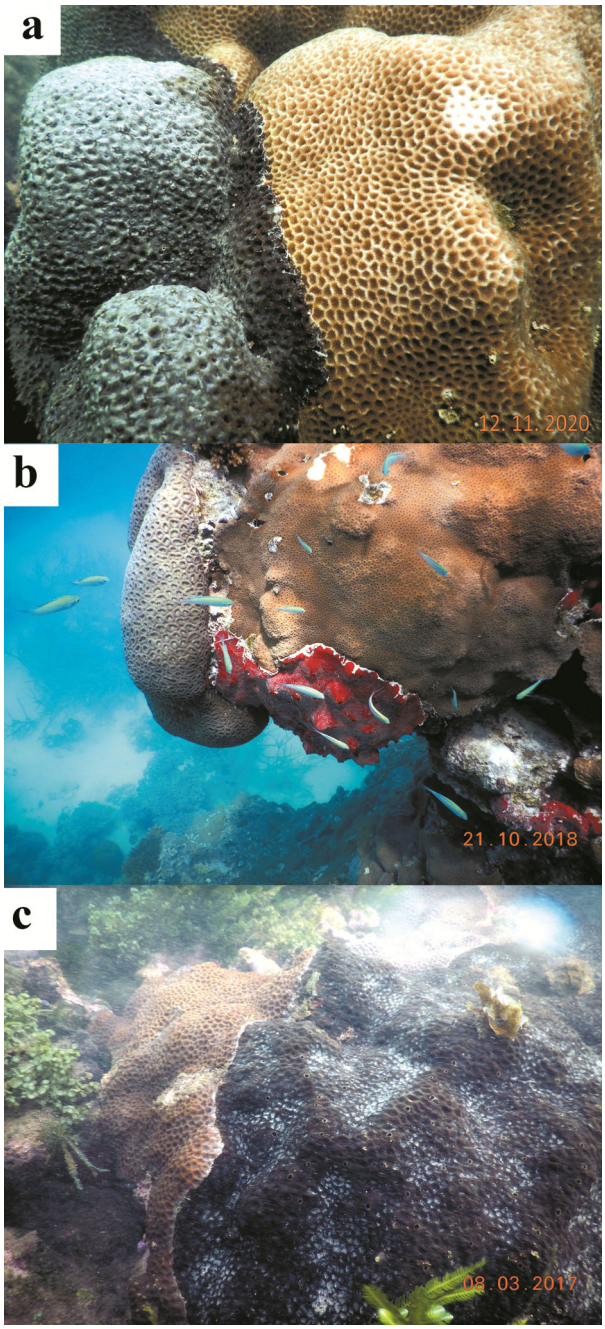

Fig. 1 — Sponges overgrowing corals in different reef areas in India: a) *Terpios hoshinota* invading a coral colony in Poovarasanpatti Island of Gulf of Mannar; b) An unknown sponge species invading a coral colony in Bangaram Island of Lakshadweep; and c) *Cliona* sp. invading a coral colony in Rock Garden area in Malvan coast, Maharashtra

the corals of Palk Bay. Das *et al.*[82] studied the extended geographical distribution of *T. hoshinota* by observing the sponge affecting corals of the Lakshadweep archipelago. Thinesh *et al.*[83] described sponge and coral-hosted bacteria from Palk Bay.

