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MACKEREL FISHERY OF THE CALICUT AREA AND ITS FLUCTUATIONS DURING THE SEASONS FROM 1980-81 TO 1985-86 *

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ABSTRACT

After relatively good mackerel fishery at Calicut in 1980-81 it touched the lowest figure in 1983-84. Improvement was noticed subsequently. Recruitment to the fishery is almost completed by September. Mainstay of recruitment at Calicut is from the products of spawning in June and August. A good annual rainfall is found to be beneficial to the fishery, but the rainfall and catch in September is found to have an inverse relation. Catch in 1970-71 is found to be well above equilibrium level. The magnitude of spawning stock in April-June period is found to have direct relation to the total catch of that season. In general, mackerel fishery is on the decline at Calicut. There are indications that the current fishing pressure on the population is more than optimum.

INTRODUCTION

ERRATIC fluctuation in the abundance of mackerel in the exploited area have very often caused great concern among the fishermen. At Calicut after relatively a good mackerel fishery in 1980-81 season when 573 tonnes of mackerel were caught, the catches dwindled to 60 t in 1983-84 season. Subsequently there was a steady improvement and in 1985-86 season the total yield of mackerel fishery rose to 351 t. The results of a preliminary study of the pattern of these fluctuations are presented in this paper. The results of this study are also compared to that of Pradhan and Reddy (1962) and Venkataraman and Rao (1973).

The authors are grateful to Dr. P. S. B. R. James, Director and Dr. A. Noble of C.M.F.R. Institute for encouragement and critical reading of the manuscript.

SOURCE OF DATA

Catch, effort and length frequency data collected from Vellayil, Calicut, regularly on the mackerel fishery during 1980-81 to 1985-86 form the basis of this paper. Daily weather reports supplied by India Meteorological Department were utilised for rainfall data for Calicut. Data presented by Venkataraman and Rao (1973) on the mackerel fishery of Calicut area during 1960-61 to 1965-66 and catch data for 1970-71 to 1975-76 taken from the records maintained at Calicut centre are also presented for a comparative study. All seasons referred to here are from April to March unless otherwise mentioned.

OBSERVATIONS

Fig. 1 shows the total landings of mackerel during different seasons and average monthly catches are shown in Fig. 2. The maximum catches are obtained in September. The average monthly contribution by different gears (Fig. 3) shows that *pattenkolli* maintains the peak in September. Fig. 4 shows the size groups available to the fishery during different

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months. Here the length range and mode of each sample are plotted against the day of sampling for reasons given by Yohannan (1979). Part B of the figure is a repetition of Part A to see the progression of size-range and modal values from one season to another.

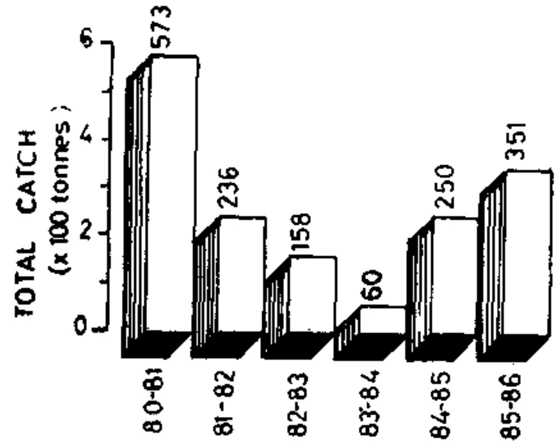

FIG. 1. The total seasonal catch of mackerel.

The figure indicate that during April, May and June the fishery solely depends on the previous season's recruits which are exploited by *Ayilachalavala* (gill net). The peak catches in June are from this group. By July the new recruits enter the fishery and *Pattenkolli* (boat seine) begins to dominate the fishery (Fig. 3, 4). By September another brood enters the fishery. There is an indication of a brood, though weak, entering the fishery in between. Indications of subsequent less important broods entering the fishery are also shown in Fig. 4.

Fig. 2 shows the average monthly rainfall and mackerel catch at Calicut. The rainfall shows a primary peak in June. Then it fall to a low value in September. There is a secondary peak in October. The September peak in mackerel catches coincides with the decrease of rainfall in that month after the primary peak. The second minor peak in catches in November coincides with the second decrease in the rainfall after the secondary peak in October.

From this general picture an examination of the variations from season to season will be interesting (Fig. 5, Table 1). With a total catch of 573 tonnes of mackerel, 1980-81 season was the best of all seasons under study. It had the maximum annual rainfall, but the rainfall during September was very low. The November peak in catches was better than the September peak. In 1981-82 the annual catch was reduced to 236 t. The total rainfall was less than that of the previous year and the September value was comparatively more. The total catch and rainfall came down further

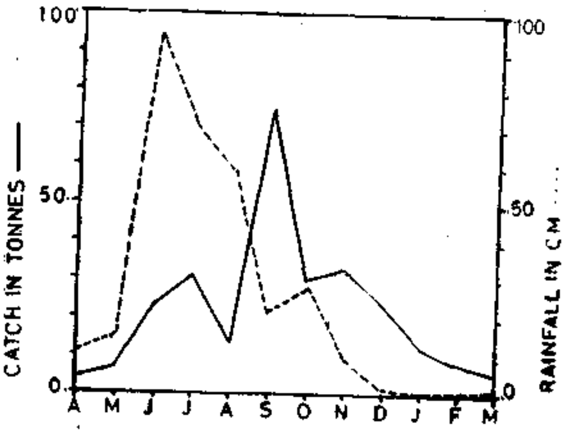

FIG. 2. Average monthly catch of mackerel and rainfall.

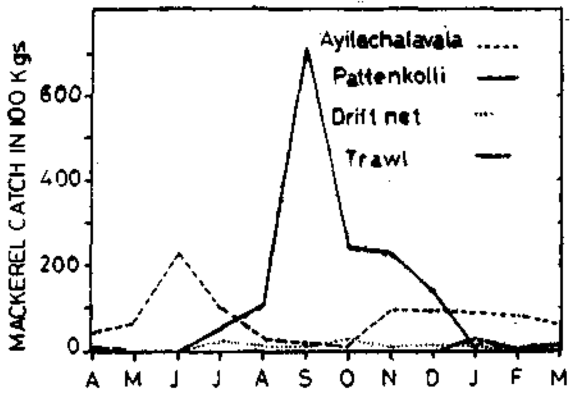

FIG. 3. Average monthly catch by different gears.

in 1982-83. In 1983-84 the catch was just 60 t. Though the rainfall was better than that of previous season the September value was an all time high and the catch in September was extremely low. In 1984-85 there was an improvement in catch and rainfall. The rainfall value in September was low. In 1985-86 a further improvement in catch was noticed though the rainfall was slightly less than that of the preceeding season. The rainfall value in September was the lowest of all seasons.

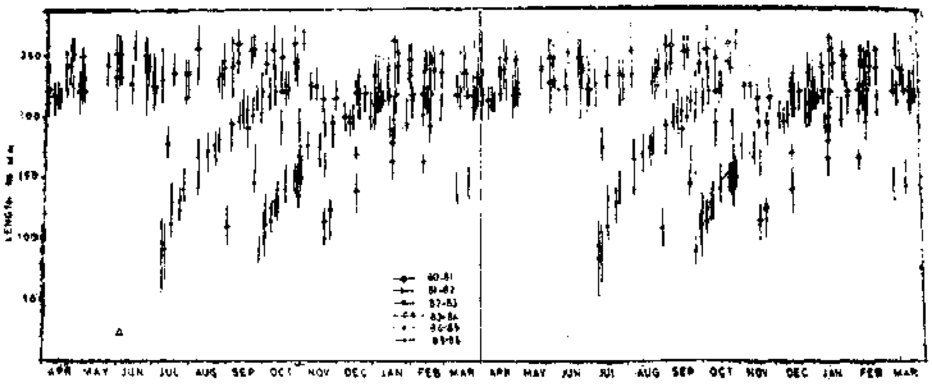

FIG. 4. Length groups and modal values observed in the fishery in different months (Part B is a repetition of part A).

From the above account it can be seen that a good rainfall in a season is beneficial to the fishery of that season. But in September when peak catches are expected an increase in rainfall is seen to affect the fishery adversely. A negative regression of catch in September on the rainfall value of that month is shown in Fig. 6. A correlation coefficient of -0.85 indicates a good inverse relation. Hence, the annual rainfall is taken without adding the September value, but subtracting it, since it is found to have adverse effect on the fishery. The regression of total seasonal catch on these values are found (Table 1). The correlation coefficient was found to be 0.898 indicating good relation. Correlation of these rainfall values with the total catch of a season from July of that year of June of next year was also studied. It was found to have a better correlation (0.93) (Table 1).

From Fig. 3 it can be seen that *Pattenkolli* is the most important gear in the mackerel fishery at Calicut. On an average it lands about 55% of the total seasonal mackerel catch. The next important gear is *Ayilachalavala* which lands about 33% of the total mackerel catch. The rest of the catch is made by drift nets, trawl nets, *Mathichalavala* and *Nethalvala*.

Table 2 gives the annual CPUE of *Pattenkolli* and *Ayilachalavala*.

Schaefer (1954) suggested that the CPUE is dependent on effort and the relation is :

$$Y/F = a + bF$$

where Y is the catch and F effort, a and b are constants. The Maximum Sustainable Yield (MSY) is given by the equation :

$$-a^2/(4b)$$

The effort required to produce this yield (fMSY) is estimated by the equation :

$$-a/(2b)$$

The F value at which the stock is completely annihilated is given by the equation :

$$-a/b$$

Fox (1970) has given a similar model with an equation

$$\text{Ln}\,(Y/F) = a + bF$$

and the MSY from the equation :

$$-(1/b)\ e^{(a-1)}$$

and the effort to produce the MSY by the equation :

$$-1/b$$

But, in his model the stock is never annihilated by any amount of fishing intensity. The estimates of these parameters based on the effort and catch of *Pattenkolli* and *Ayilachalavala* are given in Table 3. The yield curve of Schaefer superimposed on CPUE and catch data for these two gears are shown in Fig. 7.

TABLE 1. *Relation between total annual rainfall and seasonal mackerel catch*

Year	Rainfall in cm omitting Sep. value	—Sep. value	X	Season	Total mackerel catch in tonnes	
					Apr.-Mar. Y_1	July-June Y_2
1980	353	10	343	1980-81	573	523
1981	319	30	289	1981-82	236	239
1982	218	11	207	1982-83	158	130
1983	227	61	166	1983-84	60	72
1984	297	9	288	1984-85	250	266
1985	289	8	281	1985-86	351	—
			Intercept	$a_1=-378.6710$		$a_2=-342.4763$
			Slope	$b_1=2.4778$		$b_2=2.2756$
			Correlation	$r_1=0.8981$		$r_2=0.9290$

In the season 1984-85 there was an important development in the indigenous fishery at Calicut. Fishermen started using out-board engines for the propulsion of country crafts. About 22% of the country crafts were fitted with YAMAHA 7 hp engines, EVINRUDE 11 hp engines or JOHNSON 11 hp engines during that season. By 1985-86 the mechanisation spread to another 23% and the fishermen were reluctant to work in country crafts without these engines which requires more physical work with less returns. This development affected the number of effort and catch.

Now, supposing that due to mechanisation the catchability coefficient q has changed, the surplus production models of Schaefer and Fox were applied to the data for the first 4 seasons only and the results are given in Table 3. Since the *Pattenkolli* data gave a positive value for b the estimates are given only for *Ayilachalavala* data.

From Fig. 4 it can be seen that during April-June the fishery solely depend on the previous season's recruits which are sexually mature. They can be taken as the spawning stock for that season. The average monthly catch of this period is taken as roughly proportional to the spawning stock. The regression of that season's total catch on the spawning stock was estimated and the values are given in Fig. 8. An r value of 0.92 indicated good relation. Fig. 9 shows how the spawning stock and yield fluctuated from season to season.

DISCUSSIONS AND CONCLUSIONS

Average monthly catches of mackerel at Calicut for three six-yearly periods, 1960-61 to 1965-66, 1970-71 to 1975-76 and 1980-81 to 1985-86 are shown in Fig. 10. The average seasonal catches during these periods are 568 t, 1,850 t and 271 t respectively. A definite decline in the catches during the period under study is apparent. But, general pattern of the fishery continues to be the same. Peak catches are obtained in September though there are minor variations in some seasons.

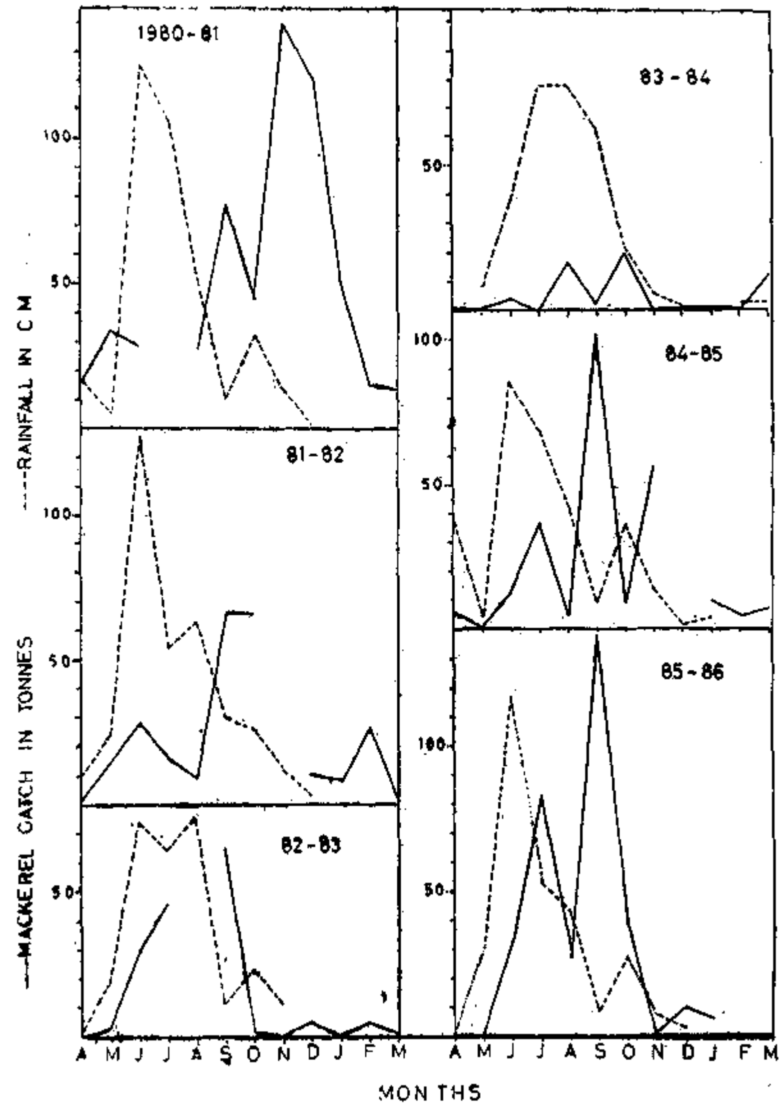

FIG. 5. Monthly catch and rainfall during different seasons.

The reasons for the peak catches in September can be found in Fig. 4. The first important brood of the season appear in July. From the figure it can be safely assumed that these are the products of spawning in June. By September they grow to an average size of around 20 cm and are available to the fishery in its maximum magnitude. In the same month the second important brood, possibly born in August, enter the fishery. These two broods contribute to the bulk of the catches in September, when the recruitment of the second important brood to the fishery at Calicut is more successful than that of the first, the month of peak landings may be in October or November. After September the catches from the first brood start declining though there is an increase in the catches from the second brood (Fig. 4). Hence, it can be said that at Calicut the recruitment is almost complete by September. It may be noted here that the height of recruitment in northern centres like Mangalore, Karwar and Goa is in October and in Maharashtra in November (Noble, 1985), indicating a northward migration of mackerel shoals. Simultaneous information as in Fig. 4 from all along the west coast alongwith the related catch data will definitely throw light on the migration and on different unit stocks, if any, of mackerel that contribute to the fishery of different areas.

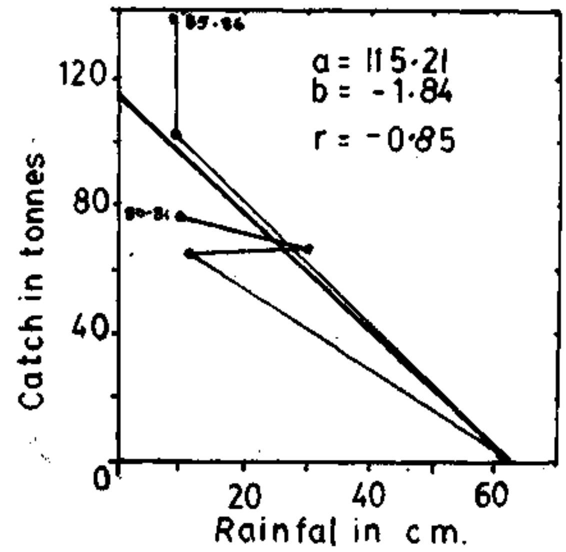

FIG. 6. Relation between catch and rainfall in September.

TABLE 2. *Effort, catch and* CPUE *of Pattenkolli and Ayilachalavala during different seasons*

	Pattenkolli			Ayilachalavala		
Season	Effort (Hrs)	Catch (kg)	CPUE (kg/hr)	Effort (Hrs)	Catch (kg)	CPUE (kg/hr)
1980-81	8,540	3,49,113	40.88	5,990	1,92,384	32.12
1981-82	8,003	1,41,127	17.63	6,353	83,712	13.18
1982-83	7,590	64,260	8.47	1,665	90,137	54.14
1983-84	7,419	16,230	2.19	1,047	28,769	27.48
1984-85	2,833	1,25,788	44.40	1,437	97,389	67.77
1985-86	4,455	2,01,696	45.27	1,197	45,106	37.68

The mackerel catch shows a definite direct relation to the amount of rainfall. It can be seen that the intensive rainfall is over before September when peak catches of mackerel are expected in Calicut. Possibly a good monsoon helps better recruitment. By September when rains subside the environmental conditions in the inshore area become conducive for the movement of mackerel shoals in full density where they are intensively fished. But, if monsoon conditions still prevail in that month it may affect the movement of shoals and the fishery. This peculiar condition may not be there in northern centres where the peak catches are made in October or November. Hence, at Calicut though the catch is having a positive regression on total rainfall the catch in September is having a negative regression on the rainfall of that month. Since the recruitment starts only in July the catch of mackerel from that month to June of next year is having a better correlation with annual rainfall.

Pradhan and Reddy (1962) has found an inverse relation between mackerel catches and rainfall at Calicut, while discussing the mackerel landings in relation to certain hydrographical factors during the season (October-September) from 1957-58 to 1959-60. The figures given by them show peak mackerel catches during the month of December instead of the present September showing a major change in the pattern of recruitment, movement or fishing. Thus the present direct relation of catches with rainfall is not comparable with their findings.

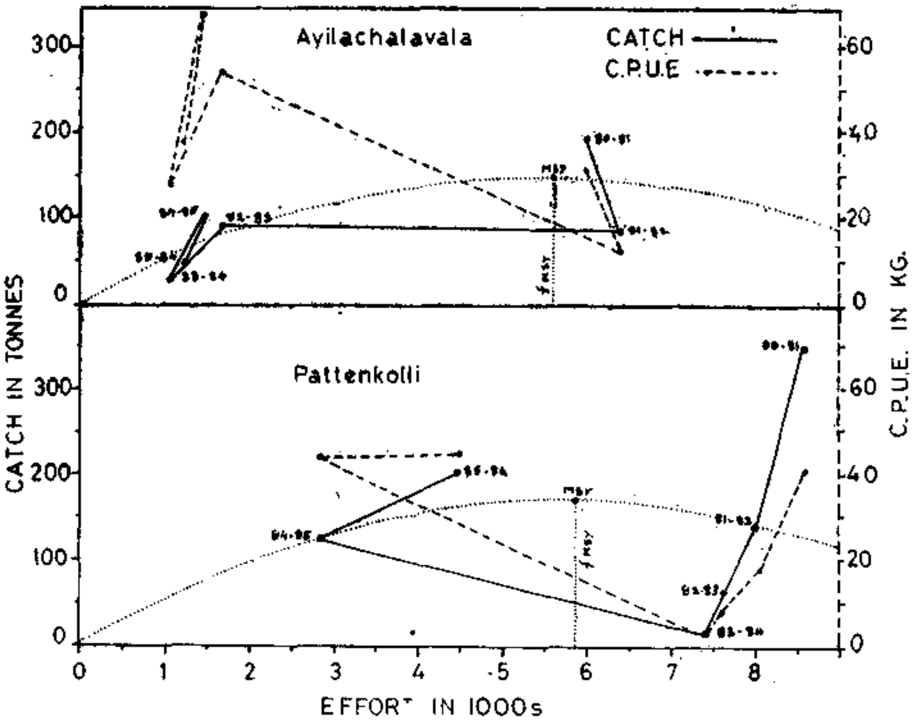

FIG. 7. Effort, Catch and CPUE relation during different seasons and Schaefer's curve.

TABLE 3. *MSY and fMSY estimated from Schaefer and Fox models*

Ayilachavala 6 seasons		Ist 4 seasons		Pattenkolli 6 seasons	
Schaefer model	Fox model	Schaefer model	Fox model	Schaefer model	Fox model
a = 52.5582	3.9843	44.9976	3.8164	58.7478	4.4196
b = —0.0047	—0.000153	—0.0035	—0.000127	—0.005	—0.000242
MSY = 146.934	129.228	143.6	131.628	172.566	126.263
fMSY = 5591.3	6535.95	6382.64	7874.0	5874.78	4132.23
MSY/fMSY = 0.026	0.02	0.022	0.017	—	—

Noble (1972) has observed an inverse relation between mackerel catches and rainfall at Karwar during the seasons 1954-55 to 1964-65. The peak landings in Karwar are late in October well after the southwest monsoon. Hence, the situation in Calicut can not be compared with that of Karwar. However, Yohannan (1977) has found a direct relation between mackerel landings and rainfall at Mangalore during 1969-73. The monsoon and consequent dynamic changes in the environment and its effect on the recruitment and movement of mackerel is an important subject to be studied in detail as the short-lived, pelagic, shoaling and migratory fish populations are very much sensitive to changes in the environment.

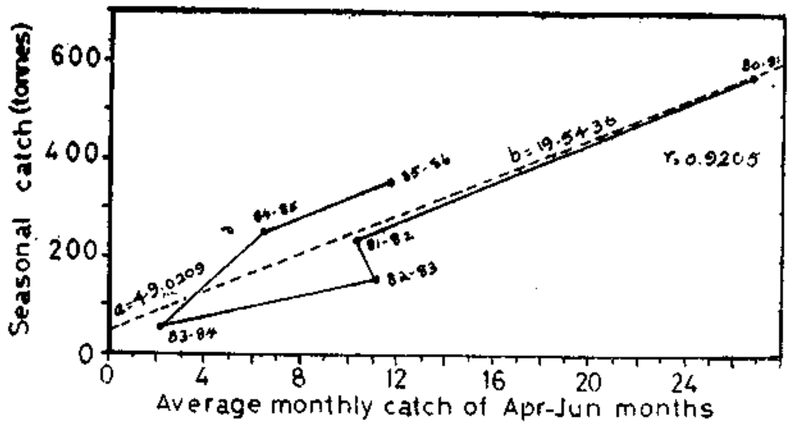

FIG. 8. Relation between spawning stock and seasonal catch.

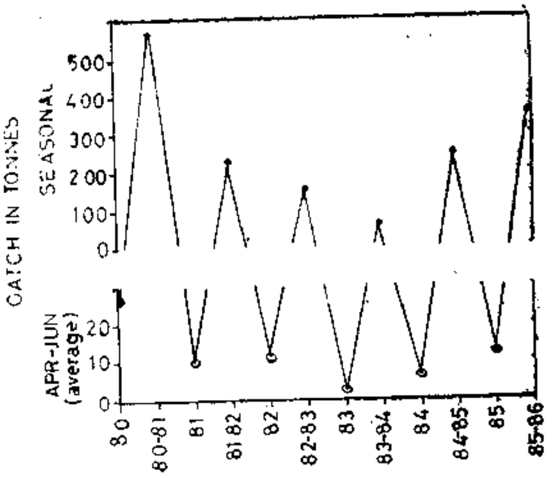

FIG. 9. Variations in the spawning stock and seasonal catch.

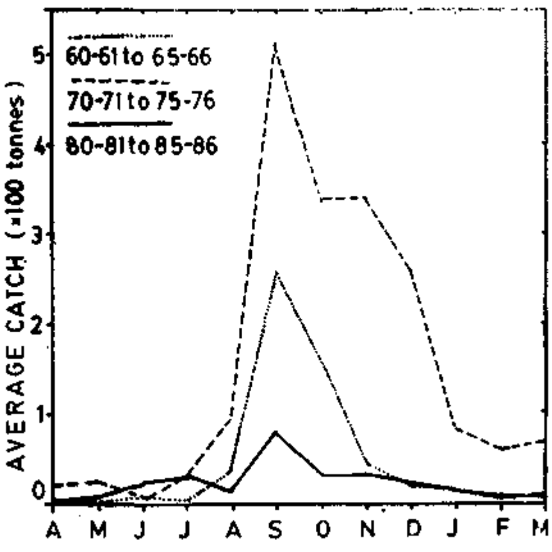

FIG. 10. Monthly average catch during different periods.

Fig. 8 indicates the dependence of catch on spawning stock. This is a warning signal indicating more than optimum fishing pressure the population can withstand. Fig. 9 clarifies the point. During each season the left line starting from spawning stock and ending at the total catch in the figure indicates the production and the right line starting from total catch and ending in the spawning stock indicates reduction due to mortalities. It can be seen that in 1980-81 and 1982-83 the reduction line is longer than the production line and consequently the total catch was decreasing. But, subsequently the situation is reversed and an increase in catches is noticed. In Fig. 7 the catch by *Ayilachalavala* stands above the MSY. The reason perhaps may not be that of intensity of effort, but a better availability of shoals in the fishing area due to certain environmental factors. The only consolation is that the situation at Calicut may, perhaps, not be quite true of the mackerel fishery throughout the west coast of India. But, still it is time we have proved it.

Sparre (1985) has cautioned against including 'too long a time series of data in the surplus, production analysis', because of the probable changes in the catchability coefficient which usually is a function of time. With the introduction of out-board engines an increase in the catchability coefficient can be expected. From Table 3 it can be seen that for *Ayilachalavala* the fMSY for the whole season is lower than the estimate for the first four seasons when out-board engines were not used and MSY/fMSY values were higher for the whole seasons' estimates which can be an indication of increased q which under the circumstances should be watched cautiously.

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POPULATION CHARACTERISTICS OF TUNA LIVE BAITS IN LAKSHADWEEP*

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ABSTRACT

Availability and abundance of both migratory and resident species of tuna live baits in desired quantity during the fishing season in the lagoons and adjacent waters coupled with their location, capture and transportation determine the success or failure of pole and line tuna fishery. It is evident that at Minicoy, capture and effective utilisation of different species of live baits has been in vogue since more than a century but in the northern group of islands where mechanised pole and line fishery is prevailing since 1963, the aimed live bait species are sprats, which are collected from shallow sand flats from near or above coral reefs. The present study reveals the occurrence and abundance of other suitable live baits with desired qualities in the deeper parts of the lagoonal ecosystem in the northern islands, the utilization of which would reduce substantial fishing pressure on the local fragile baitfish stock of sprat.

Fishery and population characteristics of seventeen species of tuna live baits collected from areas of importance to tuna pole and line fishery in the Lakshadweep are presented and discussed. Evaluation of different species is made based on their body form, colouration, behaviour pattern and survival in captivity. Habitat and seasonal distribution pattern and catch rate of different bait species are communicated. Data needs for stock assessment of these species are emphasised and strategies for the development and managemen t of baitfish fishery in the Lakshadweep is discussed.

INTRODUCTION

THE SIGNIFICANCE of live baits as limiting factor in the successful production of tunas by pole and line (live-bait) tuna fishery is generally understood. About 160 species belonging to 31 families have been identified from the world oceans for tuna pole and line fishery of which only about a dozen species chiefly belonging to Apogonidae, Caesionidae, Clupeidae, Dussumieridae and Engraulidae are the principal baits used in the major Pacific and Indian Ocean fisheries (Jones, 1964; Baldwin, 1977; Ben Yami, 1980; Silas and Pillai, 1982; Sakagava, 1987). Expansion of pole and line tuna fishing is limited by the availability of suitable live baits in quantity, their maintenance and transportation, availability of tuna schools in the fishing ground, response to chumming expertise of fishermen, etc. In Lakshadweep, the only place in India where a traditional pole and line fishery is in vogue, it is reported that the scarcity of live bait often brings about abrupt suspension of tuna fishing even during the peak tuna fishing season (Jones, 1958, 1960). A knowledge of the distribution and abundance of the natural stocks of principal tuna baitfish species with respect to their capacity for supporting the skipjack pole and line fishery is an essential prerequisite for recommending specific actions

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for the development and management of natural baitfish resources in the area. In addition, there is need to investigate the biological and population characteristics of the different species of live baits for estimating the exploitable stocks of these species and also to ascertain the suitability of culturing some of these species to supplement the natural resources.

Investigations on the live bait fishes of Lakshadweep were largely confined to Minicoy Island. The informations available are mainly from Jones (1958, 1960 a, b, 1964), Thomas (1964), Silas and Pillai (1982), Pillai *et al.* (1986), Pillai and Madan Mohan (1986), Madan Mohan and Kunhikoya (1986); Madan Mohan *et al.* (1986), Gopakumar and Mathew (1986), James *et al.* (1987), Varghese and Shanmugam (1987), Kumaran *et al.* (1989), Gopakumar and Pillai (1988, MS) and Gopakumar (1991). However, till now focused studies such as exploratory surveys on these non-target species in and around the island system is wanting. As part of the implementation of the objectives and technical programmes under the research project of the CMFR Institute entitled ' Investigations on the natural stocks and cultured tuna live baits ' an exploratory tuna live-bait resource survey was carried out around the islands and *par* areas of importance to tuna fishery such as Bitra, Chetlat, Kadamat, Perumul Par, Tinnakara-Bangaram-Parali group, Agatti, Kavaratti, Suheli Par, Kalpeni-Tilakkam-Cheriyam group and Minicoy during October 1986 to March 1987. The highlights emanated from it was published (CMFRI, 1986) and part of the first hand information documented in James *et al.* (1987), Kumaran *et al.* (1989) and Gopakumar (1991). In the present document, the distribution, abundance and population characteristics such as size composition, length-weight relationship, sex ratio, size at first maturity, fecundity and food and feeding are presented. Seasonal distribution pattern in the catch of major groups of live baits utilised in the pole and line fishery at Minicoy is communicated. The species are ranked based on the desired characteristics of a good live bait fish as given by Baldwin (1975, 1977), Yuen (1977) and Smith (1977). The imperative necessity of data on the catch, effort and size composition of different species currently utilised in the fishery is emphasised for meaningful assessment of stocks of the species for the future development and management measures. The live bait scarcity problem and some of the options for solving it are also discussed.

The authors are thankful to Dr. P. S. B. R. James, Director, CMFRI for his kind encouragement and guidance for this study. They are also thankful to Shri D. Kojan Koya and Shri O. Ismail of Minicoy Research Centre of CMFRI for their field assistance.

MATERIAL AND METHODS

Mechanised pole and line fishing boats were used for the survey. Two types of live bait nets were employed— (i) *Encircling net :* It is made of nylon mosquito netting, 47.0 × 1.45 m in size with lead sinkers and wooden floats. The net was employed for encircling the schools of sprat *Spratelloides delicatulus* which is an inhabitant of shallow sandy areas of the lagoons and (ii) *Lift net :* Made of nylon netting of 6 mm mesh, 5.87 × 5.3 m in size and operated by means of poles. First, the baitfish colonies were located by a diver and the net was lowered and kept spread in water over the colony with the help of poles. Fish meat paste was rubbed on a coir padding at the end of a bamboo pole and it was pushed up and down over the spread net. Baitfishes, thus lured gathered over the net. When sufficient number of fishes were gathered over the net, it was quickly raised and the baits collected were transferred to the baitfish tank. For baitfishes dwelling in the crevices of coral colonies like apogonids, ' drive in ' method by

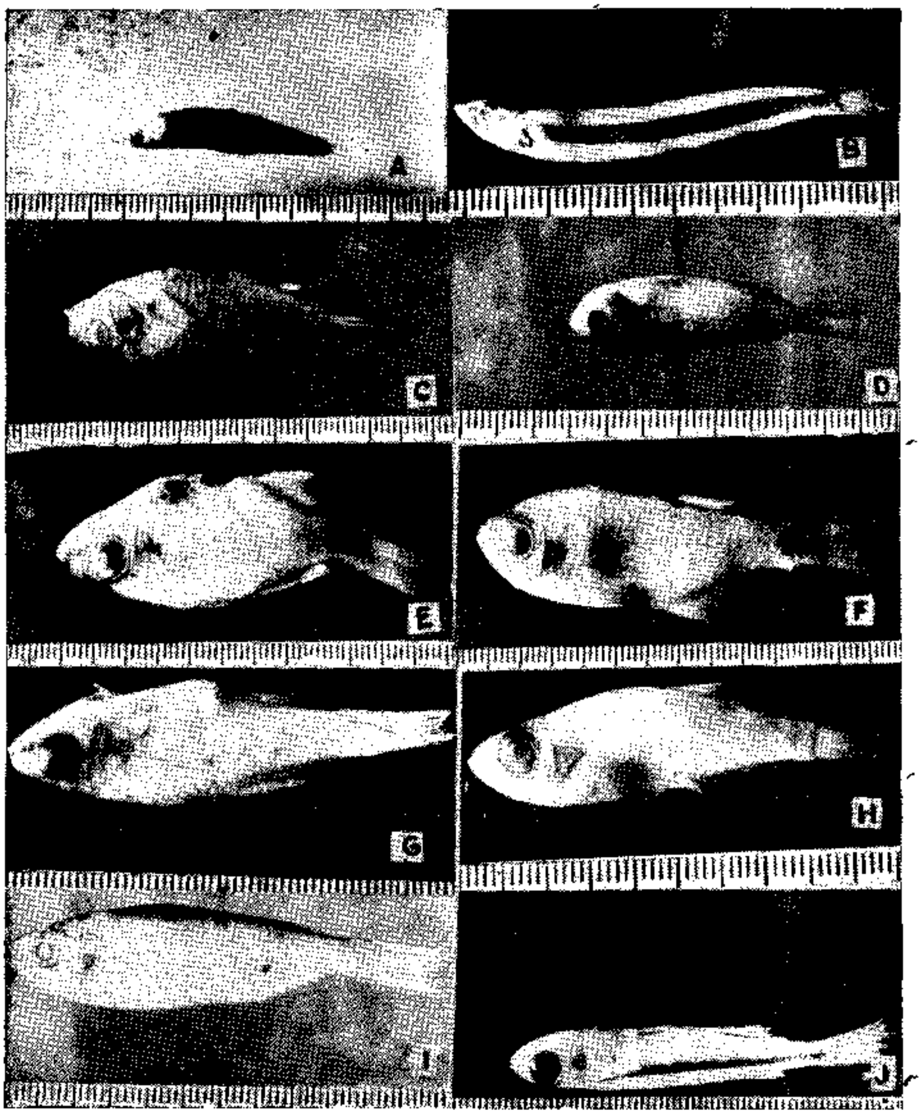

PLATE I. The common live-bait fishes of Lakshadweep: A. *spratelloides delicatulus*, B. *S. gracilis*, C. *Chromis caeruleus*, D. *Lepidozygus tapeinosoma*, E. *Archamia fucata*, F. *Apogon sangiensis*, G. *Rhabdamia gracilis*, H. *Ostorhynchus quadrifasciatus*, I. *Caesio caerulaureus* and J. *Pranesus pinguis*.

employing scare line prepared with palm leaves attached all along its length was practised. The net was used for collecting silver sprat· apogonids, caesionids and pomacentrids from the deeper parts of the lagoons.

Initially the entire lagoon was surveyed by the divers for the location of baitfish colonies and the areas of distribution were marked in the maps. Experimental fishing was done at a few randomly selected colonies from each lagoon to assess the catch rate and species composition. The samples were preserved and analysed for studying the biological characteristics. The studies on species-wise seasonality in the abundance of baitfishes at Minicoy were done by estimating the species-wise baitfish catch taken by the commercial pole and line fishing boats from September 84 to May 87.

BAITFISHES

Eventhough Jones (1964) listed 45 species belonging to 30 genera and 19 families, only 21 species belonging to five families *viz.* Dussumieridae, Apogonidae, Caesionidae, Pomacentridae and Atherinidae were commonly caught in good numbers during the investigations (Pl. I). The taxonomy followed here is based on Jones and Kumaran (1980) and Fischer and Bianchi (1984).

Dussumieridae : Sprats are slender, elongate, silvery with deciduous scales that are easily shed. Very delicate fishes and hence large scale mortality occurs at the time of capture and handling. Two species are employed commonly as live bait *viz. Spratelloides delicatulus* and *S. gracilis*. The former is the most common live bait of Lakshadweep and it is distributed in the shallow coral sand areas of the lagoons. The fish moves in schools and is caught by encircling nets. The schools are attracted towards night lights. *S. gracilis* is comparatively a deeper water species associated mostly with massive coral colonies and often coexists with an apogonid *Rhabdamia gracilis*. *S. gracilis* is more hardy than *S. delicatulus* and survives for longer periods in live bait tanks. Sprat colonies were located in all the lagoons surveyed.

Apogonidae : They are small, nocturnal and often brightly coloured resident fishes associated with corymbose, pedicellate corals with reticulately coalescent branches. Since during day time they take shelter in the crevices of coral colonies, first they are driven out from there and then fished by means of lift net. Apogonids are employed as live bait only at Minicoy Island where they are reported to be very effective live bait. They are relatively slower in movement. All the species are very hardy and can be kept in the bait tanks for prolonged periods. Eventhough 22 species are recorded from Lakshadweep, only seven species were caught in good quantities during the present study *viz. Archaemia fucata, Rhabdamia gracilis, R. cypselurus, Apogon sangiensis, A. leptacanthus, Ostorhynchus quadrifasciatus* and *O. apogonides*. The most abundant among these were *R. gracilis, A. fucata, A. sangiensis* and *O. quadrifasciatus*. Apogonids were distributed in all the lagoons surveyed except at Chetlat.

Caesionidae : Fishes with fusifor, compressed body, often brightly striped with blue, yellow and grey and juveniles in large numbers appear inside the lagoons as well as at adjacent reef areas during certain seasons. They are used as live bait at present only in Minicoy Island. Only juveniles are employed as bait and are reported to be excellent bait fish. They are very hardy and the rate of survival is very high in the bait tanks. They are migrant forms and are temporarily associated with branched or massive coral colonies. Seven species were collected during the present investigations *viz. Caesio caerulaureus, C. striatus, C. xanthonotus, Gymnocaesio gymnopterus, Pterocaesio pisang, P. tile* and *P. chrysozona* ; the most abundant were *Caesio caerulaureus* and *P. chrysozona*. Caesionids were collected from all the lagoons except at Chetlat and Bangaram-Tinnakara-Parali group.

Pomacentridae : They are small, brightly coloured with a flattened deep to oblong body associated with ramose arborescent corals. Most of the species are resident forms. Pomacentrids are employed as bait only at Minicoy. They are hardy and some species are reported to be excellent baits. Four species were collected in good numbers during the present survey *viz. Chromis caeruleus, C. nigrurus, Pomacentrus pavo* and *Lepidozygus tapeinosoma,* the former three are resident forms and the latter a migrant form. *C. caeruleus* is the most widely distributed live bait fish of Lakshadweep which was collected from all the lagoons surveyed.

Atherinidae : They are slender, silvery fishes distributed at nearshore areas of the lagoon often associated with algae. Atherinids are very hardy which can be kept in captivity for prolonged periods. They are caught by the encircling net. Atherinids are used as bait only at Minicoy and they are preferred only when the other baits are not available. Eventhough four species are recorded from Lakshadweep only one species *viz. Pranesus pinguis* was collected in good quantities. Atherinids are available in significant quantities only at Bitra, Chetlat, Kalpeni and Minicoy.

DISTRIBUTION

The lagoons and shallow adjacent reef areas of Lakshadweep provide ideal habitat for the live bait fishes. The distribution of live baits in the ten lagoons of Lakshadweep *viz.* Minicoy, Suheli Par, Kalpeni-Cheriyam, Kavaratti, Agatti Bangaram-Tinnakara, Parali group, Perumul Par, Kadamat, Bitra and Chetlat are given in Fig. 1 to 10. It is seen that the vast shallow coral sand areas of the lagoons of Suheli Par, Kalpeni-Cheriyam, Bangaram, Perumul Par and Bitra hold good potential of *S. delicatulus.* At Minicoy, Kalpeni-Cheriyam, Agatti and Kadamat lagoons, apogonids were distributed over wide areas. Large areas of pomacentrid distribution were seen at Bangaram-Tinnakara-Parali group, Suheli Par, Bitra, Kadamat, Perumul Par and Kalpeni. The distribution of atherinids is of a lower magnitude. Eventhough the areas of availability of caesionids were also mapped, it is reasonably assumed that since the caesionids are migratory, their distribution and abundance in the lagoon may vary from time to time.

A basic pattern in the spatial distribution of the various groups of live baits is discernible from the distribution pattern observed at various lagoons. *S. delicatulus* is distributed in the nearshore areas of the lagoon where there is sand flat formation. Pomacentrids are abundantly distributed in the regions next to the sand flat areas in the slightly deeper parts of the lagoons and are associated with ramose, arborescent and flabellate corals. Apogonids and the silver sprat *S. gracilis* are distributed in the still deeper parts of the lagoon associated with massive corals. Atherinids are distributed in areas very close to the lagoon beach. The distribution pattern of the migratory caesionids cannot be ascertained.

CATCH AND CATCH RATE

The total catch of the different live bait species collected during the exploratory survey from the lagoons of the different islands of Lakshadweep is presented as percentage of total catch in Table 1. Sparts constituted the major group at Suheli Par, Bitra and Kalpeni ; apogonids were present in good concentration at Kavaratti, Perumul Par and Kadamat ; caesionids contributed in relatively high proportion at Agatti, Kalpeni and Minicoy ; pomacentrids especially *Chromis caeruleus* formed the bulk of the catch at most of the islands namely, Agatti, Bangaram, Suheli Par, Chetlat and Minicoy ; and atherinids at Bitra.

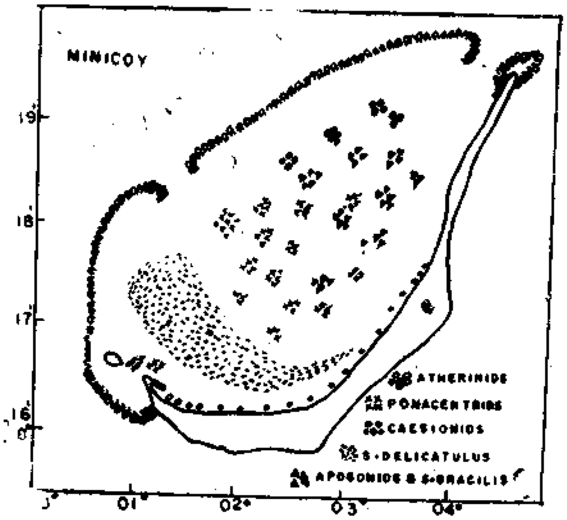

Fig. 1. Distribution of live baits in the lagoon of Minicoy.

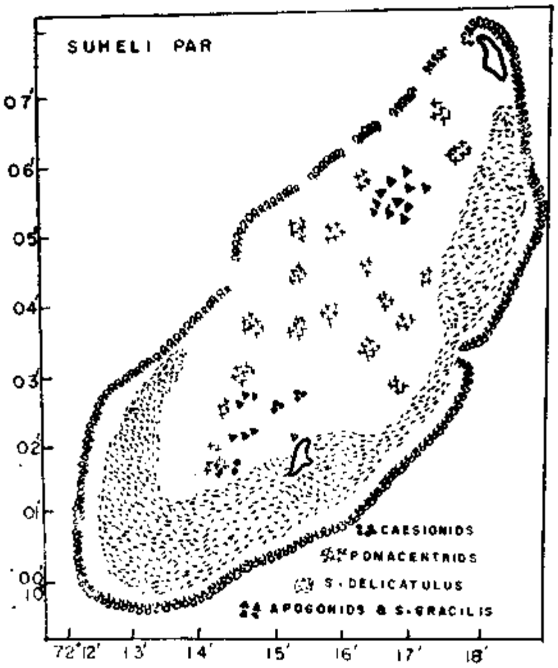

Fig. 2. Distribution of live baits in the lagoon of Suheli Par.

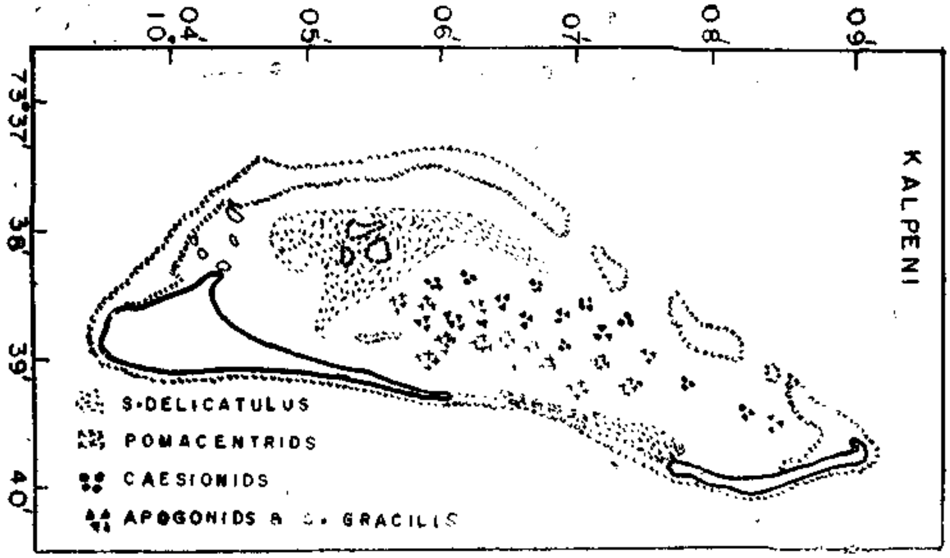

Fig. 3. Distribution of live baits in the lagoon of Kalpeni.

