Rajiv Gandhi Chair Special Publication - 2008

GLIMPSES OF AQUATIC BIODIVERSITY

Editors

Prof. (Dr.) P. Natarajan
Rajiv Gandhi Chair Professor, CUSAT, Cochin - 682 022

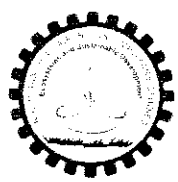
Prof. (Dr.) K.V. Jayachandran
College of Fisheries, Kerala Agricultural University
Cochin 682 506, Kerala, India

Prof. (Dr.) S. Kannaiyan
Former Chairman - National Biodiversity Authority
Chennai-600 041

Dr. Babu Ambat
Executive Director, Centre for Environment and Development
Trivandrum-695 013

Arun Augustine
Research fellow, Rajiv Gandhi Chair, CUSAT, Cochin-682 022

Published by



RAJIV GANDHI CHAIR IN CONTEMPORARY STUDIES
SCHOOL OF ENVIRONMENTAL STUDIES
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
Kochi - 22

Glimpses of Aquatic Biodiversity - Rajiv Gandhi Chair Spl. Pub., 7 : 120 - 132 (2008).

INDIAN ECHINODERMS: THEIR RESOURCES, BIODIVERSITY, ZOOGEOGRAPHY AND CONSERVATION

D. B. James
37, Sadasiva Metha Street, Metha Nagar, Chennai-600 029

Echinoderms are an interesting group of animals distributed only in the seas since they do not have osmoregulatory powers to adjust to lower salinities. They are truly stenohaline animals. At present there are 7000 living species. Their fossil history is well documented due to hard parts except in case of sea cucumbers. Nearly 13,000 species of fossils are known. They have two unique features among the invertebrates: an internal water vascular system which is operated hydraulically opening to the exterior by a perforated plate known as madreporite and the presence of tube-feet which are extension of water vascular system. They are widely distributed in all the seas right from the Arctic to the Antarctic regions. They are found right from the supra-littoral zone to the greatest depths of the oceans. Most of them live in association with coral reefs. They live on the rocky shores. Sea urchins drill into the rock for protection when there is a heavy wave action. They are highly organized animals among the invertebrates, being placed just below the Protochordate in the evolutionary tree. Yet they show some primitive characters like the radial symmetry, regeneration and in some cases asexual reproduction due to their sedentary life. Since they are highly organized animals, the sexes are separate. Fertilization is external. In some Arctic sea cucumbers there are brood pouches. The young ones are released into the icy cold waters after full development. They occur in the sandy beach. Some of the sea cucumbers are highly fossorial in habit. They are found in the muddy flats, mangrove swamps. They live among algae, sponges, gorgonians and antipatherians, particularly when they are young. Some of the species are always found in association with gorgonians. Many marine animals live in association with the Echinoderms without harming them; some of them qualify for symbiosis. There are no microscopic echinoderms, though there are some sea cucumbers which are interstitial and are 2-3 mm in length. There are no parasitic echinoderms. Some of the brittle stars that live in association with sea feathers can be termed as semi-parasitic since the brittle star shares the food of the sea feather. The group has limited economic use. The ripe gonads of some of the species of sea urchins are a delicacy for the Japanese. There is a flourishing industry of sea urchin roe on the coasts of Chili and Peru in South America. One kg of sea urchin roe costs U.S. $ 300 (Fuji, 1967; Fuji and Kawamura, 1970; Mottet, 1976). Some species of sea cucumbers are delicacy for the Chinese and Koreans. They are eaten in the fresh, frozen, chilled, canned and processed forms. The temperate species *Isostichopus japonicus* costs U.S. $ 400 per kilogram. The tropical species *Holothuria scabra* when processed commands U.S. $ 150 for the first grade. They find an important place in the traditional Chinese medicines. They have cytotoxic, ichthyotoxic, anti-microbial, anti-tumoral, anti-cancerous, anti-leukemia, anti-fouling and anti-fertility toxins. Hence they are in great demand in pharmaceutical industry in the preparation of drugs. Star fishes, brittle stars, sea urchins and sea feathers which are caught in the cod end of trawl net are dried on the beach and powdered for the fish meal preparation. Large specimens of starfishes and sea urchins are first properly preserved in strong formalin overnight and then dried in the shade. They are painted and sold as curios. The sea urchin eggs lend themselves well for embryological studies. Considerable work has been done on experimental embryology using sea urchin eggs. The present account deals with the resources, biodiversity, zoogeogaphy and conservation of Indian Echinoderms.

Resources

Some work has been done on the resources of sea urchins and sea cucumbers from different parts of the world since they are economically important (James, 1967 - 2008a; b).The sea cucumber resources of India have received attention during the last 40 years (James, 1973a; b; 1986a-d; 1988a-c; 1989a-d; 1994a-c). The sea cucumber and sea urchin resources of Andaman and Nicobar Islands have outlined by James (1983a-c) and Sastry (1981a-c; 2005), while that of Gulf of Mannar and Palk Bay has dealt with by James (1969-1994a-c). However, there is no documentation of stock assessment from Indian waters, though some work in this line has been done in other parts of the world. Without knowing the extent of the present stock, it is dangerous to allow the exploitation of this resource which is very vulnerable for over exploitation since the sea cucumbers are defenseless animals and make no attempts to escape from the captors. They also offer no resistance at the time of capture. In the Maldives, the exploitation of sea cucumbers began only in 1986 and within a few years the resource was already in need of management (Joseph and Shakeel, 1991). Since suitable sea urchins are not available for roe in the seas around India, no attempt has been made to study this resource with the exception of observation of Reuben *et al.* (1980) on the resource of the common slate pencil sea urchin *Stompneustes variolaris* from Visakhapatnam coast. The fishermen of Kanyakumari coast eat the roe of this sea urchin in fresh condition.

