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Ecology of fouling bryozoans at Visakhapatnam harbour*

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Abstract. Twelve species of bryozoans occur in the fouling communities at Visakhapatnam Harbour, of which the encrusting cheilostome-*Electra bengalensis* (Stoliczka) is by far the most common. The horizontal distribution of bryozoans at four selected stations in the harbour is recorded. Quantitative data on the seasonal abundance and settling rates of *E. bengalensis* and some of the prevailing hydrographical conditions, i.e. temperature, salinity and turbidity data, are given for one year (December 1966 to November 1967). The observations indicate that *E. bengalensis* is a continuous breeder and also a fast growing species. The influence of temperature and salinity on its breeding and abundance is discussed.

While only 12 species of bryozoans occur in the harbour, the number of species occurring in the nearby foreshore localities at Visakhapatnam ranges from 20 to 34. The effect of some factors (pollution, salinity, silting larval type and fouling) which may influence the distribution of bryozoans is discussed.

Keywords. Fouling bryozoans; ecology; *E. bengalensis*.

1. Introduction

Bryozoans are known to be one of the principal components of ' fouling '. At least 54 species of bryozoans have so far been listed from Ship's hulls from the world's oceans (Ryland 1971). Although, they are of lesser importance in terms of weight than barnacles and serpulids, some of them can cause a great nuisance by clogging intake pipes of the cooling systems. Dobson (1946) mentions the closure of an industrial salt water circuit because of heavy bryozoan fouling. Allen and Wood (1950) reported a similar instance from Australian harbours. The encrusting types not only contribute their weight to the substratum but also act as promoters for later settlements. If they happen to be copper resistant like *Watersipora arcuata* Banta, the problem can be really serious as the efficacy of most of the antifouling compositions utilizing copper compounds is drastically reduced (Skerman 1960; Banta 1969a). At some harbours of the world, like Montey harbour, USA (Haderlie 1969) and Western Norway (Nair 1961, 1962) bryozoan fouling has been reported to be very severe.

The first noteworthy mention of bryozoans as fouling organisms in Indian harbours was made by Iyengar *et al* (1957) at Bombay harbour. Subsequently, Gopalakrishnan and Kelkar (1958) reported an instance of extraordinary abundance of polyzoans during November to February, 1957–58 on copper sheathed hulls of naval

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crafts at the same harbour. These authors found that 60% of the total fouling settlement during this period was by bryozoans which were uniformly present through out the underwater portions of the hull. Daniel (1954) and Antony Raja (1959) observed a few bryozoans at Madras harbour. Ganapati *et al* (1958) mentioned three bryozoan species from Visakhapatnam harbour. More recently, Rao (1964) reported that at least two bryozoan species occurring at Bombay harbour (*Electra* sp., and *Membranipora* sp.) were copper resistant. From the same locality, Karande (1968) in his report on marine fouling organisms, mentioned 17 bryozoan species and regarded them as a major fouling group. Purushotham and Satyanarayana Rao (1971) summarized the information on fouling bryozoan species in the major Indian harbours up to 1970. Menon (1971) reported 14 species of bryozoans occurring on test panels at Cochin back waters and made a detailed study of their seasonal distribution and settling rates.

During the course of a detailed investigation on the littoral bryozoans at Visakhapatnam and its vicinity, Ganapati and Satyanarayana Rao (1968) recorded 9 bryozoan species from Visakhapatnam harbour. Since then, 3 more species have been recorded from the fouling communities. One interesting record of bryozoans at this harbour is that of *Bugula stolonifera* Ryland, which was recognised for the first time in the Indian Ocean during 1967 by Ganapati and Satyanarayana Rao (1968). This species was believed to have been introduced into the harbour through ship fouling. Similar introduction of bryozoans into new harbours, through transport by ships has been reported by various authors, elsewhere. Some of the recent bryozoan introductions into alien localities are: *Watersipora arcuata* at New Zealand (Skerman 1960) and California, USA (Banta 1969b); *Schizoporella unicornis* (Johnston) at Strait of Georgia (Powell 1970) and *Conopeum seurtii* (Canu) at the Caspian Sea (Ryland 1970).