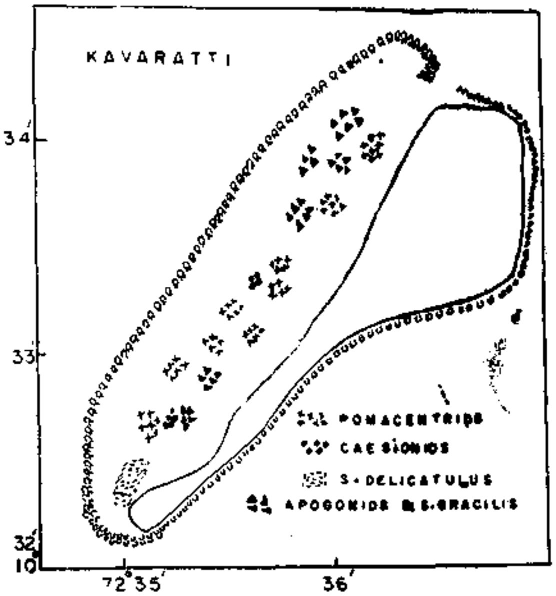

Fig. 4. Distribution of live baits in the lagoon of Kavaratti.

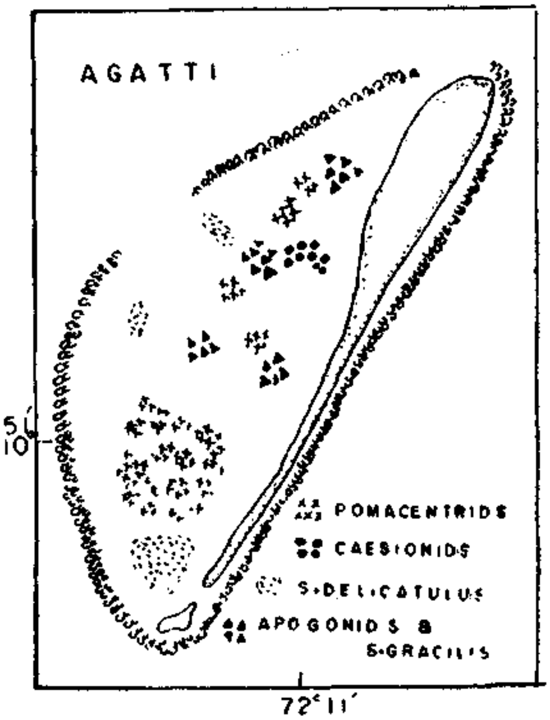

Fig. 5. Distribution of live baits in the lagoon of Agatti.

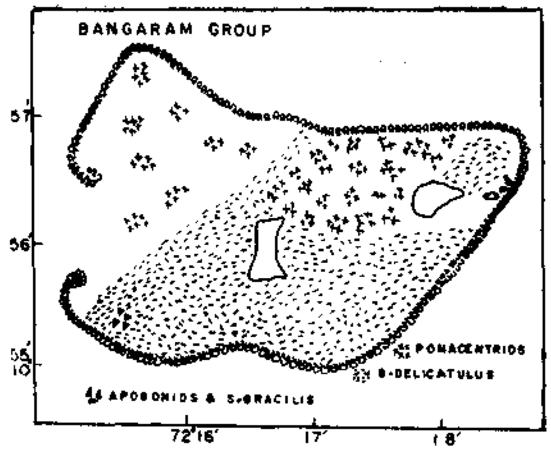

Fig. 6. Distribution of live baits in the lagoon of Bangaram Group.

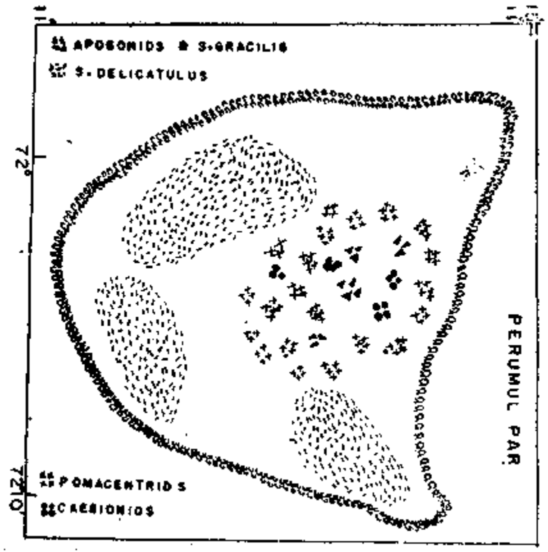

Fig. 7. Distribution of live baits in the lagoon of Perumul Par.

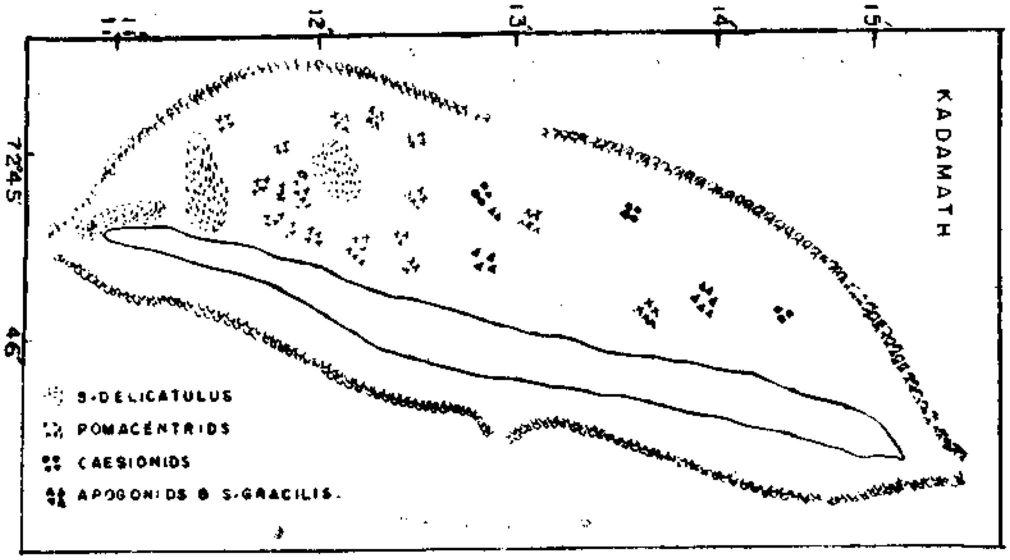

Fig. 8. Distribution of live baits in the lagoon of Kadamath.

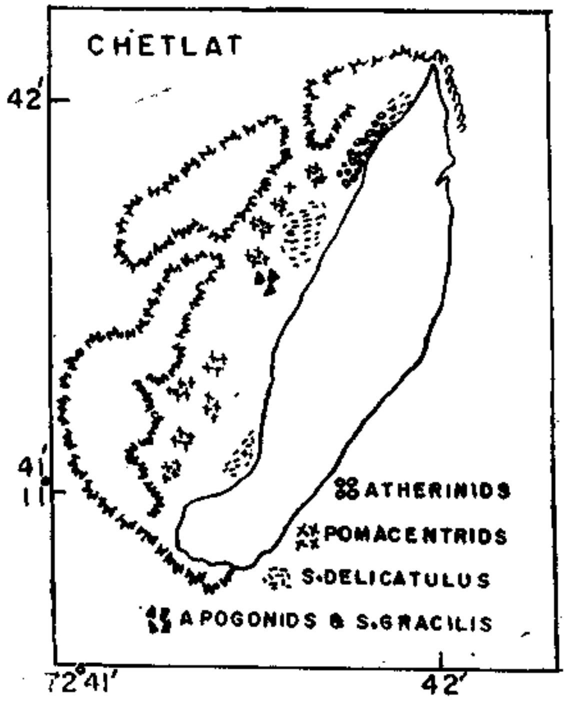

Fig. 9. Distribution of live baits in the lagoon of Chetlat,

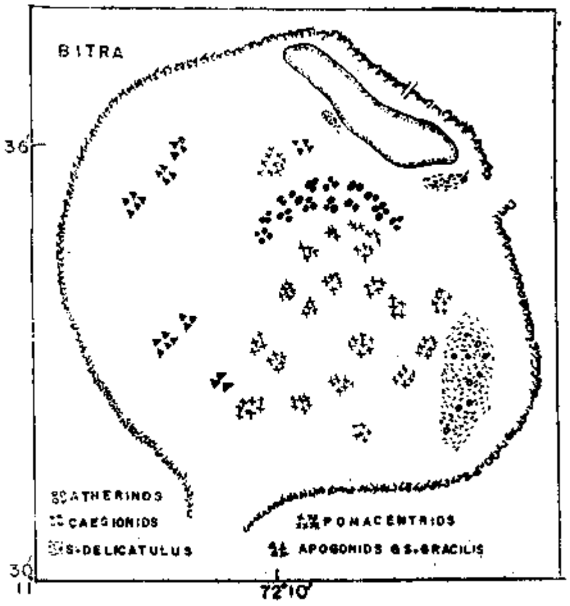

Fig. 10. Distribution of live baits in the lagoon of Bitra,

TABLE 1. *Percentage distribution of different groups of live baits in Lakshadweep*

Islands	Sprats	Apogonids	Pomacentrids	Caesionids	Atherinids	Total weight (gm)
Kavaratti	12.4	63.2	23.0	1.4	—	1,740
Agatti	12.2	38.3	34.0	15.4	—	6,535
Bangaram	22.4	1.0	75.6	1.0	—	4,900
Perumul Par	28.8	40.2	26.2	4.8	—	3,125
Suheli Par	34.6	9.8	52.0	3.6	—	3,945
Kadamat	13.1	42.4	42.5	2.0	—	4,955
Bitra	37.5	16.3	32.7	1.0	12.5	5,200
Chetlat	—	—	91.2	—	8.8	570
Kalpeni	29.6	25.6	33.2	9.7	2.0	7,590
Minicoy	22.5	28.4	38.8	10.1	0.3	6,165

TABLE 2. *Catch composition of baitfishes (in gm) collected during the survey*

Species	Kavaratti	Agatti	Bangaram	Perumul par	Suheli par	Kadamat	Bitra	Chetlat	Kalpeni	Minicoy
Dussumieridae										
S. delicatulus	215	400	1,100	750	490	650	1,250	—	1,600	1,218
S. gracilis	—	400	—	150	875	—	700	—	650	168
Apogonidae										
A. fucata	50	250	—	—	60	1,850	—	—	—	650
A. sangiensis	—	50	—	—	125	200	—	—	—	153
A. leptacanthus	—	250	—	—	125	—	—	—	—	—
R. cypselurus	—	450	5	—	—	—	—	—	—	—
R. gracilis	—	1,450	—	1,250	77	—	850	—	1,595	845
O. apogonides	1,050	5	—	—	—	—	—	—	350	100
O. quadrifasciatus	—	50	50	—	—	50	—	—	—	—
Caesionidae										
C. caerulaureus	—	650	40	150	140	—	50	—	385	410
P. pisang	—	55	—	—	3	—	—	—	—	—
P. tile	—	—	—	—	—	—	—	—	—	106
P. chrysozona	—	300	—	—	—	100	—	—	335	105
C. xanthonotus	25	—	—	—	—	—	—	—	—	—
Pomacentridae										
C. caeruleus	250	2,005	3,660	800	2,050	2,050	1,650	520	2,500	2,316
C. nigrurus	—	20	—	20	—	—	—	—	10	—
P. pavo	150	200	50	—	—	50	50	—	—	—
L. tapeinosoma	—	—	—	—	—	5	—	—	—	74
Atherinidae										
P. pinguis	—	—	—	—	—	—	650	50	510	20

Species-wise occurrence of different baitfishes in the lagoons of the islands surveyed is presented in Table 2. It is evident from the Table that the common species represented in most of the islands were *S. delicatulus*, *S. gracilis*, *R. gracilis*, *C. caerulaureus* and *Chromis caeruleus*.

Catch rate expressed as catch per operation (gms) during the survey indicate that it was maximum at Kadamat (1.24 kg) followed by Agatti (0.82 kg), Bitra (0.81 kg), Suheli Par (0.79 kg), Bangaram (0.70 kg), Perumul Par (0.63 kg) and Minicoy (0.47 kg). Low catch rates were observed at Kavaratti and Chetlat.

The seasonal trend of the catch of tuna live baits during September 1984 to May 1987 is presented in Fig. 11 a. Throughout the period of study, a bimodal distribution of abundance of live baits was noted, the primary peak during October-November and the secondary peak during March-April. Tertiary peak of less magnitude was also noted during January in 1985 and 1987.

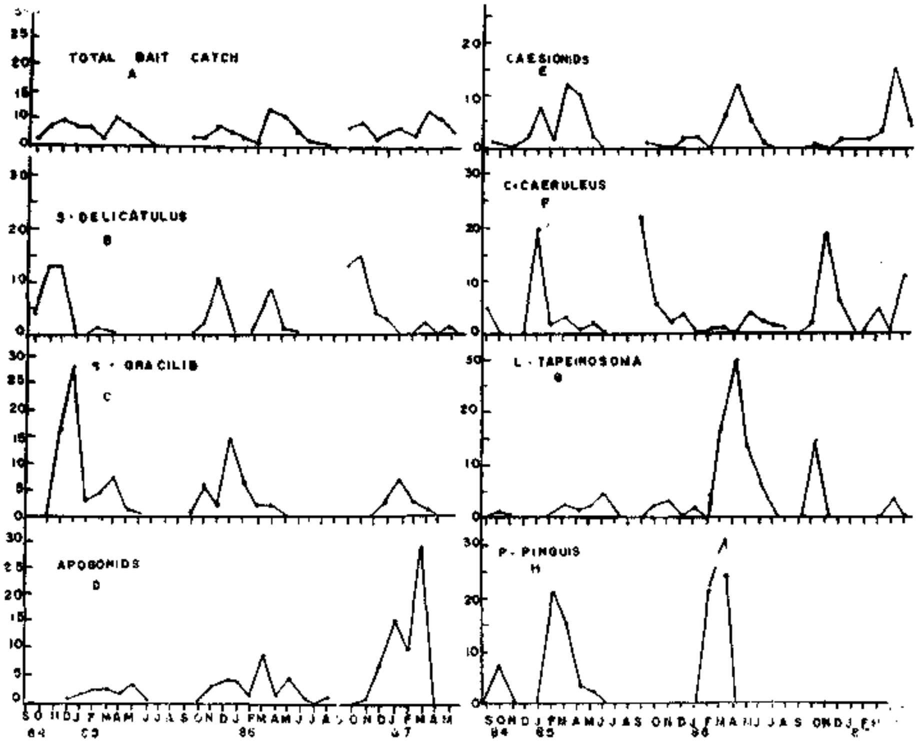

Fig. 11. a. Trend of catch of tuna livebaits at Minicoy during September '84 to May '87 and Seasonal trend of different groups of livebaits at Minicoy, b. *S. delicatulus*, c. *S. gracilis*, d. *Apogonids*, e. *Caesionids*, f. *C. caeruleus*, g. *L. tapeinosoma*, and h. *P. pinguis*.

The occurrence and abundance of important live baits such as *S. delicatulus*, *S. gracilis*, apogonids, caesionids, *C. caeruleus*, *Lepidozygus tapeinosoma* and *Pranesus pinguis* at Minicoy during the same period are shown in Fig. 11 b to h. For migratory forms such as caesionids March-May period was found to be more productive, whereas the resident species such as apogonids evinced erratic abundance pattern during most of the months.

The catch rate of tuna live baits at Minicoy during the period mentioned above indicated that the monthly catch per effort varied between 0.7 kg and 3.1 kg with the mean of 2.1 kg.

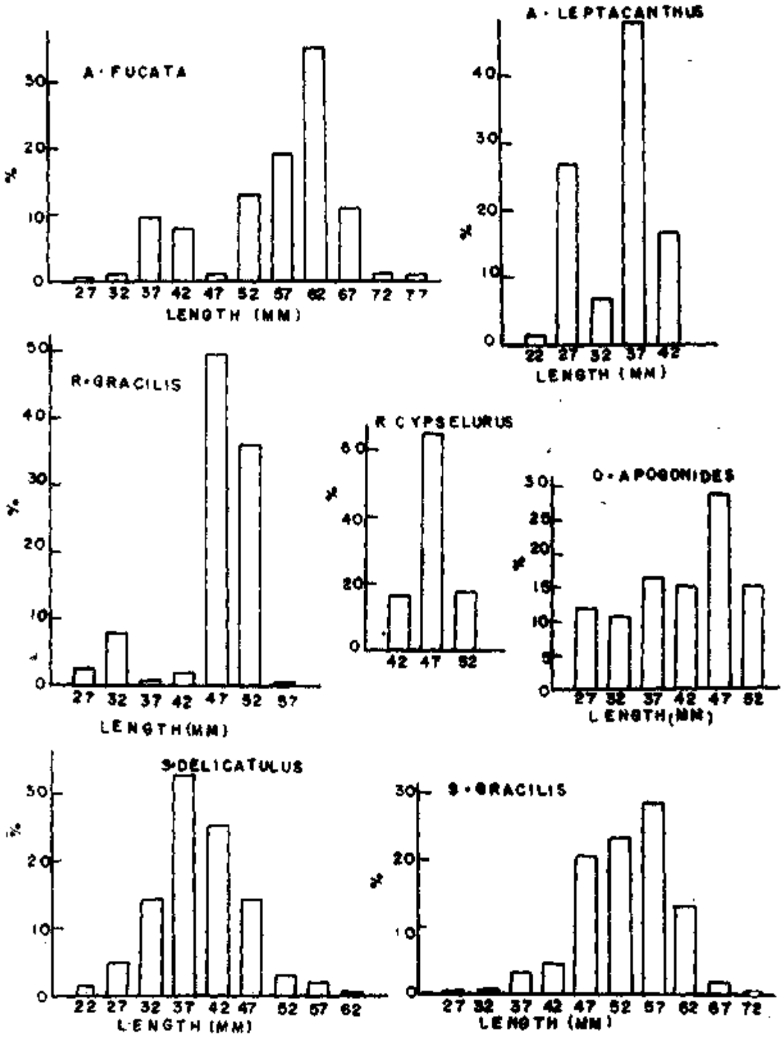

Fig. 12. Size composition of *A. fucata*, *R. gracilis*, *S. delicatulus*, *A. leptacanthus*, *R. cypselurus*, *O. apogonides* and *S. gracilis*.

BIOLOGICAL CHARACTERISTICS

Size composition : The size composition of seventeen species of live baits collected from the various lagoons of Lakshadweep is given in Fig. 12 to 14. It is seen that the common size range noted for them ranged from 25 to 79 mm.

Length-weight relationship : Length-weight relationships were calculated for males, females and juveniles separately for ten species for which adults and juveniles are employed as live bait and for juveniles only, for seven species for which only juveniles are used for live bait purpose. The number of fish used for the estimation (n), the ' r ' value and the length-weight relationship formulae are given in Table 3. The length-weight relationship plotting is given in Fig. 15 to 17.

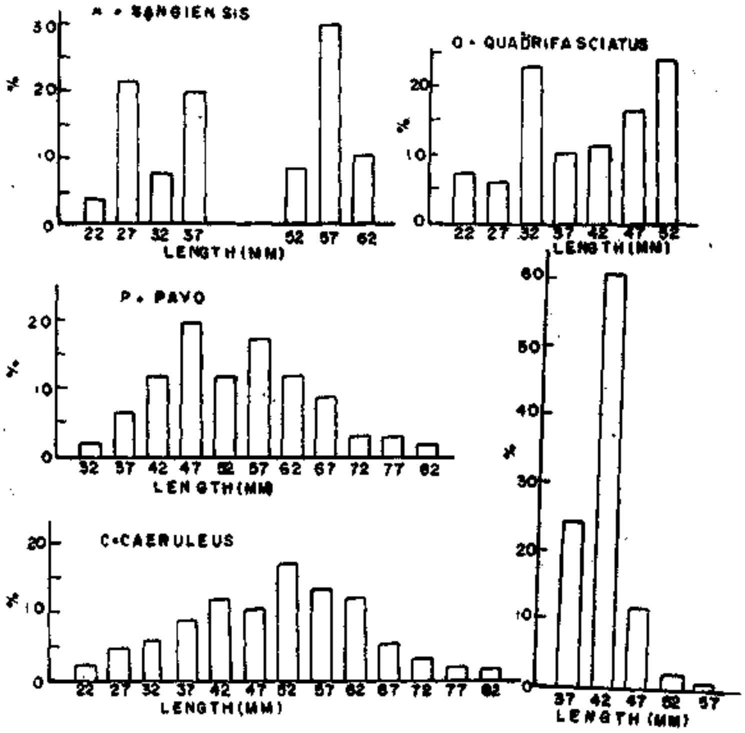

Fig. 13. Size composition of *A. sangiensis*, *P. pavo*, *C. caeruleus* and *O. quadrifasciatus*.

Size at first maturity : To determine the size at first maturity, the percentages of mature and immature specimens at 2 mm interval were determined. Maturity stages I and II were treated as immature and III to VII as mature. Size at first maturity at 50% level was calculated for ten species for which adults were also used as live baits (Fig. 18). The smallest size of mature fish obtained and the size at first maturity of the ten species are given in Table 4.

Sex ratio : The sex ratio was calculated for ten species which showed that in most cases males and females were represented in 1 : 1 ratio. However, the Male : Female ratio for ***Pomacentrus pavo*** was 1 : 1.24, for ***R. gracilis*** 1 : 2 and for *P. pinguis* 1 : 1.5. The sex ratio of different species is given in Table 5. Incubating eggs in the mouth were noted for the apogonids *viz. A. sangiensis, A. fucata* and *O. quadrifasciatus.*

Fecundity : Mature ovaries in stages IV to VI were used for estimating fecundity. Only yolked eggs were enumerated. Fecundity estimates were made for ten species and the results are presented in Table 6.

Food and feeding : Food and feeding of seventeen species were studied by gross analysis (Table 7). It was seen that all the species except *P. pavo* were zooplankton feeders and *P. pavo* was an algal browser. Apogonids are nocturnal feeders and the rest diurnal feeders with peak feeding during early morning and evening hours.

TABLE 3. *Length-weight relationships of live bait fishes*

Species		Male	Female	Juvenile
S. delicatulus	..	$W=0.015010\ L^{2.7771}$ $r=0.9416$ $n=348$	$W=0.00431\ L^{3.21149}$ $r\ \ 0.9616$ $n=317$	$W=0.00157\ L^{3.4094}$ $r=0.9871$ $n=49$
S. gracilis	..	$W=0.0018403\ L^{3.3046}$ $r=0.9398$ $n=317$	$W=0.002084\ L^{3.2381}$ $r=0.9159$ $n=355$	$W=0.015754\ L^{3.0014}$ $r=0.9898$ $n=11$
C. caeruleus	..	$W=0.011237\ L^{3.0960}$ $r=0.8859$ $n=135$	$W=0.113579\ L^{2.5613}$ $r=0.9146$ $n=109$	$W=0.04515\ L^{2.7232}$ $r=0.9532$ $n=115$
A. fucata	..	$W=0.004748\ L^{3.2641}$ $r=0.9104$ $n=76$	$W=0.004422\ L^{3.2732}$ $r=0.9105$ $n=64$	$W=0.00933\ L^{3.0581}$ $r=0.9845$ $n=37$
R. gracilis	..	$W=0.03963\ L^{2.8168}$ $r=0.7724$ $n=89$	$W=0.00161\ L^{3.4074}$ $r=0.8793$ $n=89$	$W=0.04005\ L^{2.5441}$ $r=0.8779$ $n=25$
R. cypselurus	..	$W=0.00620\ L^{3.1908}$ $r=0.8554$ $n=18$	$W=0.1023\ L^{3.3010}$ $r=0.7537$ $n=36$	—
A. sangiensis	..	$W=0.1265\ L^{2.4050}$ $r=0.7995$ $n=25$	$W=0.02181\ L^{2.9249}$ $r=0.7357$ $n=27$	$W=0.00253\ L^{2.4702}$ $r=0.9742$ $n=55$
A. leptacanthus	..	—	—	$W=0.000568\ L^{3.8869}$ $r=0.9763$ $n\ \ 70$
O. quadrifasciatus	..	$W=0.003522\ L^{3.3019}$ $r=0.9767$ $n=22$	$W=0.01376\ L^{3.0351}$ $r=0.9867$ $n=29$	$W=0.0043\ L^{3.0851}$ $r=0.9710$ $n=45$
O. apogonides	..	—	—	$W=0.020352\ L^{2.5579}$ $r=0.9715$ $n=90$
P. pavo	..	$W=0.03413\ L^{3.3106}$ $r=0.9901$ $n=21$	$W=0.05076\ L^{2.7209}$ $r=0.9300$ $n=50$	$W=0.0675\ L^{2.6064}$ $r=0.9635$ $n=20$
L. tapeinosoma	..	—	—	$W=0.608835\ L^{2.0081}$ $r=0.5383$ $n=128$

TABLE 3 (*Contd.*)

Species		Male	Female	Juvenile
C. caerulaureus	..	—	—	$W=0.008967\ L^{3.0886}$ $r=0.7881$ $n=231$
P. chrysozona	..	—	—	$W=0.004261\ L^{3.1013}$ $r=0.9606$ $n=203$
G. gymnopterus	..	—	—	$W=0.4988\ L^{2.5353}$ $r=0.7586$ $n=31$
C. striatus	..	—	—	$W=0.005094\ L^{3.1311}$ $r=0.9672$ $n=50$
P. pinguis	..	$W=0.002162\ L^{3.3043}$ $r=0.9843$ $n=71$	$W=0.001018\ L^{3.4741}$ $r=0.9793$ $n=108$	—

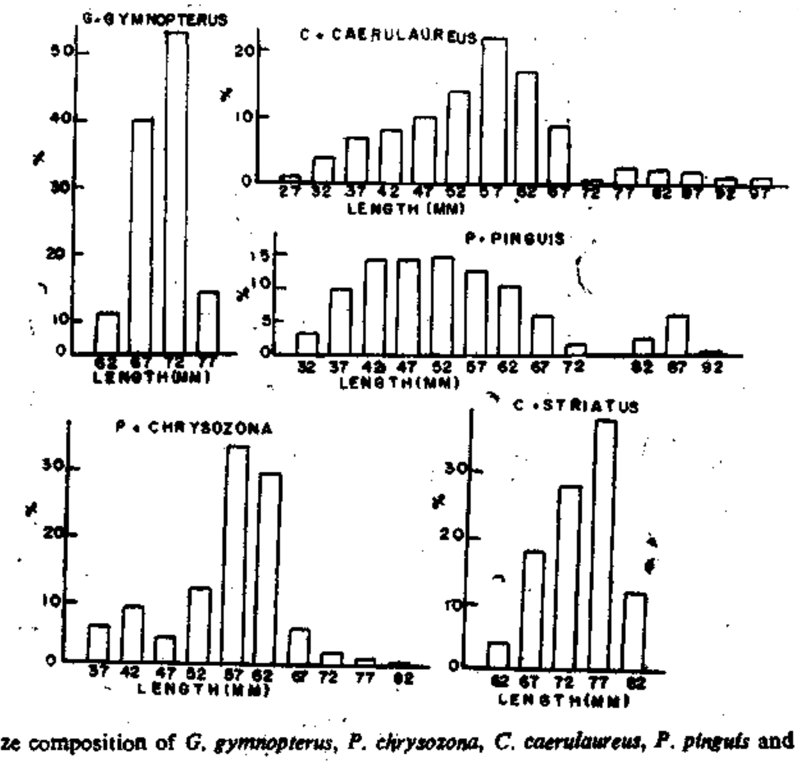

Fig. 14. Size composition of *G. gymnopterus*, *P. chrysozona*, *C. caerulaureus*, *P. pinguis* and *C. striatus*.

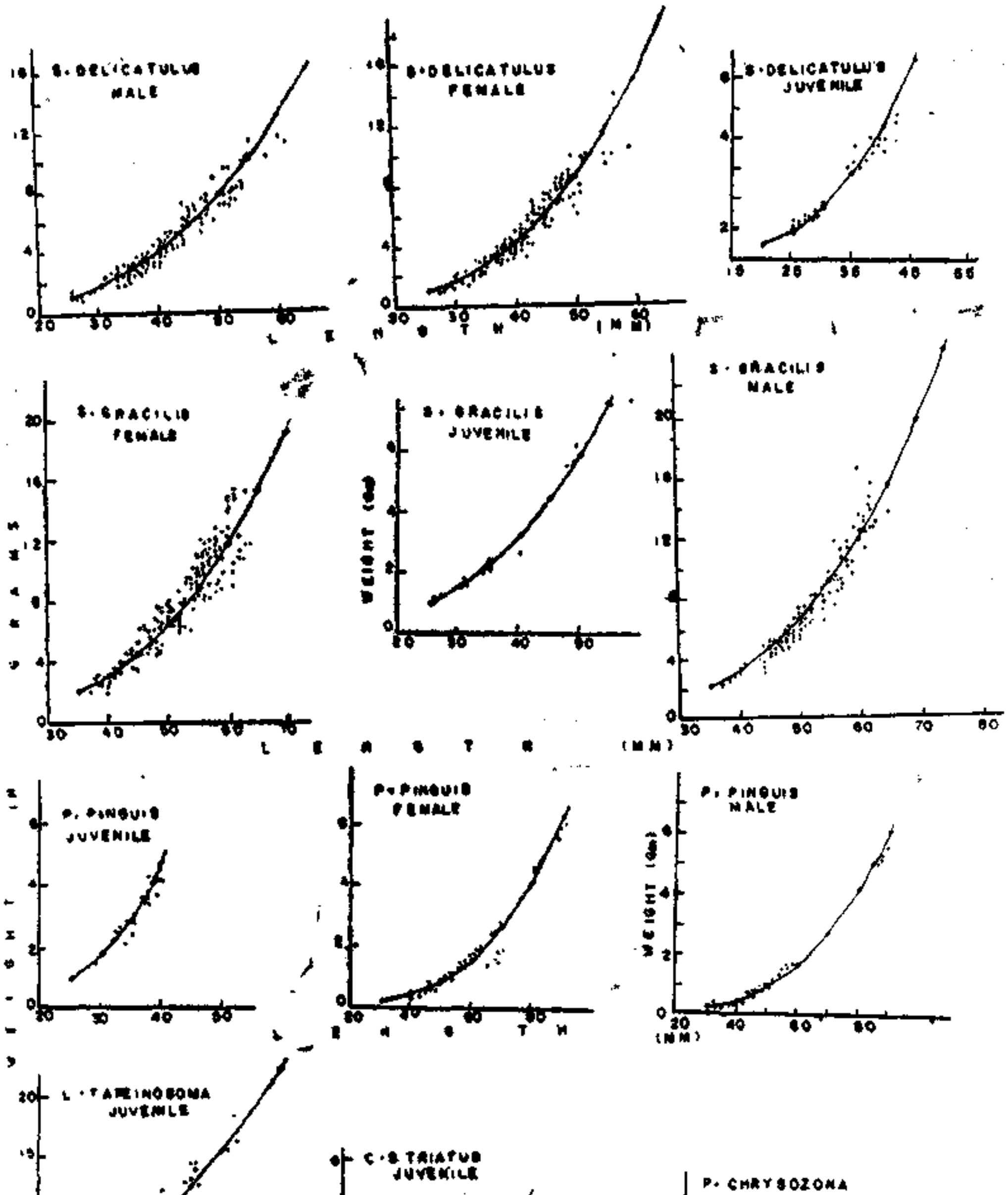

Fig. 15. Length-weight relationships of *S. delicatulus*, *S. gracilis*, *P. pinguis*, *L. tapeinosoma*, *C. striatus* and *P. chrysozona*.

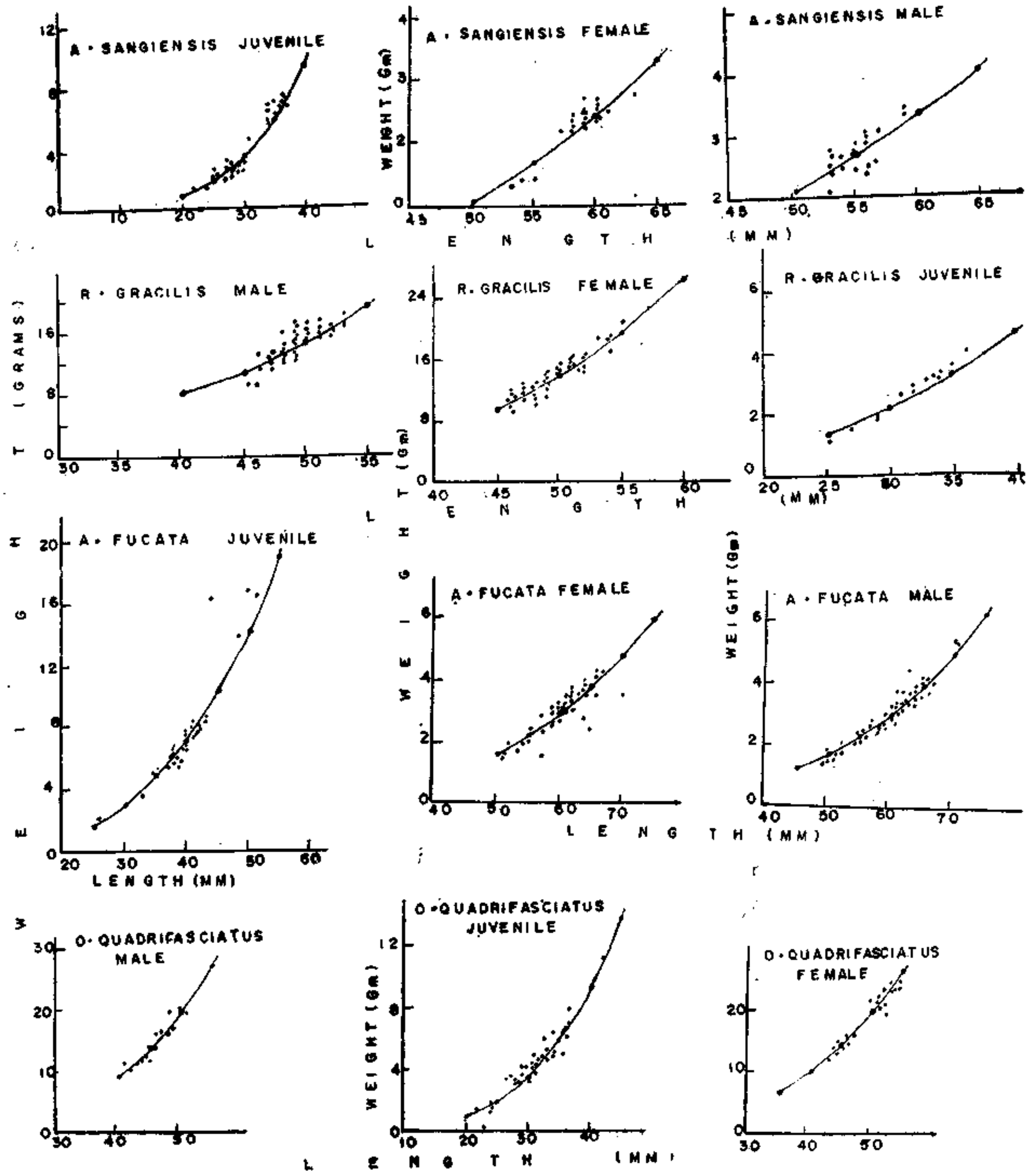

Fig. 16. Length-weight relationships of *A. sangiensis*, *R. gracilis*, *A. fucata* and *O. quadrifasciatus*.

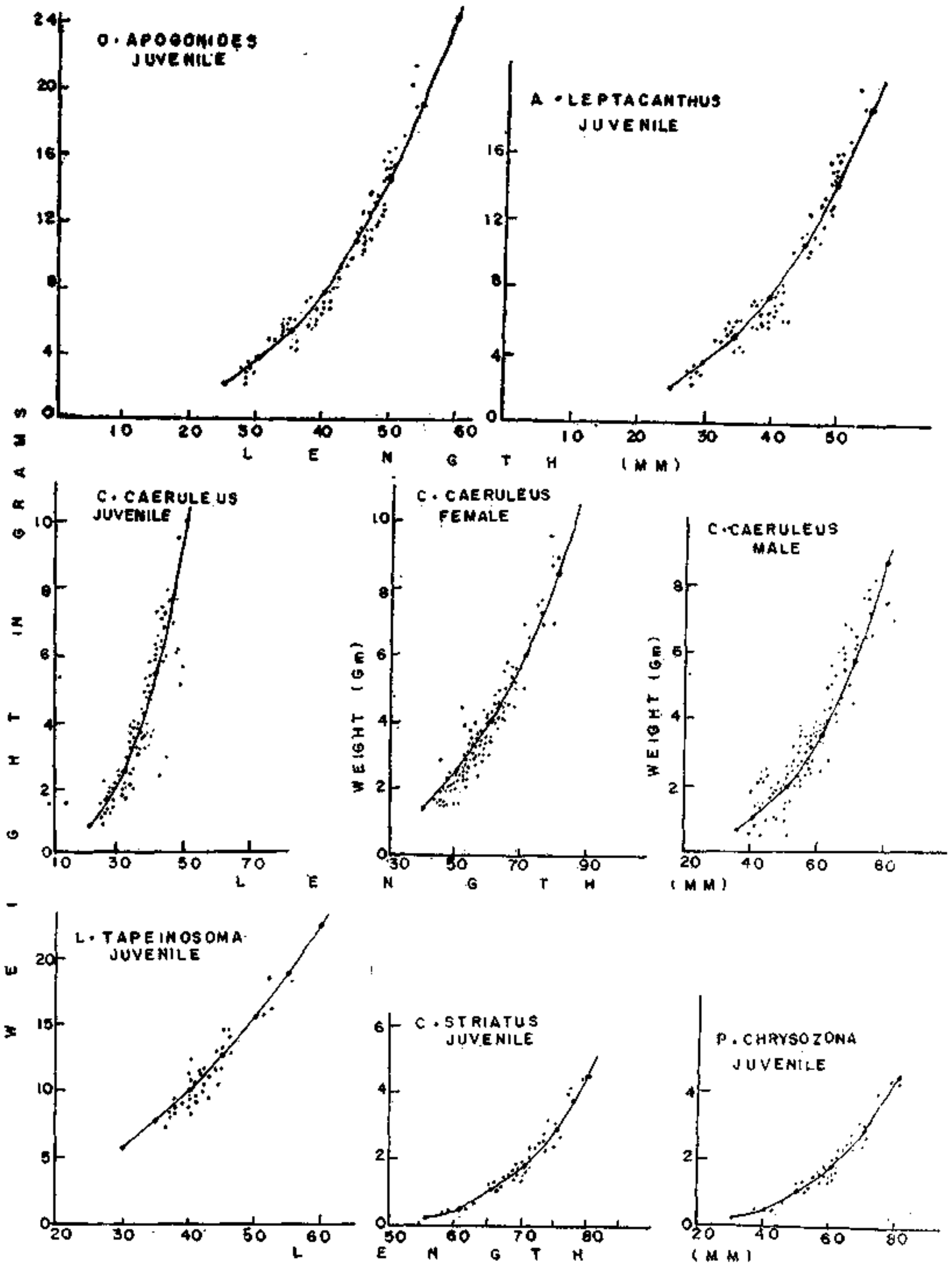

Fig. 17. Length-weight relationships of *O. apogonides*, *C. caeruleus*, *L. tapeinosoma*, *A. leptacanthus*, *C. striatus* and *P. chrysozona*.

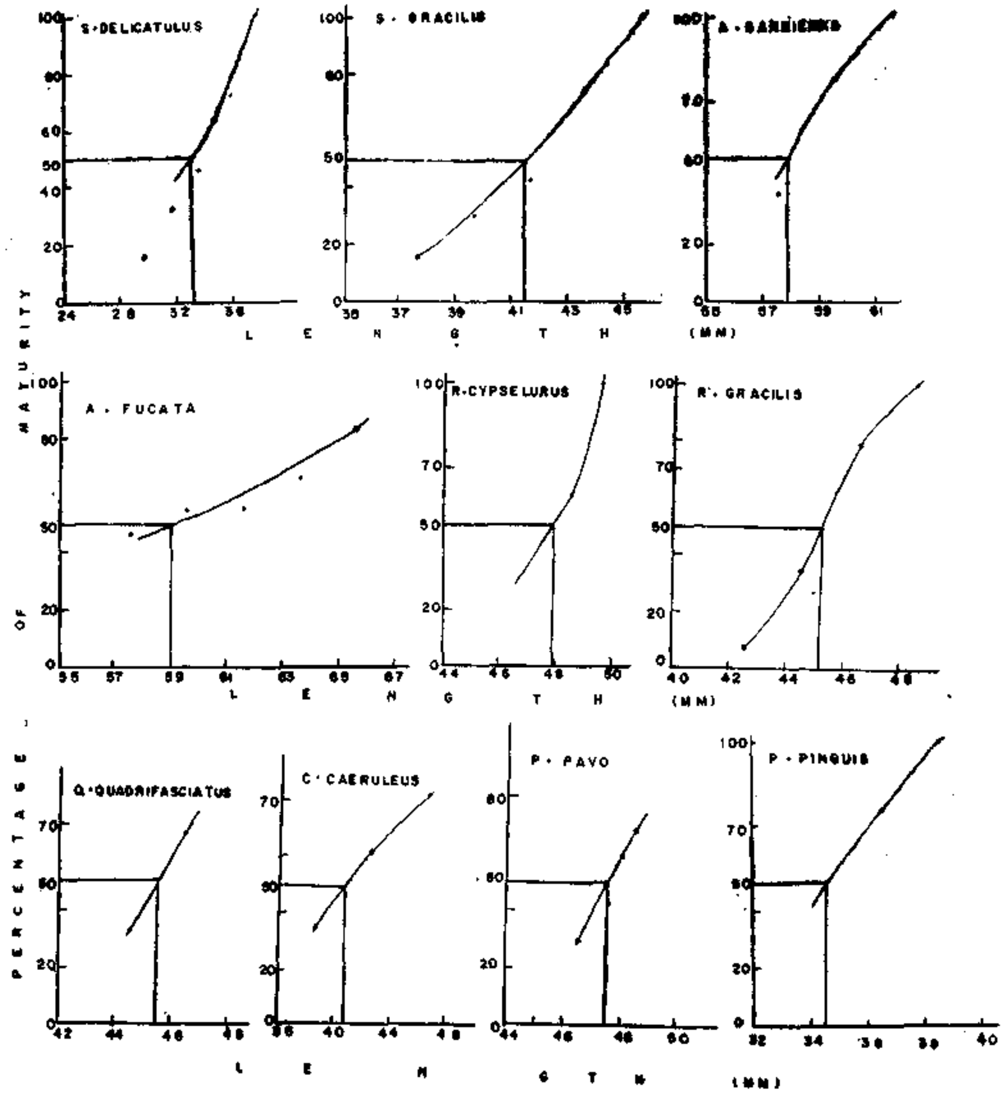

Fig. 18. Size at first maturity of *S. delicatulus*, *A. fucata*, *O. quadrifasciatus*, *S. gracilis*, *R. cypselurus*, *C. caeruleus*, *A. sangiensis*, *R. gracilis*, *P. pavo* and *P. pinguis*.

TABLE 4. *Size at first maturity of live bait fishes*

Species	Smallest mature fish observed (mm)	Size at first maturity (mm)
Spratelloides delicatulus	29	33
S. gracilis	37	41
Archamia fucata	55	59
Rhabdamia gracilis	44	45
R. cypselurus	46	48
Apogon sanglensis	57	58
Ostorhynchus quadrifasciatus	44	46
Pomacentrus pavo	46	48
Chromis caeruleus	40	41
Pranesus pinguis	34	34

TABLE 5. *Sex ratios of live bait fishes*

Species	No. of males	No. of females	Female Male :
S. delicatulus	348	317	1.1 : 1.0
S. gracilis	317	355	1.0 : 1.1
A. fucata	76	64	1.2 : 1.0
R. gracilis	89	89	1.0 : 1.0
R. cypselurus	18	36	1.0 : 2.0
A. sangiensis	25	27	1.0 : 1.1
O. quadrifasciatus	22	29	1.0 : 1.3
P. pavo	21	50	1.0 : 2.4
C. caeruleus	135	133	1.0 : 1.0
P. pinguis	71	108	1.0 : 1.5

TABLE 6. *The total length (TL) range, total weight (TW) range, fecundity (total number of yolked eggs) range and the mean relative fecundity (eggs per gm body weight) of live bait fishes*

Species	No. of fish studied	TL range (mm)	TW range (gms)	Fecundity range	Mean relative fecundity
S. delicatulus	17	38-49	0.40-0.93	235-1,087	818
S. gracilis	42	47-61	0.68-1.52	541-2,393	1,067
A. fucata	13	57-66	1.52-4.12	1,146-2,558	540
R. gracilis	15	49-54	1.30-1.74	1,509-3,225	1525
R. cypselurus	17	46-52	0.88-1.88	1,270-3,310	1,660
A. sangiensis	20	57-61	2.34-3.78	1,320-5,770	1,077
O. quadrifasciatus	16	46-54	1.45-2.52	930-2,960	1,058
P. pavo	17	47-67	2.07-6.48	1,526-6,023	909
C. caeruleus	30	48-77	2.49-9.65	1,715-22,765	1,343
P. pinguis	14	42-63	0.42-1.91	90-330	239

TABLE 7. *Food and feeding habits of live bait fishes (All are zooplankton feeders except* P. pavo *which is an algal browser)*

Species	Major food items
S. delicatulus	Copepods, decapod larvae, mysids, polychaetes, *Lucifer*, cladocerans, amphipods.
S. gracilis	Copepods, cladocerans, decapod larvae, amphipods, crustacean remains.
C. caeruleus	Decapod larvae, copepods.
P. pavo	Algal filaments.
R. gracilis	Copepods, amphipods, decapod larvae, cladocerans, mysids, fish eggs, zoea of crab, polyp of siphonophores.
R. cypselurus	Cladocerans, crustacean remains.
A. fucata	Amphipods, mysids.
A. sangiensis	Copepods, amphipods.
O. quadrifasciatus	Decapod larvae, euphausids, amphipods.
O. apogonides	Decapod larvae copepods, crab larvae, crustacean remains.
A. leptacanthus	Mysids, cumacea, copepods, amphipods.
C. caerulaureus	Copepods, decapod larvae, crustacean eggs, cladocerans, ostracods, polychaetes.
P. chrysozona	Copepods, crustacean remains, apogonid eggs, ostracods, decapod larvae, cladocerans.
P. pisang	Decapod larvae, ostracods, crustacean remains.
C. xanthonotus	Ostracods, decapod larvae, crustacean remains.
L. tapeinosoma	Copepods, crustacean eggs.
P. pinguis	Copepods, *Lucifer*, postlarvae of molluscs.