A bio-eroding sponge from *Cliona viridis* (Schmidt, 1862) species complex was reported by Ashok *et al.*[41] at Vilanguchalli Island in the Gulf of Mannar overgrowing colonies of *Turbinaria mesenterina* (Lamarck, 1816), by using them as a substrate. Ashok *et al.*[84] reported another sponge called *Clathria* (Thalysias) *reinwardtii* growing over massive and branching coral communities in the Gulf of Mannar. Then Ashok *et al.*[85] found that the coral species *Acropora muricata* (Linnaeus, 1758) withstands *T. hoshinota* by forming a pronounced disc at the branch tip upon contact with the sponge. Ashok *et al.*[42] then reported another sponge *Clathria* (Microciona) *aceratoobtusa* (Carter, 1887), affecting *Turbinaria* corals in Vilanguchalli Island of the Gulf of Mannar. Ashok[43] recently reported 103 sponge species exclusively from the reef areas of the Gulf of Mannar providing detailed descriptions, growth forms and substrate preference. A yearlong in-situ observation by Raj *et al.*[86] in the Gulf of Mannar found that photosymbiotic clionaid sponges can also be affected by temperature anomalies who reported sponge bleaching for the first time from an Indian reef. Raj *et al.*[40] undertook night diving in the Gulf of Mannar and found that the coral-competing sponge *Rhabdastrella globostellata* (Carter, 1883) is fed upon by the tiger cowrie *Cypraea tigris* (Linnaeus, 1758). Similarly, opportunistic spongivory by reef fishes in the Gulf of Mannar was reported by Emmett *et al.*[87]. On the west coast of India, Mote *et al.*[62] reported a new bio-eroding sponge species, *Cliona thomasi* (Mote, Schönberg, Samaai, Gupta & Ingole, 2019), which was in abundance and reported to be a key bio-eroder on live corals in that region. Mote *et al.*[88] also published research on the symbiodiniaceae community structure which was identified in the water surrounding the coral, *T. mesenterina* and the coral-eroding sponge, *C. thomasi*. More reports of sponges being potential winners over corals are expected in future from all the reef areas of India, given the worsening global climate change.

Threats to sponges

Sponges have been generally reported to be resilient to climate change implications as they can tolerate temperature anomalies and dirty waters[89,90]. They have also been projected to fare better than corals in future climatic scenarios, but recent studies indicate that sponges are also affected by temperature anomalies[86,91,92]. Sedimentation, nutrient enrichment and acidification can be detrimental to sponge

survival[93,94]. Threats to sponges have not been seriously looked into in the Indian waters and hence, no study has been carried out on this topic. Collection of sponges for the extraction of secondary metabolites[96] and screening of marine natural products[97] also deplete them. They are often used for ornamental purposes. Despite the legal protection, sponges are caught as by-catches in bottom-set fishing nets along the Indian coastline[98]. Discarded sponges are a common sight near the fish landing centres, especially in the Gulf of Mannar. Though sponge proliferation has been reported to be a threat in the reef areas, the loss of sponges would disrupt the key ecological roles sponges play.

Gap areas in research on sponges in India

There are many gaps in the information on sponges in the Indian waters. The marine waters of India are rich in biodiversity, however, there remain many unexplored and understudied areas which could turn out to be potential hotspots for sponges. It is vital to conduct more underwater surveys and investigations to understand the distribution and abundance of various species in Indian waters. A remarkable number of studies have been undertaken on shallow water sponges in all major coral reef regions in India but not many studies have been carried out on deep-sea sponges, which hold immense scope for recording new species from India on that frontier.

The number of works on sponge ecology, dealing with sponge behaviour and their interaction with corals, is far less than that on sponge taxonomy. Studies on the sponges in the areas of reproduction, control and competition will expand our understanding of sponges. Many long-term monitoring studies on sponges such as those on sponge interaction with reefs, sponge outbreaks, bio-fouling and effects of climate change on sponges are potential areas in sponge research. Interactions between corals and sponges need to be understood more in detail for proper management of reef areas. Studies on zooxanthellae associated with photosymbiotic sponges and their response to temperature anomalies are the need of the hour. All the climate projections predict extreme temperature anomalies in future and the prospects for the survival of coral reefs by the end of this century are bleak. Thus, a broader and deeper understanding of climate change and sponges would be of greater importance. Learning scuba diving skills and willingness to spend hours under the water is critical to doing sponge research. The study challenges the young marine biologists of our country to take up research on sponge ecology to fill the knowledge gaps.

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Conflict of Interest

The authors declare that we do not have any competing or conflict of interest.

Author Contributions

JSE: Formal analysis, investigation, resources, roles/writing - original draft; and KDR: Conceptualization, funding acquisition, and writing - review & editing.