Since bryozoans form an important component of the fouling complex in the local harbour, the present work was undertaken with a view to study their systematics and ecology which are essential to adopt effective preventive measures against their infestation.

2. Materials and methods

The Visakhapatnam harbour (Lat. 17° 41′ N. and Long. 83° 17′ E), located halfway between Madras and Calcutta, is a land locked, natural harbour. Its topographical features include a narrow entrance channel and four navigable arms radiating from a turning basin (figure 1). There are a number of industrial installations in the environs of the harbour. The waters are subjected to both industrial and domestic pollution and some of the well proved toxic pollutants are present in quantities well above the known tolerance level of marine organisms (Ganapati and Raman 1973). The harbour receives the fullest benefit of south-west monsoon (June-September) and some precipitation from the north-east monsoon (October-December).

Four stations, designated stations I to IV in figure 1, were selected for the present study. (Of these, stations I to III correspond to stations A, B, C, of an earlier study from this laboratory by Ganapati *et al* 1958). Of these, station I, located at the beginning of the entrance channel was nearest to the open sea, where the water is relatively clean and least polluted. Station II was located in the turning basin,

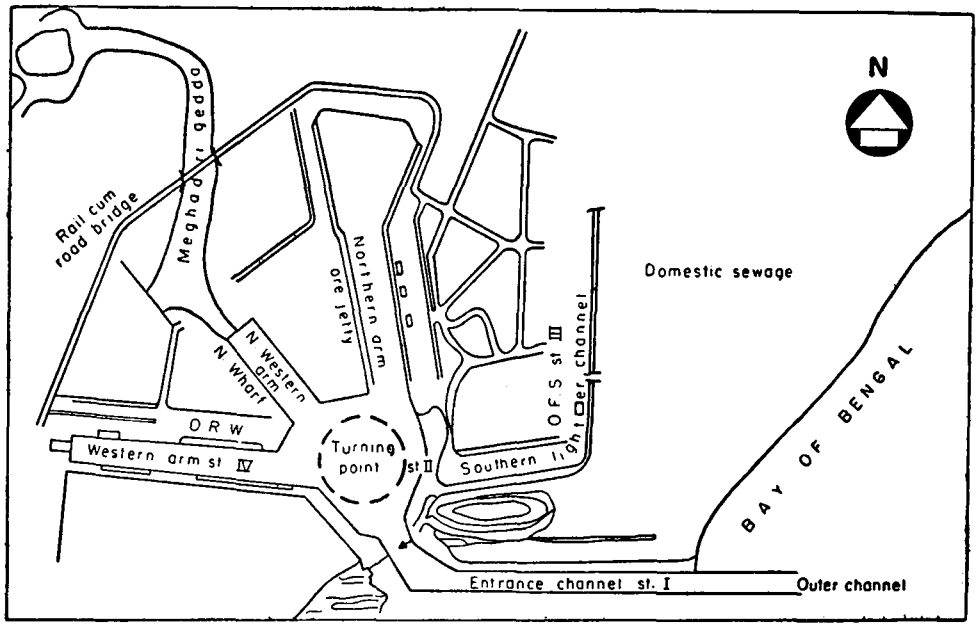


Figure 1. Visakhapatnam harbour station locations.

halfway between stations I and III. It is alternately inundated by the sea water from station I at the time of the high tide and by sewage polluted water from station III at the time of the low tide. Station III was located in the southern lighter channel, through which the town's sewage enters the harbour. There is heavy domestic pollution, high turbidity and practically anoxic conditions and emanation of H_2S at this station. Station IV is in the western arm at the INS circars jetty of the Indian Navy. Rock phosphates, sulphates and oil which spill into the waters during loading and unloading at the fertilizer and oil berths in this arm, are the principal sources of pollution.