BAITFISH EVALUATION

The desired characteristics of a good live bait fish are (i) length below 15 cm. preferably between 6-8 cm, (ii) highly reflective lateral surface, (iii) a tendency to flee towards the surface, (iv) hardiness and survival for prolonged periods in captivity, (v) a tendency to return to the boat when broadcast and (vi) relative abundance and availability to the fishery. An evaluation of the above characteristics of the tuna live baits of Lakshadweep was made based on the review of literature and field and laboratory observations, and the results are as follows :

A. Body length	1. 2.5 to 7.5 cm.
	2. 7.5 to 15.2 cm.
B. Body form	1. Elongate.
	2. Oblong.
	3. Deep bodied.
	4. Notably compressed.
C. Body colouration	1. Silvery.
	2. Light, dusky.
	3. Medium dark to dark.
	4. Dark and light.
	5. Bright colours.

D. Baitfish behaviour
1. Response to predator.
2. No response to predator.
3. Schooling or balling around vessel.
4. Disperses, dives, sounds or leaves the vessel.

E. Schooling behaviour
1. Schools at or near surface.
2. Schools at or near bottom.
3. Aggregates on or adjacent to reefs.
4. Disperses or solitary.

F. Survival in captivity
1. Good.
2. Fair.
3. Poor.

G. Baitfish evaluation
1. Excellent (High attraction rate).
2. Good (Effective, suitable, successful etc.).
3. Poor (Low attraction rate).

	A	B	C	D	E	F	G
Dussumieridae							
S. delicatulus ..	1	1	1	3	1	2, 3	1, 2
S. gracilis ..	1	1	1	3	1	2	1
Apogonidae							
A. fucata ..	1	2	5	2	3	1	2
R. gracilis ..	1	2	5	2	3	1	1
R. cypselurus ..	1	2	5	2	3	1	2
A. sangiensis ..	1	2	5	2	3	1	2
A. leptacanthus ..	1	2	5	2	3	1	2
O. quadrifasciatus ..	1	2	5	2	3	1	2
O. apogonides ..	1	2	5	2	3	1	2
Caesionidae							
C. caerulaureus ..	1, 2	2	5	1	2	1	1
C. striatus ..	1, 2	2	5	1	2	1	1
P. pisang ..	1, 2	2	5	1	2	1	1
P. chrysozona ..	1, 2	2	2	1	2	1	1
G. gymnopterus ..	1, 2	5	2	1	2	1	1
Pomacentridae							
C. caeruleus ..	1, 2	3	3	4	3	1	2
P. Pavo ..	1, 2	3	3	4	3	1	2, 3
L. tapeinosoma ..	1	2	3	1	3	1	1
Atherinidae							
P. pinguis ..	1, 2	1	1	—	1	1	2, 3

DISCUSSION

Shomura (1977) opined that none of the species used in the pole and line fishery as live bait could be described as ' perfect ' baitfish, since some species may be good for initially attracting tunas, but may not be too effective in holding the fish at the boat. However, based on the desirable characteristics some of the species can be categorised into ' good ' baitfish. From the overall picture of the evaluation of the characteristics of baitfish, it could be seen that *S. delicatulus*, *S. gracilis*, *R. gracilis*, *C. caerulaureus*, *C. striatus*, *P. chrysozona*, *G. gymnopterus* and *L. tapeinosoma* can be categorised as the best species of live baits. The high initial mortality of the sprats, especially of *S. delicatulus* at the time of capture and handling is a negative aspect of its suitability. The apogonid *R. gracilis* eventhough is an excellent bait, the availability of it all through the fishing season in the islands has to be ascertained. The juveniles of caesionids and the pomacentrid, *L. tapeinosoma* even-though are excellent baits, their migratory nature causes wide fluctuation in their availability from year to year which make them undependable species for the pole and line fishery. The sprats, apogonids and the pomacentrid *Chromis caeruleus* are the major resident species which can sustain the pole and line fishery.

The scarcity of live bait at Lakshadweep, often reported in recent years can be attributed mainly to three reasons *viz.* (i) tampering the lagoon ecosystem (ii) the wide fluctuation in the availability, of migrant bait species in certain years and (iii) the exploitation pressure due to the increased demand. With the increase in effort of pole and line fishery to northern islands the demand for live baits has increased considerably. The data collected by CMFRI indicate that the utilisation of live baits at Minicoy has increased from 2799 kg in 1981-82 to 6,457 kg in 1986-87. In the islands other than Minicoy, only *S. delicatulus* is being exploited at present as live bait, whereas the live bait resource survey has proved that vast resources of live bait species, both migrant and resident forms belonging to pomacentridae, apogonidae and caesionidae are available around Agatti, Bangaram, Perumul Par, Suheli Par, Kadamat and Bitra. Hence as recommended by James *et al.* (1987) steps should be taken to encourage exploitation of live bait species other than *S. delicatulus* also. This can avoid the dependence of tuna fishery on this single species, the scarcity of which suspends the tuna fishing as well as depletion of the stock of the species due to over exploitation.

An aspect worth considering for the better utilization of available resources is to evolve better methods of handling, holding and transportation of baits especially those which are prone to large scale mortality during capture and handling such as *S. delicatulus*. Gopakumar and Mathew (1986) reported that initial mortality of *S. delicatulus* following capture ranges from 30-80% depending on the mode of capture, size of fish and density stocked in the tank. They found that the shock mortality due to osmoregulatory stress was greatly reduced by introducing the fish to 50% sea water immediately after capture. Strusaker *et al.* (1975) studied environmental factors affecting stress and mortality of *Stolephorus purpureus* and reported a variety of factors such as capturing the fish during night time, transferring the bait by allowing the fish to swim, introducing the fish in 50% sea water immediately after capture, keeping oxygen concentration to saturation level, using green coloured tanks with rounded corners for storing bait, etc. could reduce the mortality of the bait. Smith (1977) observed that daylight loading of the bait catch, avoiding overcrowding in the bait net and use of buckets with blue colour for transferring bait substantially reduced initial mortality.

An alternative to supplement the natural baitfish resources is to culture live baits.

Shomura (1977) opined that problems faced in culturing baitfish differ markedly from place to place, especially as to the availability of land and fresh water for developing the culture facilities. Herrick *et al.* (1975) investigated the feasibility of rearing the topminnow *Poecilia vittata*, a viviparous fish by using high density cultural techniques. They reported that the cost of producing topminnows are substantially lower than the costs of capturing live bait and hence the production of topminnows on a commercial level using the techniques developed at Hawaii Institute of Marine Biology appeared to be economically feasible. Baldwin (1977) also opined that intensive culture of a suitable live bait fish appears to offer a reasonable solution in areas known to have little or no natural stocks of baitfish. However, it is felt that a substantial capital investment is required for the construction of brood ponds, rearing ponds, wells, water storage tanks, the land for locating these facilities and the costs of equipments such as pumps, compressors, generators etc. Recurring expenditures such as maintenance of equipments, electricity, food, labour, etc. are also involved. According to Collette and Nauen (1983) and Sakagawa (1986) the bait rearing is hardly feasible on large enough scale to support a major fishery for skipjack tuna. At Lakshadweep, due to the costs involved in the operations to capture natural live baits for culture practices and capital intensive culture systems, the economic feasibility of utilising the cultured baits to sustain the present small scale fishery and envisaged expansion in this sector should be carefully ascertained. Eventhough the breeding biology of only few species are known, the candidate species for holding and rearing appears to be *Chromis caeruleus*, *Rhabdamia gracilis* and *Archaemia fucata*. The mouth breeding habit of some of the apogonids is a positive aspect in their being reared in captivity.

Another aspect for solving the baitfish scarcity problem is the introduction of substitute baits. Baldwin (1977) stated that throughout the Pacific, anchovies rank first in terms of quantity used, value and general desirability as baitfishes. Based on the live bait investigations done at Vizhinjam, Luther *et al.* (1984) reported that for *Stolephorus buccaneeri* and *S. devisi* hardiness could be increased by holding them in pens and it was possible to keep the former species for about three months and the latter two months in captivity. No information is available on the *Stolephorus* resources around Lakshadweep. The feasibility of capturing and utilising whitebaits as live bait for tuna in the Lakshadweep sea needs to be explored. Since the environmental degradation deprives the live bait species of the specific microhabitat requirements to settle at the end of their postlarval pelagic life, the protection of the reef ecosystem while implementing developmental programmes in the islands is of paramount significance. In short, employment of all the species of available live baits, better utilization of captured live bait, development of economically viable confinement and transportation methods, artificial production of live baits, introduction of substitute baits and conservation of the delicate coral reef ecosystem seem to be the major options for the development and management of tuna live bait fishery in the Lakshadweep.

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DISTRIBUTION OF MEROPLANKTON IN RELATION TO THE THERMOCLINE IN THE WESTERN INDIAN OCEAN DURING DAY AND NIGHT*

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ABSTRACT

Based on 35 night and 27 day zooplankton collections made from a depth of 200 m to surface and the thermocline layer to surface, the distribution of meroplankton in relation to the thermocline was studied in the western Indian Ocean. The abundance of fish larvae both below and above the thermocline indicated that the thermocline is not a barrier for the distribution of larvae. Fish larvae showed nocturnal abundance. Their diurnal migration indicate that the major factor controlling the vertical migration is light rather than temperature. Fish eggs were found in large numbers in certain areas probably due to congregation of spawners. Larvae of bivalves and Anthozoa indicated nocturnal abundance influenced more by light than temperature. Larvae of sipunculoids and cirripeds mainly present below thermocline and Tornaria above thermocline showed nocturnal abundance. Actinotrocha and phyllosoma larvae were rare. A swarm of stomatopod larvae occurred in one collection. Cephalopod larvae indicating nocturnal abundance preferred the layer below thermocline. In general vertical migration of larvae were more influenced by light than temperature.

INTRODUCTION

THE WESTERN half of the Indian Ocean is an area where the changes brought about by the monsoon (time) is found to be outweighing the changes brought about by space in the primary and secondary production. The depth of the thermocline was found varying from shallow to deep, being subjected to the influence of monsoons. So this study was undertaken in order to find out the nature of relation, if any, existing between the thermocline and the vertical distribution of the meroplankton.

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MATERIAL AND METHODS

As part of the International Indian Ocean Expedition (1960-65), R.R.S. *Discovery* collected zooplankton samples from 62 stations in the western half of the Indian Ocean. Of these, 35 samples were collected during night and 27 samples during day. At each station two separate hauls were made, one from 200 m to surface and another from the thermocline to the surface; using Indian Ocean Standard net. The depth of the thermocline varied between 30 and 120 m. The entire observation lasted from March 1964 to August 1964. The station number with positions are depicted in Fig. 1. As a matter of convenience to explain all the 62 stations were grouped under 6 cruise tracks following mainly the time of cruise.

The numerical data of certain meroplankton taxa collected from each station in relation to the thermocline is presented in the form of graphs in Figs. 2 to 5. In presenting the data

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the unit standard haul system is found more meaningful than the number per m^3 since the initial assumption that the number of organisms is greater when the volume of water filtered is greater is not applicable for long vertical hauls, especially in relation to the non-random distribution of the organisms. But in fact the number of organisms are really more in the long haul (200-0 m) than in the short haul (thermocline to surface). Also the regression analysis showed the relationship between the two hauls, 200-0 m and the thermocline to 0 m (No./m^3) to be highly significant (99% level).

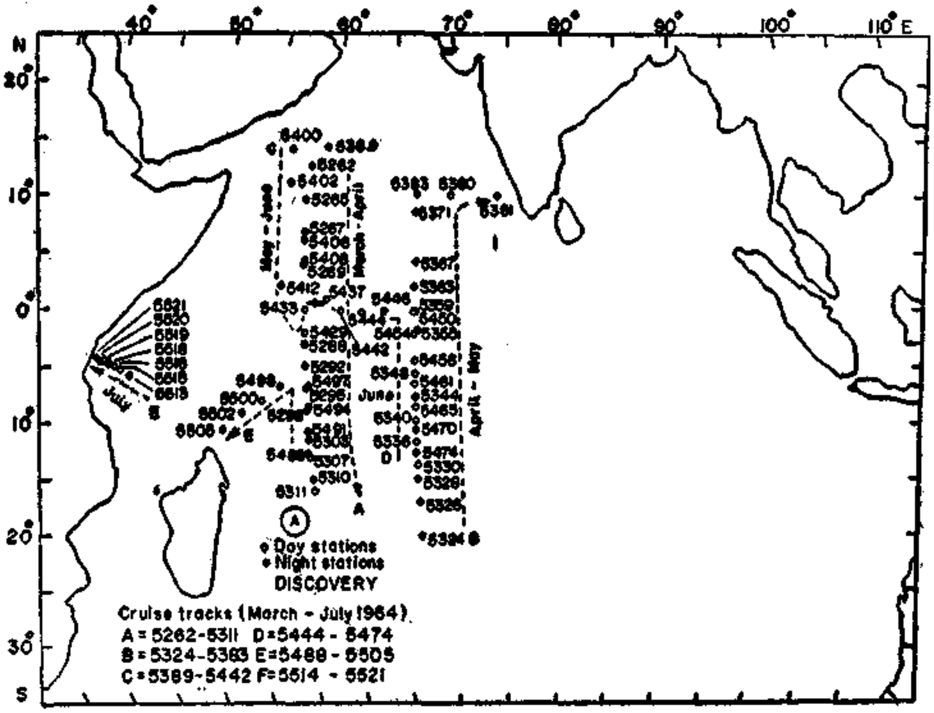

Fig. 1. Stations with positions from where the observations made.

Results and Discussion

The distribution of fish larvae in relation to the thermocline is shown in Fig. 2. Fish larvae showed nocturnal abundance having 25 larvae per haul above the thermocline and 33 larvae per haul below the thermocline, whereas they are sparsely populated above (7/haul) and below (17/haul) the thermocline in the day hauls, in the 200 m water column. Fish larval abundance below the thermocline in the day time indicates the vertical migration undergone by fish larvae to avoid surface light. The mean day level may vary according to the penetration and intensity of light in different stations.

The area explored being under the influence of monsoon and having thermocline in shallow depths due to mixing of bottom and surface waters, light penetration is low. And so fish larvae occur in most day stations, but in lesser numbers. The occurrence of fish larvae above and below the thermocline indicates that the thermocline is not a barrier for the distribution of fish larvae. However, George (1979) found fish larvae of *Rastrelliger*, sardine and tuna being abundant at specific temperature ranges.

Ahlstrom (1959) found no consistant difference in the day and night catches of larvae of *Trachurus symmetricus* off California. While Richards *et al.* (1971) found no difference in catches of *Auxis* larvae between day and night, Klawe (1963) had noted lesser catches of *Auxis* larvae at night. Ali Khan (1972), Silas (1974) and Peter (1977) recorded increased catches of fish larvae at night in the Indian Ocean, while Boonprakob and Debtaranon (1974) found positive phototaxis reaction in the larvae of *Rastrelliger neglectus*, large number of the larvae congregating at 5 to 10 m during day time and sinking to greater depths

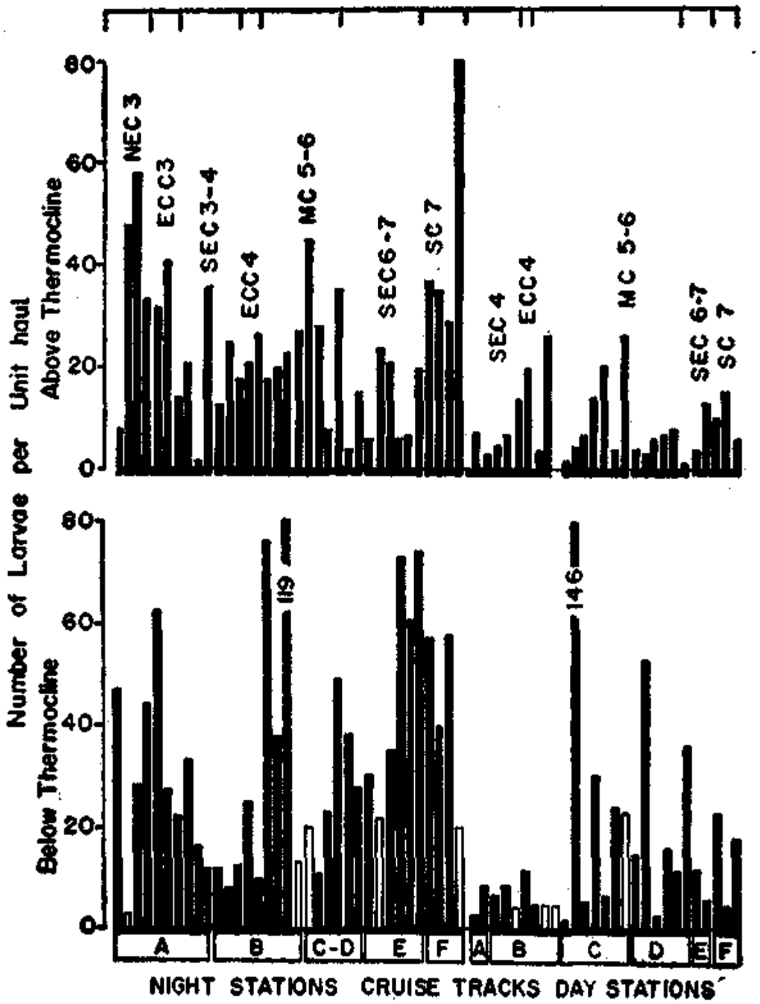

Fig. 2. Distribution of fish larvae (in terms of unit haul). Blank columns represent negative values. NEC 3—North Equatorial Current during March, ECC 3—Equatorial Counter Current during March, SEC 3, 4—South Equatorial Current during March and April, ECC 4—Equatorial Counter Current during April, MC 5, 6—Monsoon Current during May and June, SEC 6,7—South Equatorial Current during June and July and SC 7—Somali Current during July.

from dusk through night. George (1979) studying day and night larval catches showed in most cases a marginal increase in number of larvae caught at night than in the day. The larvae of *Vinciguerria* showed 100 per cent increase in the night catch, while *Sardinella* spp. and *Euthynnus affinis* showed a 50 per cent increase and all the other tuna larvae and larvae of *Rastrelliger kanagurta* showed only a marginal increase in night collections.

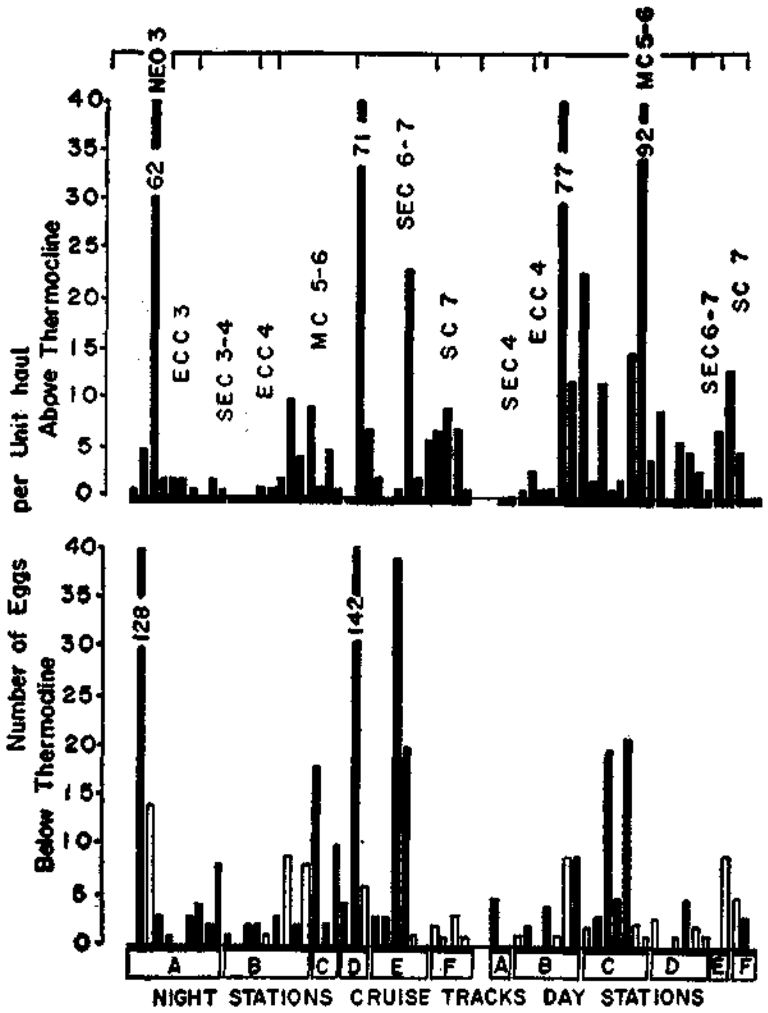

Fig. 3. Distribution of fish eggs (in terms of unit haul). Blank columns represent negative values (For abbreviations, please see Fig. 2).

Thus the diurnal variation seen in the above studies indicates that the major factor in controlling the vertical migration of fish larvae in the region under study is light rather than temperature. Of the 6 cruise tracks, Tracks A, E and F show relatively high abundance of fish larvae (50, 49 and 59 per haul respectively) which perhaps might be due to the influence of the SW Monsoon during June and July. In March-April (Track A) fish larvae are comparatively less in the South Equatorial Current (SEC) than the North Equatorial Current (NEC) and Equatorial Counter Current (ECC). In April-June (Tracks B, C and D) stations of monsoon current show less abundance than SEC and ECC. Track E falling in the area of divergence in July near northeast Madagascar and the Track F in July under the influence of Somali Current show significant increase in the number of fish larvae. Nine stations showed negative values below thermocline, giving the impression that no larvae were present. This can be due to the non-random distribution of the organisms or due to an artefact of the method used.

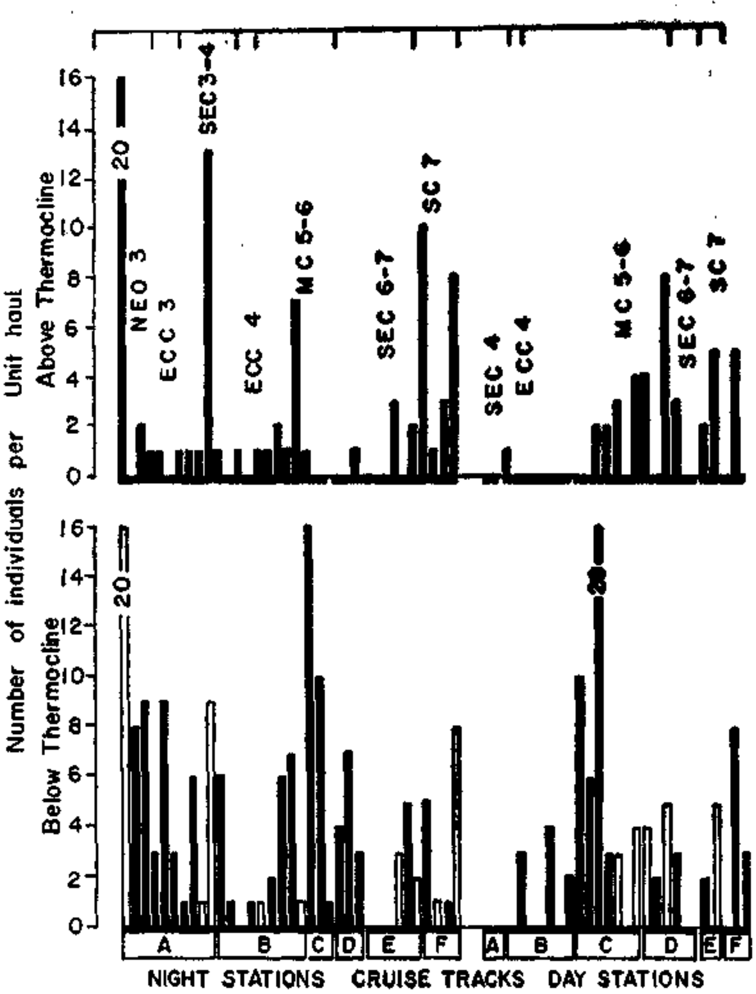

Fig. 4. Distribution of bivalve larvae (in terms of unit haul). Blank columns represent negative values. (For abbreviations, please sea Fig. 2).

The distribution of fish eggs (Fig. 3) indicates only narrow nocturnal abundance (18 per haul) compared to the day hauls (13 per haul). Of the 35 night hauls, while on an average 7 eggs were obtained from hauls above thermocline, hauls below thermocline had 11 eggs per haul. Similarly of the 27 day hauls made, collections above thermocline contained 11 eggs per haul while the collections below thermocline contained only 3 per haul. On a track-wise, Tracks C and D sampled during April-June from the area of monsoon current showed more abundance revealing highest spawning activity. The presence of large number of eggs in certain areas can be taken as proof of congregation of spawners and of spawning ground there. Above results indicate absence of light or temperature effect on the distribution of fish eggs.

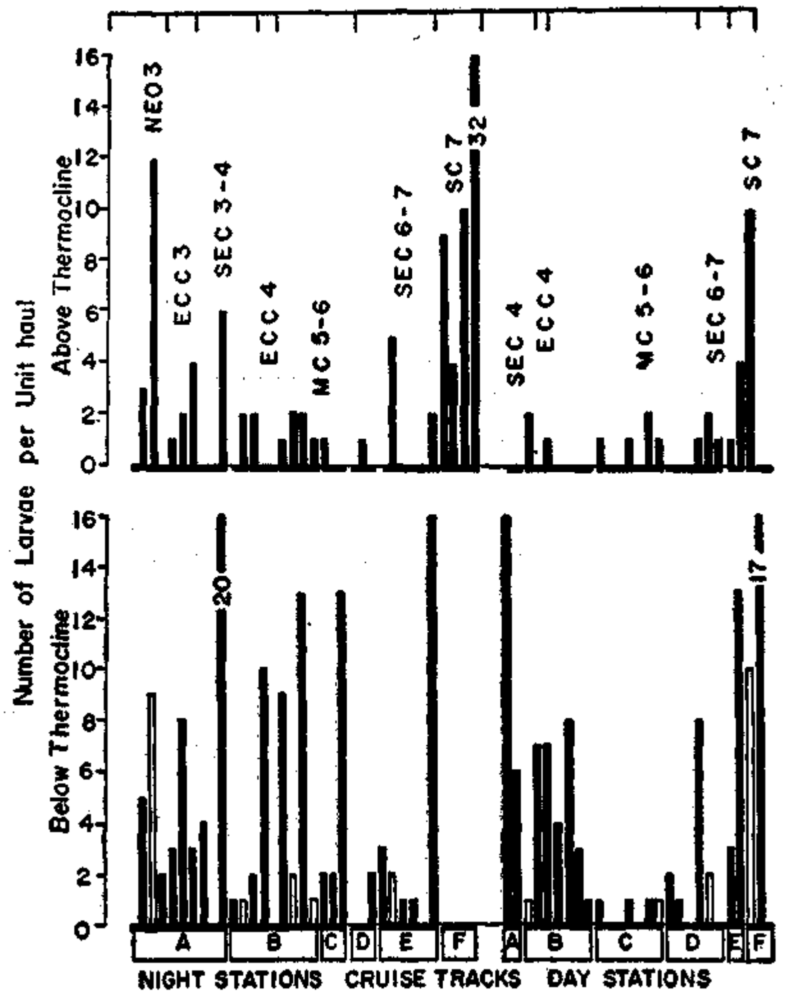

Fig. 5. Distribution of Anthozoan larvae (in terms of unit haul). Blank columns represent negative values (For abbreviations, please see Fig. 2).

Bivalve larvae (Fig. 4) were present in 32 out of 35 night stations, on an average of 3.2 larvae per haul and in only 18 out of 27 day stations with an average of 1.6 larvae per haul. This indicates nocturnal abundance of bivalve larvae in all the collections. While the night hauls made above thermocline had 2.4 larvae per haul, those collections below thermocline had 3.3 larvae per haul. In the day stations, collections above the thermocline had an average of 1.3 larvae per haul and collections below the thermocline had an average of 2.4 larvae per haul. Half of the collections made below the thermocline showed negative values.

Similar to fish larvae, bivalve larvae were also influenced more by light than the temperature during vertical migration. Of the 6 Tracks sampled, the order of abundance was C, A, F, D, B and E. Track C with maximum abundance was under monsoon currents.

Anthozoan larvae (Fig. 5) are present in 24 out of 35 night stations and 22 out of 27 day stations. Frequency of occurrence are same (20 out of 35) in samples above and below thermocline in the night collections and less (12 out of 27) above thermocline than below thermocline (17 out of 27) in the day collections. Larvae are more abundant (about 4 per haul) below thermocline than above thermocline (about 2 per haul) in both the day and night stations. However, 5 night stations and 4 day stations below thermocline showed negative values. The above results indicate that more than the temperature, the light factor acts as a control in the vertical distribution of anthozoan larvae as noted for fish larvae and bivalve larvae. Of the six tracks sampled, the stations of track F which was covered in July falling under the area of the Somali Current had the maximum abundance of 12 larvae per haul. Next to it was the Track A stations covered in March and April under the influence of major Equatorial Currents. The stations in Tracks C and D under the influence of the Monsoon Current and the South Equatorial Current had very poor larval occurrence (2 per haul).

Sipunculoidea larvae are present in 13 out of 62 stations sampled. They are mainly collected from stations in Tracks A and E during March and April period. They are mainly present in the night samples especially below thermocline.

Actinotrocha larvae are present in only 2 out of 62 stations. One day station in Track B under the influence of South Equatorial Current had 37 larvae below thermocline and only one larva above the thermocline. Another day station also in Track D influenced by the Monsoon Current had 4 larvae below the thermocline.

Tornaria larvae are present in 25 out of 62 stations. sixteen night stations had an average number of 7 larvae per haul, whereas 9 day stations had an average number of 6 larvae per haul. This indicates nocturnal abundance. Tornaria are found abundant above the thermocline in contrast to other larval forms. Tornaria are absent below the thermocline in the day stations. Maximum larvae are collected during July from the Somali Current area.

Cirripede larvae are present in 17 out of 62 stations. Of these 10 night stations had 9 larvae in each and 7 day stations had 4 larvae in each. This indicates nocturnal abundance. While the collections above thermocline had an average of one larva per haul, that of below the thermocline had an average of 6 larvae per haul.

Of the 62 stations only one day station above the thermocline in the Track C had one phyllosoma larva. Similarly four brachiopoda larvae are present in a night station above the thermocline in Track E.

Stomatopoda larvae are present in 20 out of 62 collections made. But for the 54 larvae obtained from a night station above the thermocline they are present in very few numbers in the day and night hauls and above and below the thermocline.

Cephalopod juveniles are present in 24 stations out of 62 stations sampled. 13 night stations had an average of 8 larvae per haul whereas 11 day stations had an average of 3 larvae per haul. On an average more cephalopod juveniles are present below the thermocline. Of the 6 tracks sampled tracks E and F covered during June and July had maximum number of juveniles.

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IMPACT OF SEX, SEXUAL MATURITY AND HABITAT ON THE HAEMOLYMPH PROTEIN AND COPPER OF THE GHOST CRAB *OCYPODE PLATYTARSIS* (MILNE EDWARDS)

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Abstract

The haemolymph protein and copper concentration of *Ocypode platytarsis* has been studied in three size groups of males and females separately. These haemolymph constituents have been analysed in greater detail in relation to the sex and sex differences of *Ocypode platytarsis* with a view to find out the impact of sexual maturity and habitat of males and females on the haemolymph protein and copper constituents.

Introduction

The Members of the family Ocypodidae inhabit the tidal zone. One of the major genera of the family is Ocypode which are commonly called Ghost crabs. These are nocturnal crabs found occupying different habitats of the intertidal zone. Nineteen species of Ocypode crabs have been reported so far, of which only five have been reported in Indian shores (Alcock, 1900 ; Chhapgar, 1957). Among the five, *O. platytarsis* is littoral in habitat (Rajabai Naidu, 1951 ; Takahasi, 1935). Paulraj (1980) has distinguished the stages of sexual maturity as immature, maturing and matured. Male members of *O. platytarsis* mature when the carapace width is between 20 and 30 mm and female members mature when the carapace width is between 30 and 35 mm. The present investigation aims at finding the impact of sex, sexual maturity and habitat on the haemolymph protein and copper concentration. Attempt has also been made to study the copper and protein relationships.

Materials and Methods

For the purpose of present investigation *O. platytarsis* was collected from the wave wash zone of Madras Beach. The animals were collected at night using dragnet. Measurements of Carapace width and length of the crabs were taken alongwith weight following the procedures of Sandan (1937) and Raghu Prasad and Tampi (1954). The method used to distinguish the stages of maturity of sex was by the criteria suggested by Paulraj (1980). The animals were divided into 3 groups on the basis of their carapace width (Group I consists of animals having less than 21.5 mm carapace width ; Group II between 21.5 and 30.0 mm and Group III more than 30.0 mm carapace width). Before taking measurements, the animals were immobilized by placing them in the ice chamber of the refrigerator for about 3 minutes. A pair of finely pointed divider and a millimeter scale were used to take the carapace width. The weight of the crabs were taken using the Stanton DO3T mono balance.

Blood sample

The entire investigation was carried out on the blood of *O. platytarsis*. Hence it becomes necessary that the blood available from the crab must be of significant quantity. In this regard *O. platytarsis* satisfies the requirements.

Blood was directly drawn into a fine caliberated 0.1 ml micropipette by cutting the tip of the leg and was immediately transferred to the tubes containing the required reagents for various biochemical analysis. Care was taken to see that seepage was minimal.

Estimation of protein

The haemolymph protein concentration of the crabs was determined following Biuret method of Gornall *et al.* (1949). This method was selected, because the consistency of this method has been established by Subashini (1980) and Subhashini and Ravindranath (1980, 1981) and found this method superior for crustacean blood proteins over Folin-ciocalteu and microkjeldahl methods, due to its greater consistency in performance, simplicity and stability of colour and least susceptibility for interfering substances.

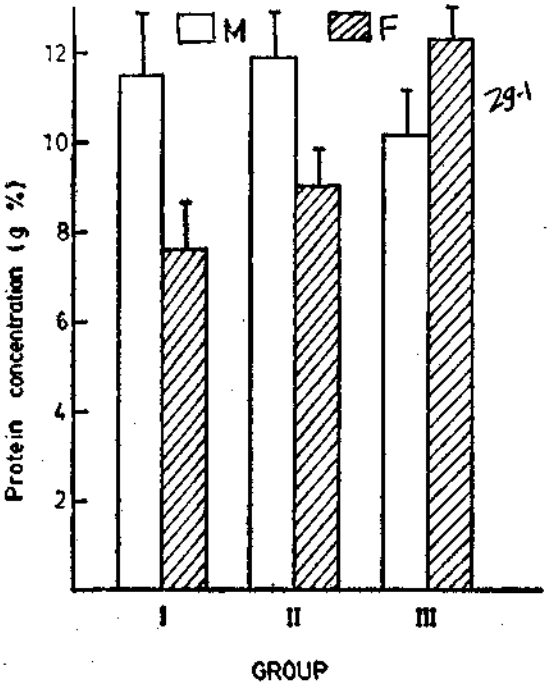

Fig. 1. Protein concentration (g %) at different groups.

Determination of copper

In the present study 2, 2^1, biquinoline method is used which is the most common spectrophotometric method, because it is very reliable, simple, stable and reproducible (Arumugam and Ravindranath, 1980, 1981).

RESULTS

The haemolymph constituents of *O. platytarsis* are studied in three size groups of males and females separately. The haemolymph constituents analysed include protein and copper.

Protein

The protein concentration differs between sexes (Fig. 1). The sex difference, though obvious in groups I and II, it is statistically significant in group II. In males, in general, the protein level ranges from 10.16 to 11.91 gm %. In females it ranges from 7.61 to 12.3 gm %. There is no difference in the protein concentration of males in relation to sexual maturity. On the other hand, the protein level increases steadily during the course of sexual maturity in females. The differences between groups II and III and I and III are significant.

Copper

The copper concentration differs between sexes in stages I, but such differences is not obvious in later stages of maturity (Fig. 2). Among the male members of the groups, the copper concentration ranges from 108.2 to 144.02 μg/ml. The difference between groups are not statistically significant. Among female members of the groups, the copper level increases from 92.03 to 128.37 μg/ml. The difference between groups I and III is statistically significant.

Copper and protein relationship

Results of analysis of copper and protein concentrations reveal that there is a significant positive correlation between protein and copper concentrations (Fig. 3). The slope of regression is statistically significant. The regression analysis confirms the close association between the two constituents. Based on the data, copper/protein ratio was calculated. Interestingly the ratio did not differ between sexes and stages of sexual maturity between males and females. The copper protein ratio has enabled calculating the quantities of copper bound and copper free proteins.

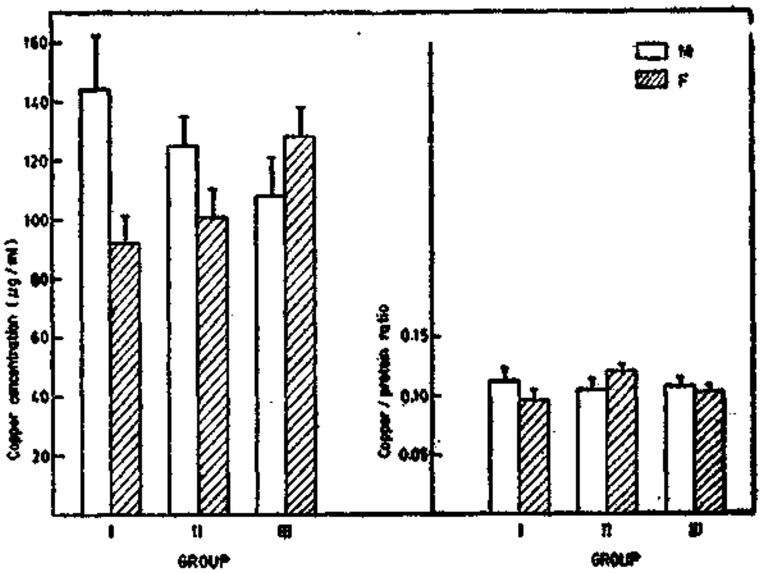

Fig. 2. Copper concentration (µg/ml) and copper-protein ratio in different groups.

Copper bound proteins

The copper bound proteins do not vary much in relation to sexual maturity in males (Fig. 4). On the other hand, significant difference is observed between stages I and II and I and III in females. The copper bound protein differs between sexes in group I, but such sex differences is not observed at later stages.

Copper free proteins

Copper free proteins (Fig. 4) differ between sexes in group II, in that they are higher in males than in females. Considering the stages of sexual maturity, the copper free proteins differ between stages II and III in both sexes. In males, there is a fall in copper free protein level in stage III. In females the reverse is true.

DISCUSSION

It is known that in general haemolymph water content in crabs ranges from 90 to 95% and the rest is dry weight with major share of protein (Subhashini and Ravindranath, 1982). The protein concentration in the haemolymph ranges from 7.61 to 12.3 gm % in *O. platytarsis*. Usually in brachyuran decapods haemolymph protein concentration rarely exceeded 10 gm %. In *Macropius holstatus*, it ranged from 1.52 to 9.42 gm % (Uglow, 1969); in *Callinectes sapidus*, it ranged from 1.46 to 10.0 gm % (Horn and Kerr, 1963; Lynch and Webb, 1973; Pauley *et al.*, 1975); in *Scylla serrata* it ranged from 2.72 to 13.0 gm % (Subhashini and Ravindranath, 1980; Arumugam and Ravindranath, 1980). It may be noted from the above given reports that the range of

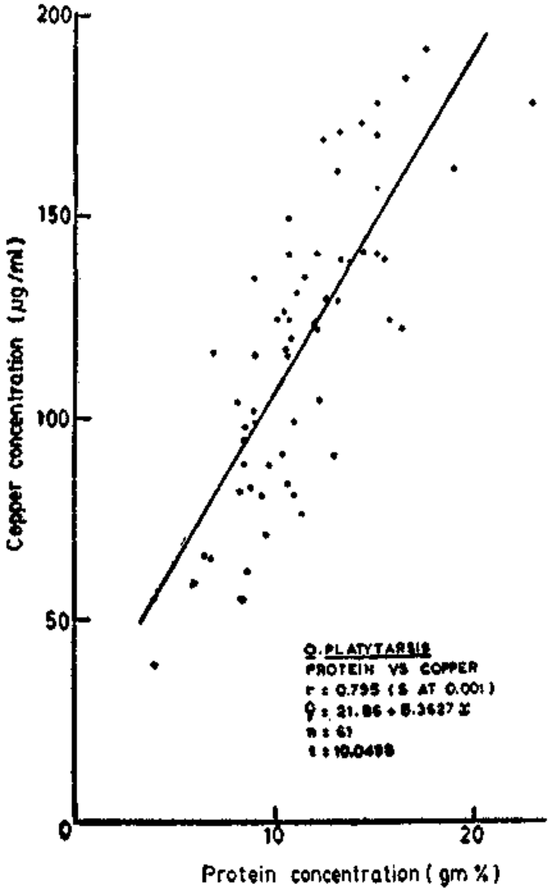

Fig. 3. Copper - Protein relationship in *O. platytarsis*.

haemolymph protein values observed for *O. platytarsis* is not uncommon in previous literature. But Ramalingam *et al.* (1981) have found that the haemolymph protein concentration is *O. platytarsis* ranged from 3 to 6 gm %. Such low values reported for *O. platytarsis* may be due to the methodology adopted by Ramalingam *et al.* (1981). It was shown that haemolymph protein value in general is always lower with Micro-Kjeldahl method, when compared with Biuret and Folin-ciocalteu methods (Subhashini and Ravindranath, 1980), because the protein value calculated after multiplying the nitrogen value with a conversion factor 6.25 and the conversion factor is applicable only to pure proteins and not to protein bound with lipids and polysaccharides (Bailey, 1967). It is known that a major fraction of haemolymph protein of the crabs is bound with lipids and polysaccharides (Paulpandian and Kannupandi, 1975).

The protein concentration in the haemolymph also differed between sexes in *O. platytarsis*. In stage II sexual maturity in males showed higher values than females. Similar results have been reported in *Penaeus marginatus* and *Macrobrachium rosenbergii* by Blaze *et al.* (1974).

The present investigation reveals that there is a close positive correlation between haemolymph copper and protein concentration, a finding in close agreement with the reports of Horn and Kerr (1963) and Colvocoresses and Lynch (1975) for the Blue crab *Callinectes sapidus* and that of Arumugam (1981) for the Mud crab *Scylla serrata*. The range of copper concentration reported for *O. platytarsis* is comparable to *Palaemon squilla, Crangon vulgaris* (Djangmah and Grove, 1970) *Palinurus interruptus* (Johnston and Barber, 1969) and *Scylla serrata* (Arumugam and Ravindranath, 1980).

The copper protein ratio of *O. platytarsis* ranged from 0.094 to 0.121 which is comparable to that of *Callinectes sapidus* (Horn and Kerr, 1969). Only pure haemocyanin is known to have the copper protein ratio of 0.2. But the low copper protein ratio reported for *O. platytarsis* suggests that copper free proteins may be present in this species. From the ratio it is clear that *O. platytarsis* is having considerably more copper bearing proteins and so it is agile as reported by Paulraj (1980). Since the major proportions of copper bearing proteins are oxygen carriers greater demand is there in the littoral and agile *O. platytarsis* which requires more of copper bound protein. It is interesting to note that the copper bearing proteins do not change much in relation to sexual maturity in *O. platytarsis*. However one may note that there is an increase in the level of copper bearing proteins in the sexual maturity in females. Probably these proteins are necessary for the reproductive activities of the females and also for egg production.

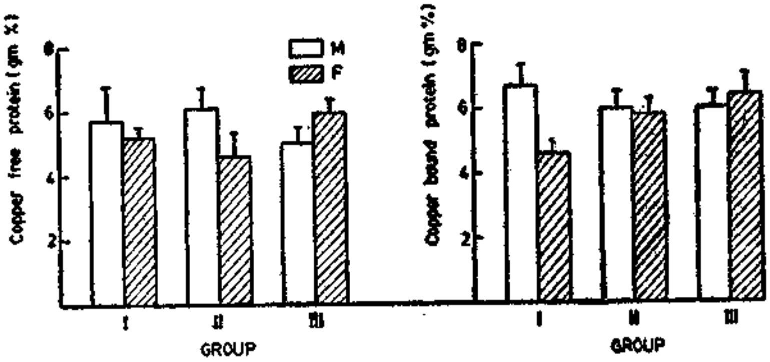

Fig. 4. Copper-free and copper-bound protein (g %) in different groups.

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MARINE PHYTOPLANKTON OF THE MANGROVE DELTA REGION OF WEST BENGAL, INDIA

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ABSTRACT

The paper deals with the taxonomic account of 46 marine phytoplankton taxa of Bacillariophyceae, Dinophyceae and Cyanophyceae, collected from mangrove delta regions of West Bengal, India. All these taxa have been recorded for the first time from this part of India. Among these, *Coscinodiscus, Rhizosolenia, Chaetoceros, Biddulphia, Pleurosigma, Ceratium* and *Protoperidinium* are found to be the dominant genera and almost present round the year.

INTRODUCTION

THERE are a few reports on systematic accounts of the marine phytoplankton of the Indian Coast ; though a considerable work has been done by a large number of scientists in temperate and polar areas (Allen. 1936 ; Bainbridge, 1953 ; Brunel. 1962 ; Hendey, 1954, 1964, 1971 ; Hustedt, 1930 ; Parke, 1953 ; Yamaji, 1968).

Regarding the Indian Ocean, Karsten (1907) and Steemann Neilsen (1939) gave some reports of phytoplankton ; Subrahmanyan (1946, 1958) reported different forms of diatoms from the Madras Coast and also listed more than three hundred species of phytoplankton from the Arabian Sea off the West Coast of India. He (1968, 1971) also added a detailed account of the Dinophyceae of the Indian Seas. Chacko (1950) reported the marine plankton of the southern Bay of Bengal around the Krusadi Island. Venkataraman (1958) contributed the report of marine diatoms from Kanyakumari and Nair (1959) reported marine diatoms from Trivandrum Coast. Wood (1963) gave a check list of Dinoflagellates from the Indian Ocean. Taylor (1966) recorded some species of phytoplankton of the South Western Indian Ocean. But there is no records of marine phytoplanktonic flora of Mangrove delta of Sundarban area of West Bengal, India. Hence, this study was undertaken and the results reported here.