References

1 Van Soest R W M, Boury-Esnault N, Vacelet J, Dohrmann M, Erpenbeck D, *et al*., Global Diversity of Sponges (Porifera) *PLoS ONE*, 7 (4) (2012) p. e35105. https://doi.org/10.1371/journal.pone.0035105

2 Ellis J, On the nature and formation of sponges, *Phil Trans*, 39 (1765) 145-147.

3 Thomas P A, The History of Spongology of the Indian Ocean, *J Mar Biol Assoc India*, 18 (3) (1976) 610-625.

4 WoRMS, Porifera. Accessed on 18 August 2020. http:// www.marinespecies.org/aphia.php?p=taxdetails&id=558

5 Sivaleela G & Venkataraman K, Indian marine sponges-their biodiversity and conservation, *Zool Surv India, National Symposium on Conservation and Valuation of Marine Biodiversity*, 2007, pp. 351–358.

6 Bell J, Davy S, Jones T, Taylor M & Webster N, Could some coral reefs become sponge reefs as our climate changes? *Glob Chang Biol*, 19 (2013) 2613–2624. https://doi.org/10.1111/gcb.12212

7 Chaves-Fonnegra A, Riegl B, Zea S, Lopez J, Smith T, *et al*., Bleaching events regulate shifts from corals to excavating sponges in algae dominated reefs, *Glob Chang Biol*, 24 (2018) 773–785. https://doi.org/10.1111/gcb.13962

8 Carter H J, Report on marine sponges, chiefly from King Island in the Mergui Archipelago, collected for the Trustees of the Indian Museum, Calcutta by Dr. John Anderson, *J Linn Soc Lond*, 21 (1887) 61–84. https://doi.org/10.1111/j.1096-3642.1887.tb00381.x

