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RESEARCH ON INDIAN ECHINODERMS - A REVIEW

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In the present paper research work so far done on Indian Echinoderms is reviewed. Various aspects such as history, taxonomy, anatomy, reproductive physiology, development and larval forms, ecology, animal associations, parasites, utility, distribution and zoogeography, toxicology and bibliography are reviewed in detail. Corrections to misidentifications in earlier papers have been made wherever possible and presented in the Appendix at the end of the paper.

INTRODUCTION

ECHINODERMS being common and conspicuous organisms of the sea shore have attracted the attention of the naturalists since very early times. Their beauty, more so their symmetry have attracted the attention of many a naturalist. Although the first paper on Indian Echinoderms was published as early as 1743 by Plancus and Gaultire from Goa there was not much progress in the field except in the late nineteenth and early twentieth centuries when echinoderms collected mostly by R.I.M.S. *Investigator* were reported by several authors. Except for these reports later papers from various regions were of desultory nature. Until the author took up studies on Indian echinoderms in 1963 information on the ecology and habits and identity of even some common echinoderms were also not known from India. As a result of his efforts nearly 200 species of echinoderms from various places along the east and west coasts of India, the Andaman and Nicobar Islands and the various Islands of Lakshadweep are known today with their habits.

The author is grateful to Dr. S. Jones, former Director of Central Marine Fisheries Research Institute for initiating to the study of these interesting organisms and also for his guidance and help at every stage. He thanks Dr. P.S.B.R. James, Director, C.M.F.R. Institute for kindly suggesting to write this review and also for his kind interest and encouragement. He also thanks Miss A.M. Clark, British Museum (Natural History), London for commenting on the correct identity of some of the echinoderms presented here.

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HISTORY

Most of the research work on Indian echinoderms relate only to taxonomy with little or no information on the ecology and other aspects of the animals. Prof. F.J. Bell (1887–1902). of the King's College, London was the first to report on the echinoderms of India along with Mr. Edgar Thurston (1887–1894) of the Madras Museum. Unfortunately some of their identifications proved to be wrong. Some of the correct identifications are given at the end of the paper in an Appendix.

In the mid sixties some work on the reproductive physiology was initiated by Prof. S. Krishnaswamy and this has resulted in the publication of a number of papers by Giese *et al.* (1964), Krishnaswamy and Krishnan (1967), Krishnan (1967, 1968), K. S. Rao (1965, 1968 a, 1968 b) and Rahaman (1966, 1968).

Dr. S. Jones initiated work on the animal associations in general and echinoderms in

particular. This has also resulted in a number of publications in the field by Jones (1964), Jones and Sankarankutty (1960), Jones and Mahadevan (1966) and Nayar and Mahadevan (1965 a, b). This work is being continued by the present author and the results will be published elsewhere.

At the suggestion of Dr. S. Jones, the present author took up work on echinoderms in 1963 and this has resulted in a number of publications (James, 1967, 1968 a, b, 1969, 1971 a, b, c, 1973 a, b, c, 1978 a, b, 1980 a, b, 1981 a, b, 1982 a, b, c, d, 1983, 1985 a, b, 1986 a, b, c, d), James and Lal Mohan (1969), Jones and James (1970) and Rao *et al.* (1985) on taxonomy, ecology, utility, zoogeography, parasites, toxicology and bibliography. Some new genera and new species and several new records came to light. James (1980 a) published an account of the history of echinodermology of the Indian Ocean.

Taxonomy

As stated earlier much of the work is done only in the field of taxonomy. Unfortunately until now there are no monographical works on Indian echinoderms. Most of the papers so far appeared are short without much details. Some of the papers added to the confusion already existing even with regard to common forms. Thanks to Miss. A. M. Clark of the British Museum, many of the misidentifications of Bell (1888, 1889, 1902) have been corrected. Some of the workers without referring to specialists have assigned echinoderms to genera found only in the Atlantic! Most of the earlier papers deal with echinoderms collected from depths by R.I.M.S. *Investigator* by Wood-Mason and Alcock (1891 a, 1891 b), Alcock (1893 a, 1893 b, 1894 a, 1894 b, 1895), Koehler and Vaney (1905, 1908) and Koehler (1914, 1922, 1927).

Along the Indian Coast the echinoderms of the Gulf of Mannar and Palk Bay are somewhat better known (Thurston, 1887, 1890, 1894; Bell, 1888; Gravely, 1927). More than hundred species are known from the Gulf of Mannar and Palk Bay, today. Chacko *et al.* (1956) merely listed some of the species from Krusadai Island in the Gulf of Mannar. Satyamurti (1976) simply gave the description of the labelled specimens in the Madras Museum collected from the Gulf of Mannar and Palk Bay without checking for the accuracy of the identifications. The author has re-examined a specimen listed by Gravely (1927) as *Ophiophragmus relictus* and described the same as *Amphioplus gravelyi* James (1973 a). The other specimens also need to be re-examined.

Plancus and Gaultire (1743) reported crown of thorns *Acanthaster planci* (Pl. I A) from Goa. The present author has examined *Ophiactis savignyi, Astropecten indicus, Holothuria (Metensiothuria) leucospilota* from Goa. Three species of echinoderms are mentioned by Thurston from Madras in the paper of Bell (1889). Gravely (1941) listed 21 species from the Madras beach. Nair (1946) described a new species of holothurian from Madras Harbour which later proved to be synonymous with known species. The present author has collected 24 species from Madras which are listed at the end of this paper. Devanesan (1930) reported a new sea urchin belonging to the genus *Chaetodiadema*. Kurian (1953) reported four species from Travancore Coast. Grideon *et al.* (1957) mentioned a few echiroderms only upto genus level from the Gulf of Kutch. Sanne and Chhapgar (1962) listed 15 species from intertidal region of Bombay. Six species of holothurians are listed by Gopalakrishnan (1969) from the Gulf of Kutch. James (1969) has catalogued many species from various places along the Indian Coast. Radhakrishna and Ganapati (1969) reported some species

from Kakinada Bay. Nagabhushanam and Rao (1969) listed six species from Orissa Coast. The identifications need to be checked since they list genera like *Asterias* which is not known from the Indo-West Pacific region and *Palmipes* which is no longer valid. James (1971 b) gave a detailed description of the ophiuroid *Amphioplus (Lymanella) depressus* from Cochin. Mary Bai and Ramanathan (1977) reported the occurrence of *Holothuria (Semperothuria) cineracens* from Kanyakumari Coast. Mary Bai (1979) reported the sea urchin *Stomopneustes variolaris* from Kanyakumari which is common. Parulekar (1981) reported five species of echinoderms from Molvan.