Authors are thankful to Shri B. N. Singh for his help and for the collection of algal sample during field survey.

MATERIALS AND METHODS

For the purpose of systematic study, the phytoplankton were collected from various parts of river networks of Sundarban delta of West Bengal, India. Collections were made round the year 1986 by phytoplankton nets of different mesh sizes from the surface waters upto the depth of 60 cm during high tides. The collecting locations were situated between 21° 32′-21° 58′ N and 87° 55′-88° 35′ E.

After collection, the net was held vertically and washed carefully with flowing sea water,

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so that all plankters were collected at the bottom of the net bucket. Then the phytoplankton samples were preserved in 5% formalin for analysis.

Before analysis, materials were cleaned by adding hydrochloric acid for dissolving the calcareous matter. After centrifugation the acid was decanted and the sediment was washed by adding water. Then concentrated sulphuric acid was added carefully. Some crystals of potassium dichromate was then added. The sulphuric-chromic acid mixture was then poured off and water was added. After proper cleaning the materials were mounted in a drop of distilled water and studied. For longer preservations materials were mounted in Canada balsam or DPX.

SYSTEMATIC DESCRIPTION OF THE SPECIES

Altogether 46 forms were recorded, representing 24 genera of Bacillariophyceae, Dinophyceae (Dinoflagellates) and Cyanophyceae. Among these *Coscinodiscus Rhizosolenia, Chaetoceros, Biddulphia, Pleurosigma, Ceratium and Protoperidinium* are found to be the dominant genera and almost present round the year.

These forms showed close resemblances to those of the Madras Coast (Subrahmanyan, 1946), Java Sea (Allen and Cupp, 1935), Japan Coast (Yamaji, 1968), the Indian Ocean (Subrahmanyan, 1958, 1968), Bay of Bengal and Bangladesh (Islam and Aziz, 1979).

Class : BACILLARIOPHYCEAE
Order : Centrales
Genus : **Skeletonema Greville**

Skeletonema costatum (Greville) Cleve (Fig. 1 i)

Cleve, 1878. *Bih. Kongl. Sv. Vet. —Akad. Handl.* **5** (8) : p. 18.

=*Melosira costata* Greville, 1866. *Trans. Micr. Soc. Bd.* **14** : p. 77, pl. 8, Fig. 3-6, (1866) ; Cupp, 1943. p. 43, fig. 6 ; Fritsch, 1935. p. 605, fig. 201 ; YDamaji, 1968. p. 27, 97.

Valves lens-shaped, ends rounded, arranged in straight chain with the help of marginal spines ; space between cells longer than cells ; frustules 8-12 μ long, 9-10 μ dia.

Locality: Prentice Island (South 24 Paraganas, W.B.).

Genus : **Coscinodiscus** Ehrenberg

Coscinodiscus eccentricus Ehrenberg (Fig. 1 a)

Ehrenberg, 1839. *Abh. Berl. Akad.*, p. 146 ; Allen and Cupp, 1935. p. 114, fig. 5 ; Fritsch, 1935. fig. 187 A ; Subrahmanyan, 1946. p. 93, fig. 29, 30, and Islam and Aziz, 1975. p. 5, pl. 1, fig. 7-8.

Cells disc-shaped, valves flat, areolae arranged in tangential series, areolae almost all of same size, number 6 in 10μ at the centre and about 8-9 in 10μ near the margin, valves 35-45μ dia. ; margin striated, 18-20 striae in 10μ.

Locality: Bhubaneswari (South 24 Paraganas, W.B.).

Coscinodiscus jonesianus (Greville) Ostenfeld (Fig. 1 d)

Ostenfeld, 1915. *Dansk Bot. Ark.*, **2** (4), p. 13, fig. 7.

=*Eupodiscus jonesianus* Greville, 1862. *Trans. Micr. Soc. N.S. Bd.*, **10** : p. 22, Pl. II, fig. 3 ; Allen and Cupp, 1935. p. 116, fig. 10 ; Subrahmanyan, 1946. p. 97, fig. 42, 45, 48.

Cells large, disc-shaped, areolae in the centre form a rosette ; areolae 4 in 10μ at the centre ; 8-9 in 10μ near the margin, 6-7 in 10μ in between margin and centre ; radial and spiral rows of areolae showing clear chamber opening ; irregular ring of interstitial meshes found ; near the margin two cone-shaped processes present at about 120° apart ; valve 150-210μ diam.

Locality : Prentice Island, Chandanpiri, and Bhubaneswari (South 24-parganas, W.B.).

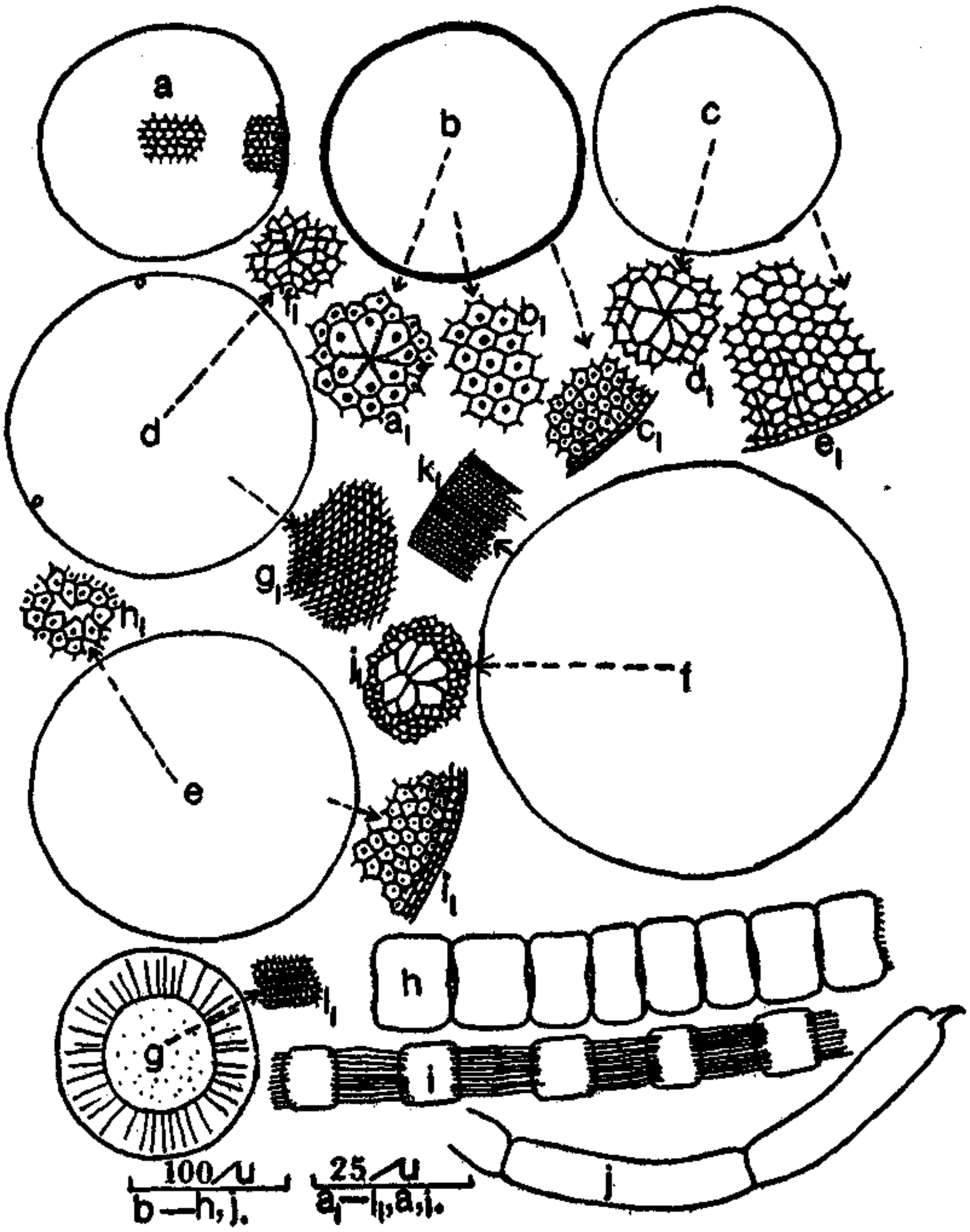

Fig. 1. a. *Coscinodiscus eccentricus* Ehrenberg ; b. *C. oculusiridis* Ehrenberg ; c. *C. perforatus* var. *pavillardi* (Forti) Hustedt ; d. *C. jonesianus* (Greville) Ostenfeld ; e. *C. asteromphalus* Ehrenberg ; f. *C. concinnus* W. Smith ; g. *Planktoniella sol* (Wallich) Schutt ; h. *Lauderia annulata* Cleve ; i. *Skeletonema costatum* (Greville) Cleve and j. *Rhizosolenia stolterfothii* H. Peragollo and a_1-l_1 — highly magnified.

Coscinodiscus oculus-iridis Ehrenberg (Fig. 1 b)

Ehrenberg, 1939. *Abh. Berl. Akad.*, p. 147 ; Allen and Cupp. 1935. p. 119, fig. 15 ; Subrahmanyan, 1946. p. 101, fig. 66-68 and 72.

Cells disc-shaped, large, dark coloured, with large areolation and a central rosette ; 3 areolae in 10μ around the rosette, 2½ areolae in 10μ between rosette and margin and 4-5 areolae in 10μ near margin ; radial and secondary spiral series present ; inner chamber opening clearly seen. Valves 160-175μ diam.

Locality: Prentice Island (South 24-Paraganas, W.B.).

Coscinodiscus concinnus W. Smith (Fig. 1 f)

Smith, 1856. *Syn. Brit. Diat.*, **2** : p. 85 ; Subrahmanyan, 1946. p. 98, fig. 44, 50, 53, 54 and 56.

Cells large, areolae in the centre form a well differentiated rosette, surrounding the centre ; areolae suddenly become smaller and slender, about 8-10 areolae in 10μ at the centre and 11-12 in 10μ near the margin. Chamber openings indistinct. Two small asymmetrical processes clearly seen at about 120° apart ; radial and secondary series regular, valves 250-300μ dia.

Locality : Chandanpiri (South 24-Paraganas, W.B.).

Coscinodiscus perforatus var. **pavillardi** (Forti) Hustedt (Fig. 1 c)

Hustedt, 1930. Rabenhorst's Kryptogamen—Fl., Bd. 7 : Teil 1, p. 447, fig. 247,

=*Coscinodiscus pavillardi* Forti, 1922. *R. Com Talassograf. Ital.*, Mem. 97 : p. 124, pl. 8, fig. 143 ; Subrahmanyan, 1946. p. 99, fig. 52, 57 and 61.

Cells disc-shaped, valves largely areolated with a central rosette, areolae in radial rows, 3-5 in 10μ around the rosette and 3-4 in 10μ near the margin ; both radial and secondary systems of areolation seen ; valves 145-165μ diam. ; margin striated, striae 6 in 10μ.

Locality : Prentice Island, Bhubaneswari (South 24-Parganas, W.B.).

Coscinodiscus asteromphalus Ehrenberg (Fig. 1 e)

Ehrenberg, 1844. *Ber. Berl. Akad.* p. 77 ; Allen and Cupp, 1935. p. 119, fig. 14 ; Subrahmanyan, 1946. p. 99, fig. 62-65.

Cell disc-shaped, valves depressed in the middle ; areolae in radial rows, polygonal, almost all of same size, 3-4 in 10μ near centres and 4-5 in 10μ near margin ; chamber opening clear ; centre with a large rosette with or without a clear area at its centre ; valves 200-215μ diam.

Locality : Chandanpiri (South 24-Parganas, W.B.).

Genus **Planktoniella** Schütt

Planktoniella sol (Wallich) Schütt (Fig. 1 g)

Schütt 1893. Pflanzenleb. d. Hochsee, p. 20, fig. 8.

=*Coscinodiscus sol* Wallich, 1860. *Trans. Micr.* Soc. Bd., *N.S.*, **8** : p. 38, fig. 1, 2 ; Allen and Cupp, 1935. p. 121, fig. 19, Fritsch, 1935. p. 607, fig. 203C ; Cupp, 1943. p. 63, fig 27 ; Yamaji 1968. p. 21 ; Islam and Aziz, 1975. p. 6, pl. 1, fig. 19.

Cell disc-shaped, flat ; valve surface areolated areolae hexagonal, arranged in parallel rows, areolae 12 in 10μ ; epitheca with wing like expansion all around provided with radial rays ; frustules 70-80μ diam. ; frustules with wing 115-132μ diam.

Locality : Prentice Island (South 24-Parganas W.B.).

Genus : **Lauderia** Cleve

Lauderia annulata Cleve (Fig. 1 h)

Cleve, 1873. *Bih. Kongl. Sv. Vet. -Akad. Handl.*, **1** (11) : p. 8 ; Allen and Cupp, 1935. p. 124 fig. 25 ; Subrahmanyan, 1946. p. 111, fig. 100, 102.

Cells cylindrical, touching the adjacent cell by their valve surface form a straight chain

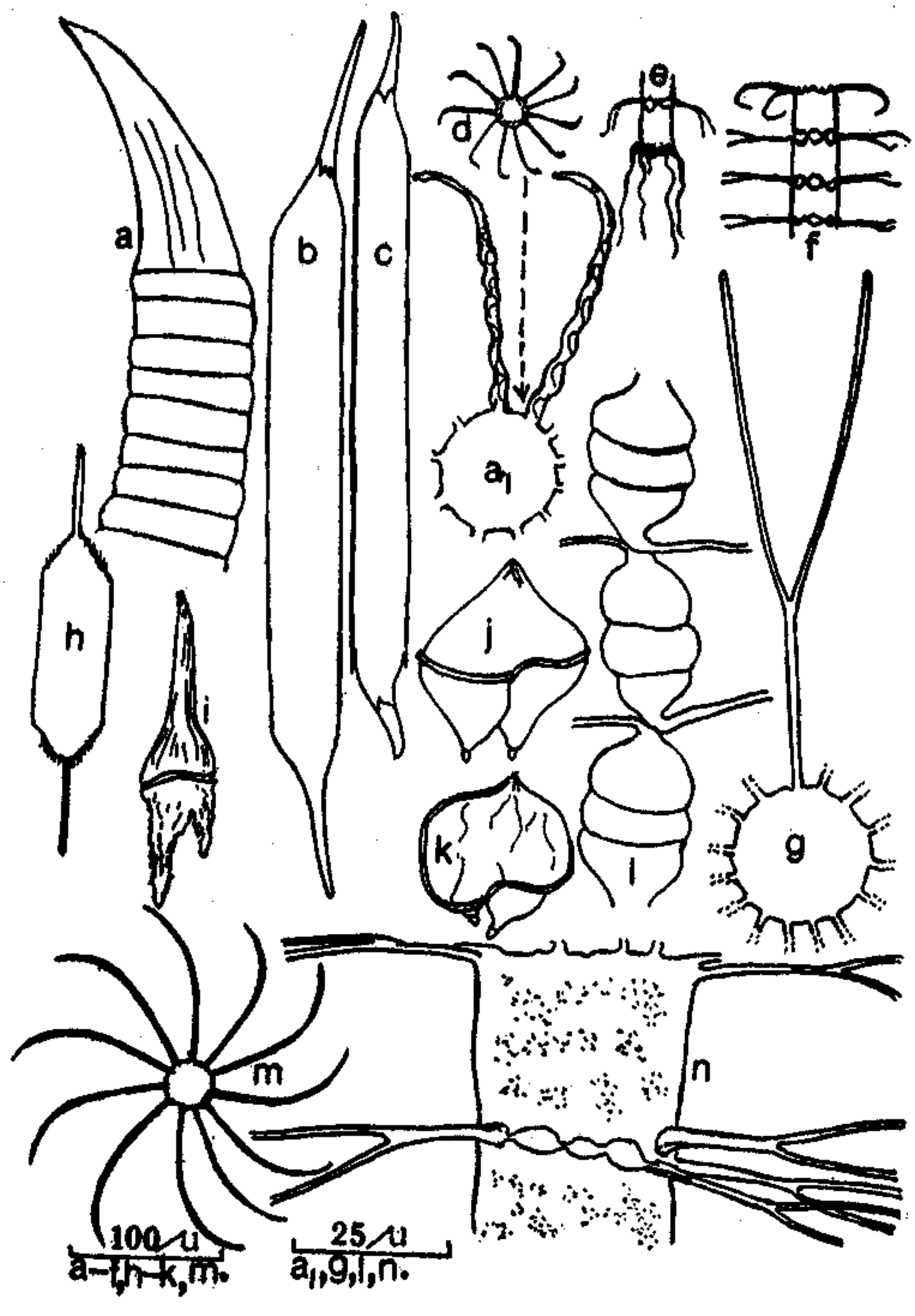

Fig. 2. a. *Rhizosolenia robusta* Norman ; b. *R. setigera* Brightwell ; c. *R. alata* Brightwell ; d, e. *Bacteriastrum comosum* Pavillard ; f, g. *B. varians* Lauder ; h. *Ditylum brightwellii* (West) Grunow, i. *Ceratium furca* (Ehrenb.) Claparede et Lachmann ; j, k. *Protoperidinium depressum* (Bailey) Balech ; l. *Chaetoceros indicus* Subrahmanyan, m. *Bacteriastrum hyalinum* Lauder var. *princeps* (Castracane) Ikari and n. *B. hyalinum* Lauder and a_1—highly magnified.

valves slightly convex with a depression in middle and raised at margin ; adjacent cells touch raised portions provided with short spines ; frustules 32-50μ long, 55-70μ diam.

Locality : Saptamukhi, Prentice Island (South 24-Parganas, W.B.).

Genus : **Rhizosolenia** Ehrenberg

Rhizosolenia stolterfothii H. Peragallo (Fig. 1 j)

Peragallo, 1888. *Bull. Soc. Hist. Nat. Toulouse*, 22 : p. 82, pl. VI fig. 44 ; Allen and Cupp 1935. p. 127 fig. 29 ; Cupp. 1943. p. 83, fig. 54. Subrahmanyan, 1946. p. 115, fig. 113, 115 and 117 ; Yamaji. 1975., p. 25, (1968) ; Islam and Aziz, p. 9, pl. 1, fig. 21.

Cells cylindrical, uniformly bent along pervalver axis and form spirally coiled chains ; valve with spine for fitting into a depression of adjoining cell ; frustules 140-160μ long, 28-34μ dia.

Locality : Prentice Island (South 24-Parganas, W.B.).

Rhizosolenia robusta Norman (Fig. 2 a)

Norman, 1861. In Pritchard *Infus.*, p. 866, pl. VIII, fig. 42 ; Allen and Cupp, 1935. p. 127, fig. 31 ; Subrahmanyan, 1946. p. 115, fig. 118-120, and 124 ; Cupp, 1943. p. 83, fig. 46 ; Yamaji, 1968. p. 109, Islam and Aziz, 1975. p. 8, pl. 1, fig. 15.

Cell crescent-shaped and cylindrical in the middle, valve ends conical, curved having fine excentric process ; intercalary bands many, robust and collar shaped ; cellwall easily breakable ; frustules 580-600μ long, 75-100μ dia.

Locality: Saptamukhi, Prentice Island (South 24-Parganas, W.B.).

Rhizosolenia setigera Brightwell (Fig. 2 b)

Brightwell, 1858. *Quart. Journ. Micr. Sc.*, 6 : p. 95, pl. V, fig. 7 ; Allen and Cupp, 1935. p. 129, fig. 37 ; Cupp, 1943. p. 88, fig. 49 ; Subrahmanyan, 1946. p. 119, fig. 127, 140 and 142. Yamaji, 1968. p. 109 ; Islam and Aziz, 1975. p. 9, pl. 1, fig. 17.

Cells rod-shaped and cylindrical ; apical processes long, hollow and slightly oblique ending in a long spine ; intercalary bands scale like ; frustules 40-50μ dia., 510-560μ long.

Locality ; Saptamukhi, Prentice Island (South 24-Parganas W.B.).

Rhizosolenia alata Brightwell (Fig. 2 c)

Brightwell, 1855. *Quart. Journ. Micr. Sc.* 6 : p. 96, pl. V, fig. 8 ; Allen and Cupp, 1935. p. 131, fig. 45 ; Subrahmanyan, 1946. p. 123, fig. 144, 148, 155.

Cells cylindrical, valves with short tube-like curved process at each end ; a small depression at the base of each process into which apex of adjoining cell fits ; intercalary bands scale like in two rows ; frustules 450-510μ long, 25-40μ diam.

Locality : Prentice Island, Chandanpiri (South 24-Parganas, W.B.).

Genus : **Bacteriastrum** Shadbolt

Bacteriastrum hyalinum Lauder (Fig. 2 n)

Lauder, 1864. *Trans. Micr. Soc.*, (12) p. 6, pl.3, fig. 7 ; Allen and Cupp, 1935. p. 132, fig. 47 ; Cupp. 1943. p. 96, fig. 56A ; Subrahmanyan, 1946. p. 125. fig. 164, 166, 167, 169 173 ; Venkataraman, 1958. p. 312 fig. 16 ; Yamaji, 1968 p. 39 ; Islam and Aziz, 1975. p. 10, pl. 3 fig. 46-48.

Cells broader than long, form chains, setae numerous 20-24, setae of two adjoining cells fuse at base ; terminal setae bent over chain axis ; frustules 27-30μ long, 32-34μ dia.

Locality : Prentice Island (South 24-Parganas, W.B.).

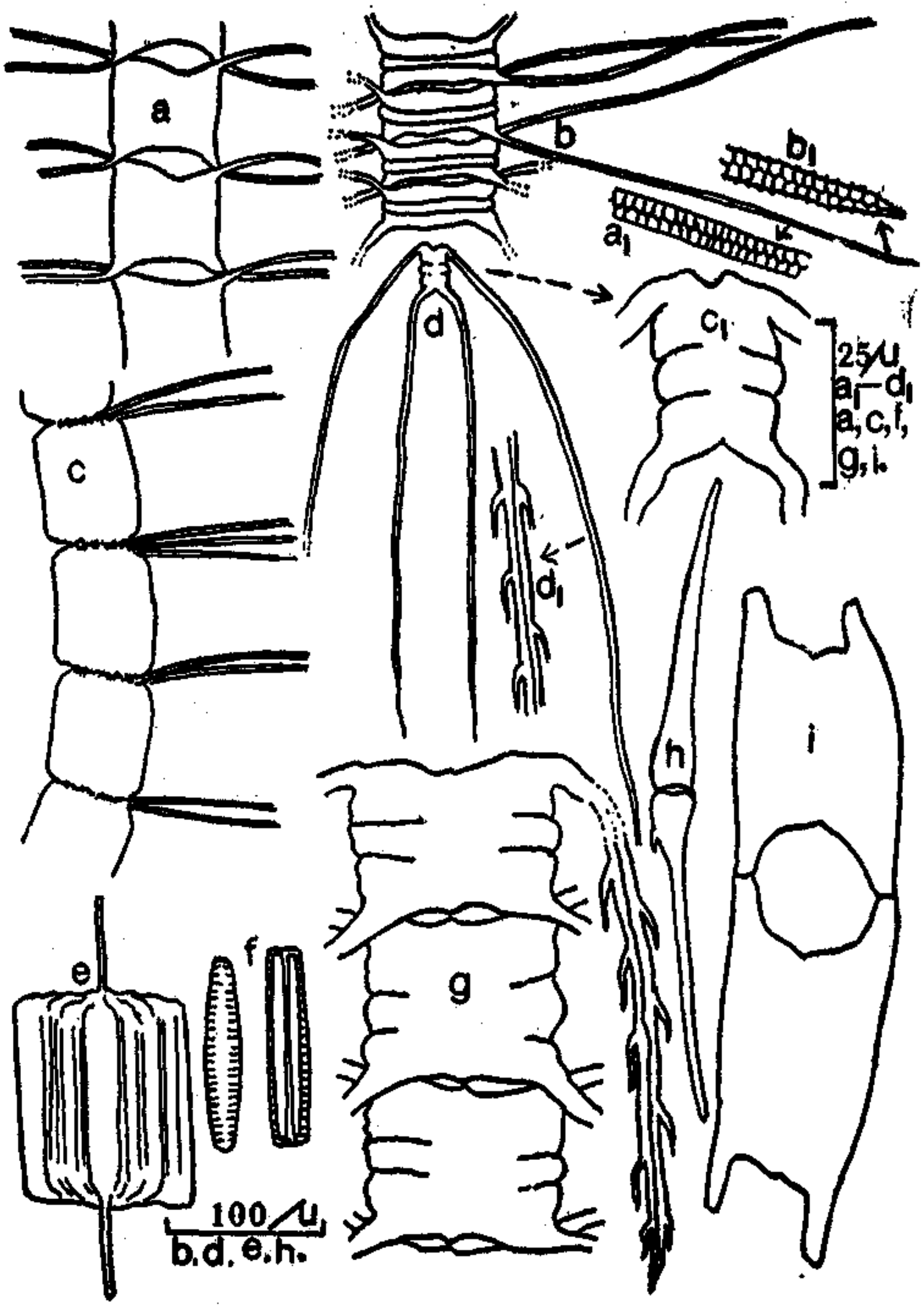

Fig. 3. a. *Chaetoceros curvisetus* Cleve ; b. *C. lorenzianus* Grunow ; c. *C. curvisetus* Cleve ; d. *C. peruvianu* Brightwell ; e. *Ditylum sol* Grunow ; f. *Diatoma vulgare* Bory var. *lineare* Grun. ; g. *Chaetoceros eibenii* Grunow ; h. *Ceratium extensum* (Gourret) Cl. f. *strictum* (Okamura and Nishikawa) Steemann Nielsen and i. *Eucampia* sp, and a_1-d_1 — highly magnified,

Bacteriastrum hyalinum Lauder var. **princeps** (Castracane) Ikari (Fig. 2 m)

Ikari, 1927. *J. On Bacter. of Japan* p. 423 fig. 3 ; Castracane, 1886. *Diat. Chall. -Exped.* p. 84, pl. 14, fig. 2, pl. 29, fig. 3 ; Subrahmanyan, 1946. p. 127, fig. 165 and 168.

Cells 20-31μ in dia., setae 11, spirally twisted.

Locality : Prentice Island, Bhubaneswari (South 24-Parganas, W.B.).

Bacteriastrum varians Lauder (Fig. 2 f, g)

Lauder, 1864. *Trans. Micr. Soc.*, p. 8, pl. III, fig. 1-6 ; Allen and Cupp, 1935. p. 133, fig. 48 ; Subrahmanyan, 1946. p. 127, fig. 170-172 and 175.

Cells in chains, squarish in girdle view ; setae 12-19, setae of two adjoining cells fuse at base ; 18-33μ dia., terminal setae with fine spines.

Locality : Prentice Island (South 24-Parganas, W.B.).

Bacteriastrum comosum Pavillard (Fig. 2 d, e)

Pavillard, 1916. *Rech. sur les diat. pelag. du Golfe du Lion*, p. 29, pl. 1, fig. 3 ; Allen and Cupp, 1935. p. 133, fig. 50 ; Subrahmanyan, 1946 p. 128, fig. 176-178.

Cells cylindrical forming chains, with apertures between adjoining cells ; setae 8-11, setae of two adjoining cells fuse at base ; anterior terminal setae curved, directed towards the posterior part and with spirally arranged spines ; fused basal part of inner setae remain perpendicular to the chain axis and the bifurcated portion bends posteriorly, posterior terminal setae thicker and hanging downwards ; cells 15-20μ diam.

Locality : Prentice Island (South 24-Parganas, W.B.).

Genus : **Chaetoceros** Ehrenberg

Chaetoceros eibenii Grunow (Fig. 3 g)

Grunow, 1881. *Van Heurck, Syn.* pl. 82, fig. 9, 10 ; Allen and Cupp, 1935. p. 135, fig. 51; Subrahmanyan, 1946. p. 128, fig. 179-181 ; Yamaji, 1968. p. 110 ; Islam and Aziz 1975. p. 11, pl. 5, fig. 69-70.

Cells cylindrical forming straight chains ; apertures between adjoining cells elliptical ; setae with bulbous base, interlocked with the opposite setae at bases and armed with spines distally ; tiny spine at the centre of the valve ; frustules 23-28μ long in girdle view, 30-325μ dia.

Locality : Prentice Island (South 24-Parganas, W.B.).

Chaetoceros peruvianus Brightwell (Fig. 3 d)

Brightwell, 1856. *Quart. Journ. Micr. Sc.* 4 p. 107, pl. 7, fig. 16-18 ; Allen and Cupp, 1935. p. 136, fig. 56 ; Subrahmanyan, 1946. p. 129, fig. 191-196.

Cells single, valves dissimilar, setae of upper valve start from near the centre of the valve in which a depression is seen and after turning run backward ; setae of lower valve start near the margin and slightly convex towards outside, then run almost parallel to the pervalvar axis ; setae four cornered with spines, frustules 23-30μ long in girdle view, 17-22μ dia.

Locality : Saptamukhi ; Chandanpiri (South 24-Parganas, W.B.).

Chaetoceros lorenzianus Grunow (Fig. 3 b)

Grunow, 1863. *Verh. zool. bot. Ges. Wien*, **13**, p. 157 pl. 5 fig. 13 ; Allen and Cupp, 1953. p. 137 fig. 58 ; Cupp, 1943. p. 118, fig. 71 ; Subrahmanyan 1946. p. 131 fig. 198-199, 202-204, 206-209 ; Islam and Aziz, 1975. p. 12, pl. 4, fig. 52-54, 56-57.

Cells form straight chain ; valve surface slightly elevated at the centre ; setae four sided, punctate-areolate ; terminal setae thicker inner setae interlocking ; apertures between frustules of varing sizes ; frustules 25-40μ long in girdle view, 45-75μ dia., setae 150-280μ long.

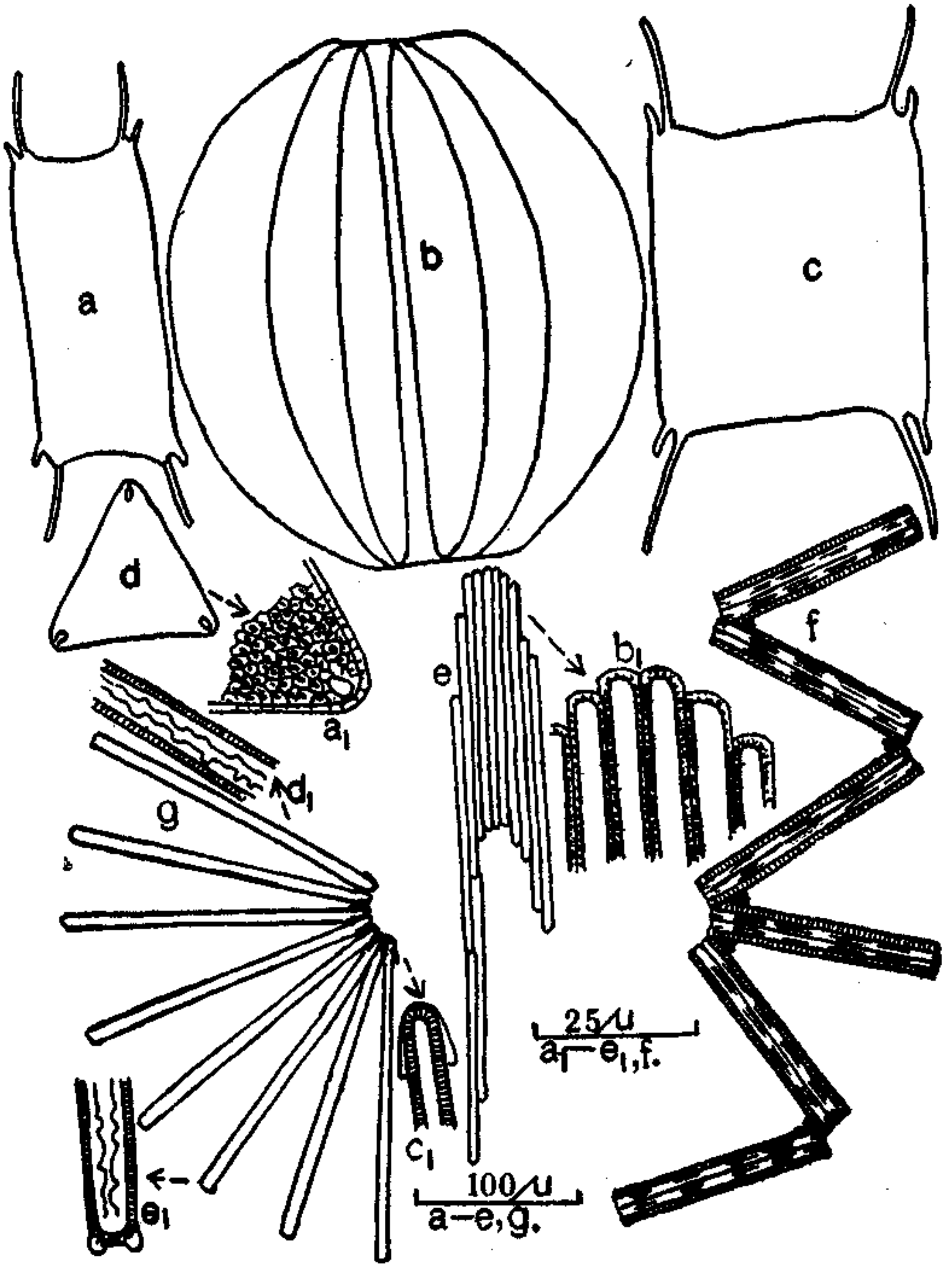

Fig. 4. a. *Biddulphia sinensis* Greville ; b. *Hemidiscus cuneiformis* Wallich ; c. *Biddulphia sinensis* Greville ; d. *Triceratium favus* Ehrenberg ; e. *Bacillaria paradoxa* Gmelin ; f. *Thalassionema nitzschioides* Grunow and g. *Thalassiothrix frauenfeldii* Grunow and a_1-e_1 — highly magnified.

Locality: Prentice Island, Chandanpiri, Bhubaneswari, Saptamukhi (South 24-Parganas, W.B.).

Chaetoceros indicus Subrahmanyan (Fig. 2 l)

Subrahmanyan, 1946. p. 133, fig. 197, 205, 210.

Cells forming straight chains, Madgeburgh-sphere-shaped in girdle view; setae starting from the corners armoured with short spines; frustules 22-28μ long in girdle view, 15-17μ dia.

Locality: Prentice Island (South 24-Paraganas, W.B.).

Chaetoceros curvisetus Cleve (Fig. 3 a, c)

Cleve, 1889. *Vidensk. Udb. Kanonbaad. Haucks Togt. danske Have*, p. 55; Cupp, 1943. p. 137, fig. 93; Subrahmanyan, 1946. p. 143, fig. 238, 244-246; Yamaji, 1968. p. 135; Islam and Aziz, 1975. p. 11, pl. 6, fig. 75 A-B.

Cells in curved chain, frustules four cornered and bent, in broad girdle view oblong; setae arising from corners of cells; all bent towards same side-towards outside of curved axis; frustules 14-19μ long 13-17μ dia., setae 30-35μ long.

Locality: Prentice Island, Bhubaneswari (South 24-Paraganas, W.B.).

Genus: **Eucampia** Ehrenberg

Eucampia sp. (Fig. 3 i)

Cells flat, united in straight chain by blunt processes; valves concave in the middle part so that a large space occurs between neighbouring cells; frustules 26-35μ long 25-28μ dia., processes 5-10μ long.

Locality: Prentice Island, Chandanpiri (South 24-Parganas, W.B.)

Genus: **Ditylum** L. W. Bailey

Ditylum brightwellii (West) Grunow (Fig. 2 h)

Grunow, v. H. Syn., pl. 114, (1881).

=*Triceratium Brightwelli* West, 1860. *Trans. Micr. Soc.*, **8**: p. 149, pl. 7, fig. 6; Cupp, 1943. p. 148, fig. 107-A, B; Subrahmanyan, 1946. p. 147, fig. 263, 264; Yamaji, 1968. p. 38; Islam and Aziz, 1975. p. 14, pl. 7, fig. 85.

Cells prism-shaped, 3-4 times as long as broad; with a central spine, rim of valve with small spines; frustules 130-155μ long, 25-50μ dia., central spine 45-55μ long.

Locality: Prentice Island, Chandanpiri, Bhubaneswari (South 24-Paraganas, W.B.).

Ditylum sol Grunow (Fig. 3 e)

Grunow, 1881. *In van Heurck, Syn.* pl. 115, fig. 1, 2; Subrahmanyan, 1946. p. 149, fig. 266; Yamaji, 1968. p. 38; Islam and Aziz, 1975. p. 14, pl. 7, fig. 86.

Cells very large, valve surface waved with a central spine, no small spines on valve, many longitudinal lines in girdle view; frustules 130-155μ long, 100-125μ dia.; spines 50-95μ long.

Locality: Prentice Island, Chandanpiri, Saptamukhi, (South 24-Parganas, W.B.).

Genus: **Triceratium** Ehrenberg

Triceratium favus Ehrenberg (Fig. 4 d)

Ehrenberg, 1841. *Abh. Berl. Akad.* 1839, p. 159, pl. 4, fig. 10; Subrahmanyan, 1946. p. 150, fig. 265, 267, 271, pl. 1, fig. 5.

Cells with three cornered valvar plane and short pervalvar axis; corners rounded, side measuring 100-110μ; areolae 2-3μ dia., almost all of same size; chamber opening clear.

Locality: Saptamukhi (South 24-Parganas, W.B.).

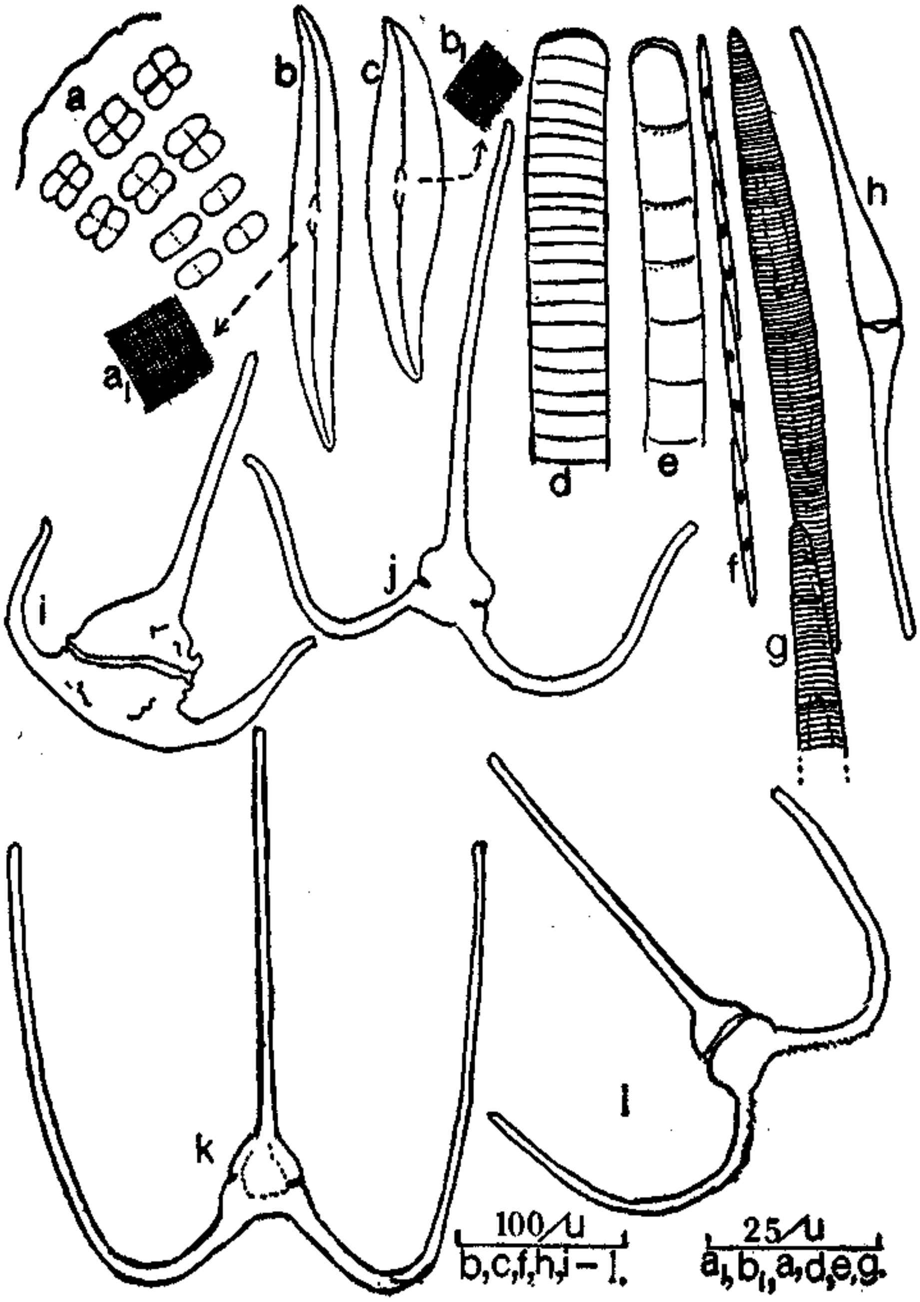

Fig. 5. a. *Merismopedia glauca* (Ehrenb.) Nag. ; b. *Pleurosigma elongatum* Smith ; c. *P. normanii* Ralfs ; d. *Oscillatoria limosa* Ag. ex Gomont ; e. *Trichodesmium thiebautii* Gomont ; f, g. *Nitzschia seriata* Cleve ; h. *Ceratium extensum* (Gourret) Cleve ; i. *Ceratium tripos* (O.F. Muller) Nitzsch ; j. *C. trichoceros* (Ehrenb.) Kofoid var. *contrarium* (Gourret) Schiller and k. *C. trichoceros* (Ehrenb.) Kofoid; l. *C. horridum* Gran and a_1-b_1 — highly magnified.

Genus : **Biddulphia** Gray

Biddulphia sinensis Greville (Fig. 4 a, c)

Greville, 1866. *Trans. Micr. Soc. Lond.*, 14 : p. 81, pl. 9, fig. 16 ; Allen and Cupp, 1935. p. 146, fig. 81 ; Subrahmanyan, 1946. p. 154, fig. 281, 289 ; Islam and Aziz, 1975. p. 13, pl. 7, fig. 93.

Cells large, valve end concave or convex ; square to rectangular in girdle view and ovate to lanceolate in valve view, with short thin blunt horns and long, thin spines at the corners ; 80-160μ (−200μ) long in girdle view, 65-150μ (−200μ) dia., horns 14-17μ long ; spines 52-58μ long.

Locality : Prentice Island, Saptamukhi, Bhubaneswari, Chandanpiri (South 24-Parganas, W.B.).

Genus : **Hemidiscus** Wallich

Hemidiscus cuneiformis Wallich (Fig. 4 b)

Wallich, 1860. *Trans. Micr. Soc. Lond.*, (8) p. 42, pl. 2, fig. 3, 4 ; Cupp, 1968. p. 170, fig. 121, (1943) ; Yamaji, p. 15. Islam and Aziz, 1975. p. 7, pl. 6, fig. 79-80.

Valves semicircular ; ventral margin straight ; ends obtuse ; frustules 300-400μ dia., each valve 140-200μ broad.

Locality : Saptamukhi (South 24-Parganas, W.B.).

Order : Pennales

Genus : **Diatoma** De Candolle

Diatoma vulgare Bory var. **lineare** Grun. (Fig. 3 f)

Grunow, 1881. *in Van Heurck, Syn.* pl. 50, fig. g, 8 ; Synonym : *Diatoma vulgare* forma *abbreviata* Pantocsek, 1902. Bacill, Bal. p. 80, pl. 9, fig. 236, *Diatoma grande* var. *linearis* Meister, 1912. Kieselalg. d. Schw. p. 62 ; Islam and Aziz, 1975. p. 15, pl. 8, fig. 95-97.

Valve lanceolate, transverse coastae present accross the valve ; frustules 28-33μ long, 5.5-6.3μ dia.

Locality : Prentice Island (South 24-Paraganas, W.B.).

Genus : **Thalassiothrix** Cleve **and** Grunow

Thalassiothrix frauenfeldii Grunow (Fig. 4 g)

Cleve and Grunow, 1880. *Beitrage Z. Kenntniss d. Arct. Diat*, p. 109 ; Allen and Cupp, 1935. p. 154, fig. 97 ; Cupp, 1943. p. 184, fig. 135 ; Subrahmanyan, 1946. p. 169, fig. 349, 351, 354-357 and 360 ; Yamaji, 1968. p. 26 ; Islam and Aziz, 1975. p. 15, pl. 8, fig. 98-99.

Cells forming stellate colony, in girdle view linear and poles dissimilar, one end bluntly pointed and other end widened ; pseudaraphe present throughout the whole length ; frutules 188-210μ long, 6-7.5μ dia., striae 12 in 10μ.

Locality : Prentice Island, Chandanpiri, Bhubaneswari (South 24-Paraganas, W.B.).

Genus : **Thalassionema** Grunow

Thalassionema nitzschioides Grunow (Fig. 4 f)

Van Heurck, 1899. *Traite des Diatomees*, p. 314, pl. X, fig 434 ; Cupp, 1943. p. 182, fig. 133 ; Subrahmanyan, 1946. p. 167, fig. 344-346 ; Yamaji, 1968. p. 27, pl. 5, fig. 13 ; Islam and Aziz, 1975. p. 15, pl. 8, fig. 100-101.

Cells form zig-zag chains due to the presence of protoplasmic cushions at junctions ; in girdle view cells linear rectangular, both poles alike ; frustules 30.5-36μ long, 4-5.5μ diam., striae 12-14 in 10μ, here striae slightly closer.

Locality : Prentice Island, Saptamukhi (South 24-Parganas, W.B.).

Genus : **Pleurosigma** W. Smith

Pleurosigma elongatum W. Smith (Fig. 5 b)

Smith, 1852. *Notes. Diat. Pleurosigma*, pl. 1, fig 4 ; Allen and Cupp, 1935. p. 157, fig. 105 ; Subrahmanyan, 1946. p. 175, fig. 380-382.

Cells slightly sigmoid, elongated, gradually attenuated, ends acute ; raphe central and sigmoid, 210-280μ long, 27-35μ broad ; striae about 21 in 10μ.

Locality: **Prentice Island** (South 24-Parganas, W.B.).