9 Dendy A, Report on the non-calcareous sponges collected by Mr. James Hornell at Okhamandal in Kattiawar in

1905–1906, *Report to the Government of Baroda Marine Zoology Okhamandal*, 2 (1916) 96–146.
10 Burton M, Addition to the fauna of Gulf of Mannar, *Ann Mag Nat Hist, London*, 5 (10) (1930) 665–676. https://doi.org/10.1080/00222933008673180
11 Thomas P A, *Studies on Sponges*, Ph.D. Thesis, University of Kerala, India, 1968.
12 Pattanayak J G, *Taxonomy of sponges of the Andaman and Nicobar Islands*, Ph.D. Thesis, University of Calcutta, India, 1998.
13 Pattanayak J G, Marine sponges of Andaman and Nicobar Islands, India, *Rec Zool Surv India*, *Occ Pap*, 255 (2006) 1–152.
14 Dendy A, The sponge fauna of Madras. A report on the collection of sponges obtained in the neighbourhood of Madras by Edgar Thruston Esq, *Ann Mag Nat Hist London*, 5 (20) (1887) 153–165. https://doi.org/10.1080/00222938709460032
15 Ali M A, Additions to the sponges fauna of Madras, *J Madras Univ, B*, 26 (2) (1956) 289–301.
16 Annandale N, Fauna of the Chilika Lake: Sponges, *Mem Indian Mu Calcutta*, 5 (1915) 23–54.
17 Reddiah K, The Coral Reefs of Andaman and Nicobar Islands, *Rec Zool Surv India*, 72 (1977) 315–324.
18 Schulze F E, Hexactinelliden des indischen Oceanes. I. Die Hyalonematiden. *Physikalische Abhandlungen der Königlischen Akademie der Wissenschaftenzu Berlin*, 2 (1895) 1–60.
19 Carter H J, Report on Specimens dredged up from the Gulf of Mannar and presented to the Liverpool Free Museum by Capt. W.H. Cawne Warren, *Ann Mag Nat Hist*, 6 (35–61) (1880) 129–156. https://doi.org/10.1080/00222938009458908
20 Dendy A, Report on a Second Collection of Sponges from the Gulf of Mannar, *Ann Mag Nat Hist,* 3 (6) *(*1889) 73–99. https://doi.org/10.1080/00222938909460303
21 Kumar A, Report on some Tetraxonid sponges in the collection of the Indian Museum, *Rec Indian Mus,* 27 (3) *(*1925) 211–229.
22 Rao H S, Indian and Ceylon sponges of the Naturhistoriska Riksmuseet, Stockholm, collected by K. Fristedt, *Rec Indian Mus*, 43 (1941) 417–496.
23 Ali M A, *Studies on sponges*, M.Sc. Thesis, University of Madras, India, 1954.
24 Ali M A, Development of the Monaxonid sponge *Lissodendoryx similis* Thiele, *Ibid*, 26 (3) (1956) 553–581.
25 Ali M A, Influence of environment on the distribution and form of sponges, *Nature*, 186 (4719) (1960) 177–178. https://doi.org/10.1038/186177b0
26 Thomas P A, Boring Sponges of Zuari and Mandovi Estuaries, *Bull Dept Mar Sci Ulliv Cachin*, 7 (1) (1975) 117–126.
27 Hornell J, Report to the government of Baroda on the marine zoology of Okhamandal Part I. Williams and Norgate, London, (1909) p. 148. https://doi.org/10.5962/bhl.title.54463
28 Dendy A, *Report on non-calcareous sponges collected by Mr. James Hornell*, (1916) 93–146.
29 Annandale N, Some sponges parasitic on Clionidae with further notes on that family, *Rec Indian Mus*, 11 (1915) 457–478.
30 Dendy A & Burton M, Report on some deep sea sponges from the Indian Museum collected by the R.I.M.S. "Investigator". Part-I. Hexactinellida & Tetraxonida (Pars.), *Rec Indian Mus*, XXVIII, 28 (1926) 225–248.
31 Burton M, Report on some deep sea sponges from the Indian Museum collected by the R.I.M.S. "Investigator" part II. Tetraxonida (Concluded) and Euceratosa, *Rec Indian Mus*, 30 (1928) 109–138.
32 Burton M & Rao H S, Report on the shallow-water marine sponges in the collection of the Indian Museum. Part I, *Rec Indian Mus*, 34 (1932) 299–358.
33 Burton M, Supplement to the littoral fauna of Krusadai Island, *Bull Madras Govt Mus*, Madras, 1 (2) (1937) 1–58.
34 Thomas P A, Studies on Indian sponges-II. Two new species of silicious sponges belonging to the genera *Aka* De Lambenfels and *Damirina* Burton, *J Mar Biol Assoc India*, 10 (2) (1968) 250–254.
35 Thomas P A, Studies on Indian Sponges-III. Two species of silicious sponges of the family Ophlitaspongiidae de Laubenfels (Class: Demospongiae Sollas, Order: Poecilosclerida Topsent), *J Mar Biol Assoc India*, 10 (2) (1968) 255–259.
36 Thomas P A, On some deep sea sponges from the Gulf of Mannar, with descriptions of three new species, *J Mar Biol Assoc India*, 12 (1 & 2) (1970) 202–209.
37 Thomas P A, Boring sponges of the reefs of Gulf of Mannar and Palk Bay. *Symposium on Corals and Coral Reefs*, (Marine Biological Association of India, Mandapam Camp. Abstracts), 1969, pp. 19.
38 Sivaleela G, Marine sponges of Gulf of Mannar and Palk Bay, *Rec Zool Surv India*, 114 (Part-4) (2014) 607–622.
39 Thinesh T, Mathews G, Raj K D & Edward J K P, Outbreaks of Acropora white syndrome and *Terpios* sponge overgrowth combined with coral mortality in Palk Bay, southeast coast of India, *Dis Aquat Organ*, 126 (1) (2017) 63–70. https://doi.org/10.3354/dao03155
40 Raj K D, Mathews G & Kumar P D, Tiger cowrie *Cypraea tigris* feeds on coral-competing sponge *Rhabdastrella globostellata* in an *Acropora* dominated reef of Gulf of Mannar, India, *Mar Freshw Behav Physiol*, 52 (2) (2019) 101–105. https://doi.org/10.1080/10236244.2019.1637701
41 Ashok A, Schonberg C, Raj K D, Bhoopathi M, Bharath M S, *et al*., A sponge of the *Cliona viridis* complex invades and excavates corals of Gulf of Mannar, southeast India, *Mar Fresh Res*, 69 (2018) 874–882. https://doi.org/10.1071/MF17247
42 Ashok A M, Calcinai B & Edward J K P, The coral-killing red sponge *Clathria* (*Microciona*) *aceratoobtusa* (Porifera: Demosponigiae) invades various coral communities of Gulf of Mannar Marine National Park, southeast India, *Eur Zool J*, 87 (1) (2020) 1–11. https://doi.org/10.1080/24750263.2019.1708486
43 Ashok A, *Distribution, Abundance and Role of Sponges in Coral Reef Ecosystem of Gulf of Mannar, Southeastern India*, Ph.D Thesis, Manonmaniam Sundaranar University, India, 2021.
44 Thomas P A, Demospongiae of Minicoy Island (Indian Ocean) Pt. 1- Orders Keratosidaagd Haplosclerida, *J Mar Biol Assoc India*, 21 (12) (1979) 10–16.
45 Thomas P A, Demospongiae of Minicoy Island (Indian Ocean) Pt. 2- Order Poecilosclerida, *J Mar Biol Assoc India*, 22 (12) (1980) 1–7.