The echinoderms of Andaman and Nicobar Islands are better known from the works of the author who collected echinoderms mostly from intertidal region. He listed 257 species known from Andaman and Nicobar Islands. (James, 1983). Bell (1887) reported 45 species from Andamans. All the five new species of holothurians reported by him proved to be synonymous with other species. Lutken (1865, 1872), Theel (1886) and Marktanner (1887) listed some asteroids, ophiuroids and holothuroids respectively from Nicobar. Anderson (1907) reported a new species of echinoid *Brevnia vredenburgi* from Port Blair. James (1968 a) gave a detailed description of this little known species. James (1969) catalogued 55 species of echinoderms from Andaman and Nicobar Islands. James (1971 a) also recorded *Ophiarthrum pictum* from Nicobar which is a new record to the Indian Ocean. G.C. Rao (1973) described juvenile stages of apodous holothurian *Patinapta ooplax* from Andamans. This species seems to be common in the supra-littoral zone at Andamans. Daniel and Haldar (1974) have stated that 32 species of holothurians are known from Andaman and Nicobar Islands based on earlier reports. G.C. Rao (1975 a, 1975 b) described a new species of *Trochodota* from Havelock Island near Port Blair and *Leptosynapta sp.* from interstitial sands of Andamans. Haldar and Chakrapani (1976) reported *Culcita schmideliana* as *C. pentangularis* from Rangat Bay Jetty. The photogtaph published by them is unmistakable. Soota and Sastry (1979) reported the starfish *Echinaster luzonicus* from Nicobar. The distnction of this species from *E. purpureus* remains to be checked. G.C. Rao (1980) reported *Trochodota havelockensis* and *Leptosynapta sp.* from interstitial sands of Andaman and Nicobar Islands. Soota *et al.* (1983) reported 19 species of holothurians from Andaman and Nicobar slands. Rao and Roy (1985) reviewed the investigations on echinoderms of Andaman and Nicobar Islands which is not complete. Recently James (1986 e, f) reported two interesting holothurians from Andamans.

Dr. Stanley Gardiner carried out an extensive survey in the Maldives and Minicoy Island, the southern most of the Lakshadweep group of Islands. Echinoderms other than holothurians were reported by Bell (1902). Corrections for some of the species have been given by A.M. Clark and Davies (1966). Holothurians of Gardiner's collection was dealt in a cursory manner by Pearson (1913, 1914). James (1969) recorded about 40 species from the various Islands of Lakshadweep. Nagabhushanam and Rao (1972) have recorded some echinoderms from the Minicoy Atoll. Some of the species have been identified only up to generic level. Daniel and Haldar (1974) listed 23 species of holothurians from the Lakshadweep. Sivadas (1977) has stated that *Acanthaster* sp. has not been reported from the Lakshadweep. James (1969) has reported *Acanthaster planci* from Kadamat Island (Lakshadweep) earlier. Murty *et al.* (1979) reported the occurrence of crown of thorns *Acanthaster planci* from Minicoy Atoll. They are of the opinion that the intensity of the present population is natural and do not seem to threaten the coral reefs. Recently Mukhopadhyay and Samanta (1983)

reported 12 species of holothurians from the Islands of Androth, Kalpeni and Minicoy. Detailed survey needs to be conducted in the Lakshadweep especially for the commercially important species of holothurians. Rao and Misra (1983) recorded the holothurian *Leptosynapta* sp. as an interstitial form from Lakshadweep.

In recent works like A. M. Clark (1967, 1968) where echinoderms from India have been commented upon precise measurements and the ratios have been given while describing the species. This is a definite improvement over the mere descriptive notes of earlier workers. The publication of a monograph by A.M. Clark and Rowe (1971) on the shallow water echinoderms of Indo-West Pacific can be said to an important landmark in the taxonomy of echinoderms. They have also corrected and commented on the identity of some of the echinoderms from India.

Anatomy

Works on anatomy are in general rare. This is particularly so in case of Indian forms. In order to fill this lacuna Indian Animal Type series was started by late Dr. K. N. Bhal. Aiyar (1938) was the first person to work on the anatomy of the sea urchin *Salmacis bicolor* (Pl. I B) and published under Indian Animal Type series on the lines of L.M.B.C. Memoirs. Aiyar and Menon (1944) reported on the spicules of *Salmacis bicolor* and *Stomopneustes variolaris*. James (1967, 1968 b) has given the gross anatomy of the holothurians *Phyllophorus (Phyllophorella) parvipedes* and *Stolus buccalis* respectively. G.C. Rao (1968) has given the anatomy of the holothurian *Psamothuria ganapatii* found in the interestitial sands of Waltair. Mary Bai and Ramanathan (1977) have published the internal anatomy of the holothurian *Holothuria (Semperothuria) cinerascens* collected from Kanyakumari coast. The present author has worked out the anatomy of the sea urchin *Stomopneustes variolaris* in detail which will be published elsewhere. Mary Bai (1978, 1980) has published on the anatomy and histology of the commercially important sea cucumber *Holothuria scabra*. Except for the works of Aiyar (1938) and Mary Bai (1980) other papers cited above give only stray observations on the anatomy of holothurians.

Mary Bai (1971) studied the regeneration in the holothurian *Holothuria scabra*. Sastry (1985 d) has published on the digestive enzymes of the sea urchin *Stomopneustes variolaris*.