Pleurosigma normanii Ralfs (Fig. 5 c)

Pritchard, 1861. *Hist Infusoria*, p. 919 ; Allen and Cupp, 1935. p. 157, fig. 106 ; Cupp, 1943. p. 196, fig. 148 ; Subrahmanyan, 1946. p. 175, fig. 378, 379 385 and 387 ; Yamaji, 1968 p. 107, fig. 6 ; Islam and Aziz, 1975. p. 16, pl. 8, fig. 108.

Valves broadly lanceolate, slightly sigmoid, ends subacute ; raphe sigmoid ; valve 205-250μ long, 40-52μ broad in the middle ; striae 18-21 in 10μ.

Locality: Saptamukhi (South 24-Parganas, W.B.).

Genus : **Bacillaria** Gmelin

Bacillaria paradoxa Gmelin (Fig. 4 e)

Smith, 1856. *W., Syn Brit. Diat.* 2 : p. 10, pl. 32, fig. 279 ; Allen and Cupp, 1935. p. 162, fig. 117 ; Subrahmanyan, 1946. p. 187, fig. 417, 421 and 427.

Cells in girdle view linear rectangular, forming a mat-like colony ; cells 152-200μ long and 5.5-7μ diam.

Locality : Prentice Island (South 24-Parganas, W.B.).

Genus : **Nitzschia** Hassal

Nitzschia seriata Cleve (Fig. 5 f, g)

De-Toni, 1891-94. *Syll. Alg.*, 2 : p. 501 ; Allen and Cupp, 1935. p. 164, fig. 124 ; Subrahmanyan, 1946. p. 191, fig. 432-434.

Cells spindle-shaped with pointed ends, arranged in long chains by overlapping tips of the cells, frustules 90-105μ long, 5-7μ dia, striae 12 in 10μ in the middle.

Locality : Prentice Island, Bhubaneswari (South 24-Parganas, W.B.).

Class : DINOPHYCEAE

Order : Peridiniales

Genus : **Ceratium** Schrank

Ceratium extensum (Gourret) Cleve (Fig. 5 h)

Cleve, 1901. *K. Sv. Vet. Akad, Handl.* 35 (5), p. 14 ; 1903, *Ark. Zool.*, 1, p. 340 ; =*C. furca* v. *mediterraneum* Gourret, 1883. *Ann. Mus. Hist. Nat. Marseille, Zool.* 1 : p. 49, pl. 1, fig. 13 ; Subrahmanyan, 1968. p. 32, fig 56, 57 ; Islam and Aziz, 1975. p. 17, pl. 9, fig. 114.

Cells very long, having long, narrow epitheca with long, straight gradually narrowed apical horn ; hypotheca shorter than epitheca and produced into long, slightly curved left horn ; right posterior horn absent ; cell proper 65-75μ long, 26-30μ dia., apical horn 135-155μ long, posterior horn 135-160μ long.

Locality : Chandanpiri, Prentice Island (South 24-Parganas, W.B.).

Ceratium extensum (Gourret) Cl. f. **strictum** (Okamura and Nishikawa) Steemann Nielsen (Fig. 3 h)

Steemann Nielsen, 1934. *Dana-Rep.*, 4, p. 14, fig. 24 ; Subrahmanyan, 1968. p. 33 ; Aziz and Islam, 1979. p. 48, pl. 3, fig. 44.

Epitheca long, narrow with slightly bent apical horn ; hypotheca shorter than epitheca, left posterior horn narrow, more or less bent ; rarely straight, right horn little developed, pointed, 4-6μ long ; cell proper 60-70μ long, 23-28μ, diam., apical horn 135-165μ long, left posterior horn 135-160μ long.

Locality : Prentice Island, Chandanpiri (South 24-Parganas of W.B.).

Ceratium furca (Ehrenb.) Claparede *et* Lachmann (Fig. 2 i)

Cleve, 1903. *Ark. Zool.*, p. 341, (1903) ; Subrahmanyan, 1968. p. 20, pl. II, fig. 7-12 ; text figs. 21-29 ; Salam and Khan, 1979. p. 34, fig. 3.

Epitheca narrowing and forms a long apical horn ; posterior horns parallel, more or less pointed, toothed, left one is double as long as the right, both ending in a point ; cell proper 40-52μ long, 34-48μ dia. ; apical horn 75-80μ long ; left posterior horn 47-56μ long, right posterior horn 25-27μ long.

Locality : Prentice Island, Chandanpiri, (South 24-Paraganas, W.B.).

Ceratium tripos (O. F. Müller) Nitzsch (Fig. 5 i)

Müller, 1786. *Animalcula infusoria fluviatilis* et *marina.*, p. 136, pl. 19, fig. 22 ; Cleve, 1901. *K. Sv. Vet. Akad. Handl*, 35 (5) : p. 14 ; Subrahmanyan, 1968. p. 35, fig 59 ; pl. III, fig. 17, 18 ; Islam and Aziz, 1975. p. 19, pl. 9, fig. 113 ; pl 10, fig 126.

Cell large, body as broad as long ; epitheca twice as broad as long ; left side contour concave, right side strongly convex ; all the horns robust ; right posterior horn weakly developed than left ; cell proper 80-85μ long, 75-82μ dia., apical horn 150-165μ long, posterior horns 120-135μ long from the place of joining ; both horns more or less equal in length.

Locality : Prentice Island (South 24-Parganas, W.B.).

Ceratum horridum Gran (Fig. 5 l)

Gran, 1902. *Rep. Norweg. Fish. Invest-* 2 (5) : p. 54, 193, 194 ; Subrahmanyan, 1968. p. 63, fig. 127 ; Islam and Aziz, 1975. p. 18, pl. 9, fig. 111.

Epitheca triangular in outline shorter than the hypotheca, produced into straight long slightly bent apical horn ; left posterior horn converging in relation to the apical horn ; right posterior horn diverging from the apical horn ; dentation at the curvatures of the posterior horns ; cell proper 39-49μ long, 38-42μ dia., apical horn 150-210μ long ; posterior right horn 230-250μ long ; posterior left horn 225-238μ long.

Locality : Prentice Island, Saptamukhi, Chandanpiri (South 24-Parganas, W.B.).

Ceratium trichoceros (Ehrenberg) Kofoid (Fig. 5 k)

Kofoid, 1908. *Zool. Anz.*, 4 (7), p. 388 ; Subrahmanyan, 1968. p. 81, pl. VII, fig. 37.

Long-horned species ; body longer than broad ; epitheca slightly oblique and longer than hypotheca ; length of hypotheca shorter than breadth ; all the three horns long and directed parallel ; both horns are more or less equal in length, cell proper 53-57μ long, 40-48μ dia., apical horn 210-240μ long, posterior horns 340-380μ long from the place of joining.

Locality : Bhubaneswari, Chandanpiri, Prentice Island (South 24-Parganas, W.B.).

Ceratium trichoceros (Ehrenb). Kofoid var. **contrarium** (Gourret) Schiller (Fig. 5 j)

Schiller, 1937. *in Rabenhorst's Kryptogamen* Fl. 10, Abt. 3, Teil 2, p. 431, fig. 471 ; Subrahmanyan, 1968. p. 82, fig. 148.

Epitheca is broader than length ; produced into straight slightly curved long apical horn ; posterior horns directed backward for a small distance and then forwardly directed, undulate, bent and diverging in relation to one another and apical horn, the right horn is smaller and not lying so farther back as of left ; the cell proper 45-50μ long, 50-55μ diam. apical horn 250-280μ long ; right posterior horn 190-220μ long, and left posterior horn 215-250μ long.

Locality : Prentice Island (South 24-Parganas, W.B.).

Genus : **Protoperidinium Bergh**

Protoperidinium depressum (Bailey) Balech (= **Peridinium depressum** Bailey) (Fig. 2 j, k)

Balech, 1974. *Hydrobiol.*, 4 (1) : p. 1 ; Bailey, 1855. *Smithsonian Inst. Contrib. Know.* p. 12, fig. 33-34; Subrahmanyan, 1968. p, 80, pl. LV, f. 4, 6, 7; Aziz and Islam, 1979. p. 44, pl. 3, f. 36-38.

Cell braod, flattened obliquely dorsoventrally; apical horn distinct, girdle slightly left handed, excavated; hypotheca with two antapical horns; cell 120-140μ long, 100-125μ diam.

Locality: Prentice Island (South 24-Parganas, W.B.).

CLASS : CYANOPHYCEAE

Order : Chroococcales

Genus : **Merismopedia** Meyen

Merismopedia glauca (Ehrenb.) Nag. (Fig. 5 a)

Gatt. 1849. *einzell. Algen*, p. 55, pl. 1D, fig. 1; Geitler, 1932. p. 264, fig. 129 d; Desikachary, 1959. p. 155. pl. 29. fig. 5.

Thallus 200μ long, 150μ broad; cells spherical to subspherical, closely arranged, colonies of 4-8 cells, cell 4.0-5.5μ long, 3-4μ broad, pale blue-green colour.

Locality : Prentice Island (South 24-Parganas, W.B.).

Order : Nostocales

Genus : **Trichodesmium** Ehrenb.

Trichodesmium thiebautii Gomont (Fig. 5 e)

Gomont, 1890. *J. de Bot.*, 4 : p. 356; Desikachary, p. 243, pl. 42, fig. 4, 5.

Trichome in free swimming bundles, colour blue green, not constricted at cross walls, thickened at apices, cells 8-10μ long, 7.5-10.0μ broad.

Locality: Prentice Island (South 24-Parganas, W.B.).

Genus : **Oscillatoria** Vaucher

Oscillatoria limosa Ag. ex Gomont (Fig. 5 d)

Agardh, 1812. Dispositio Algarum Sueciae, p. 35; Gomont, 1892. *Monogr. Oscillariees*, p. 210, pl. 6, fig. 13; Desikachary, 1959. p. 206, pl. 42, fig. 11.

Trichome more or less straight, not constricted at cross-walls, 11-14μ broad; cells 2-4μ long; end-cells flatly rounded with slightly thickened membrane.

Locality: Prentice Island (South 24-Parganas, W.B.).

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SPONGES OF PAPUA AND NEW GUINEA—PART ORDER HAPLOSCLERIDA TOPSENT

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ABSTRACT

Ten species of sponges of the order Haplosclerida from Papua and New Guinea are described here with illustrations. A new species *Strongylophora septata* is described here.

INTRODUCTION

IN THIS second part of the series on Sponges of Papua and New Guinea, 10 species of the Order Haplosclerida Topsent are dealt with in detail. The area of collection has been well illustrated in the first part of this series (Thomas, 1982).

The general classification followed here is that of de Laubenfels (1936), but following Hechtel (1985) the family Adociidae is treated under Order Haplosclerida.

Species dealt with here are rather well distributed except a new species *Strongylophora septata*. This new species falling under the genus *Strongylophora* Dendy, is erected here with some hesitation, but the distinctive nature of the characters which separate this new species from *S. durissima* Dendy (1905) which is the type of the genus from Ceylon (=Sri Lanka) pearl oyster beds and which occurs side by side with the present new species at Papua and New Guinea appear so convincing as to preclude any treatment other than what is proposed here.

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SYSTEMATICS

Order HAPLOSCLERIDA Topsent

Four families *viz.* Haliclonidae de Laubenfels, Desmacidonidae Gray, Adociidae de Laubenfels and Callyspongiidae de Laubenfels of this order are represented in the present collection.

Family HALICLONIDAE de Laubenfels

Haliclona cribricutis (Dendy) (Fig. 1 a)

Haliclona cribricutis Thomas, 1973, p. 18, pl. 1, fig. 12 ; pl. 6, fig. 8 (synonymy)

Material : One entire specimen and three bits.

Description : Entire specimen, probably repent in live condition ; irregularly tuberous with a length of 135 mm and a diameter of 20 mm ; bits represented may be parts of a

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single specimen and have conical projections arising from upper parts.

Colour : Dirty brown.

Consistency : Hard and incompressible with poor resiliency.

Oscules small and scattered all over except at or near points of attachment ; elliptical to irregular in outline and compound in nature ; diameter 2-3 mm. Pores minute, elliptical in outline and with 0.03 mm average diameter.

Surface smooth in entire specimen, but conulose in the bits. Conules disposed in a straight line forming a continuous ridge at places. Surface minutely reticulate in between conules.

Main skeleton is an irregular reticulation of stout polyspicular fibres with sparse spongin content. Meshes become rather well demarcated towards peripheral parts. Conules often supported by large main fibres (fused fibres ?). Dermal reticulation irregular with pores located at centre of each mesh. Average diameter of fibres 0.188 mm.

Spicules : (1) Oxeas. Slightly curved and abruptly to gradually pointed; size, 0.147-0.25 × 0.006-0.008 mm.

Distribution : Indian Ocean, Australian region.

Family DESMACIDONIDAE Gray

Gelliodes fibulatus Ridley (Fig. 1 b - d)

Gelliodes fibulatus Thomas, 1968 (unpublished) (non Babic, 1922, p. 234).

Material : Several bits, probably parts of the same specimen.

Description : Sponge, a clathrous mass of slender branches varying in diameter from 4 to 12 mm. These branches show a tendency to get fused with adjacent branches.

Colour : Dark brown to pale brown in dry condition.

Consistency : Brittle when dry.

Surface highly conulose ; conules formed by protruding tips of main fibres, sometimes compound and with spine-like projections (Fig. 1 b). Height of conules varies considerably from 0.5 to 4.0 mm. In actively growing parts such conules may be densely distributed and this arrangement gives a characteristic brush-like appearance to extremities of branches. A few outermost fibres originating from adjacent conules run in a parallel course, one above the other and this arrangement provides a basket-like appearance to the inter conular space. Dermal membrane retained only at some places and reinforced by spicules both proper and arenaceous. Details regarding oscules and pores could not be traced out due to dry and poorly preserved condition of material.

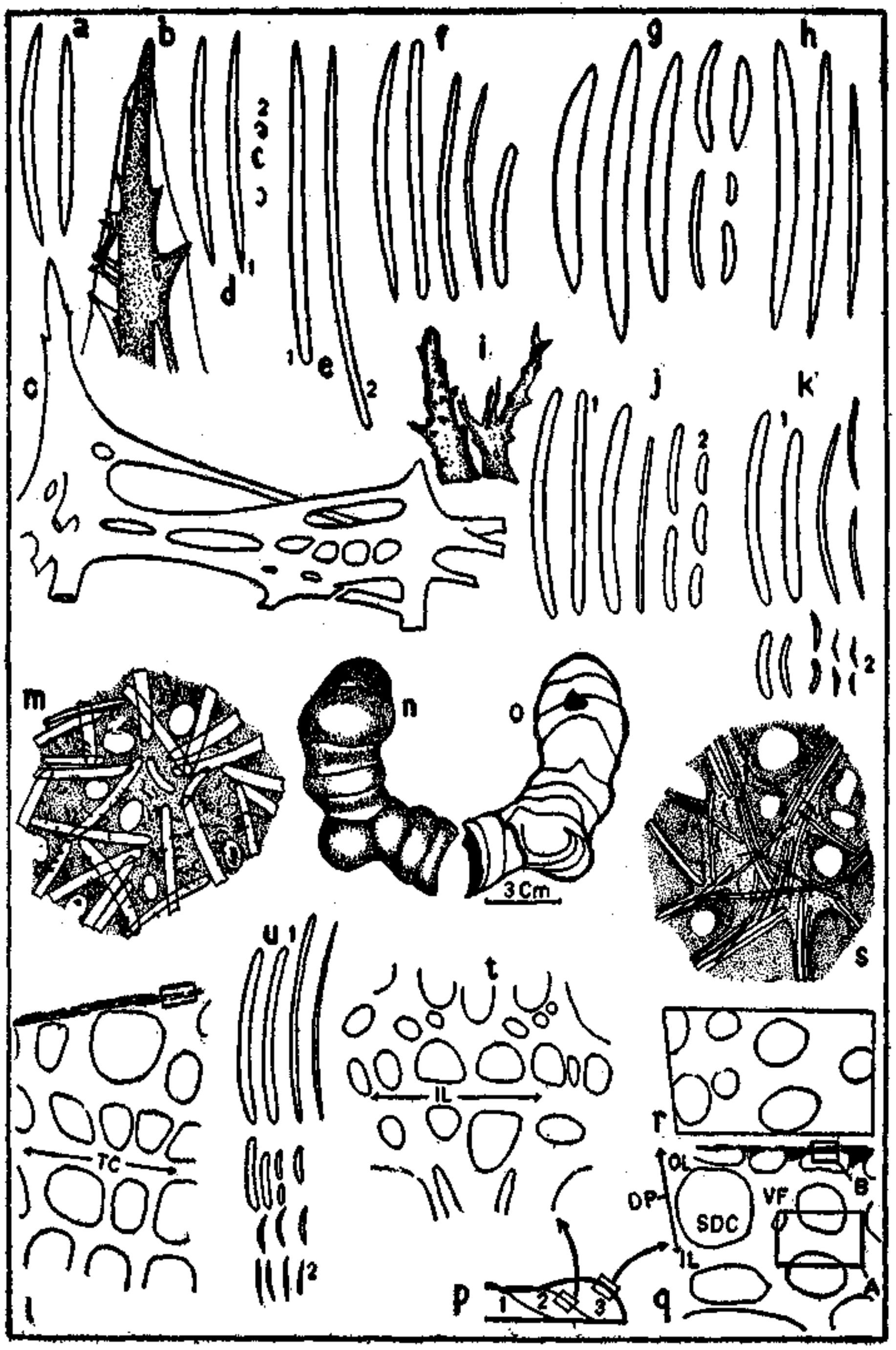
Skeleton composed of main fibres running vertically up along interior of each branch and then getting diverted into peripheral parts. These fibres may be of a compound nature at places. Spongin sparsely noted and spicules may even project partly out of fibres. Average diameter of main fibres around 0.21 mm. Connectives irregularly disposed in interior, but may assume a definite parallel course towards outer parts. Average diameter of these connectives is 0.147 mm. Spicules seen scattered outside these fibres in plenty (Fig. 1 c).

Spicules : (1) Oxeas. Gradually curved and sharply pointed: size, 0.29 × 0.010 mm when well developed (Fig. 1 d, 1). (2) Sigmas rather abundant ; chord upto 0.016 mm (Fig. 1 d, 2).

Distribution : Red Sea, Indian Ocean and Australian region.

Iotrochota purpurea (Bowerbank) (Fig. 1 e)

Iotrochota purpurea Thomas, 1973, p. 19, pl.1, fig. 8 ; pl. 7, fig. 9 (synonymy).



For explanation, please see facing page

Material : Several small bits, probably of the same specimen.

Description : Bits at hand may represent parts of a large clathrous or ramose specimen. Branches 4 to 8 mm in diameter and with conical aculiations from surface.

Colour : Black ; pigment granules of 0.008 mm average diameter distributed rather profusely in dermal as well as in interior parts.

Consistency : Rough and friable in dry condition.

Surface conulose, conules 0.5 to 1.5 mm high. Oscules and pores not traceable due to dry nature of specimen.

Dermal membrane stretches across extremities of fibres that end in surface and at places reinforced with styles. Main skeleton is a reticulation of amber-coloured spongin fibres. Primary fibres rather distinct towards peripheral parts, but irregular in deeper areas. Diameter of primaries about 0.13 mm while that of connectives 0.037 mm.

Spicules : (1) Slender styles. Dermal ; slightly curved and sharply pointed or blunt rarely. Size upto 0.252 × 0.004 mm (Fig. 1 e, 1). (2) Main styles. Slightly curved and sharply pointed, size 0.168 × 0.008 mm (Fig. 1 e, 2). (3) Birotulates. Not seen inspite of careful examination.

Distribution : Indo-Pacific.

Family ADOCIIDAE de Laubenfels

Petrosia testudinaria (Lamarck) (Fig. 1 f)

Petrosia testudinaria Thomas, 1985, p. 246, pl. 2, fig. 9 (synonymy).

Material : Three bits.

Description : Specimen available is only a radial section along the crator wall of a large specimen with a width of 2.5 cm. Bit got broken into three smaller bits in transit. Outer surface of material with small irregular protuberances, while the innter ridged radially.

Colour : Pale brown when dry.

Consistency : Hard and incompressible.

Surface highly reticulate on both sides. Oscules open at inner surface of crator, while pores on outer surface ; sometimes on localised areas.

Fig. 1. a. *Haliclona cribricutis :* Spicules, oxeas ; b-d. *Gelliodes fibulatus :* b. tip of conule, enlarged, c. Skeletal arrangement ; d. Spicules - (1) Oxeas, (2) Sigmas ; e. *Iotrochota purpurea :* Spicules—(1) Main style, (2) Dermal style ; f. *Petrosia testudinaria :* Spicules ; g. *Petrosia nigricans :* Spicules ; h. *Petrosia* (cf) *seriata :* Spicules, oxeas ; i. *Callyspongia fibrosa :* Conules ; j. *Petrosia sphaeroida* (?) : Spicules—(1) Strongyles, (2) Small strongyles ; k-m. *Strongylophora durissima :* k. spicules—(1) Strongyles, (2) Microxeas ; l. Section showing the thickened transverse connectives (TC) ; m. Derma. skeleton—area marked in Fig. 1, magnified (view from above) ; n-u. *Strongylophora septata* n.sp. n. Dorsal view of the type specimen showing the bulging nature of 'chambers' ; o. Ventral view of the type specimen showing the nature of septa and 'chambers'; p. Diagramatic representation of three adjacent 'chambers' (numbered 1-3) ; q. Dermal part marked in 'chamber' 3 of Fig. p. giving the detailed structure of dermal part (DP), the outer 'layer' (OL), inner 'layer' (IL), vertcail fibres (VF) arising from the inner 'layer' and the sub-dermal cavities (SDC) ; r. the inner 'layer' of dermal part, marked A in Fig. q. enlarged to show the plate-like structure (view from above) ; s. Dermal skeleton, marked B in Fig. q, (view from above) t. Inter-chamberal septa marked in Fig. p found in between chambers 2 and 3, enlarged. Here only inner 'layer' (IL) of dermal part retained and original outer 'layer' is continued as main skeleton of 3rd chamber and u. Spicules—(1) Strongyles and oxeas; (2) Microxeas.

Skeletal arrangement is typical of the species.

Spicules : (1) Oxeas/strongyles. Hardly divisible into two sets ; size, 0.168 – 0.375 × 0.008 – 0.016 mm (Fig. 1 f).

Distribution : Red Sea to Australian region.

Petrosia nigricans Lindgren (Fig. 1 g)

Petrosia nigricans Thomas, 1985, p. 246, pl. 2, fig. 11, (synonymy).

Material : Four bits.

Description : Thickly encrusting to massively lobose. Lobose specimen with conical projections bearing oscules at their summits ; other specimens with short stumpy projections all over their upper surface.

Colour : Chocolate brown in colour both externally and internally.

Consistency : Hard and incompressible.

Surface reticulate. Oscules at summit of conical projections, diameter upto 2 mm. Pores minute, irregular and one per mesh.

Dermal skeleton well developed and composed of a polygonal meshed net work with mesh size of 0.25 mm supporting dermal membrane which is densely packed with pigment granules. Dermal part may contain sand grains occasionally.

Main skeleton is a rectangularly meshed network, but its original nature is masked by spicules strewn in between. Pigment granules richly distributed in interior also. In peripheral parts connecting fibres may get arranged in a parallel course and as these fibres are stouter than those elsewhere, it may give a concentrically laminated appearance in cross section.

Spicules : (1) Oxeas/strongyles. All growth stages that are intermediate may be met with. Some may even be biangulate. Size varies from 0.029 – 0.218 × 0.004 – 0.012 mm (Fig. 1 g).

Petrosia (cf) seriata (Hentschel) (Fig. 1 h)

Petrosia (cf) *seriata* Vacelet, Vasseur and Levi, 1976, p. 88, fig. 67 (synonymy).

Material : One complete specimen and 3 bits ; bits may be parts of a single large specimen.

Description : Specimen (complete) has a clathrous appearance and was growing attached to substratum by many points. Size, 9 × 3 cm.

Colour : Dark brown.

Consistency : Tough and incompressible.

Surface uniform, but microscopically hispid at places. Oscules numerous and arranged serially in all bits which have ridges on surface. In complete specimen oscules are scattered irregularly on hillock-like projections ; diameter, 2 to 4 mm. Pores minute, average diameter 0.5 mm.

Dermal skeleton ill-defined at places and spicules usually placed horizontally, but occasionally get arranged vertically giving a microscopic hispidity to surface. Subdermal cavities simple, circular and rarely show signs of fusion. Diameter of these cavities may be up to 0.47 mm.

Main skeleton dense and its demarcation into distinct primaries and secondaries often impossible. Fibres may get flattened at their junction making meshes almost circular in outline. Brown pigment grannules are densely distributed in dermal as well as in deeper parts ; irregular in shape and are distributed either singly or in groups.

Spicules : (1) Oxeas, uniformly curved and gradually pointed. Stylote or strongylote modifications may also be noted. Size, 0.126 — 0.187 × 0.003 — 0.006 mm (Fig. 1 h).

Distribution ; Indo-Australian.

Petrosia sphaeroida (?) Tanita (Fig. 1 j)

Petrosia sphaeroida (?) Vacelet, Vasseur and Levi 1976. p. 89 fig. 68 ; pl. 10, figs. a, c, d.

Material : Two slices, probably parts of the same specimen.

Description : Of two slices, one is a cross-section of a vase-like specimen while other, a longitudinal section along wall. Former slice has a thickness of about 10 mm and diameter of 80 mm. Central cavity, which this slice encloses, has a diameter of 32 mm.

Colour : Brown.

Consistency : Hard and incompressible.

Surface ridged, ridges may get cut up into conules and these may be seen serially at places. Conules often blunt and with low, radiating ridges and these ridges may get connected with similar ridges originating from adjacent conules.

Dermal reticulation is coarse and summit of conules often with thicker fibres and large meshes while valleys in between conules with fine reticulation having smaller meshes. No trace of dermal membrane could be located in dry stage. Dermal reticulation has primary, secondary and even tertiary fibres as in any species of the genus *Callyspongia* Duch. and Mich. Pores in groups, often supported by larger meshes. Oscules small, 1 to 1.5 mm in diameter. Several openings varying in diameter from 1 to 1.5 mm could be located on lining of central cavity of sponge. This lining is netted as in dermal part. Main skeleton is coarsely reticulate ; fibres rather coarse and no difference between ascending and connecting fibres could be noted. Some fibres end at surface and support dermal skeleton as in the genus *Callyspongia*. Spongin content is rather meagre and the fibres may vary from 0.037 to 0.132 mm in diameter with an average mesh size of 0.37 mm. Reticulation lining the central cavity is made of coarse fibres of diameter varying from 0.09 to 0.1 mm. Fibres mostly flattened in outline and mesh size may be upto 0.56 mm in diameter. Spicules may often project out of fibres as spongin content is quite negligible.

Spicules : (1) Strongyles. Slightly curved size; 0.162 — 0.252 × 0.008 — 0.012 mm (Fig. 1 j, 1). (2) Small strongyles. Slightly curved ; size 0.042 — 0.117 × 0.006 — 0.012 mm, rarely with oxeote modifications (Fig. 1 j, 2).

Remarks : Many species of the genus *Petrosia* Vosmaer, are known to possess more or less the same spicular compliments as in the present case and to make the problem still complicated some other genera also overlap with this in this respect. Hence, a detailed study is essential to ascertain the various valid species of the genus *Petrosia* and to separate it from the other closely allied ones.

Distribution : Indo-Pacific.

Strongylophora durissima Dendy (Fig. 1 k, l, m)

Strongylophora durissima Thomas, 1986. pl. 2, fig. 7.

Material : Two bits, probably parts of the same specimen.

Description : From appearance of slices at hand it is certain that these bits represent longitudinal section of a cup-shaped specimen. Thickness of wall about 10 mm. Inner surface of bit somewhat ridged ; ridges run vertically upto rim of cup. Outer surface undulated.

Colour : Pale white.

Consistency : Hard and incompressible as in any lithistid sponge.

Oscules circular, shallow, flush with surface and compound ; diameter up to 3 mm. Pores minute. Several small openings with a diameter of 1.5 mm (average) are noted on outer side of lamella and may represent openings of commensal barnacles.

Dermal skeleton well developed and composed of an ill-defined reticulation of triangular meshes. Reticulation, at places, divisible into primary, secondary and even tertiary fibres with their diameter decreasing gradually. Spongin content negligible and spicules may even be seen distributed singly forming sides of ultimate mesh.

Main skeleton closely meshed and composed of a reticulation of fibres ; meshes irregular in deeper parts, but become distinctly rectangular towards peripheral parts. Connectives, at peripheral parts, become distinct after regular intervals (say, after two or three tiers) and since these thickened connectives (Fig. 1, l, TC) take a continuous course, the whole structure, in cross section, appears distinctly ladder-like. 4 to 7 such laminations may be noted in cross section of any actively growing part. Diameter of such thickened fibres may be upto 0.11 mm while that of main fibres only 0.056 mm. Spongin scarcely visible even in fibres.

Spicules : (1) Strongyles. Slightly curved ; smaller forms always oxeote. Size 0.024 — 0.315 × 0.005 — 0.016 mm (Fig. 1 k, l). (2) Microxeas. Dermal, angulated at the middle ; size, 0.033 × 0.002 mm (Fig. 1 k 2).

Distribution : Indo-Pacific.

Strongylophora septata n. sp. (Fig. 1 n - u)

Material : One complete specimen and 4 bits.

Description : Sponge erect in early stage of growth and may become repent in advanced stages of growth. Body with bulbous projections set in a linear pattern indicating an additional chamber formed as a result of a particular period's growth ; alternate chambers bulge more (Fig. 1 n, o, p). The total length of the complete specimen (Type) 110 mm and width, 35 mm (width taken at the largest chamber). It appears from shape of specimen that it was growing attached to substratum by one side (repent ?) and was removed from substratum by cutting it longitudinally. Other bits, however, show no sign of a lateral attachment and hence may be regarded as growing vertically up. Chambered nature of sponge quit distinct in all cases. Largest bit with maximum diameter of 30 mm.

Colour : Dermal part pale white and the interior gray.

Consistency : Hard and incompressible.

Oscules large, compound, perfectly circular and 5 mm in average diameter. Pores small, 0.04 mm in diameter and irregular to oval in shape.

Dermal skeleton thick and distinctly different from that of deeper parts both in colour and spicular arrangement. Dermal part resemble the 'rind' of any *Geodia* spp. (Fig. 1 q, DP) in general appearance. Dermal part has a 'two-layered' appearance and outer layer with its associated skeleton supports dermal membrane (OL) while inner one (IL) is a mesh-work of stouter fibres. This 'layer', when viewed from above, has a plate-like appearance (Fig. 1 r) with perforations. Fibres have a diameter of 0.094-0.28 mm and packed with strongyles. Meshes that these fibres enclose, are oval in outline with a diameter varying from 0.132 to 0.471 mm. Fibres originating vertically (Fig. 1 q. VF) from these plate-like reticulum fan out at surface as dermal skeleton. Space in between two adjacent vertical fibres quite extensive and forms distinct subdermal canals (Fig. 1 q. SDC). Since such canals are serially arranged without any sign of fusion, 'rind' appears 'two-layered' in cross section (Fig. 1 q).

Dermal skeleton is composed of strongyles in meshes as seen in *S. durissima* described earlier. Fibres divisible into primaries, secondaries and even tertiaries. Spongin content rather scarce and at places strongyles may be seen arranged horizontally. Microxeas seen ornamenting dermal meshes in varying degrees (Fig. 1 s).

Main skeleton irregular with fibres disposed in an irregular manner (Fig. 1 t, on either side of IL). No demarcation between primaries and secondaries ; spongin content neglibible.

Growth pattern : Since growth pattern noted in this new species is not common among sponges it is felt that details are worth mentioning. In this case original ' rind-like ' dermal region is retained and by subsequent growth another new chamber is added to the original one and such a pattern has not seen so far among sponges. In a sufficiently larger specimen several such chambers can be found in a superimposed fashion.

During the process of growth, there is every likelihood that some cells from the outermost ' chamber ' escape out through dermal part and form a new ' chamber ' which in structural details, bear a close resemblance to the original ' chamber '. It may be seen that dermal skeleton (' rind-like ' part) of original chamber that gets buried under new chamber, is composed only of plate like ' inner layer ' (Fig. 1 t, IL) of dermal part without any trace of outer ' layer '. Probably outer ' layer ' gets atrophied in due course as no physiological purpose is served by this part. Variation in size, at least in some parts, of chambers may be due to foul and fair seasons experienced by sponge.

Spicules : (1) Strongyles. Uniformly curved to biangulate. Size 0.016-0.294 × 0.002-0.012 mm. Young ones rarely oxeote (Fig. 1 u, 1). They are inseparable into sets. (2) Microxeas, Centrangulated with maxmium size of 0.029 × 0.002 mm (Fig. 1 u, 2).

Remarks : There is absolutely no difference between the spicules of this new species and of *S. durissima* Dendy collected from the same locality. Specimens of *S. durissima* have as characteristic lithistid appearance while the specimens belonging to the present new species differ considerably from those of the former in the structure of dermal skeleton and also in its ' chambered ' architecture. It is not known whether *S. durissima* has such a chambered architecture in its early stage of growth and the available literature on this species throws no light on this aspect. Hence, it is felt that the present new species can be retained until more data become available. Considering the presence of septa separating adjacent ' chambers ' the specific name ' *septata* ' is suggested here.

Family CALLYSPONGIIDAE de Laubenfels

Callyspongia fibrosa (Ridley and Dendy) (Fig. 1 i)

Callyspongia fibrosa Thomas, 1985. p. 248 pl. 2 fig. 14 (synonymy).

Material : Two specimens.

Description : Specimens were entirely different in their morphology ; one is finger-shaped while other lamellar. Finger-shaped specimen is divided into three branches at its apical part while lamellar one has a height of 90 mm with a lateral spread of 80 mm. Lamella has a thickness of 2 mm and one side ornamented with conules. Growing tip of this specimen transparent as fibres are thinly distributed and fibres destined to form conules are traceable throughout this transparent zone.

Colour : Brown.

Consistency : Soft and spongy with good resiliency.

Surface conulose, conules compound, 2 to 5 mm high and arranged on all sides in finger-like specimen while on one side in lamellar specimen.

Oscules and pores seen only on one side in lamellar specimen, but scattered throughout in other.

Dermal skeleton is a reticulation of smaller fibres forming fine meshes that are divisible into primaries, secondaries or even tertiaries and are cored by a single row of spicules. Main skeleton with well developed reticulation of primaries and connectives. Fibres which run through middle of lamella are stoutet (0.067 mm diameter) and these fibres curve our towards surface forming main fibres. These main fibres, at surface, support dermal reticulation. Near surface these main fibres become thin (0.042 mm diameter) and run parallel to each other. Main fibres connected in a scalariform pattern by fibres of about 0.04 mm diameter and this arrangement gives a rectangular shape to meshes. Both primaries and connectives equally cored by oxeas and spongin, pale brown in colour. In between rectangular meshes thus formed, there may be slender fibres stretching across in between arms of meshes. These slender fibres are never cored by oxeas.

Spicules : (1) Oxeas. Straight, uniformly or asymmetrically curved ; tips gradually to acutley pointed or even blunt. Size, 0.084-0.126 × 0.004-0.005 mm.

Distribution : Indian Ocean, Australian region and Atlantic Ocean (?).

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RESPONSES OF ZOOPLANKTON TO CHANGES IN HYDROSTATIC PRESSURE

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ABSTRACT

Pressure responses of a depth-regulatory nature have been demonstrated in all planktonic animals investigated. These animals responded to a rapid increase in pressure by active, continuous or intermittent, upward swimming, while a slow decrease in pressure was followed by less active downward swimming or passive sinking. The transient responses with respect to directional light varied among different species. With illumination directly from above, almost all swam upwards and towards the light in response to an increase in pressure, followed generally by a passive downward sinking or swimming away from the light when the pressure was decreased. With the illumination directly from below, movement of *Calanus* and *Clupea* larvae was still directed upwards (and away from the light) after an increase in pressure, while the nauplii of *Balanus*, *Eurydice* and zoea larvae of *Porcellana* remained mostly near or on the bottom, the last two showing evidence of dorsal reflex reactions. In horizontal experiments, with illumination from one side, the responses of most animals to an increase in pressure were first upward and then generally light-ward. With a decrease in pressure, they tended to sink or swim away from the light. Thus the depth-compensatory mechanism relies primarily on orientation to gravity and secondarily, in certain species more than others, on reactions to light. In darkness, however, the responses were clearly oriented to gravity. Sustained pressure increases stimulated the animals to swim upwards, but this was soon followed by a brief temporary depression of activities in megalopa larvae of both *Porcellana* and *Carcinus* for no apparent reason.

INTRODUCTION

FIELD experiments of Hardy and Paton (1941) suggested that behaviour associated with pressure changes might be concerned with depth-regulation. Pressure sensitivity has now been shown to be wide spread among plankton animals (Hardy and Bainbridge, 1951 ; Knight-Jones and Qasim, 1955 ; Baylor and Smith, 1957 ; Rice, 1964 ; Singarajah, 1966 ; Knight-Jones and Morgan, 1966). The most usual response seen, in captivity, is an active upward movement with increase in pressure and a passive downward sinking with decrease in pressure ; the latter is seen particularly in non-buoyant animals. Moore and Corwin (1956) found evidence in the field that some depth-related factor, presumably pressure, together with temperature and illumination, contributed to controlling the vertical distribution of a number of plankton animals. Enright (1961, 1963) demonstrated increased activities, in response to rapid changes in pressure, in inter-tidal amphipods. Sensitivity of *Nymphon gracile* to pressure changes of tidal amplitude and frequency has been shown by Morgan *et al.* (1964). Bayne (1963) observed a pressure response in the early larvae of

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Mytilus edulis and suggested that the mechanism might aid in dispersal of species. Straight-hinged and pediveliger larvae of oysters have also been shown to respond readily to changes of pressure equivalent to 190 mm Hg (Singarajah, 1979).

While evidence of pressure sensitivity continues to accumulate, the mechanism of pressure perception remains rather obscure. There is no theoretical difficulty with mechanisms involving compression of gas-filled vesicles, like teleostean swim-bladders (Harden-Jones and Marshall, 1953) and the tracheal systems of certain insects (Thorpe and Crisp, 1947), but no such compressible vesicles have been reported in marine invertebrates (apart from siphonophores). Extensive searches have shown none in such transparent animals as *Pleurobrachia*. A possible pressure perception mechanism, postulated by Digby (1961 a, b), was based on membrane tension increases, which cause changes in potentials across the surfaces of the prawn *Palaemonetes varians* and the shrimp *Crangon vulgaris*. These potentials were shown to vary with imposed pressure changes and Digby suggested that the pressure sensitivity of these crustaceans was a consequence of 'changes in area' of a hydrogen layer, a few molecules thick, which he visualized as being produced in association with these potential differences. On the other hand, subsequent observations (Enright, 1963), on the compressibility of some marine invertebrates, provide no support for the hypothesis that sensory system by which these animals perceive small pressure changes is based on ultrathin layers of gas.

The present paper deals with the results of experimental studies on various plankters, all of which showed depth-regulatory responses to pressure changes.

The author is indebted to Professor E. W. Knight-Jones for use of the laboratory facilities, his interest, encouragement and assistance with the manuscript; and to Professor G. A. Horridge for his support, electrophysiology laboratory and library facilities and advice.

MATERIALS AND METHODS

The pressure apparatus consisted of a pair of thick walled glass jars, 40 cm tall and 12 cm internal diameters, one or both of which could be used at a time (Fig. 1). Each tank was sealed with a rubber diaphragm and closed by an aluminium lid which was connected to a compressed air (or vacuum) system and mercury manometer through a series of glass T-pieces and lengths of rubber tubing. An increase or decrease of pressure was given by closing or opening one of the lengths of rubber tubing, through which air could be compressed or evacuated.

All experiments were conducted in a controlled temperature room at 12-14°C. Initial observations on behaviour were made in general room lighting, which was obliquely from above. In subsequent experiments, using directional illumination, observations were made in a 'Perspex' tank, 30 × 4 cm *i.d.*, with all sides sealed except for an aperture near one end; this aperture could also be sealed and closed tightly. The tank could be placed vertically, horizontally or in any other desired position and illuminated by a 100 W lamp shining through a slit to produce rays parallel to the axis of the tank.

In a few experiments involving changes of pressure of the kind associated with waves, the apparatus was similar to that used by Morgan *et al.* (1964) to simulate tides.

Pressure was measured in meters of sea water. Atmospheric pressure was not added as the pressure in water is directly a depth-related function and, therefore, the normal pressure at sea level was assumed to be zero (Sverdrup *et al.*, 1961).

Freshly collected plankton animals, not exceeding 15, were introduced into each tank.

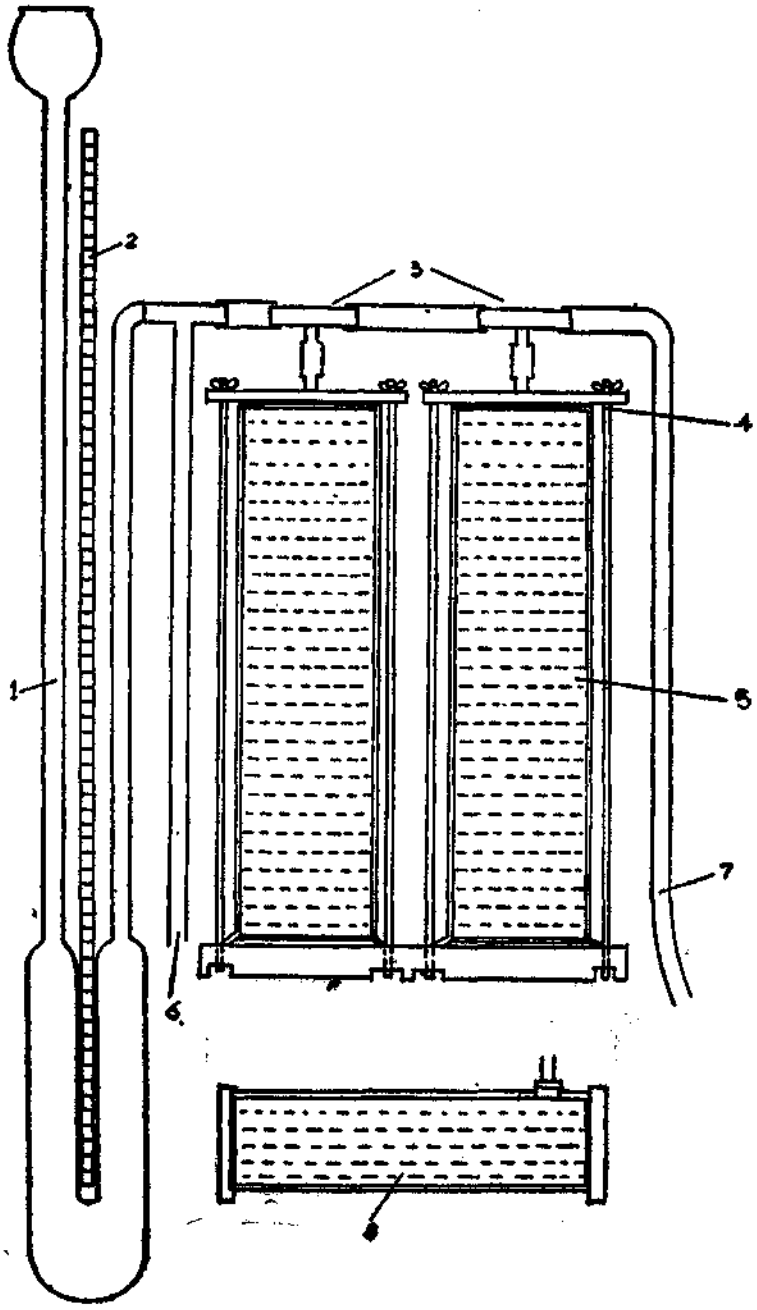

Fig. 1. Apparatus used in the experiments to measure responses to changes in hydrostatic pressure. 1. Mercury manometer, 2. Scale, 3. T-piece connections, 4. Wing-screw support system for pressure tanks, 5. Pressure tank, 6. Regulating end of the pressure tubing, 7. Connection to compressed air and 8. Pressure tank for horizontal experiments.

Each tank contained filtered sea water collected freshly from the same area where plankton hauls were made. The tank lids were secured with wing-nuts and changes of pressure were given at one minute intervals in gradually increasing magnitudes. Unless stated otherwise, the numbers of animals swimming is given for 15 sec. intervals in the upper half of tank in vertical experiments and in the half nearest to the light in horizontal experiments. Recordings in the dark was done with a red lamp switched on momentarily.

RESULTS

Essentially a depth regulatory behaviour was observed in all animals investigated, though considerable variation occurred among individuals with respect to the nature and intensity of responses, particularly under directional illumination'.

Calanus helgolandicus : These were caught in day time surface hauls during summer and subjected to changes in pressure within an hour. Initially, at normal pressure, more *Calanus helgolandicus* were seen to swim up and down near the bottom of the pressure tank, while only a few swam near the surface. With the increase in pressure, the majority swam upwards, some rapidly, but others intermittently. On decrease of pressure nearly all sank down with occasional intermittent surges upward. Clear evidence was obtained of response to changes of pressure (Fig. 2) equivalent to 2.5, 5.0, 7.5 and 10 metres of sea water. But some individual variations occurred. When pressure was increased to 10 m, all responded readily by upward movements. There was a tendency for the response to decline when the batch of animals was subjected to repeated pressure changes. Those individuals showing a tendency to remain or swim near the surface for longer periods always responded more readily (to pressure changes as low as 60.8 mm Hg) and their ability to respond was longer lasting.

With directional illumination from above and the pressure ambient, the majority remained at the bottom while some swam near the surface. On increasing the pressure to 5 m, 80% of the individuals from the bottom swam rapidly upwards, while the few that remained in the bottom half of the tank still made some attempt to swim upwards, but soon sank. On decrease of pressure, approximately the same numbers that had previously moved up from the bottom half began to sink with their usual intermittent up and down surges.

With illumination directly from below, the responses were clearly reversed. At normal pressure, of those that remained initially near the bottom only 40% swam rapidly upward in response to increase of pressure, 60% remained at the bottom. Some of the latter turning toward the light (head downwards) and others surged slowly up and down within a few cm from the bottom. On decrease of pressure, the small numbers that remained at the surface soon began to sink downwards. Amongst those that had remained near the bottom, some swam a few cm upwards, away from the light, before sinking back to the bottom.