46 Thomas P A, Demospongiae of Minicoy Island (Indian Ocean) Pt. 3-Orders Halichondrida, Hadromerida, Epipolasida and Choristida, *J Mar Biol Assoc India*, 22 (12) (1980) 8–20.

47 Prabhakaran M P, *Ecological Studies on the Seagrass Ecosystem of Minicoy Lagoon, Lakshadweep*, Ph.D Thesis, Cochin University of Science and Technology, India, 2008.

48 Mohan G, Sponge Fauna of Lakshadweep Archipelago, *Seshaiyana*, 20 (2) (2012) 3–5.

49 Thomas P A, Pillai C S G & Rajagopalan M S, Demospongiae of the Gulf of Kutch, *J Mar Biol Assoc India,* 8 (1-2) *(*1996) 124–132.

50 Subba Rao N V & Sastry D R K, Fauna of Marine National Park, Gulf of Kachchh (Gujrat): An overview, *Conservation Area Series*, (Published by the Director, Zoological Survey of India, Kolkata), 23 (2005) 1–79.

51 Thomas P A, Studies on Indian sponges VIII. Four new records of Silicious sponges *Echinochalina glabra* (Ridley and Dendy), *Higginsia mixta* (Hentschel), *Geodia lindgreni* (Lendenfeld) and *Pachamphilla dendyi* Hentschel from the Indian Ocean, *J Mar Biol Assoc India*, 19 (1) (1977) 115–122.

52 Sarà M, A rearrangement of the family Tethyidae (Porifera, Hadromerida) with establishment of new genera and description of two new species, *Zool J Linn Soc*, 110 (4) (1994) 355–371. https://doi.org/10.1111/j.1096-3642.1994.tb01479.x

53 Immanuel T, Krishnan P, Raghuraman R, Veerappan N & Dam-Roy S, New records of *Chondrilla australiensis* and *Chondrillagrandi stellata* (Demospongiae: Chondrosida: Chondrillidae) from Havelock Island, South Andaman, India, *J Threat Taxa*, 7 (14) (2015) 8167–8172. https://doi.org/10.11609/jott.2432.7.14.8167-8172

54 Ubare V V & Mohan P M, New records and range extensions of some marine sponges (Porifera: Demospongiae and Homoscleromorpha) from the Andaman Islands, India; part of the Indo-Burma biodiversity hotspot. *Zool Stud*, 57 (2018) p. 6. https://dx.doi.org/10.6620/ZS.2018.57-03

55 Pereira P & Raghunathan C, Diversity of sponges in marine protected areas of North Andaman, India, *Thalassas*, 34 (2018) 361–372. https://doi.org/10.1007/s41208-018-0073-2

56 Pereira P & Raghunathan C, New records of Indo-Pacific sponges from the Andaman and Nicobar Islands, India, *Zootaxa*, 4894 (4) (2020) 081–097. https://doi.org/10.11646/zootaxa.4894.1.4

57 Dam Roy S, Krishnan P, Raghunathan C & Vinith Kumar N V, *Cataloguing and Conservation of Marine Sponges of Andaman through DNA Barcoding*, Project Completion Report, (2013) pp. 84.