Reproductive Physiology

Considerable amount of work has been done on the reproductive physiology of echinoderms by Pearse (1969 a, 1969 b, 1969 c) and others. In India leadership in this line was given by Prof. S. Krishnaswamy under whose supervision reproductive physiology of common starfish and holothurian has been worked out. Giese *et al.* (1964) made reproductive and biochemical studies on the sea urchin *Stomopneustes variolaris* from Madras Harbour. Unfortunately the common starfish has been referred to the genus *Oreaster* by K. S. Rao (1965, 1968 a, 1968 b) and Rahman (1966, 1968) which is known only from the Atlantic. The correct name of the starfish on which they worked is *Pentaceraster regulus*. Krishnaswamy and Krishnan (1967) have worked on the reproductive cycles of *H. scabra* and found that it breeds two times in an year once in July and again in October. Krishnan (1976) made biochemical and cytochemical observations of the nucleic acids in the gonads of *Holothuria scabra*. Krishnan (1968) also made histochemical studies on reproductive and nutritional cycles of the holothurian *Holothuria scabra*. Sastry (1985 c) described the gonadal cycles in *Stomopneustes variolaris*.

Very little work is done on the physiology of echihoderms in India. Krishnan and Krishnaswamy (1970)and Krishnan (1971) have conducted studies on the transport of sugars in *Holothuria scabra*. Krishnan and Mary Bai (1977) have studied the effect of starvation on the nutrient reserves in the gut, test and gonad of *Salmacis virgulata*.

Development and Larval Forms

Echinoderms particularly sea urchins lend themselves well for developmental studies since it is easy to obtain ripe specimens, strip them, fertilise them in the laboratory and follow their development. Mortensen (1921, 1931, 1937) has produced admirable pieces of work on the development and larval forms of echinoderms. In India not much work is done in this line. K. S. Menon (1931) was the first person to describe echinoderm larvae from Madras. M.A.S. Menon (1945) and George (1953) described some echinoderm larvae from Trivandrum and Calicut respectively. Aiyar (1936) studied the early development and metamorphosis of the sea urchin *Salmacis bicolor* from Madras. Anantharaman (unpublished) worked on the development of another sea urchin *Temnopleurus toreumaticus* and other echinoderms from Madras in 1940. Prasad (1954) discussed the distribution and fluctuations of echinoderm larvae off Mandapam. Shetty (1960) published an account of early development of the common sea urchin *Stomopneustes variolaris*. James (1973 b) studied the early development of the starfish *Asterina burtoni* by allowing it to spawn in the laboratory. Meenakshikunjamma and Gopalakrishna (1977) gave description of echinoderm larvae in the Indian Ocean. In most of the above cases the larvae were identified upto class level only. Also the larvae could not be maintained beyond a few days due to feeding problems. Now with advanced hatchery techniques adopted for prawns, edible oyster and pearl oyster it should be possible to rear them to any stage by initialty feeding them with microalgal cultures.

Ecology

Most of the echinoderms being intertidal inhabiting chiefly on coral reefs, sandy beaches, muddy flats and rocky coasts have interesting ecological habits. Though a number of papers have been published on taxonomy of echinoderms notes on their habits and ecology are sadly missing. This is understandable in olden days to some extent since the material was collected and sent to specialists for reporting without furnishing them any notes on the habits. The author has made observarions on the habits of most of the intertidal echinoderms collected by him with the help of mask and snorkel (James, 1978 b). G. S. Rao (1968, 1973) has given an account ot autoecology of the holothurians *Psamothuria ganapatii* and *Patinapta ooplax* from Waltair and Andamans respectively. Nagabhushanam and Rao (1972) stated that many echinoids like *Stomopneustes*, *Echinometra* and *Salmacis* occupy depressions in the coral rocks at Minicoy island. Murty *et al.* (1979) stated that 2–3 adult specimens of *Acanthaster planci* are distributed in 1 sq.km. in the Minicoy Atoll. Reuben *et al.* (1980) have given some ecological notes on *Stomopneustes variolaris* from Waltair and stated that 8.5 numbers are distributed per sq.metre. Narasimham *et al.* (1984) estimated 2,270 tonnes of the holothuiran *Acaudina molpadoides* in Kakinada Bay which range in size from 20–160 mm in length. From their data it is seen that it is abundant where salinity is more. James (1971 a) described the ecology of the brittle star *Amphioplus depressus* from Cochin. They live on muddy bottom at a depth of 3–20 metres. They were found to live in fairly dense communities with 10 to 20 individuals in each square metre. Sastry (1985 b) has studied the boring activity of the sea urchin *Stomopneustes variolaris* from Visakhapatnam. About 8–10 burrows per linear metre occur. It is of interest that only

large forms only are found in the intertidal region In February 1985 the author presented a paper on the ecology of intertidal echinoderms of the Indian Seas, at the Second National Seminar on Marine Intertidal Ecology organised by the University Grants Commission and the Zoology Department of the Andhra University. In that paper echinoderms of the supra littoral, mid littoral and sub littoral zones are described. James (1986 c) has also presented a paper on the boring and fouling echinoderms of the Indian Seas. The adaptations of the various species including the epizoic forms are given in the paper. Echinoderms have no osmoregulation powers and therefore do not occur in estuaries and backwaters. Evangeline (1966) reported swarming of the brittle star, *Ophiocnemis marmorata* (Pl. I C) from the Ennore backwaters. The present author has also collected the holothurian *Acudina molpadioides* from Ennore backwaters. James (1978 b) has collected the apodus holothurian *Anapta gracilis* from the Krishna estuary at Machilipatnam. In all the above cases the salinity of the water in the estuary and backwaters was high just like sea water.