In some experiments the tank was positioned horizontally and the light directed from one side. With normal pressure, about 40% of the copepods collected towards either end while 20% swam more centrally. On increasing the pressure all swam instantaneously upwards, evidently in a depth-regulatory manner. Of those that remained at the end far from the light, only 20% tended to move towards the light and often with intermittent surges up and down at the surface. The rest continued to surge near the surface without marked horizontal displacement, displaying the usual 'hop-and-sink' movements. However, when the pressure was decreased, all sank and those that had moved towards the light now moved away from it, re-establishing the original pattern of distribution. In almost all experiments, during upward surges or 'hops'

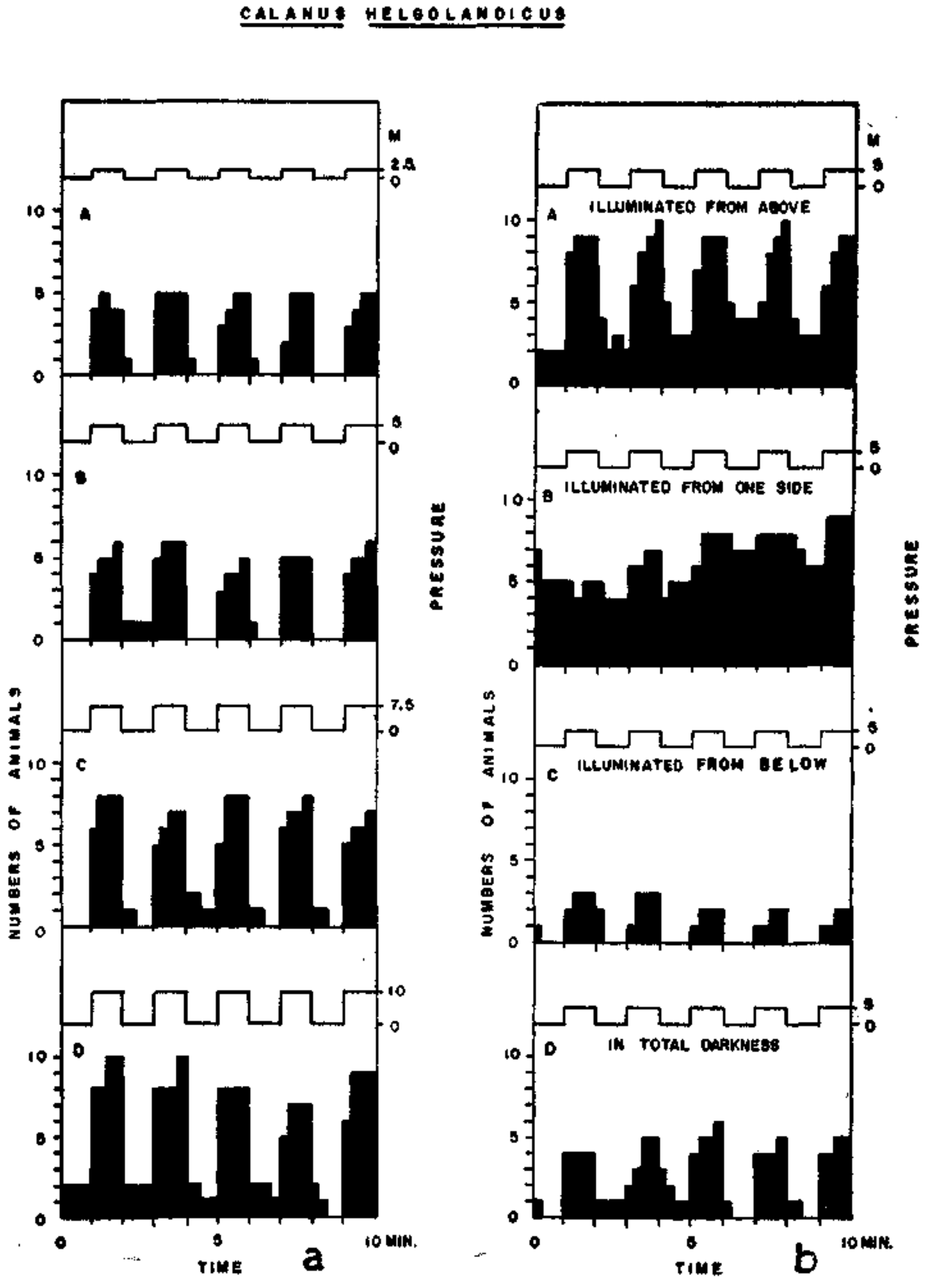

Fig. 2 a. Number of animals swimming above half-depth out of ten *Calanus helgolandicus* (Clausi), recorded every 15 seconds in an experimental tank 40 cm deep, when given pressure changes equivalent to 2.5, 5.0, 7.5 and 10 m respectively, each alternating with atmospheric pressure at 1 minute intervals, under general illumination mostly from above and b. Number of animals swimming above half-depth (or in the half nearest to the light) in an experimental tank 30 cm long, when given pressure changes equivalent to 5 m, under different conditions of illumination.

in response to pressure, the antennules were often seen to beat at high frequency.

Balanus balanoides : Freshly liberated nauplii were strongly photopositive and remained near the surface, where light was apparently maximal. However, in about half an hour some of these nauplii became photonegative and were located at the bottom of the tank. Before any negative photic signs occurred, if the larvae were subjected to changes of pressure equivalent to 2.5 m at 1 minute intervals, all responded readily by swimming up more strongly. In response to decrease of pressure, some swam down for the first time, but a proportion of these soon returned to surface. Clear responses were also seen to changes of pressure as low as 55.5 mm Hg.

After half an hour at normal pressure, some of the larvae became distinctly photonegative and remained at the bottom. With increasing pressure, all, larvae swam upwards more actively ; with subsequent decrease of pressure, a number similar to the originally photonegative animals swam to the bottom, whilst the rest swam down as far as mid-depth only to swim back to the surface.

Essentially, similar behaviour was observed in response to changes in pressures of all magnitude, but with actively also correspondingly enhanced at higher pressure (Fig. 3 a). The same batch of nauplii also responded to brief pressure pulses of similar magnitudes, lasting ½ a second, but the actual response was discernible only after the pulse, *i.e.* when the pressure had returned to normal.

Larvae hatched out from the same batch, which comprised photopositive and photonegative ones, where subjected to changes of pressure with the tank illuminated from above. All swam upward to the surface (Fig. 3 b), but a few of the more photonegative larvae soon tended to adapt a location a few cm below the surface. On release of pressure, however, more photonegative larvae began to swim rapidly to the bottom, restoring the original behavioural pattern.

When the tank was illuminated from below and at normal pressure, the originally photonegative nauplii left the bottom and swam away from the light to the surface while the photopositive ones swam down to the bottom, thus the reversal of their positions clearly indicated their photic behaviour. When pressure was imposed, all larvae that had remained near the surface now swam actively downward towards in the light (Fig. 3). Although one or two soon swam back to the surface, the majority remained at the bottom. On decreasing the pressure, some still remained at the bottom while the remainder swam upwards.

In horizontal experiments at normal pressure with illumination from one side, some of the larvae remained towards either end of the tank and a few swam randomly towards the centre. On increasing the pressure, they all first swam upwards and then light-ward. With a subsequent decrease of pressure, their earlier positions were reestablished. If, however, the tank was now illuminated with equal intensity from both sides and the pressure increased, some of the larvae that had remained near either end tended to swim towards the middle of the tank, as if to adjust to an optimal light condition.

Responses to changes in pressure in the dark were similar to those observed under general illumination and clearly the animals orientated to gravity (Fig. 3).

On subjecting the nauplii to negative pressure pulses, within a —5 m range and lasting ½ sec, under general illumination, all the larvae near the surface swam actively downwards and those that were near the bottom made further attempts to swim downward. If light was directed from above, none swam upwards in response to such negative pulses of pressure. But when the light was directed from below,

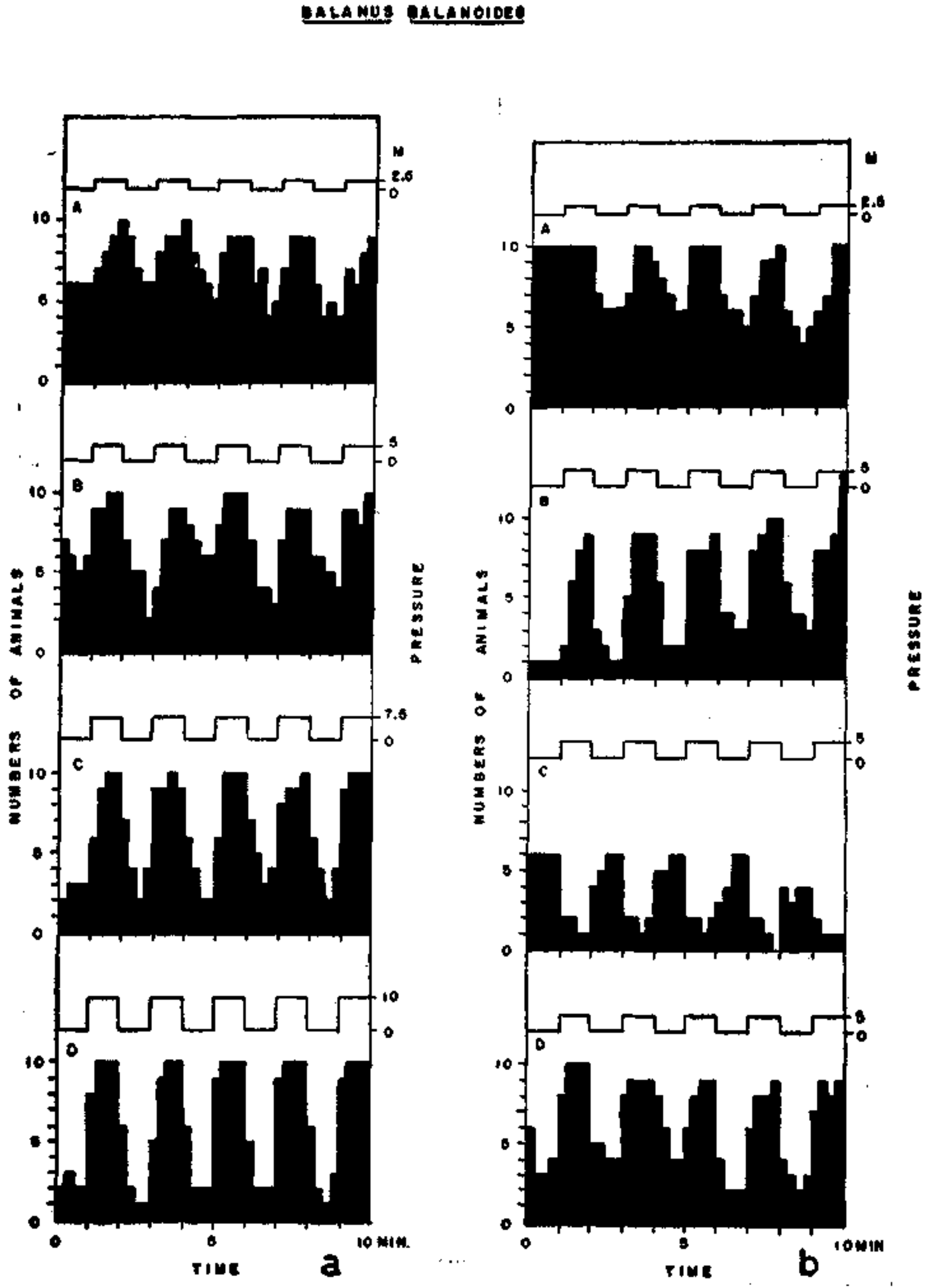

Fig. 3 a. Numbers out of ten nauplii of *Balanus balanoides* (liberated more than half an hour previously) swimming above half-depth, recorded every 15 seconds in an experimental tank 18 cm deep, in response to pressure changes equivalent to 2.5, 5.0, 7.5 and 10 m respectively, each alternating with atmospheric pressure at 1 minute intervals, under general illumination, mostly from above and b. Response of freshly liberated (within first half an hour) nauplii to changes of pressure equivalent to 2.5 m under general illumination, mostly from above. (b : c. As in B, but with illumination from below and D. As in B, but in total darkness.)

some of the originally photonegative animals responded by swimming away from the light to the surface first, after which they swam downward more rapidly toward the end of the negative pressure pulses.

Elminius modestus : Responses to changes in pressure were generally similar to those observed in *Balanus* nauplii. In general illumination, the net response to an increase of pressure was an active upward swimming and to a decrease in pressure, swimming that was directed downwards. The overt responses to short pulses of positive pressure lasting ½ a sec, were discernible only after the pressure had returned to normal.

Eurydice pulchra : The behaviour of this species, in response to changes of pressure under a variety of conditions. resembles, in many respects, that of zoea larvae of decapods. The responses clearly indicate (Fig. 4) high sensitivity to changes in pressure. With normal pressure, these animals swam rapidly at all depths. With increase in pressure, they swam rapidly upwards, whilst a subsequent decrease in pressure was followed by resumption of their usual random swimming behaviour, but mostly in the lower half of the tank. Although similar types of response were obtained with different magnitudes of pressure, their overall activity and the numbers swimming upward increased correspondingly at higher pressures. They remained sensitive to pressure changes as low as 57 mm Hg over several days. If however, clean sand collected from the sea was placed in the bottom of the vessel, they abandoned free-swimming in about six hours and remained buried in the sand, a behaviour trait presumably coinciding with the inactive phase of a tidal rhythm. Whilst in their buried state, if changes of pressure equivalent to 2.5 5.0, 7.5, 10.0 and 12.5 m were imposed, none of the animals left the bottom. Thus pressure had no obvious effect if animals were in close contact with the sand particles. But, if the sand was swirled up and a pressure increase imposed, all *Eurydice* swam rapidly upward. With a subsequent decrease in pressure, they resumed random swimming and made no attempt to bury themselves in the sand.

With illumination from above, after an increse in pressure, all animals readily swam to the surface. After reaching the surface, about 30% of these animals folded their limbs and allowed themselves to sink passively ; however they soon swam back to the surface again. On lowering the pressure, they swam rapidly downward and away from the light.

When illuminated from below, the responses to changes of pressure closely resembled those of zoea larvae of *Porcellana*. The majority of the animals usually stopped swimming with the dorsal surface downwards, in an inclined position, with the head touching the bottom. Increase or decrease of pressure caused no significant change in this behaviour. Occasionally two animals swam upwards after a reduction of pressure, only to swim downward again with pressure increase imposed. This behaviour also shows evidence of a reflex dorsal light reaction, like those described in mysids (Foxon, 1940 ; Rice, 1961).

In experiments where horizontal tank was illuminated from one side, many animals first swam upwards in a depth regulatory manner and then towards the light during increased pressure. With decreased pressure, they swam initially away, but soon many more resumed random swimming toward the light.

The behaviour in total darkness was similar to that observed under general illumination, but the movements apparently were orientated to gravity ; in addition, greater numbers swam in the lower half of the vessel during periods of low pressure.

Zoea larvae of *Porcellana longicornis :* Under normal pressure, these larvae often

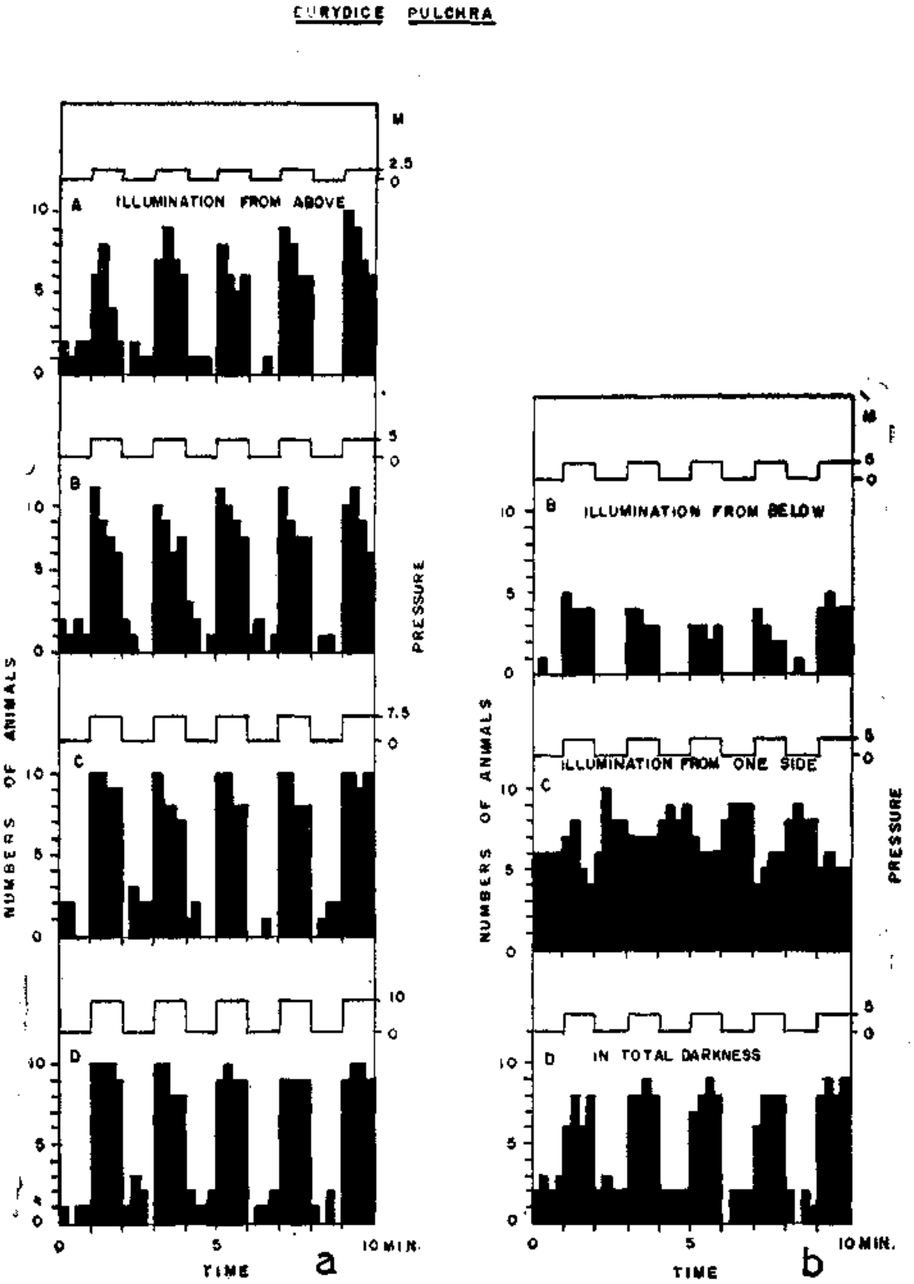

Fig. 4 a. Number of animals swimming above half-depth out of ten *Eurydice pulchra*, recorded every 15 seconds in an experimental tank 40 cm deep, when given pressure changes equivalent to 2.5, 5.0, 7.5 and 10 m respectively, each alternating with atmospheric pressure at 1 minute intervals (A. Illuminated directly from above ; and B, C and D in general illumination, mostly from above) and b. Number of animals swimming above half-depth (or in the half nearest to the light) in an experimental tank 30 cm long, when given pressure changes equivalent to 5 m, under different conditions of illumination (B, from below ; C. from one end of the experimental tank ; D. in total darkness).

floated motionless at the surface film with the rostral and paired posterior spines being evidently unwetted, or they swam at all depths, or sank rapidly. With increased pressure, all swam rapidly upwards, usually with the rostral spine foremost and with frequent backward strokes of the telson, thus reaching the surface in a few seconds (Fig. 5). Alternatively, they responded by swimming vertically upwards with the posterior pair of spines in advance, depending on the position they had previously adopted when resting on the bottom. Such swimming in the reverse position was equally effective. With decrease of pressure, most larvae sank rapidly and motionless whilst others continued to swim, but less energetically; eventually they too sank downwards, but at a lesser rate. They all showed sensitivity to changes of pressure corresponding to little low as 47.1 mm Hg.

With illumination from below and pressure normal, the larvae swam at all depths, with no strong tendency to collect near the surface. With increase of pressure, all swam rapidly to the surface and with decreased pressure they swam less actively or stopped swimming, allowing themselves to sink. Similar behaviour has been noted in megalopa larvae of *Carcinus* (Rice, 1964).

With illumination from below and pressure normal, the zoea larvae generally swam downward and remained laying with dorsal side facing the light. When pressure was increased, almost all moved actively forward, sliding on their ventral side on the bottom. Occasionally, however, a few showed outbursts of upward swimming for a few cm and then returned to their reflex dorsal light reaction. With experiments with the tank horizontal and illumination from one side, the immediate response to increased pressure was invariably quick upward movement, followed by swimming directed towards the light, with rostral spine foremost; those that already had reached the lighted end surged up and down near the surface. When the pressure was then reduced to normal, most sank and swam slowly away from the light, with the rostral spine pointing lightwards.

In total darkness, the responses were distinctly orientated to gravity and the larvae moved up and down, with changes of pressure, while maintaining their vertical posture. It appeared that this posture might have resulted automatically from the disposition of the rostral and paired posterior spines, which must influence the sinking rate. However, the orientation to light was not determined by sinking posture, for if the light was switched on momentarily from below, while the pressure was increased, the up-swimming larvae tended to dart downward without changing the posture.

Clupea harengus: A sample of benthic eggs (1.30 mm diam.) were selected from a fresh collection and subjected to changes of pressure equivalent to 10 m of sea water at one minute intervals for a period of 30 minutes. This had no obvious effect on hatching. Hatching occurred both in the experimental and control batches almost simultaneously, within two days.

The results of subjecting early yolk-sac larvae to alternate minutes of high and low pressures, equivalent to 0.8-10 m and atmosphere (zero), in a series of eight experiments are shown in Fig. 6.

At ordinary pressure, the larvae with their heavy yolk sacs are non-buoyant, but tended to swim head upwards at all depths in the pressure tank. However, recently hatched larvae were observed to be sensitive to changes of pressure as low as 60.8 mm Hg.

Under general illumination, with increase in pressure, they swam rapidly upwards; with decrease in pressure, they swam less actively downwards.

With the container lighted vertically from above and with pressure increase, almost all

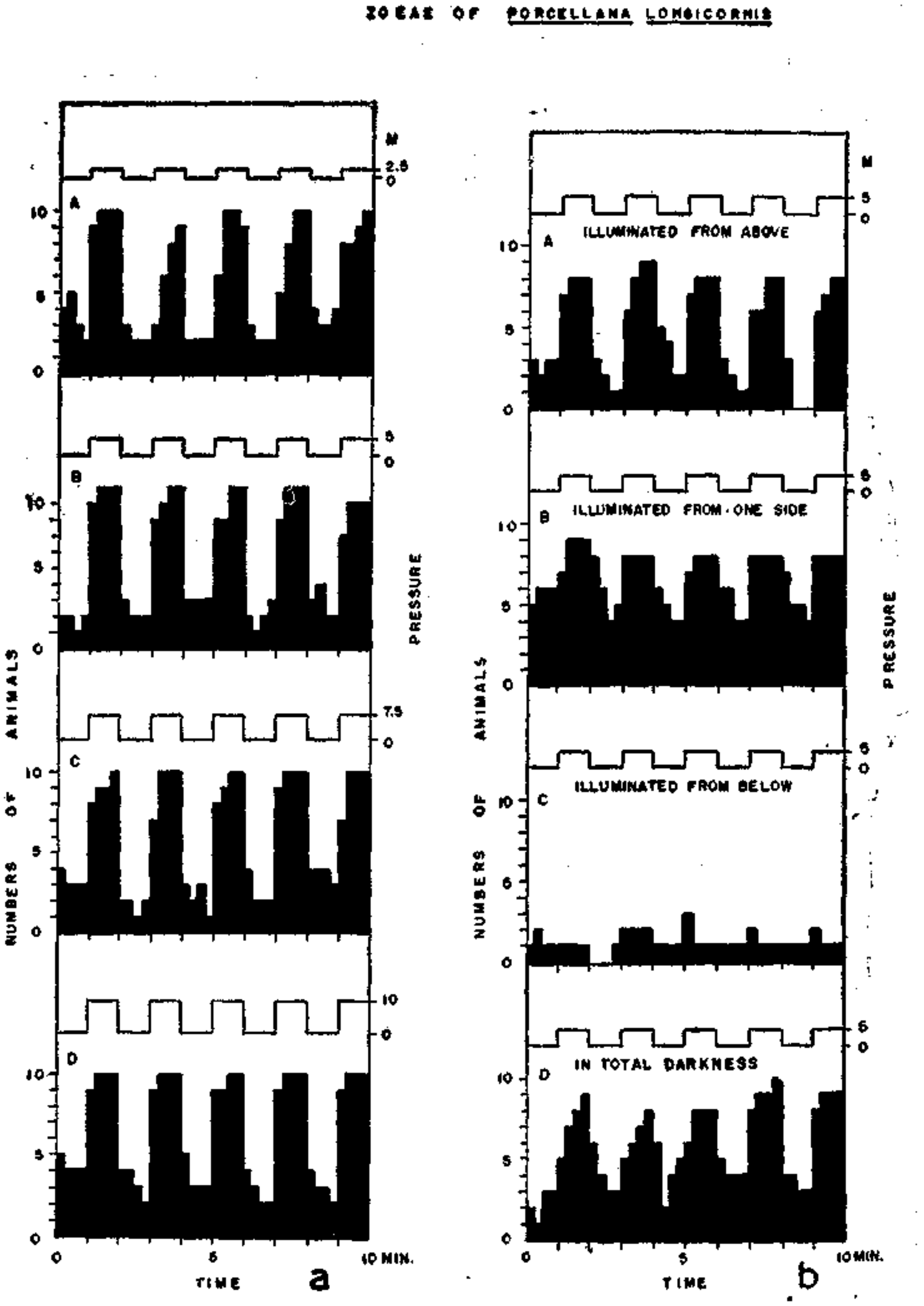

Fig. 5 a. Numbers swimming above half-depth out of ten zoea larvae of *Porcellana longicornis*, recorded every 15 seconds in an experimental tank 40 cm deep, when given pressure changes equivalent to 2.5, 5.0, 7.5 and 10 m respectively, each alternating with atmospheric pressure at 1 minute intervals, under general illumination mostly from above and b. Numbers swimming above half-depth (or in the half nearest to the light) in an experimental tank 30 cm long, under different conditions of illumination as shown in A, B, C & D.

of the larvae swam rapidly toward the surface ; with decreased pressure they tended to swim or sink downwards.

When the pressure tank was illuminated from below at normal pressure, most larvae swam downwards and remained at the bottom until pressure was increased, following which there was an active upward swimming away from the light. This behaviour was in direct contrast that of decapod larvae.

With the tank horizontal and illumination from one end, the larvae showed a general tendency to swim and collect at the end near the light during intervals of reduced pressure. When the pressure was increased, all swam instan'aneously upwards and those that had remained initially away from the light moved towards the light ; those that had already reached the lighted end made attempts to move still further upwards. It seemed that their depth compensatory mechanism relied primarily on orientation to gravity and secondarily to reaction to light.

Responses to sustained pressure increases : Freshly collected plankton animals were kept in experimental tank. During a 30 min. period at normal pressure, before any changes of pressure were imposed, the various plankton animals usually remained less actively near the bottom, with occasional, apparently spontaneous upward movements. Following a pressure increase, the responses shown were clearly depth-regulatory in nature, but the level of activities fluctuated among the different individuals and stages of the same species. The swimming levels adopted by *Calanus*, and by zoea and megalopa larvae of *Porcellana* and *Carcinus* in responses to sustained pressure increases equivalent to 5.0 m of sea water and lasting for 40 min. are shown in Fig. 7. Initially, all were stimulated to swim upward, but this was soon followed by a depression of activities in megalopa larvae of both *Porcellana* and *Carcinus* during which they sank slowly and remained near the bottom with only occasional outbursts of increased activity. However, after this temporarily reduced activity, which lasted about 10 minutes, the megalopa larvae resumed upward swimming more persistently during the last 20-30 min. until the pressure was reduced to normal. In *Calanus* and zoea larvae the increased activity persisted, with only a slight variations in swimming levels, throughout the period of sustained pressure.

DISCUSSION

Depth-regulatory responses : It is interesting to note that the behaviour of all planktonic animals examined in these experiments was depth-regulatory in nature. Behavioural responses in the different animals appear to be closely related and comparable even though there had been some subtle degrees of variability of form and intensity of response within the different stages of the same species. The most obvious mechanical responses observed in the various animals were their abilities to detect changes in ambient pressure, with resultant movements in preferencially oriented directions — an active upward swimming response to increased pressure and passive downward swimming or sinking under the influence of gravity in response to decreased pressure.

Hardy and Paton (1947) first suggested that *Calanus finmarchicus* (Gunners) might have a ' sense of depth ' and that many decapod larvae might be sensitive to even smaller changes in hydrostatic pressure and their vertical movements might be influenced by pressure difference at different depths. Early laboratory experiments (Hardy and Bainbridge, 1951 ; Knight-Jones and Qasim, 1955) showed no clear evidence of pressure sensitivity in *Calanus finmarchicus*. Rice (1962), however, eventually succeeded in demonstrating such sensitivity in this species. In contrast, the present study has shown convincing evidence for the pressure evoked responses in the relatively important and very closely related neritic species *Calanus*

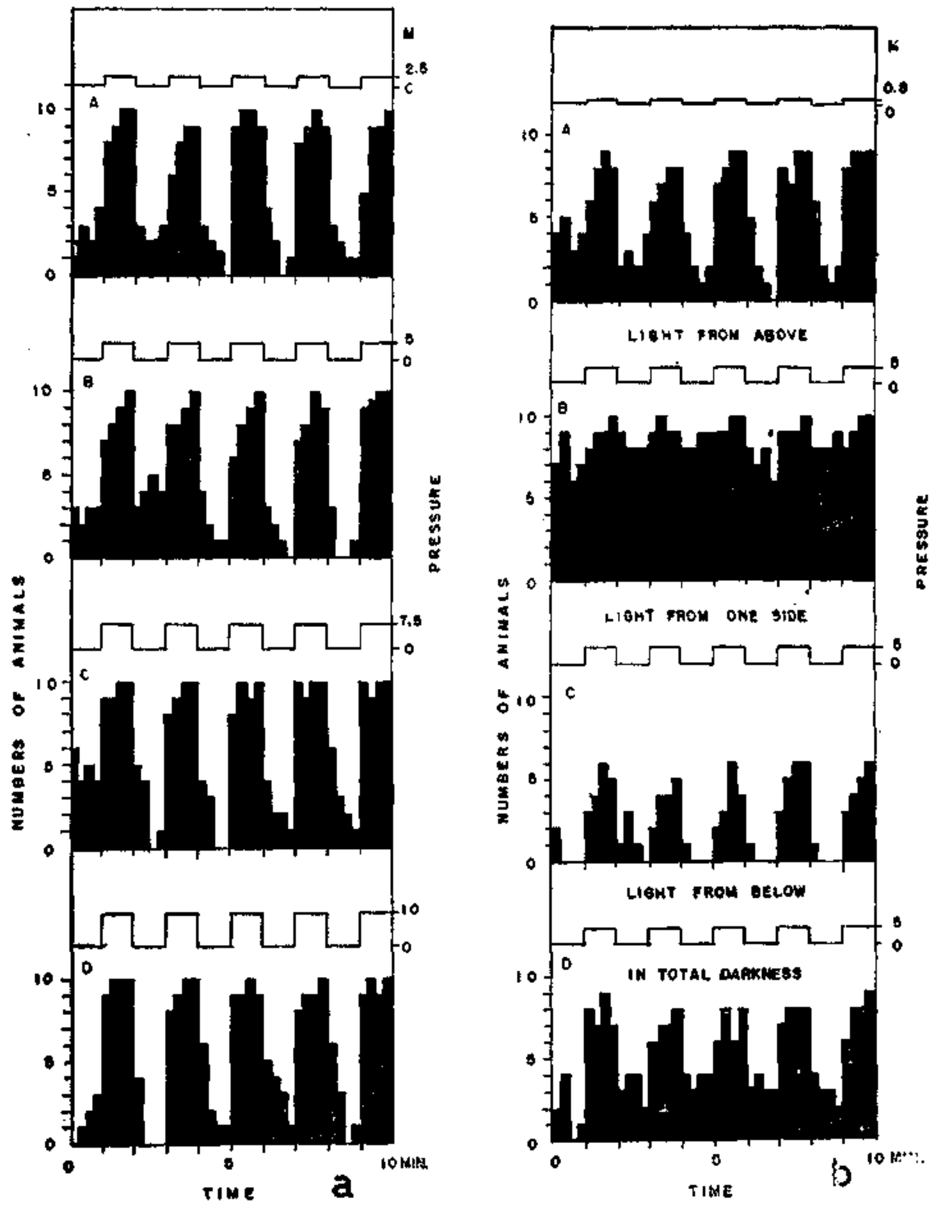
CLUPEA HARENGUS

Fig. 6 a. Numbers swimming above half-depth out of ten yolk-sac larvae of *Clupea harengus*, recorded every 15 seconds in an experimental tank 40 cm deep, when given pressure changes equivalent to 2.5, 5.0, 7.5 and 10 m respectively, each alternating with atmospheric pressure at 1 minute intervals, under general illumination, mostly from above and b. Numbers swimming above half-depth (or nearest to the light) in an experimental tank 30 cm long, when given pressure changes equivalent to 5 m, under different conditions of illumination as shown in A, B, C and D.

helgolandicus. Their ability to respond readily was long lasting, a characteristic also seen in *Sagitta setosa* (Singarajah, 1966). Although it is now known that this behaviour is fairly widespread, we do not know the exact mechanisms whereby the pressure stimulus is detected. Nevertheless, the behaviour seems to be correlated with adaptive values (Hardy, 1959; knight-Jones and Morgan, 1966; George and Marum, 1974), and probably used to adjust and maintain their optimal depth in the sea during vertical migration. Adaptive behaviour of zooplankton in response to selective forces of environment relating to vertical migration has been considered to be important (Heinle, 1981).

Calanus helgolandicus regularly flicked its antennules at a higher frequency from the onset of upward surge in response to increased pressure. It is not clear whether this has something to do with mechano-reception, though copepod antennules are known to contain both chemo- and mechano-receptors (Gill, 1986).

Behavioural response to changes in hydrostatic pressure in nauplii of *Balanus* and *Elminius* appeared strongly influenced by light where even the initially photonegative nauplii left the bottom and responded readily and strongly to pressure. In the absence of any evidence of statocysts in Cirripede nauplii, the orientation of upward movement toward the light in horizontal experiments during responses to pressure changes seems more correlated to light than to gravity. Strong photopositive responses under different conditions with fed and unfed nauplii larvae had been reported previously (Singarajah *et al.*, 1967).

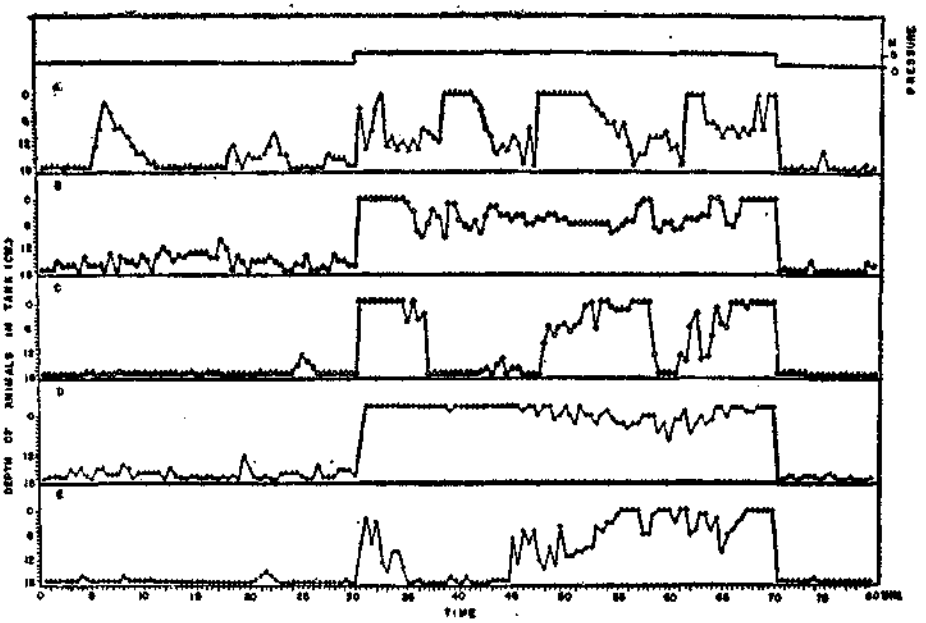

Fig. 7. Comparison of responses of different planktonic animals to sustained pressure increases under idential experimental conditions. See the swimming levels adapted to sustained pressure increase equivalent to 5.0 m by : A. *Calanus* : B. Zoea and C. Megalopa larvae of *Porcellana* : D. Zoea and E. Megalopa larvae of *Carcinus* respectively.

The apparent lack of response of *Eurydice pulchra* when in close contact with the sand particles in their burried state cannot be easily explained. If formation of the gas vesicles on the cuticle of Crustacea during pressure increase as suggested by Digby (1961 a) were to be effective as a pressure sensory mechanism then there ought to have some reactions, but none were seen. On the other hand, studies (Campenot, 1975) on shallow water lobster *Homarus americanus* and the deep-living crab *Geryon quinquedens* indicate that effects of hydrostatic pressure depress the neuromuscular excitatory potential as a result of reduction in the amount of neurotransmitters released at the nerve endings.

Because of the economic importance, behaviour of early herring larvae was largely confined to growth and survival mechanisms of larvae in the sea (Rosenthal and Hempel, 1970). The pressure sensitivity of larvae of *Clupea harengus*, which lacked a swim bladder, has not been previously reported. Sensitivity to changes in hydrostatic pressure has been considered as one of the functions of swimbladders (Qutob, 1962 ; George, 1981), but teleosts lacking swim bladders also have been shown to be clearly sensitive to changes in hydrostatic pressure (Qasim *et al*., 1963). Hardy (1959) described their remaining in the bottom of an aquarium tank after hatching, but Nikol'skii (1962) found them swimming to middler layers. Lebour (1921, 1924), on the basis of remnants of phytoplankton found in the guts of yolk-sack larvae, concluded that they swam to the surface soon after hatching. Ford (1928) also noted their abundance in the surface layers. On the other hand, Nelson-Smith (1964) reported that more larvae were caught in deep waters than in surface nets. However, recently hatched fed and unfed larvae were clearly sensitive to changes of pressure less than 60.8 mm Hg. The most obvious response in herring larvae during increase in pressure was strongly photopositive. Generally, Spooner (1933) found herring larvae to be photopositive and it seems that their depth-compensatory mechanism relies primarily on orientation to gravity and only secondarily on reaction to light. Detailed studies on sensory awareness of herring larvae in relation to light has been reported (Blaxter and Jones, 1967 ; Blaxter, 1968 ; Blaxter and Batty, 1987).

Tests for threshold pressure stimuli (Table 1) in different plankton animals suggest that sensitivity to pressure changes differs not only among different groups, but also within the developmental stages of the same species. Generally, the larvae seem to be more sensitive to pressure changes than the adults, a phenomenon also seen in different stages of oyster larvae and *Artemia* larvae (Singarajah, 1979, 1981). Similar observations have been noted in larvae of *Ostrea edulis* (Bayne, 1963).

Eurydice and zoea larvae of *Porcellana* distinctly displayed reflex dorsal light reactions which resembled closely those of mysids (Foxon, 1940 ; Rice, 1961). It is still not known whether these reactions were mediated by the optomotor system, although many organisms are sensitive to light which may strike the body and not the eyes (Steven, 1963). The strongest turning movement in the dorsal light reflex seems to be induced by laterally incident light and is comparable to gravity reflex (Waterman, 1961). However, in *Porcellana* larvae, the responses were distinctly oriented to gravity as shown by the results of experiments in total darkness. The disposition of the rostral and the posterior paired spines probably assist in maintaining posture during orientation to gravity, although statocysts may not be fully developed in the early decapod larva (Prentiss, 1901 ; Gurney, 1939).

Except for a brief temporary depression of activities, after an initial burst, the zoea and megalopa larvae of both *Porcellana* and *Carcinus* in common with other planktonic animals tested, showed no activity decline and remained consistent over the subsequent prolonged periods. The brief depression of these larvae, though, appeared adaptive.

It is now fairly well established that pressure is one of the more important parameters of marine environment which determines, together with light and gravity, the distribution of the planktonic species within their pelagic habitats.

TABLE 1. *Threshold pressure stimuli required to elicit overt responses in different species of zooplankton*

Group/Species		Stage : Larvae/Adult	Observed minimum pressure (mm Hg) required to evoke a response	General direction of swimming
Decapoda				
Porcellana longicornis	..	zoea	47.1	↑
		megalopa	47.9	↑
Carcinus maenas	..	megalopa	49.4	↑
Copepoda				
Calanus helgolandicus	..	adult	60.8	↑
Cirripede				
Balanus balanoides	..	nauplii	55.5	↑
Elminius modestus	..	nauplii	53.2	↑
Isopoda				
Eurydice pulchra	..	adult	57.0	↑
Teleost				
Clupea harangus	..	larvae	60.8	↑

The responses to changes in pressure were observed mainly under three conditions : (1) general illumination ; (2) directional illumination and (3) total darkness. Occasionally negative pressure pulses were given (see Text). The threshold responses of the same species, under different conditions, were not significantly different and therefore, the results were averaged. For clarity measurements of pressure in sea water are converted to mm Hg.

Relatively little is understood about the actual pressure selective mechanism. Swim-bladders in teleosts seem to control depth-regulatory function (McCutchen, 1958 ; Qutob, 1962 ; Laverack, 1968 ; George, 1981) and a number of other possible mechanisms are discussed (Knight-Jones and Morgan, 1966). but contains no clear baro-sensory mechanism. Neuro-transducer mechanisms are most likely to be involved in almost all pressure sensitive behaviour, like the stretch receptors in skeletal muscles (Katz, 1950) ; the deflection of ciliary receptors in *Pleurobrachia* (Horridge, 1965) ; and the deformation of Pacinian corpuscles due to pressure leading to generator potentials (Loewenstein, 1972).

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FOOD AND FEEDING BEHAVIOUR OF *NEMIPTERUS JAPONICUS* (BLOCH) POPULATIONS OFF VISAKHAPATNAM, SOUTH INDIA*

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ABSTRACT

Qualitative and quantitative analyses (volumetric and frequency of occurrence methods) of stomach contents of *Nemipterus japonicus*, caught off Visakhapatnam, are made. *Squilla*, crabs, prawns, teleosts, cephalopods, amphipods, polychaetes and other miscellaneous items in that order of preponderance constituted the food spectrum of the species. Degrees of fullness, on the basis of stomach wall distensions are assessed and average amount of feeding calculated. Feeding intensity is high during March-November and low during December-February. Nature of food is size-dependent and fishes in higher length-groups preferred large-sized prey like crabs, teleosts and cephalopods. The composition and preference of food items are not sex-dependent.

INTRODUCTION

THREADFIN BREAMS belonging to the genus *Nemipterus* constituted about 13% of the total bottom-trawl catches at Visakhapatnam during July, 1977—June, 1980 (Rao, 1981). Of the eight species of the genus, recorded from Indian waters, the Japanese threadfin bream *Nemipterus japonicus* is the most common one and forms a commercially important fishery along the Indian Coast. Although the abundance of *N. japonicus* catches varies seasonally, the species forms fishery almost throughout the year, ranging from 50% (late December-mid March) to 90% (late March-early December) of the total nemipterid catches at Visakhapatnam Fishing Harbour.

Earlier studies were either of a preliminary nature (Chacko, 1949 ; Rao, 1964 ; Kuthalingam, 1965 ; George *et al.*, 1968 ; Eggleston, 1972) or covering a very wide area (Krishnamoorthi, 1971) to draw any meaningful relationship between changes in food and feeding habits and variations in catches. The present study is confined to the waters off Visakhapatnam where commercial exploitation of the species is done.

In the present study, qualitative and quantitative analyses of stomach contents of *N. japonicus* were carried out according to seasons, size and sex. Variations in the average mount of feeding were also studied.

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MATERIAL AND METHODS

Samples of fish, each not exceeding 25 in number were collected over a 30 month period (May 1977 - October 1979) from the trawl catches landed at Visakhapatnam Fishing Harbour, which was visited twice a week. They were examined after fixation in 5%

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formaldehyde solution for about a fortnight (Windell and Bowen, 1978). The period from May to April is considered as the statistical year to follow the seasonal pattern in the feeding habits of the species. A total number of 1,443 specimens during May 1977 - April 1978 period, 1,061 specimens during May 1978 - April 1979 period and 287 specimens during May 1979-October 1979 period (half year) were examined in the present study.

The stomachs were separated after recording the date of capture, sex, standard length and stage of maturity of each fish. The degree of stomach fullness was assessed on the basis of distension of stomach folds (Rao, 1964). Average amount of feeding was calculated taking into account the number of fish with empty stomachs. Six categories of stomach fullness, namely 'empty', '¼ full', '½ full', '¾ full', 'full' and 'gorged' could be recognised. Numerical values of 0.0, 0.25, 0.50, 0.75, 1.00 and 1.50 were assigned respectively to the above categories. The values gained by all the stomachs examined in a given sample were averaged to obtain the average amount of feeding according to season, size, sex and stage of maturity. The fish in a given sample were considered to be intensely fed when the average amount of feeding reached 0.75 or above.

Each stomach was considered as a unit and the stomach contents were separated qualitatively first, to the nearest taxon possible and their quantity was determined volumetrically. Frequency of occurrence of each item was also taken into account to find out the relative preference of different items. Details of the analyses are according to Hynes (1950) and Windell and Bowen (1978).

The index, designated as 'Index of Preponderance' proposed by Natarajan and Jhingran (1961) was calculated to grade the relative importance of the food items.

RESULTS

Regular food items in the order of importance (overall % composition from May 1977 to October 1979) were *Squilla* spp. (18.32%), crabs (13.95%), prawns (11.71%), juveniles of eels (0.86%) and other teleosts (7.26%), cephalopods (3.90%), amphipods (2.17%) and polychaetes (1.54%). Occasional items were small brittle stars, holothurians, mole-crabs, isopods, small bivalves gastropods and fish scales, which were grouped under the category of 'miscellaneous items'. Crabs were mainly represented by *Charybdis* sp. and *Neptunus* sp. The prawns encountered in the stomachs were mainly penaeid prawns. Juveniles of eels were the most preferred item of the teleost food component. The other teleosts met within the stomachs were flatfish, anchovy, *Bregmaceros* sp., apogonids, silver-bellies and small *Trichiurus* sp. Cephalopods were represented by *Sepia* sp. and *Loligo* sp. of small size and occasionally octopods. Amphipods could not be identified since they were found mostly in broken condition. Among the polychaetes, *Polydora* sp., eunicids, aphroditids and glycerids were common.