Information on the occurrence and species composition of bryozoans was gathered from scrapings of the jetty-piles carried out periodically at all the four stations. To obtain quantitive data, wooden racks with grooves holding glass plates of the size 10×10 cm in a horizontal position were suspended 30 cm below the low water mark at these stations, but, due to vandalism, series after series of test panels were lost at all the stations excepting at the Naval Base (Station IV) which is a protected area. The methods followed to study the settling rates and seasonal abundance of bryozoans at this station are as follows: The glass plates were periodically removed at intervals of 1-week, 2-week, 3-week, and 4-weeks. Fresh sets of plates were introduced as soon as the old plates were removed. This would give information on the exact settlement during these intervals as well as the growth of the organisms. The glass plates were gently washed with sea water and brought to the laboratory in plastic containers having sufficient water. The number of colonies settled on each plate was counted with the aid of a binocular dissecting microscope. On the monthly panels, however, enumeration of individual colonies was difficult due to intense overlapping of the colonies and only the percentage coverage was taken into consideration for these plates. The area

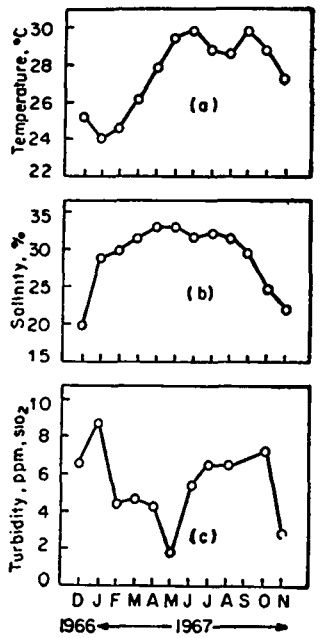


Figure 2. Hydrographical conditions at naval base.

occupied by the largest colony settled and the number of zooids in the colonies was also noted.

Data on temperature, salinity and turbidity of the sea water at the naval base for the period December 1966 to November 1967 are given in figure 2. The data were based on the analysis of water samples collected at weekly intervals bewteen 8.30 am and 9.30 am, irrespective of the state of the tide.

Water temperature was measured with a centigrade thermometer of 0·2° C, sensitivity and salinity was estimated by the standard Knudsen's method. Turbidity readings were taken by a Helliges' Turbidometer.

3. Observations and results

3.1. *Observations from the jetty piles*

Twelve species of bryozoans were collected during the present study from the jetties at Visakhapatnam harbour, of which, *B. Neritina* (Linnaeus), *B. stolonifera* Ryland. *A. distans* Busk, *Z. verticillatum* (delle Chiaje), *E. bengalensis* (Stoliczka) and *B. gracilis* Leidy were conspicuous in the collections by virtue of their size, density and frequency. Of these, *E. bengalensis* is an encrusting species and *B. gracilis* has creeping stolons but the rest have erect growth forms. All these species were represented in the collections made through out the year. Judged by the presence of embryonated ovicells/young colonies in the collections, they appear to breed throughout the year. Maximum size recorded for *B. neritina* was 80 mm (March-June 1967); for *B. stolonifera*, 55 mm (May, 1967); for *A. distans*, 90 mm (March-June 1967); for *E. bengalensis*, 1200 mm (December 1967-January 1968). The largest of the fouling bryozoans in the local harbour is *Z. verticillatum*, whose flaccid, gelatinous growths

attain heights of up to 1 m during the summer months. While all these six species were present on the jetties at stations I, II and IV, only two species, *E. bengalensis* and *B. gracilis* were represented at the highly polluted station III. The colonies of *E. bengalensis* at the station were thinner compared with the colonies at other stations and the zooids of *B. gracilis* attained relatively larger sizes (length of the zooid = 0·5 mm width of the zooid = 0·25 mm) compared with the forms at other stations (length of the zooid = 0·3 mm, width of the zooid = 0·2 mm).

The other bryozoan species were delicate, stolonate and inconspicuous in the field and do not contribute significantly to the fouling. These species and their stationwise occurrence in the harbour is given below:

Savignyella lafontii (Audouin) at station I; *N. papauensis* (Busk) at station I; *B. klugei* Cook at stations I, II, IV; *S. sibogae* (Harmer) at station I; *V. pavida* (S. Kent) at station IV and *B. nitens* Alders at stations I and IV.