Biodiversity

In the nineteenth century,a lot of work has been done on the taxonomy of echinoderms, based primarily on the material collected by the various expeditions like Challenger, Valdivia, Siboga, Albatross, etc. The collections made by H.I.M.S. Investigator in the seas around India from deeper waters have been published by Alcock (1893a-c; 1895) and Koehler and Vaney (1905; 1908) . Most of the species were dredged from deeper waters and they were known only from the first report. Further, there is no record of such deep water species which may perhaps due to the non dredging. Except for the Crinoids, other reports were all published in French and also there were some misidentifications. From the world oceans, nearly 7,000 species were reported and from the seas around India 770 species are reported, most of them from deeper waters. The group-wise species abundance is given below.

Group	World Oceans	Seas around India
Crinoids	600	80
Asteroids	1,800	200
Ophiuroids	2,000	150
Echinoids	800	140
Holothuroids	1,400	200
Total	**6,600**	**770**

Very few papers on taxonomy of echinoderms were available prior to 1963. After the author took up a detailed works on taxonomy of all groups of Indian echinoderms since 1963, many publications on the subject were came out, as seen in the following table. Some of the papers have also been published by other Indian echinoderm taxonomists since 1963.

Region	Prior to 1963	During 1963-2008
West coast	5	16
Lakshadweep Islands	4	28
Gulf of Mannar and Palk Bay on the Indian side	7	42
East coast	4	43
Andaman and Nicobar Islands	4	56
Total	**24**	**185**

Zoogeography

Clark (1946) has stated that 'Owing to their relatively sedentary habits, the aversion to fresh or even brackish water, the brevity or complete absence of free swimming larval life and usually small bathymetrical range, echinoderms are remarkably suitable as material for studying changes in shorelines or relation of land masses to each other!' Although they have a wide occurrence, the distributional range for each species is somewhat narrow. Clark and Rowe (1971) listed 1,029 species known from the East coast of Africa to the Hawaiian Islands. Of these only 57 species alone have a wide distribution from the East coast of Africa to the Hawaiian Islands. There are very few species which are truly tropicopolitan in distribution and are found in the Indian, Pacific and Atlantic Oceans. All these point to the narrow range of distribution of each species.

Echinoderms of the Gulf of Mannar and Palk Bay, the Andaman, Nicobar and Lakshadweep Islands can be easily termed as indicator species for each region. In the Gulf of Mannar and Palk Bay, the large Asteroid *Pentaceraster mammillatus* is common and conspicuous. Whereas this species is not found in the Islands of Andaman, Nicobar and Lakshadweep. In the Lakshadweep Islands, small forms of *Linckia multifora* including comet forms are very common. However, *Linckia multifora* is rare and only large sized ones are seen in the Gulf of Mannar, Palk Bay and Islands of Andaman and Nicobar. In Andamans, *Archaster typicus* is common on the mud flats with males and females pairing, which is not found in Gulf of Mannar and Lakshadweep Islands. There are many other species which are characteristic for a particular region only.

James (1986a-d) stated that the Echinoderm faunal composition of Sri Lanka and on the opposing shores of India in the Gulf of Mannar and Palk Bay is different. He came to this wrong conclusion that since he compared the Echinoderms of the coral reefs of Sri Lanka with that of the Echinoderms of Gulf of Mannar and Palk Bay of India, mostly collected from the inter-tidal region. In fact, the Echinoderm faunal composition on the reefs of Sri Lanka and that of the Gulf of Mannar and Palk Bay reefs on the Indian side is the same.

Yamaguchi (1977) termed the Asteroids as Continental and widely distributed oceanic group. They are found in widely separated Oceanic islands. The Echinoderms of Lakshadweep appear in general to be Oceanic whereas those from Andaman and Nicobar Islands appear to be continental in nature, though some exceptions are found in both regions. The Echinoderms of the Gulf of

Mannar and Palk bay also appear to be Oceanic in nature like that of Sri Lanka. Clearly much work remains to be done to define distribution of the two groups.

Conservation

In India only sea cucumber resources were exploited for processing prior to 2001 and exported chiefly to Singapore. From there it was re-exported to other countries like China where it is consumed. The processed sea cucumber is known as *Beche-de-mer*. The word *Beche-de-mer* is a Frenchified Portuguese word meaning slug of the sea. It is also known as *haisom* in Chinese. Although the term *Beche-de-mer* denotes a sea cucumber, the word refers to the processed holothurians in the trade parlance. As a delicacy, it has become part of life and tradition for the Chinese who eat *Beche-de-mer* on festive occasions like the Chinese New Year Day. *Beche-de-mer* procured in dry form is soaked in water, cleaned and cooked in many delicious ways.

The *Beche-de-mer* industry is very ancient one in India being introduced by the Chinese more than one thousand years ago. It is essentially a cottage industry needing very little investment in rural coastal areas. The Chinese were directly supervising the processing along the Gulf of Mannar and Palk Bay nearly one hundred years ago. The Chinese had trade with southern India and Sri Lanka by junks of large size and it is believed that *Beche-de-mer* and pearls figured among the Indian products in exchange for porcelain, silks and sweetmeats.