58 Pattanayak J G & Mitra S, Marine Sponges, In: *Fauna of Karnataka*, edited by Director, (Published by the Director, Zool. Surv. India, Kolkata), *State Fauna Series*, 21 (2013) 1–595.

59 Kavungal V, George R, Thomas, P A, Manisseri M & Shylaja G, Diversity and distribution of shallow water sponges (Porifera) in the coastal waters from Enayam to Kollam, south-west coast of India, *Indian J Fish*, 61 (2014) 52–57.

60 Varsha M S, Joshi K K & Jasmine S, *Six new species of Hyattella (Porifera: Dictyoceratida: Spongiidae) from the Southern Coast of India, J Mar Biol Assoc India*, 62 (1) (2020) 1–19. https://dx.doi.org/ 10.6024/jmbai.2020. 62.1.2206-01

61 George A, Van Soest R, Sluka R & Lazarus S, Checklist of marine sponges (Porifera) of peninsula India, *Zootaxa*, 4885 (2) (2020) 277–300. https://doi.org/10.11646/ zootaxa.4885.2.10

62 Mote S, Schönberg C H L, Toufiek S, Vishal G & Baban I, A new clionaid sponge infests live corals on the west coast of India (Porifera, Demospongiae, Clionaida), *System Biodivers*, 17 (2) (2019) 1–17. https://doi.org/ 10.1080/14772000.2018.1513430

63 Rao J V, Usman P K & Bharat Kumar J, Larvicidal and insecticidal properties of some marine sponges collected in Palk Bay and Gulf of Mannar waters, *Afr J Biotechnol*, 7 (2) (2008) 109–113.

64 Boobathy S, Soundarapandian P, Subasri V, Vembu N & Gunasundari V, Bioactivities of protein isolated from marine sponge, *Sigmadocia fibulatus*, *Curr Res J Bio Sci*, 1 (3) (2009) 160–162.

65 Chairman K, Ranjitsingh A & Ramesh M, Screening twelve species of sponges for biomedical activity in Gulf of Mannar Tuticorin Coast, *Int J Mar Sci*, 2 (2012) 43–50.

66 Skariyachan S, Challapilli S B, Packirisamy S, Sridhar V S & Kumargowda S T, Monitoring and assessment of the therapeutic impact of metabolites extracted from sponge-associated bacteria screened from Gulf of Mannar, southeast coast of India, *Environ Monit Assess*, 192 (2020) p. 241. https://doi.org/10.1007/s10661-020-8201-x

67 Meenatchi R, Brindangnanam P, Hassan S, Rathna K, Kiran G S, *et al*., Diversity of a bacterial community associated with *Cliona lobata* Hancock and *Gelliodes pumila* (Lendenfeld, 1887) sponges on the South-East coast of India, *Sci Rep*, 10 (1) (2020) p. 11558. https://doi.org/10.1038/s41598-020-67717-9

68 Baig U, Dahanukar N, Shintre N, Holkar K, Pund A, *et al.*, Phylogenetic diversity and activity screening of cultivable actinobacteria isolated from marine sponges and associated environments from the western coast of India, *Access Microbiol*, 3 (9) (2021) p. 000242. https://doi.org/ 10.1099/acmi.0.000242

69 Lekshmi N, Umar M D, Dhaneesha M, Joseph R, Ravinesh R, *et al*., Endophytic Fungi Isolated from the Marine Sponges as a Source of Potential Bioactive Compounds, *J Aquat Biol Fish*, 2 (2020) 58–66.