Animal Associations

Echinoderms show very interesting associations with other organisms or with themselves. Dr. Jones being a renowned naturalist is a pioneer in this field. He not only made several interesting observations himself, but encouraged others to work in this line. Jones (1964) reported the association of the starfish *Pentaceros hedemani* (= *Pentaceraster regulus*) and a hesinoid polychaete *Podarke angustifrons*. This association appears to be common in the Gulf of Mannar and Palk Bay. Jones and Sankarankutty (1960) observed the association of the pea crab *Harovia albolineata* on the feather star *Lamprometra sp.* (= *Lamprometra palmata*). Chopra, (1932) Jones and Mahadevan (1966) have recorded the association of the pea crab *Pinnotheres decanensis* from the sea cucumber *Holothuria (metriatyla) scabra.* The present author made detailed observations on how the crab gains entry into the holothurian and these will be published elsewhere. Another species of crab *Lissocarcinus orbicularis* is found to live as a commensal among the tentacles of the holothurian *Actinopyga mauritiana* at Port Blair, Andamans. Sometimes even two or three were found to live on a single specimen. The tentacular collar is deep like a cup in which the tentacles are situated. This offers excellant protection for the crabs. The crabs were never seen outside and they come out only when the holothurian is killed. The crab is brown with white patches and it is well camouflaged on this species of holothurian which is brown with white patches. Both males and females were collected. Bakus (1973) has also mentioned about this association. James (1978 a) reported *Pinnotheres sp.* from the holothurian *Pseudocolochirus violaceus* from Mandapam. The association of Carapid fish with holothurians is well known. Mukerji (1932) gave an account of the fishes associated with holothurians from Andamans. Arnold (1953) presented some observations on the habits of Carapid fish. The author has collected the fish *Encheliophis (Jordanicus) gracilis* from the holothurian *Holothuria (Thymiosycia) arenicola* and another species of fish *Encheliophis vermicularis* from Port Blair. Detailed observations were made on the behaviour of the fish which will be published elsewhere. Jones and Kumaran (1980) have reported two Carapid fishes *Carapus parvipinnis* and *Carapus homei* from the holothurian *Holothuria marmorata* (= *Bohadschia mormorata).* They also reported *Carapus mourlani* from the body cavity of the starfish *Culcita novaeguinea* (Pl. I D). The author has also cut open many specimens of *C. schemdeliana* at Port Blair, but did not find any Carapid fish inside the body-cavity. Ganapati and Sastry (1972) have studied the association of the Alpheid *Athanas indicus* on the sea urchin *Stomopneustes*

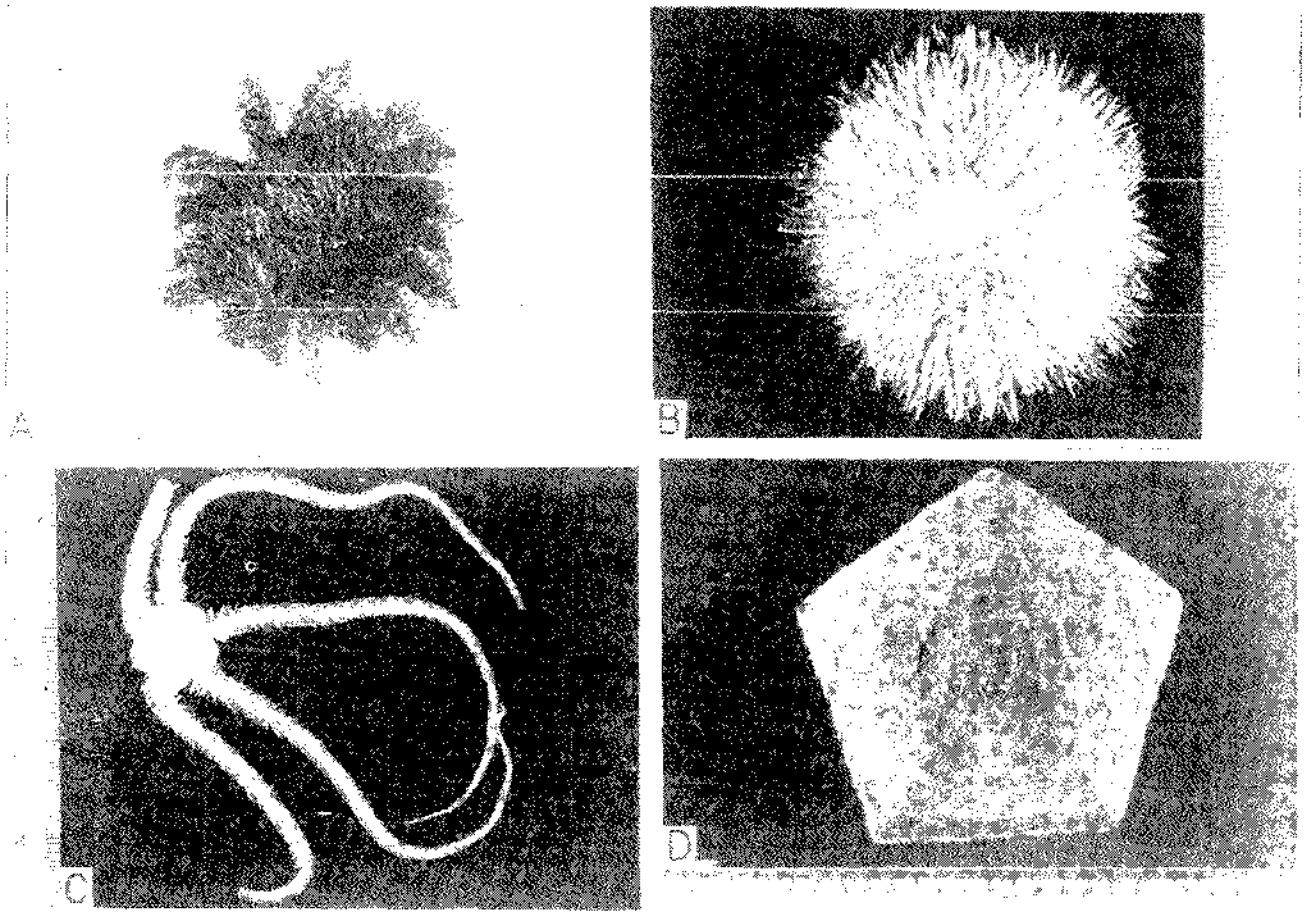

PLATE I A. *Acanthaster planci*. B. *Salmacis bicolor*. C. *Ophiocnemis marmorata* and D. *Culcita schmideliana*.