There are over 1,400 species of sea cucumbers in the world oceans(Seleuka,1987; Semper 1868; Theel, 1886; Wood-mason and Alcock,1891a; b; Thurston1894; Sluiter, 1901; Peason, 1903-1914b; Clark, 1912-1946; Doderlein, 1915-1924; Fischer,1919; Mortensen,1928-1951; Panning,1929-1949; Heding,1931; Diechmann,1941;1958;Jones and James, 1970; Pillai *et al.*, 1990; James and Lal Mohan,1969; James and James,1994; James and Bhaker,1994; James and Badrudeen,1995; 1997; James, 2003). In the seas around India, nearly 200 species of sea cucumbers are known, of which, 75 are from shallow waters within 20 metres depth. Of these shallow water species, 15 are of commercial value. Sea cucumbers which are large in size with thick body walls are used for processing. It is only the processed skin of sea cucumbers is consumed after cooking. Different species of sea cucumbers are processed in different ways. Basically there are three steps for processing, namely, de-gutting, boiling and drying.

World landings of sea cucumbers were estimated at 25,000 tonnes in 1983, which increased to 1, 20,000 tonnes by 1990. The major part of the catch is constituted by the temperate species, *Isostichopus japonicus* and the minor portion by the tropical species. In the late 1980's and early 1990's, Indonesia was the major world producer and exporter to a tune of 4,700 tonnes of dried material per year. The Philippines emerged as the second major producer and exporter of dried sea cucumbers in the mid 1990 with catches around 20,000 tonnes per year. Other major exporters are the Fiji Islands, Japan, Madagascar, Papua New Guinea, Solomon Islands, Thailand and the U.S.A. Trends during 1990's indicated that the number of producer countries and the species in trade increased world-wide both in tropical and temperate regions. In Hong Kong, import statistics of Special Administrative Region (SAR) indicated an increase from 25 source countries during 1987-89 to 49 countries that exported *Beche-de-mer* in 2000-2001. During the period 1983-1990, a dramatic increase in the demand for *Beche-de-mer*, coupled with decline in the landings of sea cucumbers, promoted research on the fishery of commercial species. The trade in sea cucumber reached a global annual figure of about 13,000 tonnes of processed sea cucumbers valued at U.S. $ 60 million (Asha, 2008).

The sea cucumbers do not offer any resistance at the time of capture, as they are harmless animals. Hence, they are easily exploited from any region. Due to the continuous exploitation of sea cucumbers without any regulation, their population dwindled alarmingly. As a conservation measure, the Ministry of Environment, Government of India imposed a ban on the export of processed material less than 75 mm in length. This ban should have been effective since there is no internal market for this product. But in practice, it was not so, since the undersized processed material was taken in the hand baggage by air passengers who traveled to Singapore. In order to curb this, the Ministry of Environment, Government of India banned the collection of all species of sea cucumbers from the Indian coast, the Gulf of Mannar, Palk Bay, Andaman, Nicobar and Lakshdweep Islands, under the Wild Life Protection Act, 1972. This total ban on the collection of all species of sea cucumbers has caused severe impact on the lives of 2,000 fishermen (divers, processors and middle men) along the Gulf of Mannar and Palk Bay, who solely subsist on the fishing of sea cucumber. Stock assessment studies have to be undertaken and also sample surveys have to be made to observe the abundance and size, since there was no fishing from 2001 to the present time. Then only decision can be taken to lift the ban partially subject to same conditions.

Because of the high demand from the International market and inadequate fishery management practice of the sea cucumbers has caused depletion to the existing stocks. The releasing of the hatchery produced juveniles of the commercial sea cucumbers to a natural habitat is called restoration, restocking or reseeding. This is gaining importance world-wide as the only way to replenish the natural stocks of depleted sea cucumbers.

Acknowledgement: The author is thankful to Shri M. Kathirvel, Principal Scientist, Central Institute of Brackish water Aquaculture, Chennai for critical reading of the manuscript and suggesting improvements.

References

Alcock, A. 1893a. New species of *Echinolampas*, *Brissopsis* and *Lovenia*. *J. Asiat. Soc. Bengal*, 62: 173-176.

Alcock, A. 1893b. Natural history Notesfrom H.M. Indian Marine Survey Steamer, *Investigator* Commander C.F. Oldham, R.N. Commanding. An account of the collection of Deep-sea Asteroidea. *Ann. Mag. Nat. Hist.*, (6)11: 73-121.

Alcock, A. 1893c. Natural history Notesfrom H.M. Indian Marine Survey Steamer, *Investigator* Commander C.F. Oldham, R.N. Commanding. An account of the collections made during the season 1892-93. *J. Asiat. Soc. Bengal*, 62(4): 171-173.

Alcock, A. 1894a. A guide to the zoological collections exhibited in the invertebrate gallery of the Indian Museum.115. 1 folding plate, Calcutta, 8 Vol. (Ech. Ast. Oph.Crin. Hol.), II, B, i: D, i.

Alcock, A. 1894b. Echinoderma of the Indian Museum. Illustrations of Zoology of R.I.M.S. Investigator, Echinoderma, Part I, Pls. I-III, Calcutta.

Alcock, A. 1895. Echinoderma of the Indian Museum. Illustrations of Zoology of R.I.M.S. Investigator, Echinoderma, Part II, Pls. I-III, Calcutta.

Asha, P.S. 2008. Holothurian resources of India. In: *Training Manual on GIS and Marine Biodiversity*, Loyola College, Chennai, 255-261.

Clark, A.H. 1912. Crinoidea. Echinoderms of the Indian Museum, Calcutta.