70 Mote S, Gupta V, De K, Nanajkar M, Damare S R, *et al*., Bacterial diversity associated with a newly described bioeroding sponge, *Cliona thomasi*, from the coral reefs on the West Coast of India, *Folia Microbiol*, 66 (2021) 203–211. https://doi.org/10.1007/s12223-020-00830-4

71 Feby A & Nair S, Sponge-associated bacteria of Lakshadweep coral reefs, India: resource for extracellular hydrolytic enzymes, *Adv Biosci Biotech*, 1 (2010) 330–337. https://doi.org/10.4236/abb.2010.14043

72 Mohan G, Ajith Kumar T T & Balagurunathan R, Antimicrobial activities of secondary metabolites and phylogenetic study of sponge endosymbiotic bacteria, *Bacillus* sp. at Agatti Island, Lakshadweep Archipelago, *Biotechnol Rep*, 11 (2016) 44–52. https://doi.org/ 10.1016/j.btre.2016.06.001

73 Annandale N, Some sponges commonly associated with oysters and mussels in Madras Harbour and the Chilka Lake,

In: *Fauna Symbiotica indica*, No. 5, *Rec Indian Mus*, 10 (1914) 149–158. https://doi.org/10.5962/bhl.part.5625

74 Nayar K N & Mahadevan S, Underwater ecological observations in the Gulf of Mannar, off Tuticorin. II. The occurrence of the *Synaptid Ohondrocloea* along with the massive sponge Petrosia, *J Mar Biol Assoc India*, 7 (1) (1965) 190–291.

75 Dahihande A S & Thakur N L, Differential growth forms of the sponge *Biemna fortis* govern the abundance of its associated brittle star *Ophiactis modesta*, *J Sea Res*, 126 (2017) 1–11. https://doi.org/10.1016/j.seares.2017.06.007

76 Kumar S & Thomas P A, Biodiversity Studies on Bioeroding Sponges Infesting Brown Mussel of the South West Coast of India, *J Mar Biol Aquacult*, 1 (2) (2015) 1–3. https://doi.org/10.15436/2381-0750.15.008

77 Kiruba-Sankar R, Chadha N K, Dam-Roy S, Paramita B S, Neelam S, *et al*., Marine sponges as biological indicator of oligotrophic Andaman waters, *Indian J Geo-Mar Sci*, 45 (2) (2016) 338–341.

78 Namboothri N & Fernando S A, Coral-Boring Fauna of the Great Nicobar Island, In: *Ecology of Faunal Communities on the Andaman and Nicobar Islands*, edited by Venkataraman K, Raghunathan C & Sivaperuman C, (Springer, Berlin, Heidelberg), 2012. https://doi.org/10.1007/978-3-642-28335-24

79 Thinesh T, Jose P A, Hassan S, Selvan K M & Selvin J, Intrusion of coral-killing sponge (*Terpios hoshinota*) on the reef of Palk Bay, *Curr Sci*, 109 (6) (2015) 1030–1032.

80 Raj K D, Bharath M S, Mathews G, Aeby G S & Edward J K P, Coral-killing sponge *Terpios hoshinota* invades the corals of Gulf of Mannar, Southeast India, *Curr Sci*, 114 (5) (2018) 1117–1119. https://doi.org/10.18520/cs/v114/i05/1117-1119

81 Thinesh T, Meenatchi R, Pasiyappazham R, Jose P A, Selvan M, *et al*., Short-term *in-situ* shading effectively mitigates linear progression of coral-killing sponge *Terpios hoshinota*, *PLoS ONE*, 12 (8) (2017) e0182365. https://doi.org/10.1371/journal.pone.0182365

82 Das R R, Sreeraj C R, Mohan G, Abhilash K R, Samuel V K D, *et al*., Incursion of the killer sponge *Terpios hoshinota* Rützler & Muzik, 1993 on the coral reefs of the Lakshadweep archipelago, Arabian Sea, *J Threat Taxa*, 12 (14) (2020) 17009–17013. https://doi.org/10.11609/jott.5790.12.14.17009-17013

83 Thinesh T, Meenatchi R, Lipton A N, Anandham R, Jose P A, *et al*., Metagenomic sequencing reveals altered bacterial abundance during coral-sponge interaction: Insights into the invasive process of coral-killing sponge *Terpios hoshinota*. *Microbiol Res*, 240 (2020) p. 126553. https://doi.org/10.1016/j.micres.2020.126553

84 Ashok A, *Clathria* (Thalysias) *reinwardtii* (Porifera, Demospongiae)-An active space competitor on the coral communities of Gulf of Mannar Marine Biosphere Reserve-Southeast India, *International Conference in Marine Science and Aquaculture*, 2019.