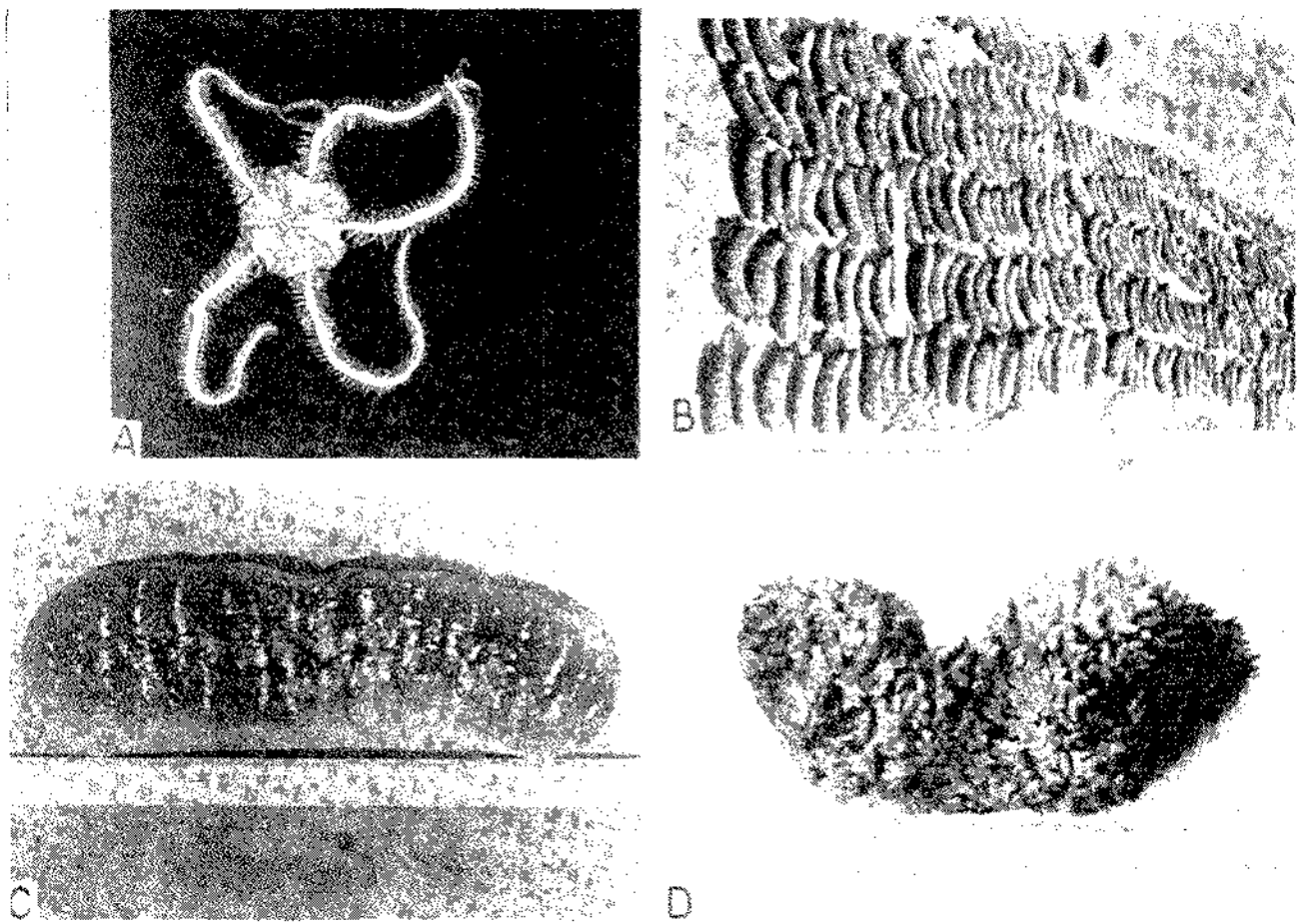

PLATE II. A. *Ophiomaza cacaotica*, B. *Beche-de-mer* or *Trepang*, C. *Holothuria scabra* and D. *Thelenota ananas*.

variolaris from Visakhapatnam coast. The present author also observed this association in Vizhinjam. Sastry (1981) reported on the crustacean associates from the Bay of Bengal. Kathirvel (personal communication) has seen a black crab living in association with the sea urchin *Stomopneustes variolaris* at Muttom, near Cape Comorin. The association of the ophiuroid *Ophiomaza cacaotica* (Pl II A) with feather stars is well known and is even considered as semiparasitic (A. M. Clark, 1967 c). H. L. Clark (1921) recorded the same species of birttle star from the feather star *Capillaster sentosa* from Singapore and from *Heterometra reynaudi* from Palk Strait and Sri Lanka. The brittle star *Gymnolophus obscure* was collected from the feather star *Comanthina schlegeli*. Panikkar and Prasad (1952) have reported on the association of the brittle star *Ophiocnemis marmorata* with the medusa *Rhopilenema hispidum* from Mandapam. The author has also collected the brittle star *Ophiocnemis marmorata* from Mandapam in 1963 from the same medusa. Evangeline (1966) reported *A. flagellatus* from the Ennore Backwaters. Chacko *et al.* (1953) also recorded this ophiuroid from the jelly fish *Acromites flagellatus*. H.L. Clark (1946) has collected the brittle star *Ophiogymna lineata* by dredging over alcyonarian beds belonging to the genus *Spongodes sp.* The present author has also collected the brittle star from the same aloyonarian. Ganapati and Radhakrishna (1963) recorded a hesionid polychaete from the holothurian *Molpadia* sp. (= *Acaudina molpadioides*) as an instance of inquilinism from Kakinada Bay. Nayar and Mahadevan (1965 a) recorded *Chondrocloea striata* (= *Synaptula striata*) from the sponge *Petrosia sp.* Nayar and Mahadevan (1965 b) have also recorded the feather stars *Lamprometra* sp. and *Comanthus* sp. from the gorgonid *Juncella* sp. from the pearl banks off Tuticorin. Sastry (1985 a) reported the occurrence of the polychaete *Polydora antennata* from the sea urchin *Stomopneustes variolaris*. James (1987 a) submitted a paper on animal associations in echinoderms.