From the above it could be seen that while all the species excepting the brackish water *V. pavida* occur at station I with relatively less polluted waters, only two species, *E. bengalensis* and *B. gracilis* could be collected at the most heavily polluted station III. Nine species (*E. bengalensis, B. neritina, B. stolonifera, B. klugei, V. pavida, A. distans, Z. verticillatum, B. gracilis* and *B. nitens*) were collected from the station IV and 7 species (*E. bengalensis, B. neritina, B. stolonifera, B. klugei, A. distans, Z. verticillatum* and *B. gracilis*) from station II.

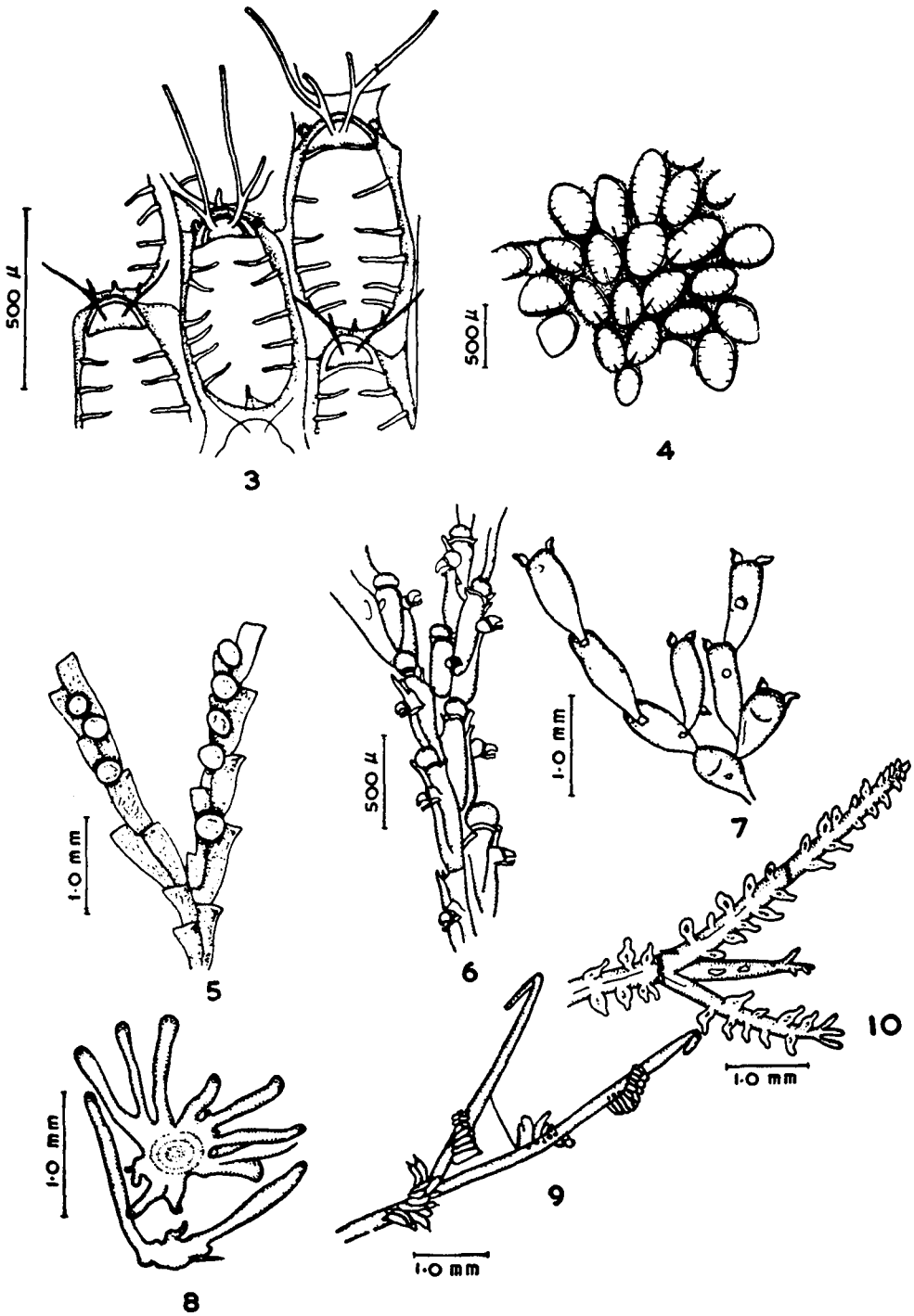
The bryozoans occurring in the Visakhapatnam harbour are presented in figures 3–15.