Clark, A.H. 1931. A Monograph of the existing Crinoids 1(3). Super family Comasteridae. *Bull. U.S. natn. Mus.*, 82(3): 1-816.

Clark, A.H. 1941. A Monograph of the Existing Crinoids. 1(4b). Super Family Mariametrida (concluded the family Colobometridae) and Super Family Tropiometrida (except the families Thallassometridae and Charitometridae). *Bull. U.S. natn. Mus.*, 82(4c): 1-383.

Clark, A.H. & Clark, A.M. 1967. A Monograph of the Existing Crinoids. 1(5). Suborders Oligogophreata (concluded) and Macropreata. *Bull. U.S. natn. Mus.*, 82(5): 1-860.

Clark, A.M. 1967a. Notes on the family Ophiotrichidae (Ophiuroidea). *Ann. Mag. Nat. Hist.*, (13)9: 637-655.

Clark, A.M. 1967b. Notes on Asteroids in the Bristish Museum (Natural History). V. Nardoa and some other Ophiodiasterids. *Bull. Br. Mus. Nat. Hist.*, (Zool.), 15: 169-198.

Clark, A.M. 1968. Notes on some tropical Indo - Pacific Ophiotrichidae and Ophiodermatids. *Bull. Br. Mus. Nat. Hist.*, (Zool.), 16: 277-322.

Clark, A.M. & Rowe, F.W.E. 1971. Monograph of the shallow-water Indo-Pacific Echinoderms. Trustees of the British Museum (Natural History), London, 238.

Clark, H.L. 1907. The Apodous holothurians. *Smithson. Contr. Knowl.*, 35: 1-206.

Clark, H.L. 1921. The Echinoderm fauna of Torres Strait. *Pap. Dep. Mar. boil. Carnegie Inst. Wash.*, 10: 1-223.

Clark, H.L. 1922. The holothurians of the genus *Stichopus*. *Bull. Mus. Comp. Zool. Harv.*,65: 39-74.

Clark, H.L. 1938. Echinoderms from Australia. *Mem. Mus. Comp. Zool. Harv.*, 55: 1-596.

Clark, H.L. 1946. The Echinoderm fauna of Australia. *Publ. Carnegie Instn.* No. 566: 1-568.

Deichmann, E. 1941. The Holothuridea collected by the Velero III during the years 1931-38. Part 1. Dendrochirota. *Allan Hancock Pacific Exped.*, 8: 61-153.

Deichmann, E. 1958. The Holothurioidea collected by the Velero III and IV during the years 1931-1954. Part 2. Aspidochirota. *Allan Hancock Pacific Exped.*, 11: 249-349.

Doderlein, L. 1915. Die Arten der Asteroiden – Cattung *Anthenas* Gray. *Jahrb. D. nass. Ver. f. Nat.*, 68: 21-53.

Doderlein, L. 1917. Die Asteriden den Siboga-Expedition. I. Die Cattung *Astropecten* und stammesgeschichte. *Siboga Exped. Monogr.*, 46a: 1-191.

Doderlein, L. 1920. Die Asteriden der Siboga Expedition. II. Die Cattung *Luidia* und ihre stammesgeschichte. *Siboga Exped. Monogr.*, 46b: 1-47.

Doderlein, L. 1924. Die Asteriden der Siboga Expedition. II. Pentagonasteridae. *Siboga Exped. Monogr.*, 46(2): 49-60.

Doderlein, L. 1935. Die Asteriden der Siboga Expedition. III. Creasteridae. *Siboga Exped. Monogr.*, 46: 71-110.

Doderlein, L. 1924. Die Asteriden der Siboga Expedition. III. Die Unter familie Oreasteridae. *Siboga Exped. Monogr.*, 46c: 295-368.

Fell, H.B. 1960. Synoptic keys to the genera of Ophiuroidea. *Zool. Publs. Vict. Univ. Wellington*, No. 26: 1-44.

Fisher, W.K. 1919. Starfishes of the Philippine Seas and adjacent waters. *Bull. U.S. natn. Mus.*, 100(3): 1-546.

Fuji, A. 1967. Ecological studies on the growth and food consumption of Japanese common littoral se urchin, *Strongylocentrotus intermedius* (A. Agassiz). *Mem. Fac. Fish. Hokkaido Univ.*, 15: 83-160.

Fuji, A. & Kawamura, K. 1970. Studies on the biology of the sea urchin VII. Bio-economics of the population of *Strongylocentrotus intermedius* on a rocky shore of Southern Hokkaido. *Bull. Jap. Soc. Sci. Fish.*, 36: 763-775.

Heding, S.G. 1931. On the classification of the Molpadids. *Vidensk. Meddr. Dansk. Naturh. Foren.*, 92: 275-284.

Heding, S.G. & Panning, A. 1954. Phyllophoridae. Eine Bearbeitung der polytentaculaten Dendrochiroten Holothurien des Zoologischen Museums in Kobenhagen. *Spoilia zool. Mus. Haven.*, 13: 1-209.

James, D.B. 1967. *Phyllophorus* (*Phyllophorella*) *parvipedes* Clark (Holothuroidea), a new record to the Indian seas. *J. mar. biol. Ass. India*, 7: 325-327.

James, D.B. 1968a. Studies on Indian Echinoderms-1. Re-description of the echinoid *Breynia vredenburgi* Anderson from Andaman Sea with emended description *J. mar. biol. Ass. India*, 8(2): 76-81.

James, D.B. 1968b. Studies on Indian Echinoderms-2. The holothurian *Stolus buccalis* (Stimpson) with notes on iits systematic position. *J. mar. biol. Ass. India*, 8(2): 285-289.