Parasites

Being somewhat sluggish animals the echinoderms are subjected to the attack of a host of parasites. Echinoids and asteroids which have regid bodies have pedicellariae which can remove and destroy the larvae of the parasites settling over them. More than 400 parasites have been recorded from echinoderms. About one third of these live either on or in holothurians which appear to be very suitable hosts for parasites. The brittle stars are more agile and escape from the attack of parasites to some extent. In Indian our knowledge of parasites of echinoderms is limited. C.P. Rao (1964, 1965) described a new genus and a new species of copepod parasite from the star fish *Pentaceraster hedemani* (= *Pentaceraster regulus*). The copepod parasite *Pseudoanthssis suculentus* was collected from the sea urchin *Stomopneustes variolaris*. A single parasitic gastropod *Thyca* sp. belonging to the family Capulidae is collected from the body surface of the starfish *Goniodiscaster scaber*. The shell of the parasite has single whorl and slightly bent and trumpet shaped. It was found attached to one of the infromarginal plates. Amphiurid brittle star *Amphipholls squamata* has both external and internal copepod parasites. The external copepod parasite *Cancerella* sp. belongs to the family Asterocheridae. It is found attached to the ventral side at the base of arm with the head of the parasite always directed towards the mouth of the host. About 30% of the brittle stars belonging to this species are found to have an endoparasitic copepod *Philichthys* sp. in the genital bursae. It occurs only in large specimens where the genital bursae are well developed. The presence of the parasite alters the shape of the disc from round to oval. The colour of the bursae with the parasites is pink. Jones and James (1971) have pulished and

account of an internal gastropod parasite belonging to the family Stiliferidae from the cloacal chamber of the holothurian *Holothuria atra*. Over 1300 specimens of *Holothuria atra* ranging in length from 80 to 350 mm were examined for internal commensals, and parasites, and of these, eight were found to harbour gastropods belonging to the genus *Stilifer* in their cloacal chhmbei. Thirteen parasites were collected in all, of which three had egg capsules between the shell and the pseudopallium. The parasite appears to be new to science and its early development is worked out.

Utility

As a group echinoderms have little utility except for some sea cucumbers and some sea urchins. Some of the starfishes are dried and sold as curios in Singapore and Honkong markets It is interesting to note that due to their beauty and symmetry one starfish *Protoreaster lincki* was collected by the late Salar Jung a connoisseur of art and is deposited in his museum at Hyderabad. The smaller starfishes, brittle-stars, sea-urchins and sea-feathers are dried along with other bycatch and used as poultry feed. The ripe eggs of some species of sea urchins are prized food items in Japan and other South East Asian Countries. James (1983) has mentioned about the Sea cucumber and sea urchin resources from Andamans. The ripe gonads of the sea urchin *Stomopneustes variolaris* are eaten in raw condition near Cape Comorin. Reuben *et al.* (1980) have estimated 1224 metric tonnes of *Stomopneustes variolaris* in 30 km coast line at an average rate of 8.5 numbers per sq.m. along the Visakhapatnam Coast. The ripe gonads of the sea urchin *Tripneustes gratilla* are in much demand. It is abundant in some of the Lakshadweep Islands. This species is distributed in the Gulf of Mannar and also at Andamans. One sea urchin *Salmacis virgulata* occurs in good numbers off Madras. Specimens with test diameter varying from 50 to 65 mm are caught in the trawlers. Some of them have ripe eggs weighing about 10 g. The potential of this resource remains to be studied and exploited.

The holothurians are the most important group commercially in echinoderms. Certain species of holothurians are used in the preparation of *Beche-de-mer* or *Trepang* (Pl II B) which is used in soups in China and other South East Asian countries. The suitable holothurians are degutted, boiled and dried and this forms the commercial product *Beche-de-mer*. This product has no internal market. At present India is exporting about 20 lakhs worth of *Beche-de-mer* annually. This is at present contributed by a single species *Holothuria scabra*. There are half a dozen commercially important species. Some of these holothurians are more valuable than *H. scabra* but are not unfortunately used due to ignorance. Hornell (1917) traced the history and revival of the *Beche-de-mer* industry in India. James (1973 a) has given an account of the *Beche-de-mer* resources of India. Jacob (1973), Shenoy (1977) and Durairaj (1982) have published general accounts of *Beche-de-mer* industry in India. James (1983) published an account of the *Beche-de-mer* resources of Andamans and also described the nacent *Beche-de-mer* industry there Soota *et al.* (1983) have listed 11 species of holothurians from Andamans used in *Beche-de-mer* industry Of these *Holothuria atra, Stichopus chloronotus* and *S. varigatus* are definitely not useful for *Beche-de-mer* preparation. The utility of *Bohadschia marmorata, Holothuria edulis, H. hilla* and *H. impatiens* remains to be seen. Durairaj *et al.* (1984) studied the quality of *Beche-de-mer* in trade and shrinkage of the specimens during processing. Recently James (1986 a) has described methods for the improvement of the quality of *Beche-de-mer*. At present the industry is restricted to the Gulf of Mannar and Palk Bay and to some extent around Port Blair. Hornell (1917) stated that

he has seen small quantity of *Beche-de-mer* dried in Kilton Island in 1908. Three species of commercial importance were observed there. The methods of curing were different from those adopted in the Gulf of Mannar and Palk Bay and they resembled closely to those in Australia and Polynesia. Unfortunately at present there is no processing in Lakshadweep and there is an urgent need to extend the industry to these Islands. Thorough survey of the resources of the Gulf of Kutch and other places along the Indian coast line has to be urgently conducted. Government of India has put a ban on the export of *beche-de-mer* below 3" in 1982 in order to conserve the resource. Detailed studies on the resources and biology of commercially important holothurians has to be undertaken before taking a decision to lift the ban. The holothurian *Thelenota ananas* (Pl. II D) is very important in Lakshadweep.