3.2. *Quantitative data gathered from glass plates immersed at naval base*

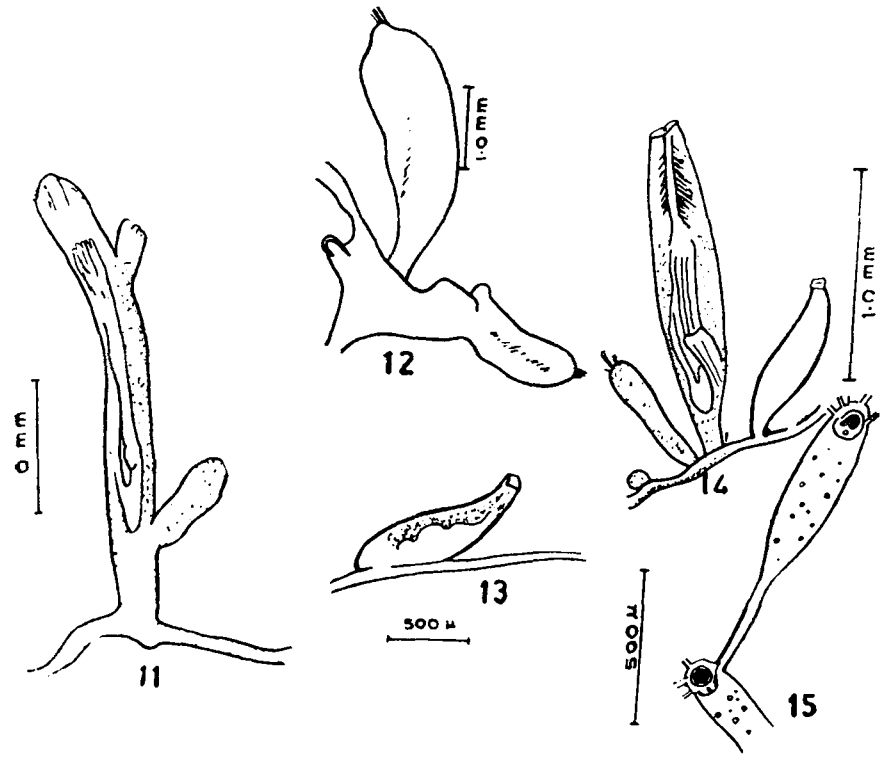
At this station, the following species of bryozoans settled on the glass plates; *B. neritina, B. stolonifera, B. gracilis, B. nitens* and *E. bengalensis*. Of these, the settlement of the first 4 species was sporadic. The texture of the substratum, angle of immersion of the test plates and over-crowding could be some of the probable factors imposing limitations on their settlements on the glass plates used. But *E. bengalensis* settled regularly on the test plates. The information on the settling rates, abundance and growth of this species based on the observations made during December 1966 to November 1967 are presented below:

Settlement of colonies of the encrusting bryozoan *E. bengalensis* was noticed on the glass panels (1-weekly, 2-weekly, 3-weekly and monthly panels) throughout the period under investigation (December 1966 to November 1967). On the 1-week panels, the newly attached cyphonautes, ancestrulae and other young stages of the colony were seen. The largest size attained by the colonies on the 1-week panels was 60 sq mm. The colonies on the 15-day panels were generally circular and the largest colony on these panels covered an area of 400 sq. mm. By 3-weeks, the once circular colonies became wrinkled at the periphery, and the largest size attained by these colonies was 850 sq mm. The first signs of sexual maturity were observed on these colonies. At the end of 1 month, the colonies were irregular patches and intense overlapping between the colonies was observed. The largest colony found on the monthly panels covered an area of 1,150 sq. mm and was 5.0 cm at the largest diameter. After 1 month, *E. bengalensis* was usually seen overgrown by other fouling organisms and only a few broken patches could be seen on the glass plates.