James, D.B. 1969. Catalogue of echinoderms in the reference collection of the Central Marine Fisheries Research Institute. *Bull. Cent. Mar. Fish. Res. Inst.*, 7: 51-62.

James, D.B. 1971a. Studies on Indian Echinoderms-3. *Ophiarthrum pictum* (Muller & Troschel), a new record from the Indian Ocean with additional notes on the species. *J. mar. biol. Ass. India*, 12: 136-138.

James, D.B. 1971b. Studies on Indian Echinoderms-4. On the brittle star *Amphioplus gravelyi sp. nov.* and *Amphioplus depressus* (Ljungman) from the Indian coasts. *J. mar. biol. Ass. India*, 12: 139-143.

James, D.B. 1973a. *Beche-de-mer* resources of India. *Proc. Living Resources of the seas around India.* CMFRI Spl. Publ., 706-711.

James, D.B. 1973b. Studies on Indian Echinoderms-5. New and little known Star fishes from the Indian seas. *J. mar. biol. Ass. India*, 15(2): 556-559.

James, D.B. 1978. Studies on Indian Echinoderms – 6. Re-description of two little known holothurians with a note on an early juvenile of *Holothuria scabra* Jaeger from Indian Seas. *J. mar. biol. Ass. India*, 18: 55-61.

James, D.B. 1980. History of Echinodermology of Indian Ocean. *J. mar. biol. Ass. India*, 18(2): 298-309.

James, D.B. 1981a. Studies on Indian Echinoderms-7. On a new Family Labidodematidae (Holothuroidea: Aspidochirotidae) with a detailed description of *Labidodemas rugosum* (Ludwig) from the Andamans. *J. mar. biol. Ass. India*, 23(1&2): 82-85.

James, D.B. 1981b. Studies on Indian Echinoderms-8. On a new genus *Phioelegans* (Ophiuroidea: Ophiuridae) with notes on *Ophiolepis superba* H.L. Clark, 1938. *J. mar. biol. Ass. India*, 23(1&2): 15-18.

James, D.B. 1982a. Studies on Indian Echinoderms-9. *Ophionereis andamanensis sp. nov.* (Ophiuroidea: Ophiureidae) from Port Blair, Andamans. *J. mar. biol. Ass. India*, 24(1&2): 33-35.

James, D.B. 1982b. Studies on Indian Echinoderms-10. *Ophiocoma anaglyptica* Ely (Ophiuroidea: Ophiocomidae), a new record from the Indian Ocean with notes on other species of *Ophiocoma* from Indian Seas. *J. mar. biol. Ass. India*, 24(1&2): 36-41.

James, D.B. 1982c. Studies on Indian Echinoderms-11. On *Protankyra tuticorenensis sp.nov.* and other apodus holothurians from the Indian seas. *J. mar. biol. Ass. India*, 24(1&2): 92-105.

James, D.B. 1983a. Sea-cucumber and sea-urchin resources. *Bull. Cent. Mar. Fish. Res. Inst.*, 34: 85-93.

James, D.B. 1983b. Research on Indian Echinoderms – A review. *J. mar. biol. Ass. India*, 25 (1&2): 91-108.

James, D.B. 1984. Studies on Indian Echinoderms-15. On *Psolus mannarensis sp. nov.* and other Dendrochirotids from Indian seas. *J. mar. biol. Ass. India*, 26(1&2): 109-122.

James, D.B. 1986a. The holothurian resources. *Marine Fishery Resources and Management. CMFRI, ,Cochin, R & D Series*, 10: 1-4.

James, D.B. 1986b. Studies on Indian Echinoderms – 12. *Holothuria (Acanthotrapeza) pyxis* Selenka, an interesting holothurian from the Andamans. *J. Andaman Sci. Ass.*, 2(1): 31-36.

James, D.B. 1986c. Studies on Indian Echinoderms-13. *Phyrella fragilis* (Ohshima) (Echinodermata: Phyllophoridae), a new record from the Indian Ocean with notes on its habits. *J. Andaman Sci. Ass.*, 2(1): 37-38.

James, D.B. 1986d. Zoogeography of the sahhlow-water Echinoderms of Indian seas. In: P.S.B.R. James (ed.). *Recent Advances in Marine Biology*, Today and Tomorrow's Printers and Publishers, new Delhi, 569-591.

James, D.B. 1988a. Boring and fouling echinoderms of Indian waters. In: Marine Deterioration. Oxford and IBH Publishing Co. Pvt. Ltd., 227-238.

James, D.B. 1988b. *Ophiocoma doderleni* Loriol, a new record of brittle star from Andamans. *J. Andaman Sci. Ass.*, 4(2): 139-140.

James, D.B. 1988c. Echinoderm fauna of the proposed National Marine Park in the Gulf of Mannar. *Proc. Symp. Endangered Marine Animals and Marine Parks*, Mar. Biol. Ass. India, 403-406.

James, D.B. 1989a. *Beche-de-mer*: Its resources, fishery and industry. *Mar. Fish. Infor. Serv. T & E Ser.*, 92: 1-35.

James, D.B. 1989b. A handbook on *Beche-de-mer*. Issued on the occasion of the Workshop on *Beche-de-mer*, at Mandapam Camp during February 23-25, 1989. Central Marine Fisheries Research Institute, Cochin, 32 (in Tamil with English summary).

James, D.B. 1989c. Echinoderms of Lakshadweep and their zoogeography. *Bull. Cent. Mar. Fish. Res. Inst.*, 43: 97-144.