Culture

There does not seem to be any report or paper on the culture of sea cucumbers from any part of the world. In view of the good prices (US $ 17.00 per Kg offered for export the possibilities have to be explored. James (1985) made an attempt to culture *Holothuria scabra* (Pl II C) by collecting young forms and stocking them in enclosed areas. In February, 1978 a total of 462 juveniles of *H. scabra* ranging in length from 65 to 160 mm (model class 81–90 mm) were collected from the Sesostris Bay and broadcast in an enclosed area of 1.5 hectares near Aberdeen jetty. The bottom was partly muddy and partly sandy. At the end of July, 1978, they had grown to 190–290 mm. The results were also published in CMFRI Newsletter (Anon., 1978). The incomplete experiment gave some indication of the possibilities of semi-culture of sea cucumbers. The most important aspect of culture is the development of hatchery system. Mortensen (1937, 1938) studied the development of many commercially important holothurians on the Egyptian coast of Red Sea. Now these experiments have to be repeated and the larvae have to be fed by microalgae till they reach doliolaria stage. Later they can be transfered to enclosed muddy areas and allow them to grow. This is an area of research which needs to be attended immediately.

Distribution and Zoogeography

The study of zoogeography of echinoderms is interesting owing to their relatively sendentary habits, their aversion to fresh or even brackish water, the brevity or complete absence of a free simming larval life and usually small bathymetrical range. Bell (1887 b) wrote on the zoogeography of Indian echinoderms. James (1971 c) mentioned the distributional pattern of the echinoderms of the Indian Ocean. G. C. Rao (1980) described the zoogeography of the interstial forms like *Trochodota havelockensis* and *Leptosynapta sp.* from Andamans. Sastry (1985 b) made observations on the distribution of *S. variolaris* along Visakhapatnam coast. James (1985 a) published a detailed paper on the zoogeography of shallow-water echinoderms of Indian Seas. He noted that despite the close proximity of India to Sri Lanka there is a marked difference in the species composition of echinoderms along the respective coasts. This distributional pattern is rather difficult to explain since most of the echinodems have a wide range of distribution in the Indo-Pacific region. As many as 178 species of echinoderms are known from the shallow waters within 20 metres depth on the Sri Lanka side whereas from the opposite shore in India only 103 species are known from the Indian side, 14 are recorded for the first time by the author. It should be noted that after the survey H. L. Clark (1915) on Sri Lanka echinoderms there is no report on them from that region. Since most of them are widely distributed species atleast some of them are likely to be

taken on the Sri Lanka side. Not only some species but some genera and even families are not represented on the Indian side. This difference in distribution cannot be due to inadequate collection on the India side as the author has made extensive and intensive collections regularly in the Gulf of Mannar and Palk Bay along the Indian coast for seven years and has also examined all the echinoderms collected by the underwater survey team over a number of years form the pearl banks off Tuticorin. Suitable habitats do occur for the echinoderms on the Indian side also. This difference in distribution could be due to the role played by the currents and is indicative of the presence of a barrier which does not favour movements of echinoderms from Sri Lanka to the Indian side. Another important factor is the 'area effect' referred to by Price (1982). The Sri Lankan coast is far more extensive than that of the narrow coast line of the Gulf of Mannar and Palk Bay on the Indian side. Therefore corresponding increase in species diversity is apparent. A. M. Clark (1980) commented on the poorness of the echinoderm fauna of Hong Kong. It shows remarkable resemblence to the faunal composition of the Gulf of Mannar and Palk Bay on the Indian side in the total absence of the forms belonging to the family Ophiocomidae.

Toxicology

Some of the echinoderms have toxins in their bodies as a defensive mechanism. These toxins are of medicinal value. James (1980 b) conducted some experiments on the toxin of the holothurian *Holothuria atra*. D. S. Rao *et al.*, (1985) described the bioactivity of Indian echinoderms. Much work remains to be done in this line.

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Bibliographies are of great use in research work and their importance needs no special mention. Yentisch (1962) edited a partial Bibliography of the Indian Ocean for the International Indian Ocean Expedition under U.S. Programe for biology in which one section is devoted to echinoderms. James and Lal Mohan (1969) brought out a Bibliography of the echinoderms of the Indian Ocean where nearly 700 references are listed. Jones (1971) while editing the Bibliography of the Indian Ocean updated the echinoderm section.

APPENDIX

Identification By Bell (1887)	Correct Identification
Acanthaster echinites E & S	*Acanthaster planci* (Linnaeus)
Fromia tumida Bell	*Fromia indica* (Perrier)
Scytaster novae-caledoniae Perrier	*Nardoa lemonnieri* Koehler
Ophiolepis annulosa M & T	*Ophiolepis superba* H. L. Clark
Echinometra lucunter Leske	*Echinometra mathaei* (de Blainville)
Chirodota rufescens Brandt	*Polycheira rufescens* (Brandt)
Haplodactyla andamanensis Bell	*Acudina molpadioides* (Semper)
Holothuria albida Bell	*Holothuria (Halodeima) edulis* Lesson
Holothuria cadelli Bell	*Holothuria (Metriatyla) scabra* Jaeger
Holothuria lineata Bell	*Holothuria (Lessonothuria) pardalis* Selenka
Holothuria papillata Bell	*Holothuria (Acanthotrapeza) pyxis* Selenka
Holothuria mormorata Jaegar	*Bohadschia marmorata* Jaeger
Holothuria monocaria Lesson	*Holothuria (Thymiosycia) hilla* Lesson
Holothuria vagabunda Selenka	*Holothuria (Mertensiothuria) leucospilota* Brandt

Identification By Bell (1888)	Correct Identification
Antedon palmata Muller	*Lamprometra palmata* (J. Muller)
Antedon reynaudi Muller	*Heterometra reynaudi* (J. Muller)
Actinometra parvicirra Muller	*Capillaster multiradiatus* (Linnaeus)
Oreaster lincki de Blainville	*Protoreaster lincki* (de Blainville)
Oreaster thurstoni Bell	*Pentaceraster affinis* (M & T)
Asterina cepheus M & T	*Asterina burtoni* Gray
Salmacis sulcata Agassiz	*Salmacis virgulata* L. Agassiz
Echinometra lucunter Leske	*Echinometra mathaei* (de Blainville)
Laganum decagonale Leske	*Laganum depressum* Lesson
Echinodiscus bisforis Gm	*Echinodiscus bisperforatus* Leske
Echinolampas oviformis Gm	*Echinolampas ovata* (Leske)
Brissus unicolor Leske	*Brissus latecarinatus* (Leske)
Haplodactyla australis Semper	*Acaudina molpadioides* (Semper)
Holothuria marmorata Jaeger	*Bohadschia marmorata* Jaeger
Holothuria monocaria Lesson	*Holothura (Thymiosycia) hilla* Lesson
Holothuria vagabunda Selenka	*Holothuria (Mertensiothuria) leucospilota* Brandt