The number of colonies settled on the 1-week, 2-weekly and 3-weekly glass panels



Figures 3-10. 3. *E. bengalensis* (Stoliczka)—Few well grown zooids 4. *E. bengalensis* —Young colony. 5. *B. neritina* (Linnaeus) 6. *B. Stolonifera* Ryland. 7. *B. Klugei* Cook. 8. *N. papauensis* (Busk) 9. *A. distans* Busk. 10. *Z. verticillatum* (dellé Chiaje).



Figures 11-15. **11.** *V. pavida* S Kent. **12.** *S. sibogae* (Harmer) **13.** *B. nitens* Alder. **14.** *B. gracilis* Leidy. **15.** *S. lafontii* (Audouin).

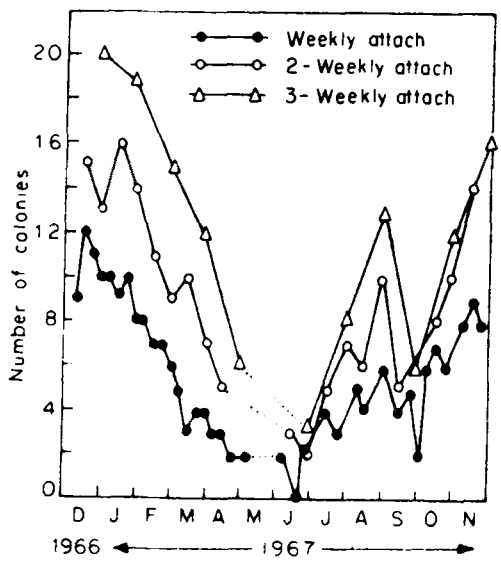


Figure 16. Seasonal settlement of *E. bengalensis* at Visakhapatnam harbour.

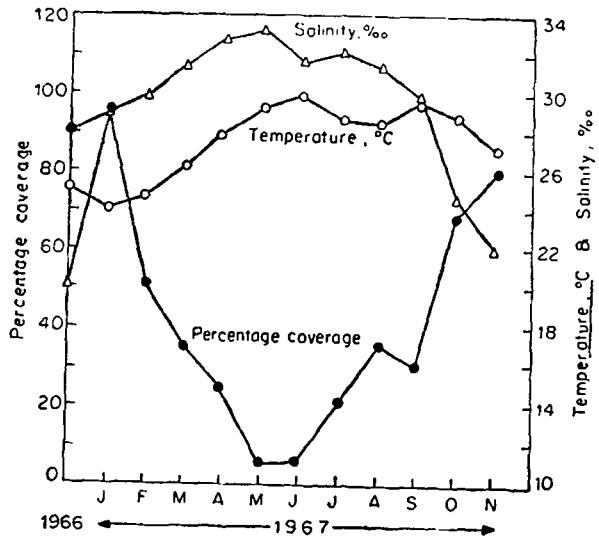


Figure 17. Percentage coverage on *E. bengalensis* on 1-month glass panels at Visakha patnam harbour.

during December, 1966 to November, 1967 is plotted in figure 16. The percentage coverage of *E. bengalensis* was taken as an index for assessing the abundance in case of the monthly panels, where enumeration of individual colonies was not possible (figure 17).

The settlement and abundance of this bryozoan were heavy during December 1966 and January 1967 and again during October 1967. During these periods of abundance, the growth of the colonies was very fast and on several occasions small serpulids, and barnacles were seen smothered by this bryozoan.

4. General observations and discussion

The present study revealed that a total of 12 species of bryozoans occur at Visakhapatnam harbour, of which *S. sibogae* is a new record for the Bay of Bengal and *B. stolonifera* to the Indian Ocean. All these bryozoan species are known from the fouling assemblages in different parts of the world.

The observations made during December 1966 to November 1967 on the settling rates and abundance of *E. bengalensis* clearly indicate that breeding is continuous in this form as evident by the appearance of young colonies, throughout the year, on weekly panels. The growth of this encrusting bryozoan is very fast. A comparison with the growth of *E. angulata* Levinsen (another common fouling species reported from several harbours and worked out in detail at Mie Prefecture, Japan and considered by Mawatari (1953) as a 'fast' growing species) shows that the growh in *E. bengalensis* is even faster than in *E. angulata*. Sexual maturity is also attained at an younger age (21 days) compared with the above species (3 months).