85 Ashok A M, Schönberg C H L, Laju R L & Edward J K P, Coral-killing sponge *Terpios hoshinota* in Southeast India-bested by *Acropora muricata*? *Mar Biodivers*, 49 (2019) 1069–1070. https://doi.org/10.1007/s12526-019-00966-8

86 Raj K D, Schönberg C & Emmett J S, Space competition under thermal stress; clionaid sponge versus favid coral, Gulf of Mannar, India, *Reef Encounter*, 37 (1) (2022) 48–51. https://doi.org/10.53642/PLDR6830

87 Emmett J S, Raj K D, Mathews G & Laju R L, Opportunistic spongivore fishes in a reef of Gulf of Mannar, India, *Environ Biol Fish*, 104 (6) (2021) 1251–1262. https://doi.org/10.1007/s10641-021-01150-3

88 Mote S, Gupta V, De K, Hussain A, More K, *et al*., Differential Symbiodiniaceae association with coral and coral-eroding sponge in a bleaching Impacted marginal coral reef environment, *Front Mar Sci*, 8 (2021) p. 666825. https://doi.org/10.3389/fmars.2021.666825

89 Carballo J L, Effect of natural sedimentation on the structure of tropical rocky sponge assemblages, *Ecosci*, 13 (2006) 119–130. https://doi.org/10.2980/1195-6860(2006)13[119:EONSOT]2.0.CO;2

90 Schönberg C H L & Juan-Carlos O, Is sponge bioerosion increasing? *Proc 11th Int Coral Reef Symp*, 16 (2008) 520–523.

91 Hill M, Walter C & Bartels E, A mass bleaching event involving clionaid sponges, *Coral Reefs*, 35 (2016) p. 153. https://doi.org/10.1007/s00338-016-1402-7

92 Marlow J, Davy S, Shaffer M, Haris A & Bell J, Bleaching and recovery of a phototrophic bioeroding sponge, *Coral Reefs*, 37 (2018) 1–6. https://doi.org/10.1007/s00338-018-1680-3

93 Gochfeld D, Easson C, Freeman C, Thacker R & Olson J, Disease and nutrient enrichment as potential stressors on the Caribbean sponge *Aplysina cauliformis* and its bacterial symbionts, *Mar Ecol Prog Ser*, 456 (2012) 101–111. https://doi.org/10.3354/meps09716

94 Goodwin C, Rodolfo-Metalpa R, Picton B & Hall-Spencer J, Effects of ocean acidification on sponge communities, *Mar Ecol*, 35 (2014) 41–49. https://doi.org/10.1111/maec.12093

95 Bell J, McGrath E, Biggerstaff A, Bates T, Bennett H, *et al*., Sediment impacts on marine sponges, *Mar Poll Bull*, 94 (1-2) (2015) 5–13. https://doi.org/10.1016/j.marpolbul.2015.03.030

96 Skariyachan S, Rao G A, Patil M R, Saikia B, Bharadwaj K V, *et al*., Antimicrobial potential of metabolites extracted from bacterial symbionts associated with marine sponges in coastal area of Gulf of Mannar Biosphere, India, *Lett Appl Microbiol*, 58 (3) (2014) 231–241.

97 Joseph B & Sujatha S, Pharmacologically important natural products from marine sponges, *J Nat Prod*, 4 (512) (2011) p. 12.

98 Ramkumar B & Ramakritinan C M, Devastation Effect of Traditional Bottom-Set-Gill Net Fishery on *Clathria frondifera* (Bowerbank, 1875) in Northern Gulf of Mannar, India, *Int J Sci Nat*, 8 (2) (2017) 269–73.