James, D.B. 1989d. *Beche-de-mer* resources of Lakshadweep. In: Marine Living Resources of the Union Territory of Lakshadweep – An indicative survey with suggestions for development. *Bull. Cent. mar. Fish. Res. Inst.*, 43: 144-149.

James, D.B. 1990. Sea urchin roe - A potential resource for export. *Seafood Export J.*, 21(6): 26-36.

James, D.B. 1991. Echinoderms of the Marine National Park, South Andamans. *J. Andaman Sci. Ass.*, 7(2): 19-25.

James, D.B. 1993a. Part II.Sea urchin culture. In: Sea weed, Sea urchin and Sea cucumber. Handbook on Aquafarming, Marine Products Export Development Authority, Cochin, 23-30.

James, D.B. 1993b. Part III. Sea cucumber culture. In: Sea weed, Sea urchin and Sea cucumber. Handbook on Aquafarming, Marine Products Export Development Authority, Cochin, 33-37.

James, D.B. 1994a. An annotated bibliography on sea-cucumbers. *CMFRI Spl. Publ.*, 58: 1-92.

James, D.B. 1994b. Holothurian resources from India and their exploitation. In: *Proc. Natl. Workshop on Beche-de-mer*, (Eds. K. Rengarajan and D.B. James, *Bull. Cent. Mar. Fish. Res. Inst.*, No. 46: 27-31.

James, D.B. 1994c. Zoogeography and systematic of holothurians used for *Beche-de-mer* in India. *Proc. Natl. Workshop on Beche-de-mer*, (Eds.) K. Rengarajan and D.B. James, *Bull. Cent. Mar. Fish. Res. Inst.*, 46: 34-36.

James, D.B. 1995a. Taxonomic studies on the species of *Holothuria* (Linnaeus, 1767) from the seas around India. Part 1. *J. Bombay nat. Hist. Soc.*, 92(1): 43-62.

James, D.B. 1995b. Taxonomic studies on the species of *Holothuria* (Linnaeus, 1767) from the seas around India. Part 2. *J. Bombay nat. Hist. Soc.*, 92(2): 190-204.

James, D.B. 1995c. Animal association in echinoderms. *J. mar. biol. Ass. India*, 37(1&2): 272-276.

James, D.B. 1996. Notes on the family Goniasteridae (Echinodermata: Asteroidea) from the Indian Seas. *J. mar. biol. Ass. India*, 38(1&2): 133-138.

James, D.B. 1998a. On the occurrence of the gastropod parasite *Prostilifer* sp. on the holothurian *Holothuria scabra* Jaeger at Tuticorin. *Mar. Fish. Infor. Serv. T & E Ser.*, 157: 26

James, D.B. 1998b. Ecological significance of echinoderms of the Gulf of Mannar. In: *Workshop on Coastal Biodiversity of Gulf of Mannar*, M.S. Swaminathan Research Foundation, Chennai, 118-128.

James, D.B. 1998c. On little known holothurian *Stichopus vastus* Sluiter with notes on other species of *Stichopus* from the seas around India. *Mar. Fish. Infor. Serv. T & E Ser.*, 158: 12-15.

James, D.B. 1998d. *Holothuria* (*Microthele*) *fuscogilva* Cherbonnier, a new record from India with a note on its export potential and processing. *Mar. Fish. Infor. Serv. T & E Ser.*, 158: 15-16.

James, D.B. 1999a. Abnormal asteroids from the seas around India. *Mar. Fish. Infor. Serv. T & E Ser.*, 159: 21-22.

James, D.B. 1999b. *Holothuria* (*Thymioscycia*) *arenicola* Semper, a rare holothurian from the Gulf of Mannar. *Mar. Fish. Infor. Serv. T & E Ser.*, 161: 15.

James, D.B. 2000. Sea cucumbers. In: *Marine Fisheries Research and Management*. (Eds.) V.N. Pillai and N.G. Menon, Central Marine Fisheries Research Institute, Cochin, pp. 124-151.

James, D.B. 2001. Twenty sea cucumbers from seas around India. *Naga, ICLARM Quarterly*, 24 (1&2): 4-8.

James, D.B. 2003. Echinoderm diversity in India. In: Marine Faunal Diversity in India. Marine Biological Station, Zoological Survey of India, Chennai, 332-340.

James, D.B. 2004a. Indian Sea cucumbers. Issued on the occasion of *International Conference and Exposition on Marine Living Resources of India for food and medicine.* during February 27-29, 2004, 1-9p.

James, D.B. 2004b. A bibliography on Indian sea cucumbers. *The Fisheries Technocrats Forum, Chennai, Tech. Bull.*, No. 2: 1-28.

James, D.B. 2004c. *Calliaster childreni* Gray (Echinodermata: Asteroidea), a new record from the Indian Ocean. *Fishing Chimes*, 24(6): 60.

James, D.B. 2005a. Sea cucumber resourcesof India and their potential for culture. *Proc. Ocean Life, Food and Medicine, Expo.*, Aquaculture Foundation of India, Chennai, pp. 90-101.

James, D.B. 2005b. Conservation of coral reef fauna and flora in the Gulf of Mannar. *Proc. Natl. Seminar on Rejuvenation and Reclamation of Coral reefs in the Gulf of Mannar* (Eds.) M. Sakthivel and J. Ronald, pp. 34-53.

James, D.B. 2006a. Identification of Indian sea cucumbers and culture techniques. In: *Manual for National Training Workshop on Marine Coastal Biodiversity Assessment for Conservation and Sustainable Utilization*, Suganthi Devadason marine Research Institute, Tuticorin, 20-24.