Seasonal variations in food and feeding habits

The study reveals a general pattern of high feeding intensity (according to average amount of feeding) during the May-October/November period and low feeding intensity during the December-February/March period (Table 1).

Index of preponderance : According to the index, *Squilla* was the most preferred food item in all the periods (26.40 in 1977-1978, 29.63 in 1978-1979 and 29.24 in May-October 1979 period and 28.38 during the whole period of investigations, May 1977-October 1979) (Table 2). Crabs and prawns were the next in importance. Teleosts, other than eel juveniles and cephalopods maintained the fourth and fifth ranks respectively. Amphipods, polychaetes, eel juveniles and other miscellaneous items occupied sixth to nineth places (Table 2).

TABLE 1. *Specimens examined and values of average amount of feeding in different months (from May* 1977 *to October* 1979)

		May	June	July	August	September	October	November	December	January	February	March	April
Total number of specimens examined	(a)	44	152	65	59	192	98	130	128	164	143	174	94
	(b)	49	—	77	75	130	107	120	101	111	93	132	66
	(c)	69	24	71	38	45	40	—	—	—	—	—	—
Number of empty stomachs	(a)	4	19	Nil	10	28	18	36	48	78	26	53	22
	(b)	5	—	9	9	10	13	25	40	50	66	20	8
	(c)	8	Nil	Nil	Nil	2	Nil	—	—	—	—	—	—
Average amount of feeding	(a)	0.79	1.08	1.10	0.82	1.01	0.78	0.63	0.43	0.46	0.66	0.50	0.71
	(b)	0.56	—	0.81	0.88	0.86	0.79	0.76	0.46	0.53	0.27	0.79	0.82
	(c)	0.96	0.99	1.04	0.99	0.86	1.05	—	—	—	—	—	—

(a) May 1977 to April 1978. (b) May 1978 to April 1979. (c) May 1979 to October 1979.

Seasonal variations in the indices of preponderance (Fig. 1) of different food items are detailed below. (Digested matter is excluded in describing the ranks of the food items.)

Squilla

Squilla was the most preferred food item throughout the period of investigation (particularly during July-November period) according to index of preponderance (Fig. 1).

TABLE 2. *Indices of preponderances of different food items of* N. japonicus *during different periods*

		May '77-April '78	May '78-April '79	May-October '79	May '77-October '79
Squilla	..	26.40 (2)*	29.63 (2)	29.24 (1)	28.38 (2)
Crabs	..	14.59 (3)	9.21 (4)	21.91 (2)	13.64 (3)
Prawns	..	9.32 (4)	16.85 (3)	20.65 (3)	13.39 (4)
Eel juveniles	..	0.22 (10)	0.14 (9)	0.01 (10)	0.15 (10)
Other teleosts	..	5.59 (5)	6.38 (5)	10.40 (5)	6.61 (5)
Cephalopods	..	1.42 (6)	6.05 (6)	1.88 (6)	2.84 (6)
Amphipods	..	0.28 (9)	0.26 (7)	1.55 (7)	0.40 (7)
Polychaetes	..	0.68 (7)	0.14 (10)	0.12 (8)	0.37 (8)
Miscellaneous items	..	0.47 (8)	0.22 (8)	0.06 (9)	0.32 (9)
Digested matter	..	41.03 (1)	31.12 (1)	14.19 (4)	33.90 (1)

* Figures in parentheses indicate the ranks of individual food items in their respective periods.

Crabs

In general, crabs occupied second to fourth positions from June 1977 to January 1978 according to index of preponderance and later they were elevated to first position during February-April 1978. The indices in 1978-79 are too erratic to discern any definite trend in the occurrence of crabs. The item gained high index values during July-October 1979 period (Fig. 1).

Prawns

Prawns occupied first to third positions during May-September 1977 after which they were relegated to lower positions. In 1978-1979, the item gained higher ranks (first to third) almost throughout except in May 1978 (fourth) and January 1979 (sixth). In the half year study, prawns occupied higher positions in all the six months (Fig. 1).

Juveniles of eels

The item was the most preferred among the teleosts ingested by the species. However, the item showed no seasonal trend in its abundance (Fig. 1).

Other teleosts

The item ranked first to fourth positions during August 1977-March 1978. In 1978-1979, teleosts were relegated to lower positions, namely second to fifth positions throughout the year (Fig. 1).

Cephalopods

In 1977-1978, the item's rank varied from second (January 1978) to eighth (June 1977). But in 1978-79, the item occupied third to fifth positions during September 1978-March 1979 period. In the succeeding half year period, however, the item was relegated to fifth or sixth position (Fig. 1).

The other recognisable food items, namely amphipods and polychaetes are of minor importance in the diet of *N. japonicus*, as observed from their low indices (Fig. 1).

different length groups. Number of specimens examined and values of average amount of feeding in different length groups are represented in Fig. 2.

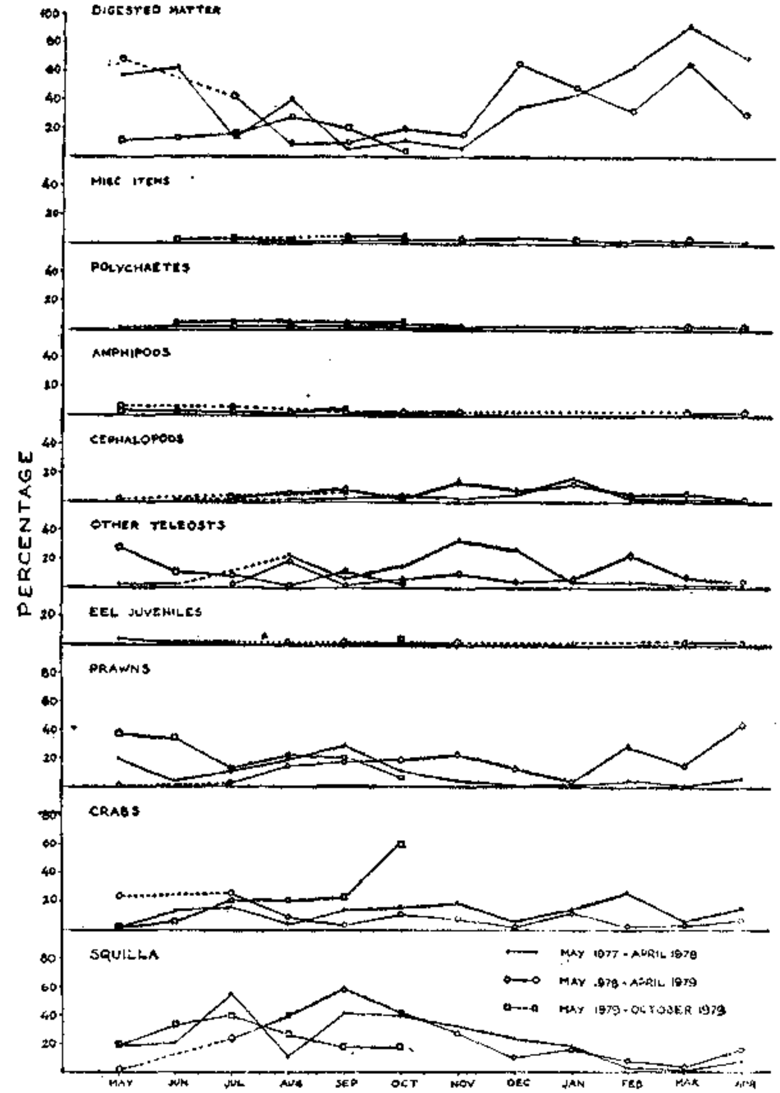

Fig. 1. Monthly variations in the indices of preponderance of different food items.

Size-related variations in food and feeding habits

Values of indices of preponderance are taken as the basis of studying the variations in food composition (barring digested matter) in

Squilla

The item ranked first in most of the length groups in 1977-1978, excepting 9.1-10.0 cm, 15.1-17.0 cm and 18.1-19.0 cm length groups in which it ranked second. In 1978-1979, the trend was slightly different. *Squilla* was of secondary importance in the lower length groups (8.1-11.0 cm) and again in the 17.1-19.0 cm length groups. In all the length groups between 11.1 cm and 17.0 cm, the item ranked first (Fig. 3).

Crabs

Crabs occupied first or second position in the higher length groups (16.1-19.0 cm) and second or third position in the size range of 9.1-16.0 cm in 1977-1978. In the next year, the food item generally occupied second or third position throughout the size range (Fig. 3).

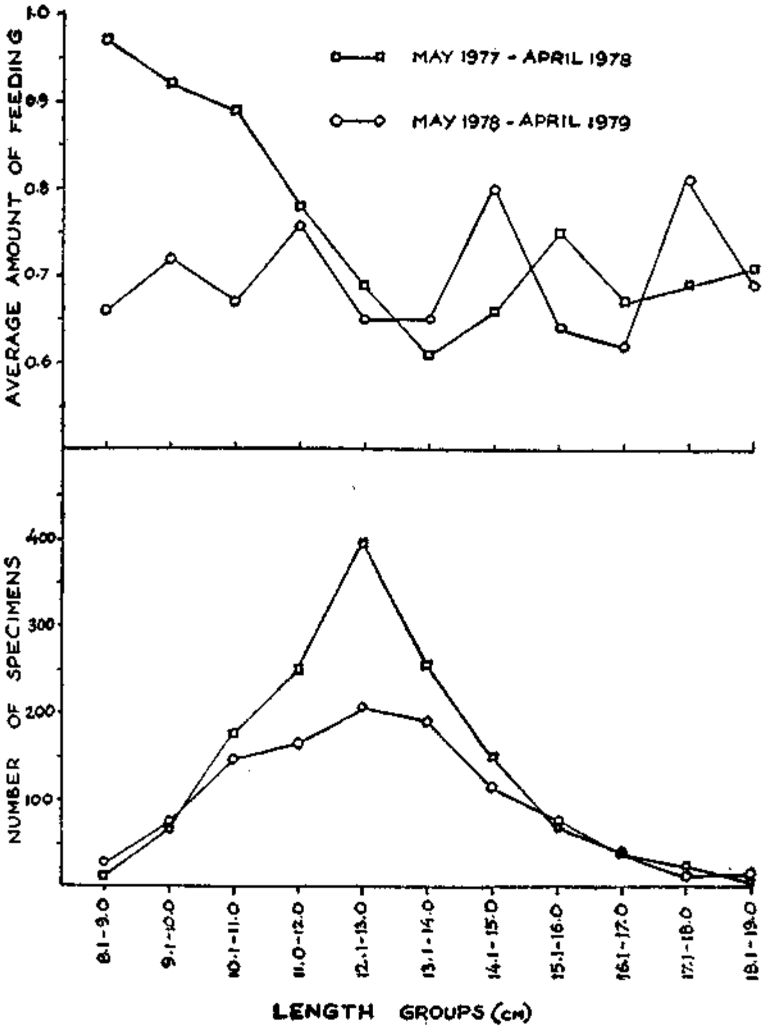

Fig. 2. Number of specimens examined and values of average amount of feeding in the different length groups.

Prawns

In 1977-1978, prawn component was graded as second or third in all the groups of 8.1-15.0 cm size range, showing a decline thereafter (fourth or fifth in the 15.1-19.0 cm size range). In 1978-1979, prawns ranked first in the lower

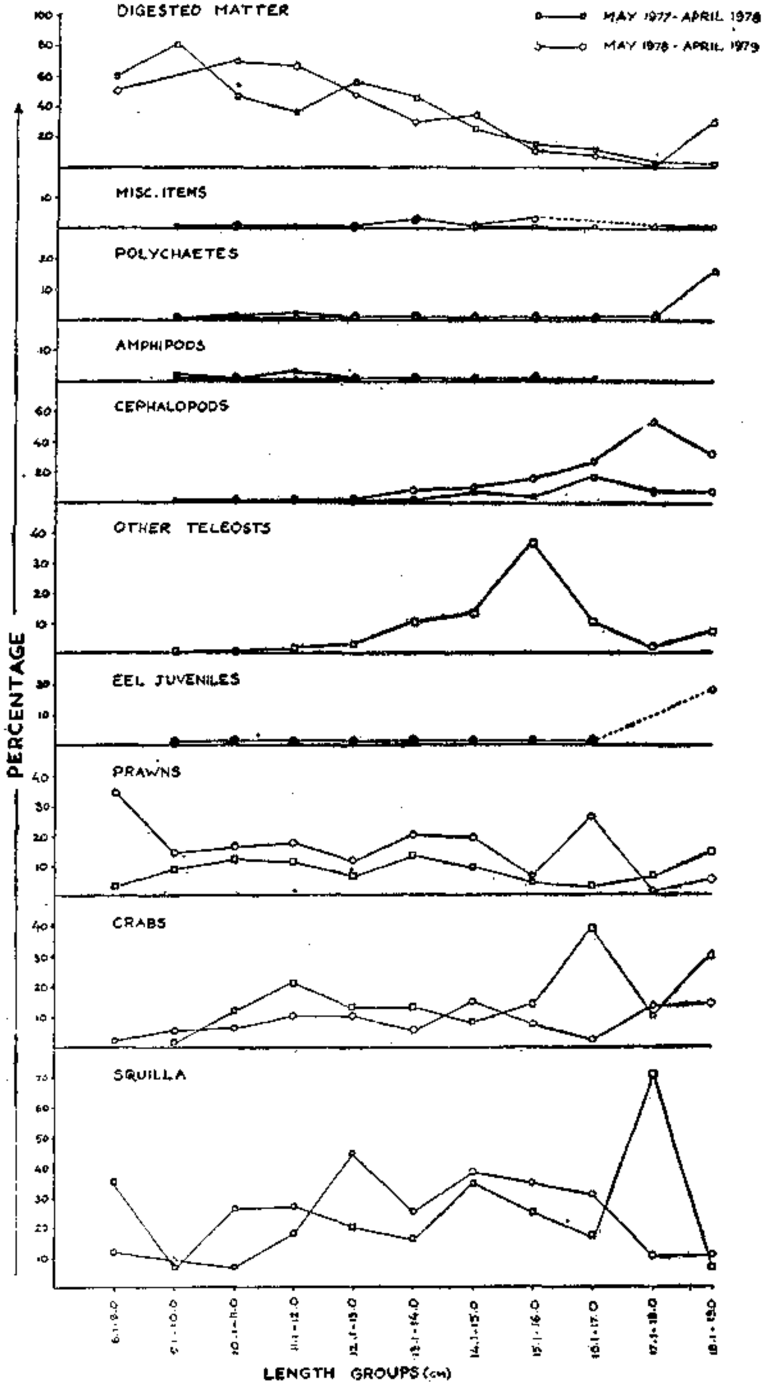

Fig. 3. Variations in the indices of preponderance of food items in the different length groups.

length groups of 8.1-11.0 cm, second in the size range of 11.1-15.0 cm and declined further in the higher length groups. Prawn component was a preferential food item in the length range of 8.1-15.0 cm (Fig. 3).

Juveniles of eels

The item ranked fifth to ninth in the grading indices of different length groups in the two years. The juveniles occupied second position in the 18.1-19.0 cm length group in 1977-1978 (Fig. 3).

Other teleosts

Teleosts were graded first in the 15.1-16.0 cm and second in the 14.1-15.0 cm length groups in 1977-1978. In the remaining length groups, the item's rank varied from fourth to sixth. In 1978-1979, teleosts maintained fourth or fifth rank in all the length groups except in 15.1-16.0 cm and 17.1-18.0 cm length groups, in which the item was positioned second (Fig. 3).

Cephalopods

While the item was graded fifth to eighth in the size range of 9.1-16.0 cm, they occupied higher positions in higher length groups (16.1-19.0 cm) in 1977-1978. In the next year, cephalopods ranked first in the 17.1-19.0 cm length range and second in the 16.1-17.0 cm length group. In both years, the preponderance of cephalopods was high in higher length groups (16.1-19.0 cm) (Fig. 3).

Amphipods and polychaetes occupied relatively higher positions in lower length groups than in higher length groups (Fig. 3).

Food and feeding habits in relation to sex

A total number of 725 males and 718 females during May 1977-April 1978 and 498 males and 563 females during May 1978-April 1979 were examined for the study.

Tables 3 a and 3 b show indices of preponderance of various food items in males and females respectively during May 1977-April 1979.

In the food of both males and females, *Squilla* ranked first (barring digested matter). Crabs, prawns, teleosts and cephalopods, in that order, showed their importance in the food of males (Table 3 a). In the food of females, prawns occupied a higher position than crabs (Table 3 b). Indices of food items of minor importance like amphipods and polychaetes varied from males to females.

These analyses show that there are no marked differences in the food composition between males and females.

DISCUSSION

The Japanese threadfin bream *Nemipterus japonicus* is essentially a carnivore feeding on crustaceans (*Squilla*, crabs and prawns) teleosts, cephalopods, amphipods and polychaetes in that order and miscellaneous items like brittle stars, holothurians, small bivalves, gastropods, mole crabs, isopods and megalopa larvae.

The various components of the food spectrum indicate that the species is mainly a bottom feeder. Food items such as *Squilla*, crabs, prawns, teleosts, cephalopods are actively mobile and are hunted before they are ingested by the predator, namely *N. japonicus*. The bream shaped body with forked caudal fin is designed for moderately fast swimming. Large eyes indicate that the fish feeds by sight, which is further highlighted by the absence of tactile organs. Feeding activity appears to be much reduced in the night (Rao, 1964) which is further supported by the fact that remains of digested matter constituted the bulk of the stomach contents in the samples landed ashore in the morning after night-fishing during the December-February/March period.

Preliminary examination of stomach contents of other species, *i.e. N. tolu, N. mesoprion*

TABLE 3 a. *Indices of preponderance of different food items in males of* N. japonicus *during May* 1977-*April* 1979

Food items		Vol. (ml)	Occ.	V_i	O_i	$V_i O_i$	$\frac{V_i O_i}{\Sigma V_i O_i} \times 100$
Squilla	..	90.00	290	22.42	17.92	401.77	29.28 (2)*
Crabs	..	44.85	284	11.17	17.55	196.03	14.29 (3)
Prawns	..	58.40	209	14.54	12.92	187.86	13.69 (4)
Eel juveniles	..	12.45	25	3.10	1.55	4.81	0.35 (9)
Other teleosts	..	63.90	103	15.92	6.37	101.41	7.39 (5)
Cephalopods	..	56.00	67	13.95	4.14	57.75	4.21 (6)
Amphipods	..	1.80	88	0.45	5.44	2.45	0.18 (10)
Polychaetes	..	6.90	54	1.71	3.34	5.71	0.42 (8)
Miscellaneous items	..	6.95	58	1.73	3.58	6.19	0.45 (7)
Digested matter	..	60.25	440	15.01	27.19	408.12 $\Sigma V_i O_i$	29.74 (1)
Total	..	401.50	1618	100.00	100.00	1372.10	100.00

* Figures in parentheses indicate the ranks of individual food items.
Number of specimens examined : 1,223.
Average amount of feeding : 0.73.

TABLE 3 b. *Indices of preponderance of different food items in females of* N. japonicus *during May* 1977-*April* 1979

Food items		Vol. (ml)	Occ.	V_i	O_i	$V_i O_i$	$\frac{V_i O_i}{\Sigma V_i O_i} \times 100$
Squilla	..	63.60	285	22.86	18.15	414.91	25.59 (2)*
Crabs	..	31.00	231	11.14	14.71	163.87	10.11 (4)
Prawns	..	39.90	186	14.34	11.85	169.93	10.48 (3)
Eel juveniles	..	4.00	11	1.44	0.70	1.01	0.06 (10)
'Other' teleosts	..	39.15	82	14.07	5.22	73.44	4.53 (5)
Cephalopods	..	24.20	50	8.70	3.18	27.67	1.71 (6)
Amphipods	..	2.55	117	0.92	7.45	6.85	0.42 (7)
Polychaetes	..	5.10	54	1.83	3.44	6.30	0.39 (8)
Miscellaneous items	..	4.10	45	1.47	2.88	4.23	0.26 (9)
Digested matter	..	64.65	509	23.23	32.42	753.17 $\Sigma V_i O_i =$	46.45 (1)
Total	..	278.25	1570	100.00	100.00	1621.38	100.00

* Figures in parentheses indicate the ranks of individual food items.
Number of specimens examined : 1,281.
Average amount of feeding : 0.70.

and *N. delagoae* available at Visakhapatnam indicated that nemipterids, as a whole, are sight-feeders.

TABLE 4. *Specimens examined and values of average amount of feeding in the different length groups (cm) during May* 1977-*April* 1979

		8.1-9.0	9.1-10.0	10.1-11.0	11.1-12.0	12.1-13.0	13.1-14.0	14.1-15.0	15.1-16.0	16.1-17.0	17.1-18.0	18.1-19.0
Number of specimens examined ..	(a)	9	66	175	252	394	253	152	70	42	24	6
	(b)	23	71	145	164	204	189	117	73	39	20	13
Average amount of feeding ..	(a)	0.97	0.92	0.89	0.78	0.69	0.61	0.66	0.75	0.67	0.69	0.7
	(b)	0.66	0.72	0.67	0.76	0.65	0.65	0.80	0.64	0.62	0.81	0.61

(a) May 1977-April 1978. (b) May 1978-April 1979

Chacko (1949) observed high quantities of both phytoplankton and zooplankton in the guts of *N. japonicus* obtained from the Gulf of Mannar and remarked that the species occasionally fed at the bottom. Rao (1964), who worked out the daily rhythmicity in feeding of several fishes from Visakhapatnam and its northern regions, observed teleosts, anemones, amphipods, prawns, *Squilla* and cephalopods and several other organisms in smaller quantities in the guts of *N. japonicus*. Kuthalingam (1965) from Mangalore found that penaeid prawns constituted the main food of the species up to a depth range of 30 m and the fish that were obtained from 30-50 m depth range contained large quantities of fish remains in their stomachs. *Squilla* also made its appearance in these samples. George *et al.* (1968) from Cochin noticed that the important food organisms were echiuroids, amphipods and polychaetes which formed the bulk of the diet. *Squilla*, crabs and prawns which are considered the most important food organisms in the present study, occupied much lower positions in the grading index given by them. Krishnamoorthi's (1971) findings (based on samples from Andhra-Orissa Coast) and results of the present study in respect of food spectrum, food preference, seasonal variations in food habits, feeding activity and feeding behaviour agree with each other. Eggleston (1972) observed that *N. japonicus* fed on crustaceans, fish, cephalopods, polychaetes and lamellibranchs in the northern China Sea (Hong Kong).

The above account obviously reveals some geographical differences in the food composition of *N. japonicus*. At one extreme are the planktonic organisms reported from the Gulf of Mannar (Chacko, 1949) where the bottom, is sandy and rocky (Luther, 1975). At the other extreme are the immobile benthic fauna like anemones and isopods reported by Rao (1964) from samples collected off Barua and Puri where the feeding grounds are mostly muddy or slimy in nature (FAO, 1961). Although regional differences in the food of the fish might arise because of the nature of the substratum, which may vary with depth in the same locality, the fact that the fish feeds by sight is undeniable. In the light of such overwhelming support upholding the strict bottom feeding behaviour of the fish, feeding on plankton as reported by Chacko (1949) is rather untenable. The gill rakers of *N. japonicus* are not suitable for plankton feeding.

Important food items, namely *Squilla*, crabs, prawns, teleosts and cephalopods are abundant—with some minor variations—during the June / July - November / December period of the study. In the samples landed during December - March period, majority of the stomachs contained only remains of digested matter.

The present investigation suggests that the nature of food of the species is size-dependent. Fish in higher length groups, more often ingested cephalopods, crabs and teleosts in large quantities than those in lower length groups. The occurrence of such actively mobile benthic organisms like crabs, cephalopods, *Apogon* spp. and *Trichiurus* sp. in the higher length groups indicates that larger fish feed very close to or near the bottom, feeding on actively moving organisms. Although amphipods and polychaetes are not highly preferred food items, their higher grading in lower length groups, according to the index of preponderance, indicates the tendency of *N. japonicus* to feed at deeper levels (predating on actively moving organisms) as they grow larger. These observations also suggest that as the fish grow to larger sizes, the feeding spectrum of the species narrows down to a very few number of organisms of larger size. These observations are in conformity with the views expressed by Eggleston (1972) who studied the feeding habits of three species of *Nemipterus* in the waters of Hong Kong (South China Sea).

From the present study it is obvious that comosition and preference of food is the same in both sexes. But observations on average amount of feeding in both sexes, show that males exhibit a little higher feeding intensity than females.

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ELECTROPHORETIC PROTEIN PATTERNS OF FARM GROWN AND WILD EDIBLE OYSTER *CRASSOSTREA MADRASENSIS* FROM DIFFERENT LOCATIONS

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Abstract

Electrophorograms of adductor muscle, mantle and gill of farm grown and wild edible oyster *C. madrasensis* exhibited distinct differences. Marked protein pattern variations were also evident between the oysters of Ennore Estuary and Muttukadu Backwater near Madras in Tamil Nadu, India. Tissue, environment and locality specific differences have been discussed in the light of number, thickness and staining densities of protein fractions.

Introduction

Aquatic organisms present a striking challenge for applied genetics. Most cultivable species still lack information of their genotype and phenotype. Electrophoretic studies of serum protein, muscle protein, plasma protein and haemoglobin, especially of higher vertebrates have revealed species specific pattern (Connell, 1953; Tsuyuki *et al.*, 1962). Gene variant patterns with frequencies characteristic of particular geographic areas or races have been observed in *Bateygobius* and Pomacentridae (Gorman *et al.*, 1976 ; Gorman and Kim, 1977). Here an attempt has been made to find out the regional variation of protein pattern of commercially important edible oyster *Crassostrea madrasensis.*

The authors are grateful to Dr. M. J. George for his help and suggestions.

Material and Methods

Oysters for the present study were collected from three locations, namely the natural beds of Ennore, Muttukadu and Muttukadu oyster farm. The oysters were shucked and the meat was thoroughly washed with cold double distilled water and then blotted dry. The mantle, gill and adductor muscle were dissected out. One gram of each tissue was homogenised with ice cold double distilled water. The homogenate was centrifuged for 15 minutes at 3000 rpm. The supernatant containing dissolved water soluble proteins was used as the sample for electrophoresis. Polyacrylamide gel (7%) electrophoresis was performed, making use of the procedure of Laemmli (1970) at 4°C, 240 volts, 48 mA for 3½ hours. After completion of electrophoresis, gels were stained with coomassie Brilliant Blue. Gels were destained and stored in 7% acetic acid. They were photographed and scanned in ultrascanner.

Results

The results of 17 experiments carried out on tissues from the mantle, gill and adductor

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muscle of the edible oyster on the electrophoretic protein fractions have been assigned numbers by keeping in mind the number of crests found to correspond to the number of distinct proteins and the areas under the crests proportional to their concentrations.

Mantle

The mantle tissue of *C. madrasensis* of Ennore Estuary exhibited ten protein fractions of which 3 bands were thick 3 thinner and others were minor bands whereas in the farm bred oyster 5, 6, 7 & 8 th fractions were absent there being only six bands and in Muttukadu specimens 7 th and 8 th fractions were absent there being only eight bands (Fig. 1). Thus six protein bands were common for all the oysters obtained from the three different localities. The remining 4 smaller or thinner bands showed variations or altogether absent.

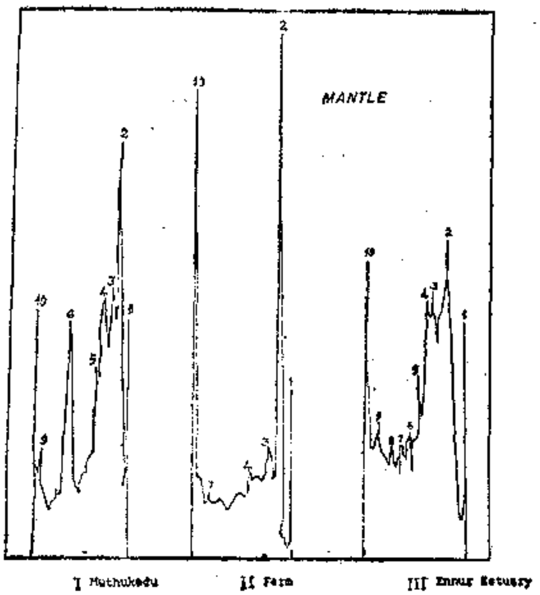

Fig. 1. Electrophorogram of mantle tissue of edible oyster from Muttukadu, Muttukadu Farm and Ennore Estuary.

Gill

C. madrasensis of Ennore and farm area expressed eleven protein fractions in the gills tested. In Muttukadu *C. madrasensis* specimens, fractions 6, 8 and 9 were absent. Totally eight common bands were seen in the gill of *C. madrasensis* of different areas tested (Fig. 2).

Adductor muscle

Totally ten protein fractions were observed in the adductor muscle of *C. madrasensis* (Fig. 3). All the ten protein fractions were observed in the muscle of *C. madrasensis* of farm area. In the muscle of Ennore Estuary area specimens 6th, 8th and 9th fractions were absent and in *C. madrasensis* of Muttukadu 5th and 7th bands were absent. There were common six bands of muscle.

Environmental parameters

The environmental parameters such as salinity, temperature and dissolved oxygen and their annual range in the three different places are shown in Table 1.

TABLE 1. *Environmental parameters of three different localities*

Place	Salinity (‰)	Temperature (°C)	Dis. oxygen (ml/l)
Ennore ..	14.52-33.4	28.0-34.0	3.52-5.24
Muttukadu	13.86-39.7	28.1-34.0	3.14-5.82
Muttukadu Farm ..	6.32-36.0	28.5-34.5	3.00-5.30

DISCUSSION

The edible oyster *C. madrasensis* is widely distributed on the east and west coasts of India. Several view points have been expressed regarding the similarities and dissimilarities of protein patterns of the same species occurring in different localities. Geographical variations in biochemical and serological tests have been reported due to a variety of physiological processes, activities and tolerances by Menzel (1956), Numachi (1962) and Hilman (1964). Galtsoff (1964) however, observed that the shell morphology was being influenced by local environmental conditions, but did not report any consistent variation among geographically distinct populations.

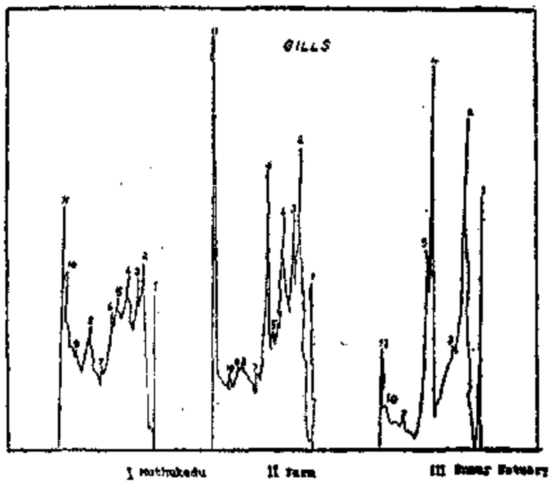

Fig. 2. Electrophorogram of gill tissue of edible oyster from Muttukadu, Muttukadu Farm and Ennore Estuary.

The present electrophoretic study of the different tissues of the same species from areas suggests that the samples from Ennore, Muttukadu and oyster farm possess distinct protein patterns in terms of the number of bands and also in presence or absence of certain protein fractions. These variations may be brought about by the differences in the environment especially salinity and exposure of the natural beds during low tide, and the resultant physiological stresses. Avise and Smith (1984) studying the bio-chemical genetics of the blue gill *Lepomis macrochirus*, has suggested that the reason for this type of variation may be the discontinuous nature of aquatic habitat. Janson and Ward (1984) has mentioned that the differences in populations occupying different areas separated by physical barriers could be related directly to environmental pressure like exposure during low tide and to substrata occupied by them. A heterogenous environment would enhance genetic variation and a homogenous environment erode variation according to Fujiyo *et al.* (1983).

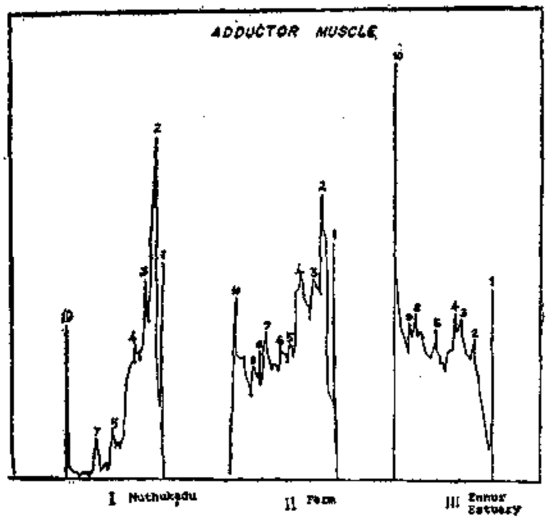

Fig. 3. Electrophorogram of adductor muscle of edible oyster from Muttukadu, Muttukadu Farm and Ennore Estuary.

The results of the present study suggest that the natural oyster beds of *C. madrasensis* which lie in the intertidal area being subjected to tidal amplitude and also facing a complex of environmental changes undergo considerable physiological stresses, and this has resulted in the protein band variations as reported here.

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ECOLOGY OF THE CYCLOPOID COPEPODS FROM THE COCHIN BACKWATER

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ABSTRACT

The ecological investigations on the cyclopoid copepods, wherein various trends in the occurrence and seasonal abundance in Cochin Backwater, an estuarine system, have been studied. The material is based on regular weekly zooplankton samples collected from two fixed stations during January, 1970 to December, 1971. The various trends in the occurrence and abundance of 28 species of planktonic cyclopoid copepods belonging to 5 genera and 4 families are dealt with. The effect of salinity and temperature on their distribution is also elucidated.

INTRODUCTION

COPEPODS especially cyclopoids form an important constituent of the plankton and play a significant role in the estuarine ecosystem. Cyclopoid copepods with their larvae constitute the food of many fish larvae and plankton eating food fishes, and hence their fluctuation in abundance have a direct bearing on the local fisheries. Many commercially important food fishes, most of which are found in good numbers, constitute the fishery in Cochin Backwater especially at the head of the estuarine system around Cochin. Several species of cyclopod copepods which have been recorded only from neritic and oceanic waters were encountered in brackish waters showing their euryhaline nature. During the Southwest monsoon season and soon after, salinity goes low in the estuary and its visinity and this is similar to the prevailing condition in the estuarine head. Thus, the organisms inhabiting such a coastal estuarine system at certain periods of the year are able to withstand drastic changes. Another possible factor is the great increase in the available food supply that is found in the region of such estuaries.

Earlier works on this group of copepods in Indian estuaries is confined to the description of species or records of their occurrence in different areas. George (1958) made an attempt at quantitative study of the planktonic copepods of Cochin Backwater mentioning of only *Oithona* sp. and its occurrence. Wallershaus (1969, 1970) gave a detailed treatment of the taxonomy of some of the copepods of the estuarine system chiefly calanoids found around Cochin. Thompson and Easterson (1977) studied the dynamics of cyclopoid copepod population in Cochin Backwaters. In this account the various trends in the occurrence and abundance of 28 species of planktonic cyclopoid copepods are dealt with. The effect of salinity and temperature on their distribution is also elucidated.

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ment of India, Ministry of Education Senior Research Scholarship during the period of which this investigation was carried out.

MATERIAL AND METHODS

The material for the present study is based on regular zooplankton samples collected from two fixed stations (Fig. 1) for two years from January, 1970 to December, 1971. Tows were made for 10 minutes (5 minutes subsurface and 5 minutes along the surface) and the speed of the boat in each tow was kept at 1-1.5 knots. The conical net used had a diameter of 0.5 m with nylon gauze of 0.33 mm mesh size. The volume of the water filtered was determined by 'TSK-487' flow meter. The samples were preserved in 5% formalin. Along with each plankton collection, measurements of temperature and salinity were also made from the same station.

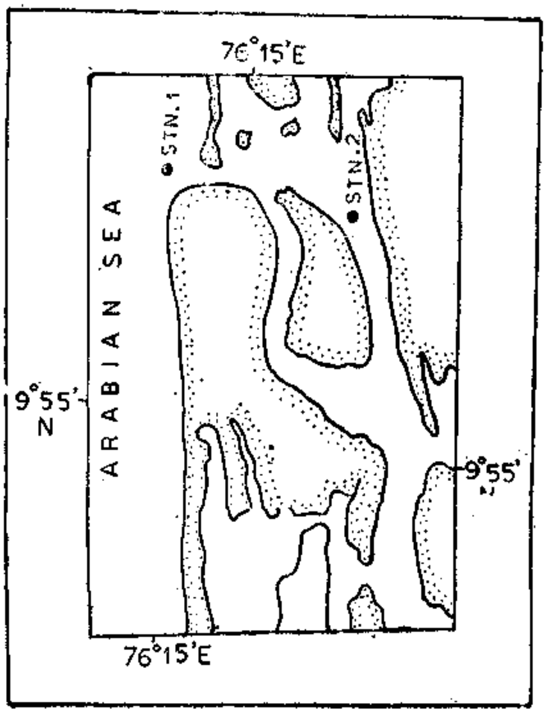

Fig. 1. Part of the Cochin Backwater showing the stations from where material was collected for ecological study.

By the displacement method the total quantity of zooplankton was studied volumetrically. Through a close meshed gauze attached to the bottom of a cylindrical tube, the samples were strained and was allowed to drain off on paper towelling, after which a known volume of 5% formaldehyde was added to it. The total volume of the sample was estimated since the values obtained thus was so small. Since the volume of plankton was less in most of the samples, for the enumeration of cyclopoid copepods, entire samples were examined. The number of each species of cyclopoid copepod present in the samples was tabulated.

Total estimate for 1000 m^3 of water filtered have been calculated and monthly averages are plotted for the same period. In studying the numerical abundance and correlations, standard statistical methods were used.

ENVIRONMENT

The northern portion of the Vembanad Lake is called the Cochin Backwater (09° 58'N, 76°15'E) and it is a typical estuary and includes part of a long chain of canals. The ecosystem of the area is influenced by the sea and fresh water of which, the influence of the latter being considerable during the monsoon period. It has a perennial connection with the Arabian Sea, which form the main entrance to Cochin Harbour. This region is subjected to regular tidal influence and the tides of this area are of semi diurnal nature whose maximum range is about 1 m. There also exists a similar connection with the Arabian Sea at Azhicode, about 25 km north of Cochin which also has a bearing on the hydrography of the Vembanad Lake. Variation of annual temperature at Cochin being 28°-34°C and average annual rainfall based on data from 1967-1972 is about 1080 mm, of which about 75% occurs during the Southwest Monsoon (June — September).

Environmental features

The topography and hydrography of the Cochin Backwater has been reported by a number of recent workers (George, 1958; George and Kartha, 1963; Ramamirtham and Jayaraman, 1963; Cheriyan, 1967; Qasim *et al.*, 1969; Qasim and Gopinathan, 1969; Sankaranarayanan and Qasim, 1969; Josanto, 1971; Gopinathan and Qasim, 1971; Menon *et al.*, 1971; Gopinathan, 1972; Wellershaus, 1972; Sumitra *et al.*, 1972; Pillai *et al.*, 1973; Pillai and Pillai, 1973; Qasim *et al.*, 1974; Madhupratap and Haridas, 1975; Nair *et al.*, 1975; Joseph and Pillai, 1975). There seems to be three distinct periods in any year noticing the trend in salinity of this area (1) a period of low salinity — June to September; (2) a period of gradual rise in salinity — October to January; and (3) when the surface salinity of Cochin Backwater is comparable to that of the adjacent inshore waters — February to May.

Temperature remains uniform throughout the water column and records its higher values due to warm weather and solar radiation during the period January to April. A gradual fall in temperature at the surface and a rapid lowering at the bottom were noticed with the onset of monsoon during July and thence onto August which is mainly due to the intrusion of cold water into the estuary (Ramamirtham and Jayaraman, 1963; Sankaranarayanan and Qasim, 1969). The thermal gradient which usually develops by June lasts till September-October. During November-December, the temperature records a fall and this usually coincides with the onset of Northeast monsoon.

Various seasonal environmental features of the Cochin Backwater have been reviewed by Sankaranarayanan and Qasim (1969). Little change in dissolved oxygen is noticed in surface layers, but at deeper layers during the monsoon months, very low oxygen values were recorded, and when the marine condition begin to occur, this gradient disappears. During the monsoon months, pH values are low. A pronounced fall in alkalinity is seen during monsoon months and also recovery of values were observed during the same period. From January to May, the nutrient concentration is homogeneous, but high concentrations are recorded during the monsoon months with gradient zone in different depths. Solar radiation and its penetration in the Cochin Backwater have been studied by Qasim *et al.*, (1968) and according to them the maximum solar radiation reaches the surface during December to March and the minimum from June to September, 250-500 g cal/cm^2/day being the range of radiation intensity.

PHYSICAL FEATURES

Salinity

The mean monthly variation of surface salinity during the period of observation are shown in Fig. 2 a. The yearly cycle of variations was more or less similar in 1970 and 1971. A decreasing trend in surface salinity was noticed from higher values in March-April and a sharp fall at the onset of Southwest monsoon in June. From June to August, this decline was continued, after which period, a steady increase till December was recorded. A slight decline was noted during December January and after that until March-April, the values evinced an increasing trend.

Temperature

Observations in the variations on monthly mean values of surface temperature at stations are shown in Fig. 2 b. The annual cycle of variations was observed to be more or less similar in 1970 and 1971. The maximum value were recorded during April and minimum value during September, 1970. A steady increase in temperature from March to April

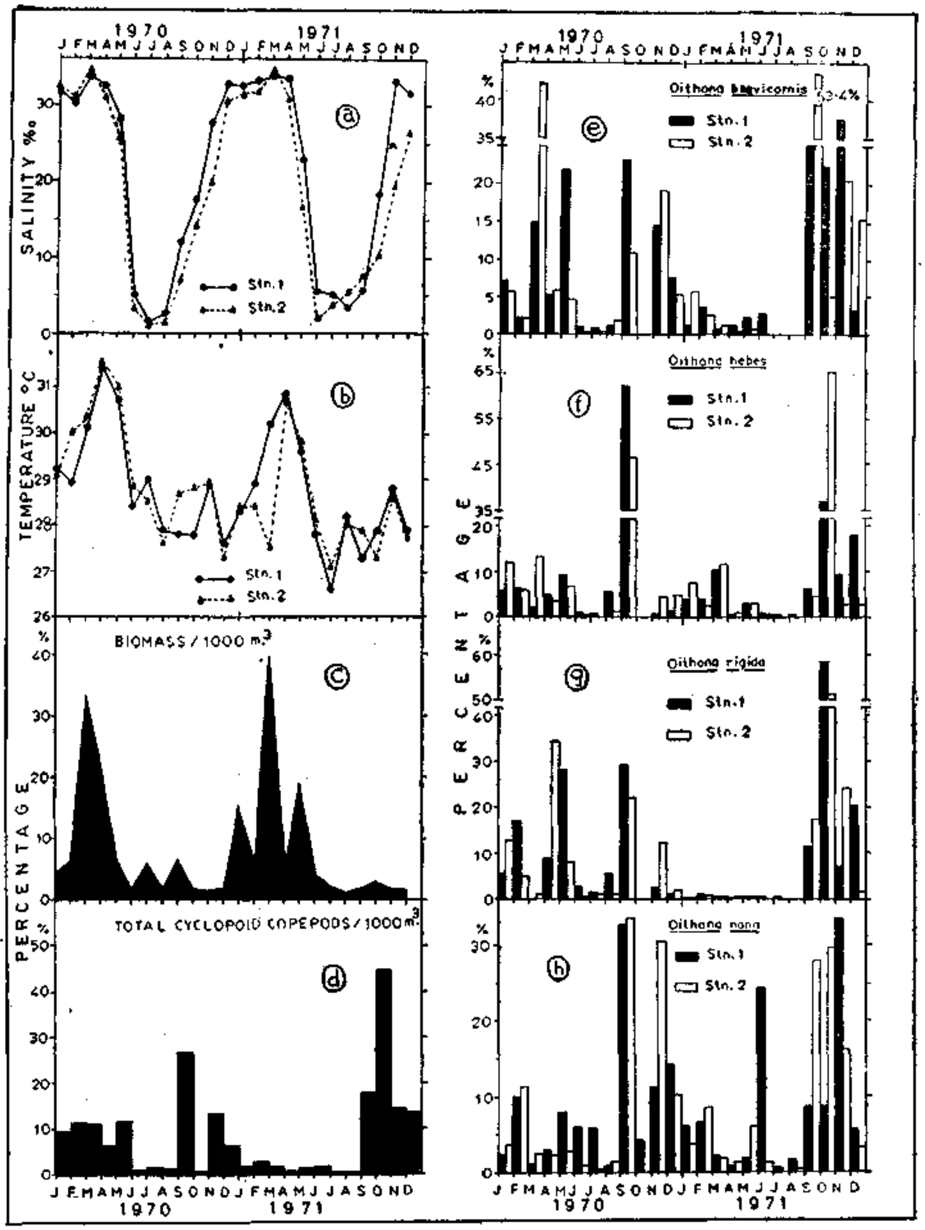

Fig. 2 a. Fluctuation in salinity from January, 1970 to December, 1971, b. Fluctuation in temperature, c. Monthly fluctuation of zooplankton biomass, d. Monthly fluctuation in composition of total cyclopoid copepods. Relative percentage by counts of cyclopoid copepods in the Cochin Backwater, e. *Oithona brevicornis*, f. *O. hebes*, g. *O. rigida* and h. *O. nana*.

was noticed and registered a peak in April and a fall in May. Till August its downward trend was continued after which during October in 1970, a gradual increase was noted, followed by a gradual decline during the following months. A rapid increase in surface temperature was observed from January onwards.

BIOLOGICAL FEATURES

The variation in the distribution of the mean monthly displacement volumes of zooplankton from January, 1970 to December, 1971 are shown in Fig. 2 c. During January to May, usually the plankton volumes were relatively high and during June to August, they were low. In the September to November period, a secondary maximum was noticed. In 1970 and 1971, the yearly cycle of variations was more or less similar, but from year to year the period of maxima showed slight variations. As previously noted, during June to August, the rainfall was maximum and this has a significant effect on the distribution of zooplankton of this area, since the dominant species constituting the bulk of the zooplankton are marine in origin. Many marine organisms migrate from the environment consequent to the heavy rain and the resultant large influx of fresh water into the estuarine system.