A perusal of the hydrographic conditions at Visakhapatnam harbour indicates that temperature fluctuated very little, the range being only 5·8°C (24°C in January 1967 to 29·8°C in June 1967) but the salinity variations were considerable—12·76% (20·1%

in December 1966 to 32·86% in June 1967). Several authors working on tropical marine organisms maintained that in tropics, where temperature conditions are constant or nearly constant, marine animals breed continuously (Semper 1883; Orton 1920). Paul (1942), discussing the various factors influencing the breeding of marine organisms at Madras harbour, concluded that ' the balance of evidence favours the idea that temperature is not the all important factor causing the breeding of tropical marine organisms'. Commenting on the influence of temperature on the marine wood borers of India, Becker (1958) expressed that the influence of temperature on rhythm of development of the borers is not significant, as the temperature in Indian harbours fluctuates very little during the course of the year, though 'the high average warmth limits the distribution of all species sensitive to high temperature'.

On the other hand, several workers suggested that of all the hydrographical factors, it is the salinity, whose fluctuations are more pronounced, that plays the major role in the settlement and growth rates of major marine fouling organisms in Indian harbours (Paul 1942; Daniel 1954; Nair 1967). The settlement of a number of fouling organisms was reported to be very much reduced during the monsoon periods when the salinity drops considerably in the Indian harbours and the quality of fouling is generally poor during the low saline periods. At Visakhapatnam harbour also, the low saline period, October to January, is generally poor in fouling (Ganapati *et al* 1958) and it is significant in this context, that *E. bengalensis* flourishes well even during the low saline periods. From figure 17 it could be readily seen that all the months where percentage coverage of *Electra bengalensis* exceeded over 40% of the glass plate were months with salinities averaging less than 30%. This preference for lower salinities by *E. bengalensis* becomes quite obvious when viewed in the background of its distributional records, which are always from brackish water localities. Stoliczka (1869) obtained the type material from a tank where the waters are only ' 1/5 as saline as sea water'. Robertson (1921) placed this species along with the brackish water membraniporids. Cook (1968) and Powell (1971) both considered this species as a brackish water bryozoan. In India, it has been so far reported from the Bombay harbour (Santhakumaran and Pillai 1970) and Cochin back waters (Menon 1971) apart from the type locality, Snod Island (Sunderbans). It is interesting here to recall the observations of earlier workers (Ganapati and Rao 1959) that during the southerly current period, the entire Bay of Bengal, in general, present nearly estuarine conditions. The distributional records as well as our observations indicate that this species flourishes even in lower salinities although extreme conditions may not be conducive for continuous breeding as observed by Menon (1971) at Cochin where its settlement was restricted to pre-monsoon and post-monsoon periods. During the monsoon period (June to September) which is characterized by very heavy rainfall and consequent lowering of salinity which became almost fresh, no settlement of *E. bengalensis* was observed at Cochin.

At Cochin harbour, none of the fourteen bryozoans which appeared on test panels was present throughout the year (Menon 1971). In a general way, the extreme variations in hydrographic conditions under the influence of the south-west monsoon at Cochin impose severe stresses on the continuous breeding of several marine organisms, bryozoans included. But, at Bombay and Madras harbours, instances of continuous settlement of bryozoans are reported (Paul 1942; Daniel 1954; Karande 1968; Santhakumaran and Pillai 1970). The absence of marked seasonal variations in the hydrographical conditions of the magnitude experienced at Cochin, probably

explains the continuous breeding of bryozoans at Visakhapatnam, Madras and Bombay harbours.