James, D.B. 2006b. Sea cucumber of Gulf of Mannar. Colour poster issued by Tamil Nadu Forest Department. The Wild Life Warden, Gulf of Mannar Marine National Park, Ramanathapuram.

James, D.B. 2006c. Distribution and identification of Indian sea cucumbers. *GOMBRT Publication* 3: 40-53.

James, D.B. 2007a. Echinoderm biodiversity. In: *Workshop on Biodiversity and Conservation Strategies on the Threatened and Endangered Species of the Gulf of Mannar Marine Biosphere*, Fisheries College and Research Institute, Tuticorin, 56-62.

James, D.B. 2007b. Echinoderms of the west coast of India. *Fishing Chimes*, 27(7): 19-21.

James, D.B. 2007c. Common sea cucumbers of the Gulf of Mannar. In: Capacity building in identification of marine scheduled animals: Training-cum-Information Manual, Gulf of Mannar Biosphere Reserve Trust, Ramanathapuram & Suganthi Devadoson Marine Research Institute, Tuticorin, 60-63.

James, D.B. 2008a. Diversity of Echinoderms in India. In: *Training Manual on GIS and Marine Biodiversity*, Loyola College, Chennai, 221-230.

James, D.B. 2008b. A field guide for identification of common echinoderms of the Gulf of Mannar. In: *Training Manual on GIS and Marine Biodiversity*, Loyola College, Chennai, 231-253.

James, D.B. & Badrudeen, M. 1995. Deep water Redfish – A new resource for the Indian *Beche-de-mer* industry. *Mar. Fish. Infor. Serv. T & E Ser.*, 137: 6-8.

James, D.B. & Badrudeen, M. 1997. Observations on the landings of the sea cucumber *Holothuria spinifera* at Rameswaram by *chanku madi*. *Mar. Fish. Infor. Serv. T & E Ser.*, No. 149: 6-8.

James, D.B. & Bhasker, B.K. 1994. Present status of the *Beche-de-mer* industry in the Palk Bay and the Gulf of Mannar. In: *Proc. Natl. Workshop on Beche-de-mer*, (Eds. K. Rengarajan and D.B. James, *Bull. Cent. Mar. Fish. Res. Inst.*, No. 46: 85-90.

James, D.B. & James, P.S.B.R., 1994. Handbook on Indian Sea cucumber. *CMFRI Spl. Publ.*, No. 59: 1-46.

James, D.B. & Lal Mohan, R.S., 1969. Bibliography of the Echinoderms of the Indian Ocean. *Bull. Cent. Mar. Fish. Res. Inst.*, 15: 1-43.

James, D.B. & Nithyanantham M., 2003. Collection, preservation and identification of Echinoderms. In: Marine Faunal Diversity in India. Marine Biological Station, Zoological Survey of India, Chennai, 341-349.

Jones, S. & James. D.B., 1970. On the Stiliferid gastropod in the cloacal chamber of *Holothuria atra* Jaeger. *Proc. Symp. Mollusca*, Mar. Biol. Ass. India, 3: 799-804.

James, D.B., Pillai, C.S.G. & Gopakumar, G. 1990. A case study of infestation of *Acanthaster planci* in Andaman waters. *Mar. Fish. Infor. Serv. T & E Ser.*, No. 106: 1-3.

Joseph, L. & Shakeel. 1991. The *beche-de-mer* fishery in the Maldives only a few years old, but already in need of management. BOBP Newsletter, 2-5.

Kawamura, K. 1973. Fishery biological studies on a sea urchin *Strongylocentrotus intermedius* (A. Agassiz). *Sci. Rep. Hokkaido Fish. Exp. Stn.*, 16: 1-54.

Koehler, R. & Vaney, C.1905. Echinodermata of the Indian Museum. Part IV. An account of littoral Holothuroidea collected by the R.I.M.S. Investigator, 55.

Koehler, R. & Vaney, C. 1908. Littoral Holothuroidea. *Echinoderms of the Indian Museum*, Calcutta, 1-54.

Mortensen, T. 1928. Monograph of the Echinoidea. I. Cidaroidea, 551.

Mortensen, T. 1935. *Monograph of Echinoidea. Bothriocidaroidea, Melonechinoida, Lepidocentroida and Stirodonta*, 1-647, Copenhagen.

Mortensen, T. 1940. Monograph of the Echinoidea. III. 1. Aulondonta. 370. Copenhagen.

Mortensen, T. 1943a. Monograph of the Echinoidea. III. 2. Camerodonta. I. 553. Copenhagen.

Mortensen, T. 1943b. Monograph of the Echinoidea. III. 3. Camerodonta. II.446. Copenhagen..

Mortensen, T. 1948. Report on the Echinoidea of the Murray Expedition. Part 2. *Sci. Rep. John Murray Exped.*, 1933-1934, 9: 1-15.

Mortensen, T. 1951. Monograph of the Echinoidea. V. 2. Spatangoida, 2, 593, Copenhagen.

Mottet, M.G. 1976. The fishery of sea urchins in the family Strongylocentrotidae. *Tech. Rep. Wash. Dep. Fish.*, 20: 1-66.

Panning, A. 1929-1935. Die Gattung *Holothuria. Mitt. Zool. St. Inst. Hamb* , 44 (1929): 91-138; 45 (1934): 24-50, 65-85 & 85-107; 46 (1935): 1-18.

Panning, A. 1944. Die Trapagfisscherei. *Mitt. Zool. StInst. Hamb.*, 49: 1-76.