Identification By Bell (1889)	Correct Identification
Anthenea acuta Perrier	*Anthenea pentagonula* (Lamarck)
Goniodiscus granuliferus Gray	*Goniodiscaster scaber* (Mobius)
Oreaster mammillatus Aud	*Pentaceraster regulus* (M & T)
Cucumaria semperi Bell	*Hemithyone semperi* (Bell)
Colochirus quadrangularis Jaeger	*Pentacta quadrangularis* (Lesson)
Ophiothrix aspidota M & T	*Macrophiothrix aspidota* M & T

Identification By Thurston (1887)	Correct Identification
Pentaceros muricatus Thurston	*Protoreaster lincki* (de Blainville)
Laganum decagonale Leske	*Laganum depressum* Lesson
Goniodiscus granuliferus Gray	*Goniodiscaster scaber* (Mobius)
Echinolampas oviformis Gm	*Echinolampas ovata* (Leske)

Identification By Thurston (1890)	Correct Identification
Temnopleurus renynaudi L. Agassiz	*Temnopleurus toreumaticus* (Leske)
Salmacis sulcata Agassiz	*Salmacis virgulata* L. Agassiz
Oreaster thurstoni Bell	*Pentaceraster affinis* (M & T)
Oreaster lincki de Blainville	*Protoreaster lincki* (de Blainville)
Echinodiscus bisforis Gm	*Echinodiscus bisperforatus* Leske
Colochirus quadrangularis Jaeger	*Pentacta quadrangularis* (Lesson)

Identification By Thurston (1894)	Correct Identification
Goniodiscus granuliferus Gray	*Goniodiscaster scaber* (Mobius)
Anthenea acuta Perrier	*Anthenea pentagonula* (Lamarck)
Pentaceros muricatus Thurston	*Protoreaster lincki* (de Blainville)
Pentaceros thurstoni Bell	*Pentaceraster affinis* (M & T)
Asterodiscus elegans Gray	*Asterodiscides elegans* Gray
Asterina cepheus M & T	*Asterina burtoni* Gay
Linckia miliaris V. Martens	*Linckia laevigata* (Linnaeus)
Echinometra lucunter Leske	*Echinometra mathaei* (de Blainville
Echinodiscus bisforis Gm	*Echinodiscus bisperforatus* Leske
Cucumaria semperi Bell	*Hemithyone semperi* (Bell)
Colochirus quadrangularis Jaeger	*Pentacta quadrangularis* (Lesson)
Haplodactyla australis Semper	*Acaudina molpadioides* (Semper)
Holothuria marmorata Jaeger	*Bohadschina marmorata* Jaeger
Holothuria monocaria Lesson	*Holothuria (Thymiosycia) hilla* Lesson
Holothuria vagabunda Selenka	*Holothuria (Mertensiothuria) leucospilota* Brandt
Synapta recta Semper	*Synaptula recta* (Semper)

Identification By Gravely (1927)	Correct Identification
Pentaceros hedemani (Lutken)	*Pentaceraster regulus* (M & T)
Asterina cephea (M & T)	*Asterina burtoni* Gray
Ophiophragmus relictus (Koehler)	*Amphioplus graveylii* James

Ophiothrix hirsuta M & T	*Macrophiothrix aspidota* (M & T)
Holothuria lubrica Selenka	*Holothuria (Selenkothuria) moebii* (Ludwing)
Holothuria monocaria (Lesson)	*Holothuria (Thymiosycia) hilla* Lesson
Thyone sacellus (Selenka)	*Stolus buccalis* (Stimpson)
Synapta recta Semper	*Synaptula recta* (Semper)
IDENTIFICATION BY GRAVELY (1941)	CORRECT IDENTIFICATION
Tropiometra encrinus A. H. Clark	*Tropiometra carinata* (Lamarck)
Astropecten mauritianus Kohler	*Astropecta indicus* Doderlein
Thyone sacellus (Selenka)	*Stolus buccalis* (Stimpson)
Pentaceros hedemanni Lutken	*Pentaceraster regulus* (M & T)
IDENTIFICATION BY KURIAN (1953)	CORRECT IDENTIFICATION
Ophiocnemis sp.	*Ophiocnemis marmorata* (Lamarck)
IDENTIFICATION BY HARDAR & CHAKRAPANI (1976)	CORRECT IDENTIFICATION
Culcita pentangularis Gray	*Culcita schmideliana* (Retzius)

LIST OF ECHINODERMS COLLECTED FROM MADRAS

Tropiometra carinata (Lamarck)
Luidia maculata Muller & Troschel
L. hardwicki (Gray)
Astropecten bengalensis Doderle
Stellaste requestris (Retzius)
Metrodira subulata Gray
Anthenea pentagonula (Lamarck)
Pentaceraster indicus (Koehler)
Ophiocnemis marmorata (Lamarck)
Ophiactis savignyi Muller & Troschel
Ophiothrix exigua Lyman
Astropyga radiata (Leske)
Salmacis bicolor L. Agassiz
S. virgulata L. Agassiz
Temnoplewrus torewmaticus (Leske)
Echinodiscus auritus Leske
Clypeaster humilis (Leske)
Metalia sternalis (Lamarck)
Stolus buccalis (Stimpson)
Phyllophorus (Phyllophorella) parvipeds H.L. Clark
Phyllophorus (Urodemella) brocki Ludwig
Holothuria (Theelothuria) spinifera Theel
Bohadschia marmorata Jaeger
Acaudina molpadiiodes (Semper)

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