4.1. *Remarks on the paucity of bryozoans at the harbour*

One striking feature observed during the present investigation is the impoverished bryozoan fauna (12 species) at the harbour area compared with the nearby foreshore localities at Visakhapatnam where the number of species occurring ranges from 20 to 34 (Satyanarayana Rao 1975). A perusal of the literature shows that ' not all shallow water bryozoans occur in fouling'. Recent experiments have shown that many bryozoans display habitat preferences, and the larvae select their preferred substrates according to their settlement behaviour. Ryland (1971) commenting on the small numbers of bryozoan species in fouling communities remarked ' only that minority of species which do not display marked substratum specificity occur in fouling'. Some of the factors which are known to influence the distribution of bryozoans, particularly those species occurring in the harbours, are discussed below:

4.1.1. *Pollution:*

It is known that various pollutants may affect the organisms directly by their toxic effects or indirectly through depletion of oxygen. Recently, Powell *et al* (1970) have shown that hydrocarbon pollutants (coal tar) adversely affects the reproduction of the bryozoan *Schizoporella unicornis.* Nair (1961) also noted that pollution adversely affects the bryozoan abundance at Western Norway. Oil and grease pollution, in general, are known to suppress fouling organisms (Woods Hole Oceanographic Institute 1952).

As already mentioned, Visakhapatnam harbour is subjected to both domestic and industrial pollution. Amongst the harbour stations investigated, the most severely polluted area is the Southern Lighter Channel (St. III) where only 2 species of bryozoans could be collected, of which *B. gracilis* is by far the most frequently occurring species. It is interesting to note here that Nair (1961) also reported the occurrence of another member of the same genus *B. imbricata* (Adams) from a highly polluted locality with high turbidity and low salinities at Western Norway.

The healthy non-polluted open coast stations are typically characterised by a greater number of species (20–34) in our collections while the polluted harbour stations support only a few species (12).

4.1.2. *Salinity:*

It is known that salinity is also an important factor determining the distribution of bryozoans—relatively fewer number of species occur in estuaries or nearshore environments with lowered or fluctuating salinities (Cook 1968; Maturo 1968). In specialized situations like harbours, where the salinities are low due to land drainage and fluctuations marked, only a few species of marine organisms capable of tolerating these conditions would flourish. Moreover, the bryozoans in the brackish water are typically characterized by a lack/absence of calcification (Carra da *et al* 1965). Our observations on the paucity of bryozoans as well as the striking, absence of heavily calcified species such as *Hippopetraliella magna* (d'Orbigny)

Thalamoporella gothica (Busk) var. *indica* (Hincks), *Steganoporella buskii* Harmer (which are very common at the open coast stations) in the harbour area agree well with the above observations.

4.1.3. *Silting:*

Maturo (1959) and Nair (1961) considered silting a major factor preventing the establishment of bryozoans at Beaufort and Western Norway respectively. Silt accumulates in considerable quantities in enclosed harbours. The settling of suspended matter may either smother the sessile organisms or produce substrata unsuitable for their attachment. In the local harbour, silting is quite considerable due to constant dredging operations. As much as 250 g of suspended matter were found accumulated on the horizontal surfaces of glass plates which were kept immersed for only a fortnight. Bryozoan species occurring at the nearby areas may never succeed in colonizing the heavily silted objects at the harbour.

4.1.4. *Larval type and fouling:*

The majority of bryozoans possess a lecithotropic type of larva which metamorphose whithin a few hours and whose powers of dispersal are rather restricted. Heavy settlement of bryozoans, therefore, usually occurs on structures close to the breeding colonies (Corlett 1948; Wisely 1959; Ryland 1971). Moreover, the harbour structures in general, and test surfaces in particular, impose severe space restrictions. Smothering by other dominant organisms is a severe problem facing bryozoan settlements, particularly, the encrusting species. It is interesting to note here that excepting *E. bengalensis* all the other bryozoan species at the harbour are not of the encrusting type. Probably the erect species requiring only a little basal space, could easily be accommodated compared with the encrusting types.

The fouling bryozoans show a dearth of diversity of species, limited to a few successful foulers like, *B. neritina*, *Z. verticillatum*, *B. gracilis*, etc. The species occurring on the harbour structures at Visakhapatnam are also known from fouling communities from other parts of the world. While several aspects of the biology of bryozoans and their physiological requirements are yet to be understood, particularly the behavioural aspects of the short lived but sensitive larvae (response to light, salinity, temperature, colour, etc.) it is hazardous to come to any definite conclusions without experimental evidence.

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