Panning, A. 1949. Versuch einer Neuerdnung der Familie Cucumeridae. *Zool. Jb.*, 78: 404-470.

Pearson, J. 1903. Holothuroidea. In: W.A. Herdman (Ed.). Report to the Government of Ceylon on the Pearl Oyster Fisheries of the Gulf of Mannar. *London (Royal) Suppl. Rep.*, 5: 181-208.

Pearson, J. 1913. Notes on the Holothuroidea of the Indian Ocean. I. The genus *Holothuria*. *Spolia Zelon*, 9(34): 49-101.

Pearson, J. 1914a. Proposed re-classification of the genera *Mulleria* and *Holothuria*. *Spolia Zeylon*, 9(35): 163-172.

Pearson, J. 1914b. Notes on the Holothuroidea of the Indian Ocean. *Spolia Zelon*, 9(35): 163-172.

Pillai, C.S.G., James, D.B. & Gopakumar, G. 1989. Report on the Survey of Coral reefs, bait fishes and *Acanthaster planci* in the Marine National park and adjacent waters in South Andamans. Report to the Andaman Administration, 1-14.

Reuben, S., Appa Rao T. & Samson Manickam, P.E. 1980. Sea urchin resources of Waltair coast. *Symposium on Coastal Aquaculture, Mar. Biol. Ass. India,* (Abstract).

Rowe, F.W.E. 1969. A review of the Family Holothuroidae (Holothuroidea: Aspidochirotida). *Bull. Brit. Nat. Hist. (Zool.)*, 18(4): 119-170.

Roxsd, H.A. 1928. Philippine littoral Echinoidea. *Philipp. J. Sci.*, 36: 243-270.

Sastry, D.R.K. 1981a. On some crustacean associates of Echinodermata from the Bay of Bengal. *Rec. zool. Surv. India*, 79: 19-30.

Sastry, D.R.K. 1981b. On the occurrence of the brittle star *Ophiophrixus confines* Koehler (Echinodermata: Ophiuroidea) in the Indian Ocean. *Curr. Sci.*, 50(12): 554-555.

Sastry, D.R.K. 1981c. Emendation of the name *Peronella rullandi* (Koehler) (Echinodermata; Echinoidea). *Bull. Zool. Surv. India*, 4(2): 239.

Sastry, D.R.K. 1985a. Occurrence of the spionid polychaete, *Polydora antennata* (Calaparede) on the sea urchin, *Stomopneustes variolaris* (Lamarck) at Visakhapatnam. *Second Natl. Seminar on Marine Intertidal Ecology*, Department of Zoology, Andhra University, Waltair, Abstract No. 41.

Sastry, D.R.K. 1985b. Observations on the distribution of *Stomopneustes variolaris* (Lamarck) (Echinodermata: Echinoidea) at Visakhapatnam. *Second Natl. Seminar on Marine Intertidal Ecology*, Department of Zoology, Andhra University, Waltair, Abstract No. 42.

Sastry, D.R.K. 1995. Echinodermata. *Zool. Surv. India, Wetland Ecosystem Series 1. Fauna of Chilka Lake*, 477-478.

Sastry, D.R.K. 1998a. Echinodermata. *Zool. Surv. India, State Fauna Series 3. Fauna of West Bengal*, Part 10: 463-481.

Sastry, D.R.K. 1998b. Some Echinoderms new to Mahatma Gandhi Marine National Park with two new records from India. *Proc. Symp. Island Ecosystem and Sustainable Development,* 133-138.

Sastry, D.R.K. 1999. Echinodermata of Great Nicobar Island, Bay of Bengal. *J. Andaman Sci. Ass.*, 15: 91-93.

Sastry, D.R.K. 2002. Echinodermata associated with coral reefs of Andman and Nicobar Islands. *Rec. zool. Surv. India*, 100(Part 3&4): 21-60.

Sastry, D.R.K. 2005. Echinoderms of Andaman and Nicobar Islands, Bay of Bengal: An Annotated List. *Rec. Zool. Surv. India, Occ. Paper* No. 233: 1-207.

Selenka, E. 1867. Beitrage zur Anatomie und Systematik der Holothurie. *Z. wiss. Zool.*, 17: 281-374.

Semper, C. 1868. Holothurien. *Reisen im Archipel der Philippines*. 2. Wussenschaftlieche Resultate. Weisbaden. 288 .

Sluiter, C.P. 1901. Die Holothurien der Sgiboga Expedition. *Siboga Exped. Monogr.*, 44: 1-142.

Theel, H. 1886. Holthuroidea. Part 2. *Rep. Scient. Results Voy. HMS Challenger (Zool.)*, 39: 1-290.

Thurston, E. 1894b. Rameswaram Island and fauna of the Gulf of Mannar. Madras (Madras Government Museum), *Sci. Ser.* No. 1: 78-138.

Wood-Mason, J. & Alcock, A. 1891a. Natural History Notes from H.M. Indian Survey Steamer '*Investigator*', Commander R.F. Hoskyn, R.N. Commanding. *Ann. Mag. Nat. Hist.*, 6(7): 12-15.

Wood-Mason, J. & Alcock, A. 1891b. Natural History Notes from H.M. Indian Survey Steamer '*Investigator*', Commander R.F. Hoskyn, R.N. Commanding. On the results of Deep Sea dredging during the season 1890-1891. *Ann. Mag. Nat. Hist.*, (6)8: 427-443.

Yamaguchi, M. 1977. Larval behaviour and geographic distribution of coral reef asteroids in the Indo-West Pacific region. *Micronesica*, 13(2): 283-296.