From January to April (peak in March) the mean monthly data of zooplankton biomass shows high values and low values during August, 1970. A secondary peak was observed in July. During the Northeast monsoon period (October-December), a downward trend in the values was noted. Although low values were met with in April, 1971, the seasonal trend in increase was maintained. Thus the zooplankton abundance showed more or less a similar pattern of variation from year to year despite changes in the seasonal abundance of the cyclopoid copepod in the plankton.

Total cyclopoid copepod population

A total of 28 species of cyclopoid copepods were identified and the data presented here pertains to the species which occur in the estuary.

Two maxima were apparent during the period, a minor peak during the pre-monsoon period and a major one during the post-monsoon months (Fig. 2 d). Aside from the first maxima noted either during the months of March, April or May of any year, it was seen that greater number of species of cyclopoid copepods were present in the estuary during October to March when the temperature and salinity values were higher. A drastic diminution of the stock was noted from April onwards with least numbers occurring during the monsoon months. Following the monsoonal minimum noted, the average monthly catches increased from August onwards and registered a major peak during September in 1970, and October in 1971. A gradual decline in population was noted in October, 1970 and November in 1971.

During this period, other planktonic organisms such as fish eggs, fish larvae, chaetognaths, hydromedusae, ctenophores and lucifers were abundant in the estuary, of these the fish larvae and chaetognaths are known to feed extensively on cyclopoid copepods especially copepodites. The presence of fish eggs in abundance in the plankton samples during May indicates that fishes were spawning at that time in the estuary, the postlarvae and juveniles of which could have made serious inroads on the existing stock of copepods. Studies on the seasonal occurrence of the carnivorous forms carried out by George, 1958 ; Vannucci *et al.*, 1970 ; Santhakumari and Vannucci, 1971 ; Srinivasan, 1971 ; Nair, 1971 ; Menon *et al.*, 1971 reveal that their abundance in the plankton coincide with that of cyclopoid copepods in the Cochin Backwater.

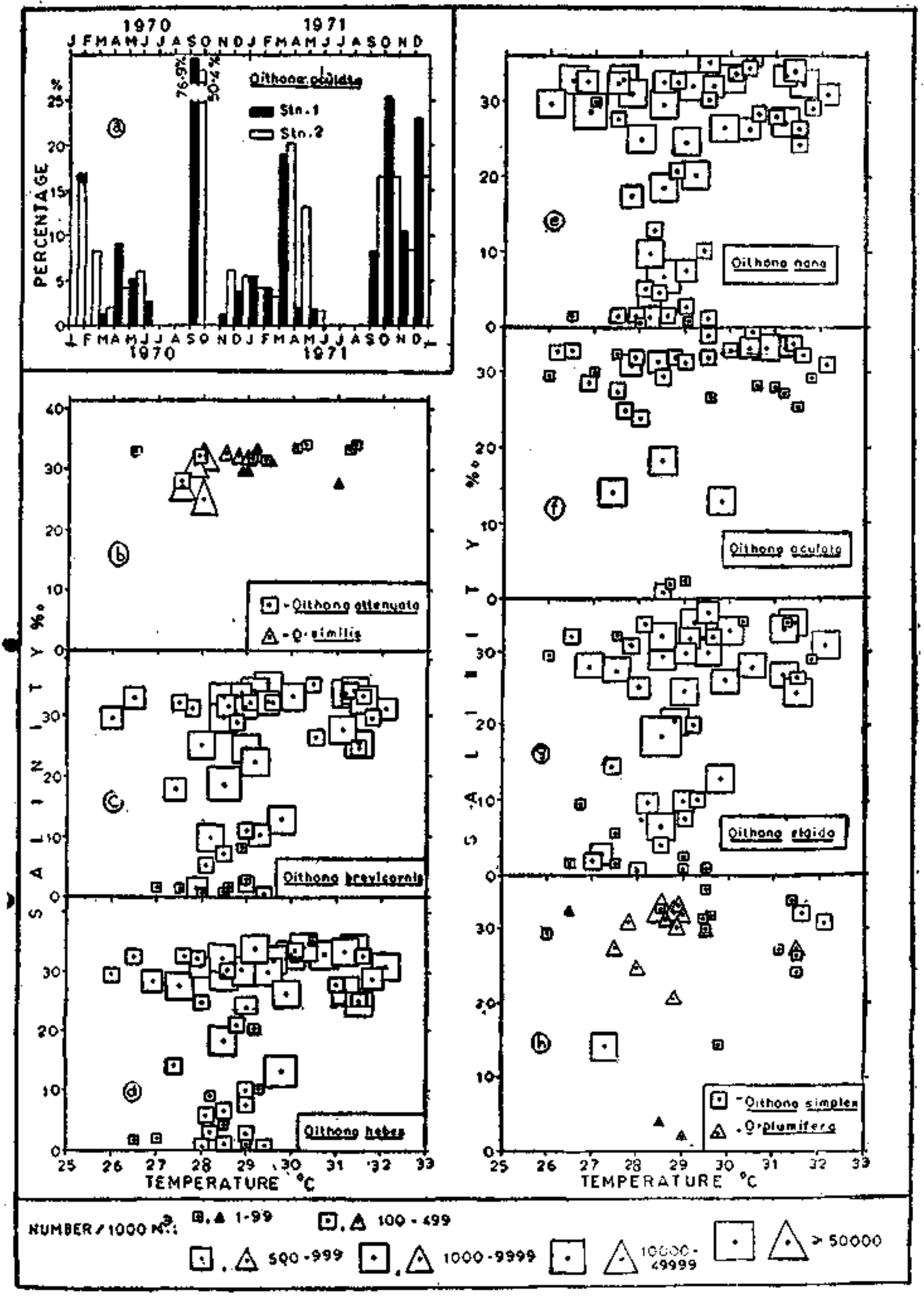

Fig. 3 a. Relative percentages by counts of cyclopoid copepod *Oithona oculata*. T-S-P diagrams and species abundance of b. *Oithona attenuata* and *O. similis*, c. *O. brevicornis*, d. *O. hebes*, e. *O. nana*, f. *O. oculata*, g. *O. rigida* and h. *O. simplex* and *O. plumifera*.

All these above observations suggest that these carnivorous forms occur in the plankton in good numbers when there is also an increase in the cyclopoid copepod population in the estuary and diminish soon after when the cyclopoid copepod decrease in their numbers. No study has been carried out on the feeding behaviour and the propensities of these predators, but it is felt that a good proportion of cyclopoid copepods as nauplii, copepodites and adults form food for other zooplankters. Moreover the occurrence of these predatory forms in the Cochin Backwater in large numbers indicates a very high secondary production in the estuary.

DISTRIBUTION OF ADULT CYCLOPOID COPEPODS

During the post-monsoon months in 1970 and 1971, the adult population of copepods represented by cyclopoid species were highest. Almost all the species recorded decline in number to varying degrees by the end of May or June, although certain typical brackish-water species such as *Oithona hebes, O. brevicornis, O. rigida* and *O. nana* continued to be present in good numbers. In several species, during the end of pre-monsoon months (May-early June), decline was constant and in the beginning of October-November period, a reversal in trend was noted. A unimodal pattern of distribution was noticed when the adults of all the species were taken together, although it was found that several of them showed more than one peak and the peak was not synchronised in these species when different species were studied separately. One of the peak periods observed of majority of copepod species corresponds with the period September-April, which is the season of population abundance in the estuary.

OCCURRENCE AND SEASONAL DISTRIBUTIONS

The species-wise analyses of the numerically more abundant species are dealt with below.

Oithona brevicornis Giesbrecht (Fig. 2 e)

This is one of the common species present in the plankton in abundance during pre-monsoon months and to a lesser extent during monsoon and post-monsoon months during 1970, but the case was reversed during 1971. During 1970, it was numerous during March to May, September and November and was absent in October. In 1971, a minor peak was seen in February and numerically abundant during September-December. From the pattern of distribution it was evident that it occurs in the plankton throughout the year, but in more numbers during high saline and warm waters of the pre-monsoon and post-monsoon months.

Oithona hebes Giesbrecht (Fig. 2 f)

This species was present in the plankton in abundance during the pre-monsoon and to a higher extent during post-monsoon months during 1970 and 1971. During 1970, it was numerous during January to May, August and September and in 1971 during January to March and September to December. The major peak in 1970 was observed during September and in 1971 during October. From the pattern of distribution it is evident that this species prefers the warm and high saline waters of the pre-monsoon and post-monsoon months.

Oithona rigida Giesbrecht (Fig. 2 g)

This is a common species present in the plankton in good numbers during the pre-monsoon and to a higher extent during the post-monsoon months. During 1970, it was numerous during January, April, May, September and November and in 1971, it was more abundant during the period September to December. In 1970, its peak period was observed in April, after which dwindled in numbers, but a secondary peak was seen in

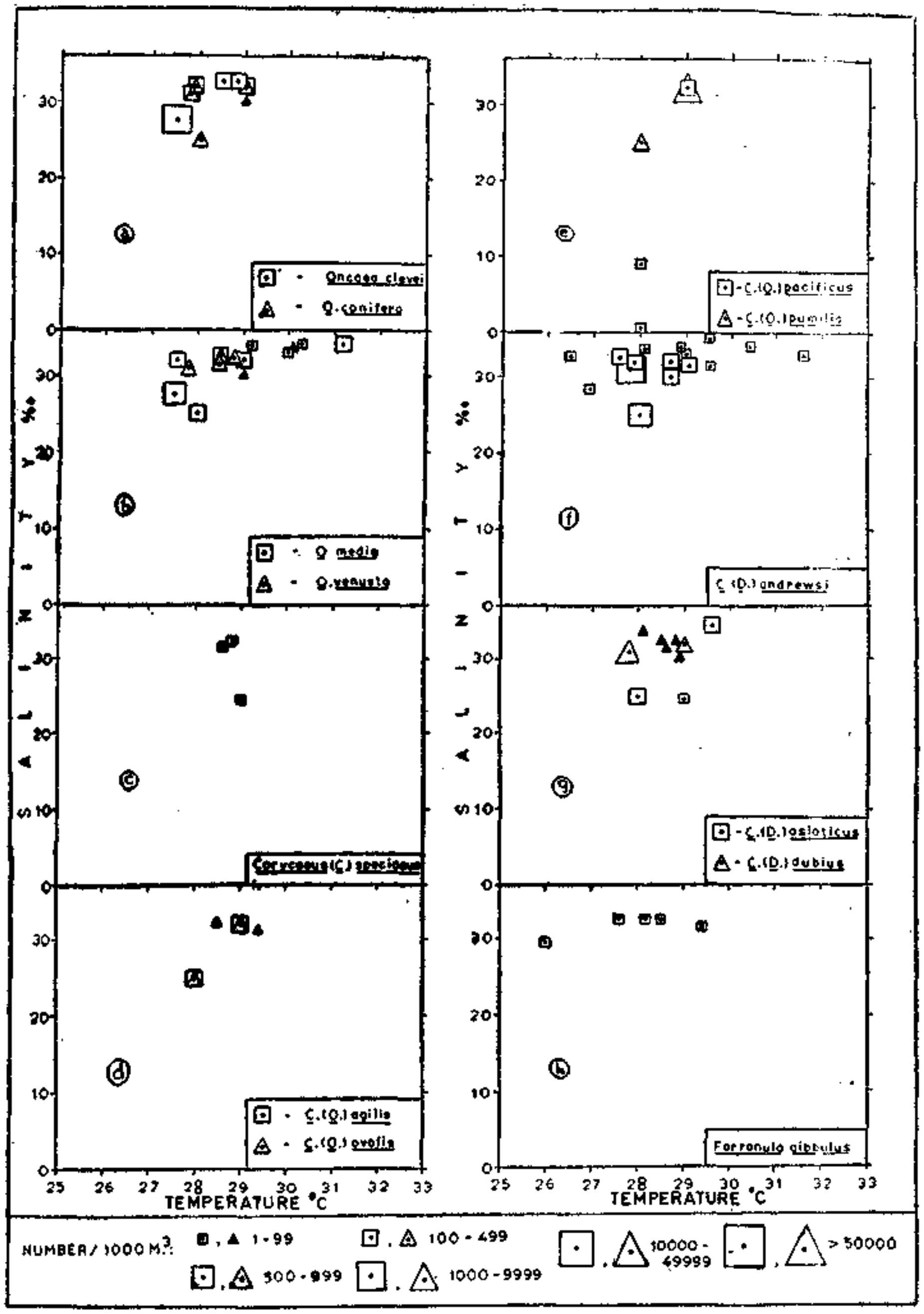

Fig. 4. T-S-P diagrams and species abundance of a. *Oncaea clevei* and *O. conifera*, b. *O. media* and *O. venusta*, c. *Corycaeus (Corycaeus) speciosus*, d. *C. (Onychocorycaeus) agilis* and *C. (O.) ovalis*, e. *C. (O.) pacificus* and *C. (O.) pumilis*, f. *C. (Ditrichocorycaeus) andrewsi*, g. *C. (D.) asiaticus* and *C. (D.) dubius* and h. *Farranula gibbulus*.

TABLE 1. *Species-wise average monthly occurrence of cyclopoid copepods* (No/1000 m^3)

Species (1)	Year (2)	Stn. (3)	J (4)	F (5)	M (6)	A (7)	M (8)	J (9)	J (10)	A (11)	S (12)	O (13)	N (14)	D (15)
Oithona attenuata	A	1	235	—	47	47	—	—	—	—	—	—	—	—
		2	47	—	47	47	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	470
		2	—	—	—	—	—	—	—	—	—	—	—	470
O. plumifera	A	1	423	—	47	—	—	—	—	—	—	—	235	—
		2	454	—	—	—	188	—	—	—	—	—	—	47
	B	1	—	—	—	—	—	—	—	—	—	—	—	235
		2	—	—	—	—	—	—	—	—	—	—	—	235
O. similis	A	1	188	—	—	—	—	—	—	—	—	—	—	—
		2	188	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	1,410	6,932
		2	—	—	—	—	47	—	—	—	—	—	—	1,175
O. simplex	A	1	47	—	—	—	159	—	—	—	—	—	71	94
		2	71	—	—	47	—	—	—	—	—	—	—	94
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	47	—	—	—	—	—	—	—	—	—
Oncaea clevei	A	1	188	—	—	—	—	—	—	—	—	—	—	—
		2	235	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	470	470
		2	—	—	—	—	—	—	—	—	—	—	—	1,880
O. conifera	A	1	47	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	470	—	470	235
		2	—	—	—	—	—	—	—	—	—	—	—	235
O. media	A	1	188	—	—	47	—	—	—	—	—	—	—	—
		2	117	—	—	94	—	—	—	—	—	—	—	—
	B	1	—	47	—	—	—	—	—	—	—	—	470	235
		2	—	—	—	—	—	—	—	—	—	—	—	1,175

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
O. mediterranea ..	A	1	—	—	—	—	—	—	—	—	47	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
O. venusta ..	A	1	94	—	47	—	—	—	—	—	—	—	235	—
		2	141	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
Corycaeus (*Corycaeus*)	A	1	—	—	—	—	—	—	—	—	—	—	—	—
crassiusculus		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	235
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (*C.*) *speciosus*	A	1	47	—	—	—	47	—	—	—	—	—	47	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (*Ditrichocorycaeus*)	A	1	—	—	—	—	—	—	—	—	—	—	—	—
affinis		2	47	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (*D.*) *andrewsi* ..	A	1	59	—	—	—	47	—	—	—	—	—	—	94
		2	94	—	94	47	—	—	—	—	—	—	—	—
	B	1	—	47	—	—	—	—	—	—	—	—	470	1,410
		2	—	70	47	—	—	—	—	—	—	—	—	940
C. (*D.*) *asiaticus* ..	A	1	—	—	—	—	47	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	47	—	—	—	—	—	—	—	—	235

TABLE 1 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
C. (*D.*) *dahli* ..	A	1	—	—	—	—	94	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (D.) *dubius* ..	A	1	94	—	—	—	—	—	—	—	—	—	47	—
		2	70	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	47	—	—	—	47	—	—	—	—	470	940
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (*D.*) *subtilis* ..	A	1	71	—	47	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (*Onychocorycaeus*) *agilis*	A	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	470	—
		2	—	—	—	—	—	—	—	—	—	—	—	235
C. (*O.*) *ovalis* ..	A	1	47	—	—	—	—	—	—	—	—	—	—	—
		2	47	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	470	—
		2	—	—	—	—	—	—	—	—	—	—	—	235
C. (*O.*) *pacificus* ..	A	1	47	—	—	—	—	—	—	—	47	—	—	—
		2	—	—	—	—	—	—	—	—	94	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	1,410	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
C. (*O.*) *pumilis* ..	A	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	1,410	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
Farranula gibbulus	A	1	47	—	—	—	—	—	—	—	—	—	—	—
		2	47	—	—	—	—	—	—	—	—	—	—	47
	B	1	47	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—
Sapphirina nigromaculata	A	1	—	—	—	—	—	—	—	—	—	—	—	47
		2	—	—	—	—	—	—	—	—	—	—	—	—
	B	1	—	—	—	—	—	—	—	—	—	—	—	—
		2	—	—	—	—	—	—	—	—	—	—	—	—

A = 1970 ; B = 1971

September. During 1971. the secondary peak was in October.

Oithona nana Giesbrecht (Fig. 2 h)

This is one of the common species present in the plankton and found in abundance during the pre-monsoon months and to a higher extent during post-monsoon months. A major peak was observed during October, 1970 and 1971. The maximum number of this species were seen during September to December during both the years.

Oithona oculata Farran (Fig. 3 a)

This species is present in the plankton samples during the pre-monsoon and post-monsoon months. The major peak was observed during September 1970 and 1971. It was absent in the plankton during July, August and October in 1970 and during June to August in 1971. It was present in the plankton samples in good numbers during September to December.

Several other species appear only occasionally and details about their seasonal cycles and relative abundance are given in Table 1 for a period of two years for the two stations.

SEASONAL FLUCTUATIONS

George (1958), Tranter and Abraham (1971), Pillai *et al.*, (1973) and Madhupratap *et al.*, (1975) have attempted studies on the seasonal cycle of different group of copepods through the course of a year from the Cochin Backwater. Similar investigations carried out from the inshore waters along the west coast of India revealed that the peak period of occurrence was during January to February along Trivandrum coast (Menon, 1945); during October to December at Calicut (George, 1953; Subrahmanyan, 1959; Mukundan, 1971) and during March to April and October to November in the inshore waters off Bombay (Pillai, 1968). From all these studies it is evident that the copepod density along the western coastal waters of India is higher during October to March. The characteristics of the inshore coastal waters exert profound influence on the seasonal rhythm as it is evident in the pattern of occurrence and distribution of the copepod in the Cochin Backwater.

Many species of pelagic cyclopoid copepods exhibit distinct seasonal periodicity as it is evident in the monthly distribution of species.

TABLE 2. *Maximum abundance recorded for 5 species of cyclopoid copepods in the Cochin Backwater during January 1970 to December 1971 for the two stations*

Species	Stn.	January 1970 to December 1970	January 1971 to December 1971
Oithona brevicornis	1	September	November
	2	March	September
Oithona nana	1	September	November
	2	September	October
Oithona hebes	1	September	October
	2	September	October
Oithona oculata	1	September	October
	2	September	March
Oithona rigida	1	September	October
	2	September	October

The following categories of ecological subdivisions can be made out in the Cochin Backwater based on the pattern of distribution and seasonal occurrence.

(i) Species which occur either throughout the year or for most part of the year: *e.g. Oithona brevicornis, O. hebes, O. nana. O. rigida, O. oculata.*

(ii) Species which occur only during certain months of the year apparently influenced by higher salinity: *e.g. Oithona plumifera, O. simplex, O. attenuata, Corycaeus (Ditrichocorycaeus) andrewsi*, etc.

(iii) Species which are very rare and occur sporadically in small numbers in Cochin

Backwater, the distribution of some of which may be considered fortuitous: *e.g. Oithona similis, Oncaea venusta, O. media, O. conifera, O. clevei, Corycaeus* (*Onychocorycaeus*) *pacificus, C.* (*O.*) *Ovalis, C.* (*O*) *agilis, C.* (*O.*) *pumilis, C.* (*Ditrichocorycaeus*) *asiaticus, C.* (*D.*) *dubius, C.* (*D.*) *affinis, Farranula gibbulus.*

ROLE OF TEMPERATURE AND SALINITY ON THE DISTRIBUTION

In the estuary, environmental changes are of prime importance because of their action directly upon the physiological processes of the organisms, especially upon the rate of metabolism reproductive cycle and longivity which have a direct bearing on their relative abundance. Not merely species, but many genera and even higher systematic categories are confined entirely, or nearly so to a particular watermass. The relationship of a particular species with T-S can be utilised as a character which determines the range and tolerance of that species when it occurs at a particular environment and is also an useful instrument for understanding the ecology of the species. There are hardly any references from the Indian Seas on the effect of environmental changes on the abundance of a given species of planktonic cyclopoid copepods.

The monthly fluctuation in composition of the total cyclopoid copepod in the Cochin Backwater during the two year period January 1970 to December 1971 are shown in relation to T-S diagram (Fig. 2). In Fig. 3 b-h and 4 a-h, the occurrence and abundance of the following species namely *Oithona similis, O. attenuata, O. brevicornis, O. nana, O. oculata, O. rigida, O. simplex, O. plumifera, Oncaea clevei, O. conifera, O. media, O. venusta, Corycaeus* (*Corycaeus*) *speciosus, C.* (*Onychocorycaeus*) *agilis, C.* (*O.*) *ovalis, C.* (*O.*) *pacificus, C.* (*O.*) *pumilis, C.* (*Ditrichocorycaeus*) *andrewsi, C.* (*D.*) *asiaticus, C.* (*D.*) *dubius,* and *Farranula gibbulus* in the temperature and salinity ranges are also drawn.

Distribution of species

Distribution pattern of 23 species of calanoid copepods that were recorded from Cochin Backwater during 1968-1969 has been briefly discussed by Pillai (1971) and the range of salinity within which each species occurs, and came to the conclusion that particularly the marine forms in the estuary have restricted distribution.

28 species of cyclopoid copepods have been studied in the present observation. Based on the observed salinity values and the range of salinity within which each species occur, the species are divided into two groups as follows:

Group A: *Species which generally occur in salinity less than 25‰.*

Oithona brevicornis, O. hebes, O. rigida, O. plumifera, O. nana, O. oculata, Corycaeus (*Onychocorycaeus*) *pacificus.*

Group B: *Species which occurs in salinity above 25‰.*

Oithona similis, O. simplex O. attenuata, Oncaea venusta, O. media, O. clevei, O. conifera, O. mediterranea, Corycaeus (*Corycaeus*) *speciosus, C.* (*C.*) *crassiusculus, C.* (*Ditrichocorycaeus*) *subtilis, C.* (*D.*) *affinis, C.* (*D.*) *andrewsi, C.* (*D.*) *dubius, C.* (*D.*) *dahli, C.* (*D.*) *asiaticus, C.* (*Onychocorycaeus*) *ovalis, C.* (*O.*) *agilis, C.* (*O.*) *pumilis, Farranula gibbulus, Sapphirina nigromaculata.*

The following species namely *Oithona similis, Oncaea venusta, Corycaeus* (*Corycaeus*) *crassiusculus, C.* (*Ditrichocorycaeus*) *subtilis, C.* (*D.*) *affinis, C.* (*D.*) *dubius,* and *Sapphirina nigromaculata* which are categorised under Group B, have limited distribution in the estuary during the pre-monsoon months when the salinity in the estuary is in par with that of nearshore waters.

DISCUSSION

The Cochin Backwater receives run off from the Southwest monsoon between June and August and also some rain from the Northeast monsoon from October to December. The discharge from the rivers during the monsoon period reduces the salinity of the backwater system considerably. Thus for six months of the year, the environment is subjected to drastic changes due to the influx of fresh water. The estuarine area for the remaining six months (December to May) is relatively stable with regard to temperature and salinity, particularly near the mouth of the estuary from where the collections were made for the present study. During the hot pre-monsoon period, evaporation and reduced flow of fresh water results in an increased salinity of the whole system. Based on the hydrographical condition of the Cochin Backwater, three seasons can be recognised in any year as indicated earlier. Thus fluctuating hydrological conditions influence the ecosystem resulting in the seasonal and biological cycles of cyclopoid copepods.

This study tends to show that of all the physico-chemical factors, salinity is pivotal in controlling the occurrence and abundance of cyclopoid copepods in the Cochin Backwater. Owing to the perennial connection with the sea, there is a regular ingress and egress of marine plankters to the backwater, caused in part by the tidal flow. This was evident, for most of the species studied, the maximum abundance was met with during the pre-monsoon months, when the estuary was less turbulant and the hydrographical parameters were comparable to the inshore waters.

The mixo-euryhaline population tend to re-establish themselves in the estuary after the monsoon as evidenced by a general reversal from limnophilous condition to the monsoon period. With steady high tidal influence and watermass movements, pockets of high saline water persist in the lower layers in the estuary. On the distribution of surface salinity, Ramamirtham and Jayaraman (1963) remarked that with high salinity at the bottom and almost freshwater at the surface, there is a very sharp gradient of salinity resulting from the stratification, during the monsoon months. Studies on the salinity changes in the Cochin Backwater corresponding to tidal variation were studied by Qasim and Gopinathan (1969) and they opined that during the monsoon period large quantities of freshwater enter the estuary, resulting in very low saline waters at the surface and a denser layer of saline water at the bottom. Moreover differences induced by tides are well pronounced at the surface and bottom during this season and the mixing gets prevented with the result that brackishwater at the surface remains more or less undisturbed. Since zooplankton collections were not made from the bottom layers, the effect of this layer on the distribution of cyclopoid copepods could not be ascertained. There is reason to believe that since some species do not completely disappear, it can be migrating to this higher saline bottom waters or present in the pockets of high saline waters.

The tidal action is quite conspicuous throughout the year in the Cochin Backwater. During the post-monsoon months, the maximum tidal ranges were about 1 m. The entire water column gets well mixed during this period and the salinity of the backwater increases at the flow and decreases at the ebb. During this period along with the tidal current, several marine species of the cyclopoid copepod population also enter the estuarine system. This is evident from the nature of the cyclopoid copepod population of the backwater. Several of the species present are marine forms that have been recorded from the coastal waters of this region and some species have a very wide distribution and are found in tropical waters in almost all the world oceans. The marked fluctuation in abundance of the various typically marine forms is easily explained when linked up with the widely varying salinity of the estuarine waters. It is also observed that such species propagate in the estuary (e.g. *Oithona simplex*, *O. attenuata*, *Corycaeus* (*Ditrichocorycaeus*) *andrewsi*, *Oncaea clevei*, *C.* (*Onychocorycaeus*) *agilis* from the end of post-monsoon period to throughout the pre-monsoon period, but are uncommon during the low salinity regime.

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BIOFOULING BY *PERNA VIRIDIS* IN A DEEP SUBMARINE TUNNEL SYSTEM AT KALPAKKAM

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ABSTRACT

A preliminary assessment of biofouling in a seawater tunnel has been made from a study of the fouling biomass collected from different depths in the tunnel and from the trash racks at the tunnel intake. Fouling biomass was found to be dominated by the green mussel *Perna viridis*. Data on size-frequency distribution of mussels indicated the possibility of the entry of juvenile mussels through the intake into the tunnel system. It appears that the mussels moved along the length of the tunnel and grew up in size as it reached the fore-bay end. Biomass of green mussels on the trash racks was found to be 57 kg/m^2 in six months.

INTRODUCTION

MOST of the studies on biofouling in Indian coastal waters over the years have been directed to an understanding of the deterioration of timber in Indian coastal waters. As a consequence of a sustained effort put up by the Forest Research Institute, Dehradun, over this several years, our present understanding in this area is fairly comprehensive (Purushothaman and Rao, 1971 ; Tiwari *et al.*, 1984). Added to this have been the efforts of Naval Laboratories to cope with the problem of biofouling and corrosion on ship hulls (Karande, 1968) as well as the many researches carried out by independent investigators on the problem of boring and fouling in harbours, coastal waters and oceanic islands (Karande, 1978 ; Nair, 1984). The list of references are very exhaustive and what has been cited here are only a selected few. On the other hand, studies on the problem of biofouling in seawater intake conduits of power stations have been relatively very few. Some of the first attempts in this direction have been those of Godwin (1980) and Karande *et al.* (1983) in the coastal waters at Kalpakkam. The magnitude of the problem in temperate waters and the strategies for coping with these have been fairly well documented (Jensen, 1977). Marine growths interfere with the flow of water and some times completely blocks trash racks and strainers. As the fouling community grows some of these organisms break off from the intake conduit surfaces and are carried to the condenser water boxes, quite often blocking the condenser tubes.

The problem of marine growth is found to be particularly severe at Kalpakkam, south of Madras, where a nuclear power station is using seawater for condenser cooling purposes. The dominant fouling organism forming the stable community in the seawater intake conduit at Kalpakkam is the green mussel *Perna viridis* which is found to be growing profusely on the trash racks at the seawater intake and in lesser abundance at a depth of even upto 42 metres in the seawater intake tunnel (Nair *et al.*, 1987).

The authors are grateful to Commander Gupchup and his men from the Eastern Naval Command, Waltair for collecting the samples for our studies from MAPS fore-bay during their diving inspection from 4th to 6th April 1986.

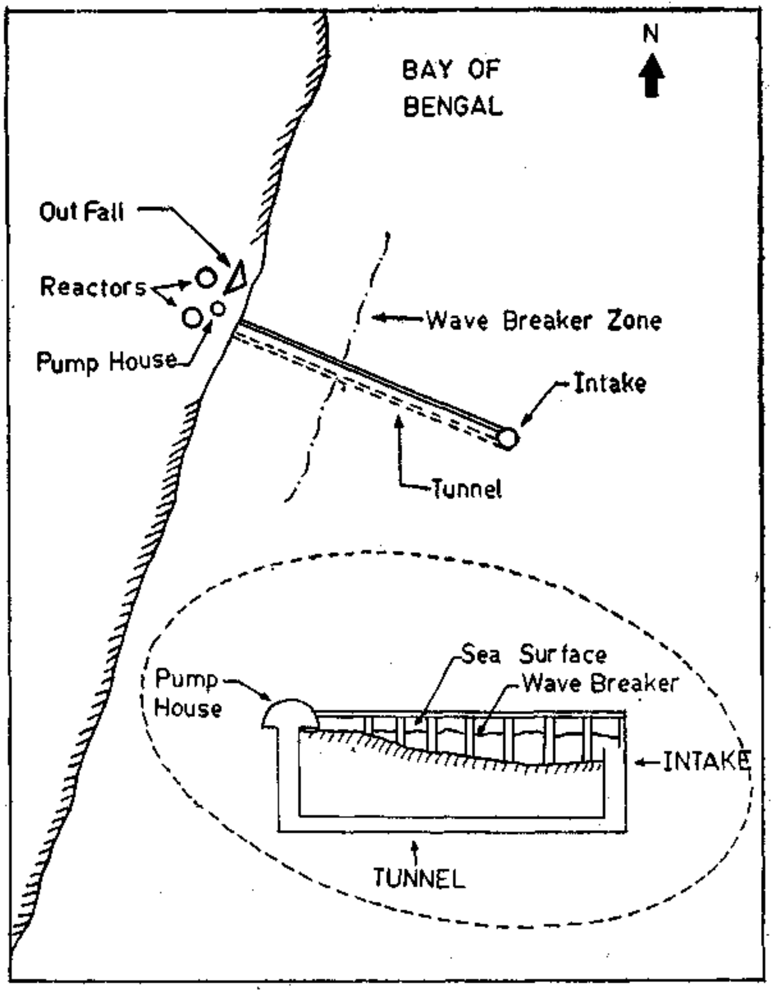

Fig. 1. A schematic diagram showing the MAPS reactors, seawater intake system and the outfall structure.

SEAWATER INTAKE SYSTEM

The Madras Atomic Power Station (MAPS) consisting of two units, each 235 MW(e) uses seawater for condenser cooling as a once-through system. The seawater cooling system consists of an intake structure, located 420 m away from the shore in the sea, a tunnel 468 m long and 54.4 m below mean sea level (MSL), a fore-bay and pump-house, condensers and the out fall stucture (Fig. 1). The tunnel is horse-shoe shaped, 3.8 m in diameter and is connected at seaward end to the surface through a vertical shaft 4.25 m in diameter. At the landward end the tunnel is connected to the fore-bay through another vertical shaft which is 6 m in diameter and 56 m deep. The tunnel slopes from seaward end to the landward end with a slope of 1/250. A schematic diagram of the tunnel is shown in Fig. 2.

Seawater enters the intake shaft through 16 windows each 3.2 m high and 2 metres wide, located radially on the intake structure. From the intake shaft water flows by gravity into the fore-bay. At the fore-bay 12 pumps (6 for each unit) draw seawater and circulate through the condensers and other heat exchangers. The warm water from the heat exchangers is discharged onshore through an outfall structure with a built in facility to change the direction of flow with the aid of sluice gates. The coolant seawater flow when all the 12 pumps are running, works out to be about 3.0 m/sec.

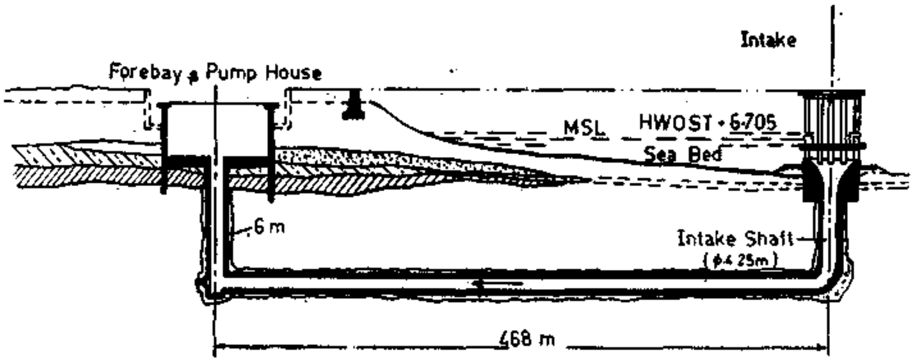

Fig. 2. A schematic diagram of submarine intake tunnel.

MATERIALS AND METHODS

A diving team from the Indian Navy examined the fore-bay shaft during 4th to 6th April, 1986 upto a depth of 42 m to assess the extent of fouling on the shaft walls. The divers collected samples of foulants from 3, 15, 30 and 42 m depths. At 42 m foulants from a 40 cm × 30 cm area was also collected to get a quantitative estimate of the biomass. Samples of marine life collected by the divers from the fore-bay shaft walls were examined for their faunistic composition. The bulk sample after taking the weight of the total biomass was preserved in formalin for detailed study. The major groups were later sorted out and identified. The length-frequency distribution of *Perna viridis* (which formed the bulk of the fouling biomass), was also analysed.

On the 8th of April two trash racks were withdrawn from the intake for routine maintenance. These were found to be heavily fouled by mussels. A representative sample of the fouling biomass from the two trash racks were also collected and used for assessing the total biomass, species composition of the fouling complex and length-frequency distribution of the principal foulant *Perna viridis*.

RESULTS

Data on the length-frequency distribution of *Perna* collected from different depths as well as a trash rack are given in Fig. 3-7. Data on the relative abundance of different organisms found at different depths in the fore-bay shaft are given in Table 1.

General observation

The divers estimated that the thickness of foulant biomass on the bell-mouth of the onshore shaft was 45 to 60 cm and the growth tapered to a thickness of about 10 cm at a depth of 25 m. At 42 m, the growth was not uniform and hence the thickness could not be estimated. In addition, large quantities of shells, along with black silt was found deposited on the bell area of the shaft. A quantitative sample from about 0.12 m^2 area has shown a fouling density of 4.3 kg/m^2 of which about 50% were green mussels.

TABLE 1. *Relative abundance of foulers at different depths*

	Abundance at different depths (per cent of total)							
	3 m		15 m		30 m		50 m	
Types of foulers	No	Wt	No	Wt	No	Wt	No	Wt
Green mussel ..	79.0	90.7	9.1	6.1	14.6	65.17	17.4	58.4
Brown mussel ..	1.4	1.3	16.9	12.5	53.6	8.2	61.8	24.4
Clams ..	—	—	—	—	2.8	19.5	3.3	8.3
Barnacles ..	19.5	7.8	27.3	6.4	23.0	4.4	50.0	6.7
Polychaete ..	—	—	2.6	5.6	7.0	6.0	—	—
Snail ..	—	—	2.1	3.0	—	—	—	—
Crab ..	—	—	4.0	12.0	—	—	—	—
Sea anemones ..	—	—	49.1	7.7	6.0	1.7	15.7	2.0
Oyster ..	—	—	1.3	6.4	—	—	—	

Green mussels (*Perna viridis*), brown mussels (*Perna indica*) and Barnacles (*Balanus tintinnabulam*, *Balanus amphitrite* and other *Balanus* sp.) were found at all depths. In addition, sea anemones, polychaetes (*Hydroides norvegica*), oysters (*Pinctada* sp.), clams (*Arca* sp.), snails (*Thais bufo*) and crabs were represented in the samples although not at all depths. The green mussel shells were often covered with sea anemones, barnacles, polychaetes, hydroids and brown mussels forming a fouling complex.

During 1969 to 1973, when early experiments were done on the choice of condenser tube material for the Madras Atomic Power Project, extensive biofouling due to mussels, oysters and barnacles were observed on submerged surfaces. The construction of the tunnel was completed in 1976 and the tunnel remained submerged in seawater since October 1977. The MAPS Unit-I was commissioned in July 1983 and Unit-II in September 1985.

Chlorination for biofouling control

It is common practice to resort to chlorination for control of biofouling in the cooling circuit of power stations. Based on the response of the larval forms of a few selected foulants to chlorine, an intermittent chlorination schedule was adopted for MAPS cooling water since 1979. No serious problem of biofouling was encountered during the start-up and commissioning of Unit-I in July, 1983 and until pumps for Unit II were started up during the pre-commissioning tests in March 1985. During the latter period large quantities of mussel shells (about 50 tonnes) got collected on the travelling screens. Moreover an inspection of condenser water boxes during a shut down of Unit-I in October 1984 showed that many condenser tubes were blocked by green mussel shells.

Relative abundance of foulers

From a look at the distribution of numerical and weight-wise relative abundance of different fouling groups (Table 1), it is seen that on the fore-bay shafts, green mussels account for the bulk of the biomass at all depths, although numerically brown mussels out-numbered the green mussels at 15 m and below. Other groups which made significant contribution both in terms of numbers and total biomass were barnacles and sea anemones. On the trash racks the dominance of green mussels was total, although there was a small contribution to the total biomass from the barnacle *B. tintinnabulum.*

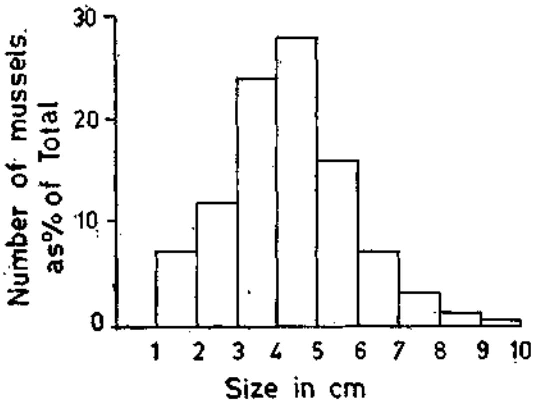

Fig. 3. Size distribution of green mussel at 3 m depth in the fore-bay shaft.

Size distribution of green mussels

The length-frequency distribution along with corresponding age in months of green mussels on a trash rack as well as on the fore-bay shaft at depths of 42 m, 30 m, 15 m and 3 m are given in the Fig. 3-7. An estimate of the age of the mussels was also made based on the study of Godwin (1980). From this data it is clear that green mussels of age groups starting from 1 to 6 months from the bulk of the fouling population on trash racks as well as in the fore-bay. However, mussels less than a month-old were found on the trash rack and mussels older than 6 months (sizes ranging from 6-10 cm) were found at 3 m depth in the fore-bay and there was a progressive increase in the occurrence of older mussels as one proceeded from intake trash racks to 3 m depth in fore-bay shaft. Although the trash racks were submerged in water only for six months, an estimate of the age of the mussels based on their length shows that upto 8 months old mussels are found on the trash rack.

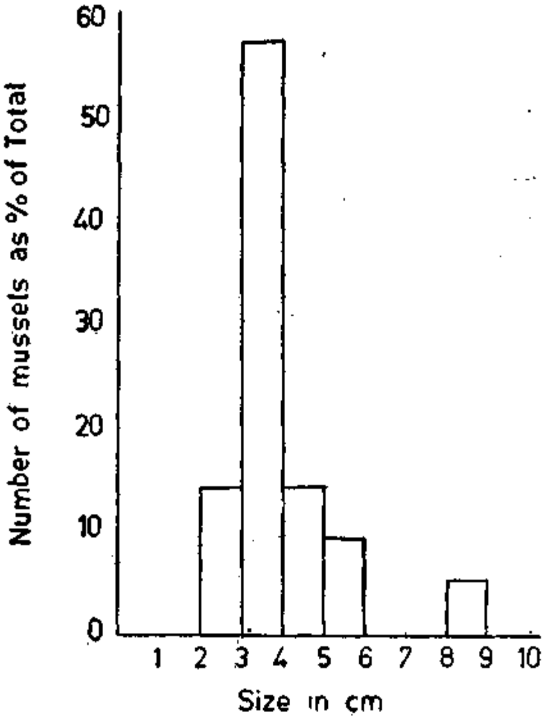

Fig. 4. Size distribution of green mussel at 15 m depth in the fore-bay shaft.

Biomass of green mussels

Mussels collected from two trash racks were used to get an estimate of the biomass build-up in the area. Two trash racks have shown a total biomass build-up of 57 kg/m² and 37.5 kg/m² respectively during a six month period. As there are 16 trash racks each having an area of 6.4 m², the total biomass from trash racks at the maximum build-up rate of 57 kg/m² amounts to a total weight of 5.8 tonnes/6 months. Assuming that at the intake shaft mussel fouling occurs upto a depth of 30 metres at the maximum value of 37.5 kg/m^2, the biomass build-up could amount to about 16 t in six months. In the fore-bay shaft as the diameter of the shaft is bigger (6 m) the biomass build-up at the same rate upto a depth of 30 m could amount to about 32 tonnes. Coincidentally in March 1985 when all the 12 pumps were operated during the start-up and commissioning of Unit II, about 50 tonnes of mussels were collected from the travelling screens. Thus, almost all the green mussel biomass which appeared on the travelling screens can possibly be accounted for by the biomass build-up of green mussels on the fore-bay and intake shafts.

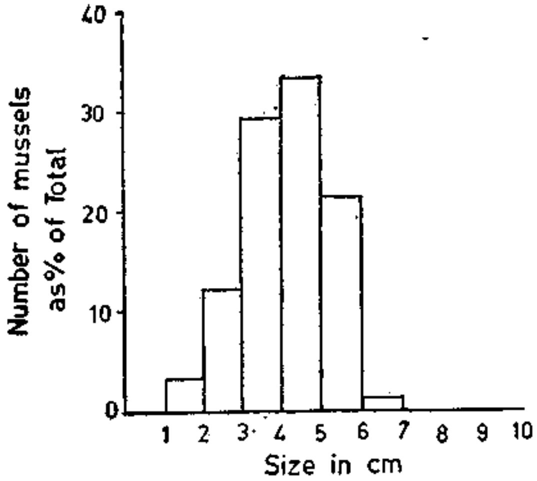

Fig. 5. Size distribution of green mussel at 30 m depth in the fore-bay shaft.

Earlier studies have shown that the average biomass build-up at Kalpakkam (Karande *et al.*, 1983) amounts to 4 kg/m^2/year, with a possible maximum of about 8 kg/m^2/year It was also pointed out that this rate is among some of the highest values ever reported. However, the present data shows a maximum value of 57 kg/m^2 for a six month period on the trash racks. This is far higher than those reported for test panels (25 kg/m^2/year) as well as light ships (40 kg/m^2 in 11 months) from other sea areas (Anon., 1952). However, the present data are very close to and only marginally lower than the very high value (64 kg/m^2 for 21 weeks) reported from the water intake tunnels of a power station in Lynn, Massachusetts (Anon., 1952). Such high rate of biomass build-up in seawater conduits is possible, because of the flowing water which brings a stream of fresh food incessantly to the sedentary mussels. Since we know that the average primary productivity of coastal waters is of the order of about 2 kg/m^2/year, the observed very high biomass build-up on the sea water conduits points to the potential of such conduits as areas of very high organic production.

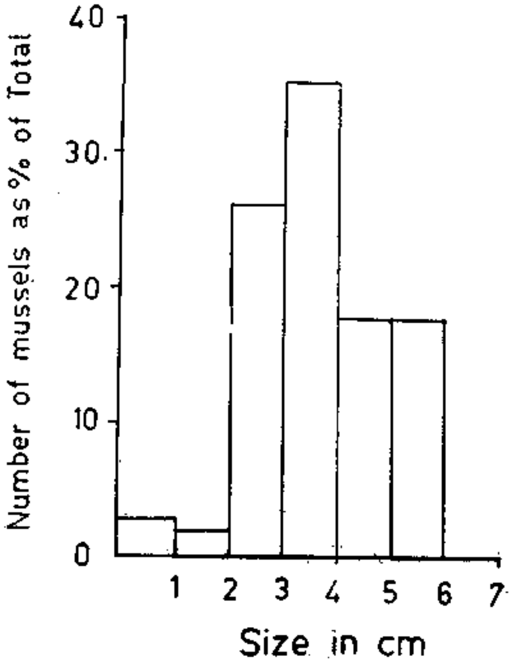

Fig. 6. Size distribution of green mussel at 42 m depth in the fore-bay shaft.

Growth of mussels

The rate of growth of mussel *Perna viridis* was studied by Godwin (1980) at Kalpakkam. These studies showed an average growth rate of 4.25 mm/month during February to May, 9.94 mm/month during June to October and 3.46 mm/month during November to January reaching a length of 88 mm in 11 months. The present data showed the presence of a few mussels of about 8 cm length on trash racks which have been put in seawater only six months before, thus amounting to an average growth rate of 12.7 mm/month. The inference from this observation could be either (i) the rate of growth of mussels in the coastal water is higher than those observed prior to the commissioning of the reactors or (ii) juvenile mussels of a few millimetre size have moved from adjoining areas and settled on the trash racks.

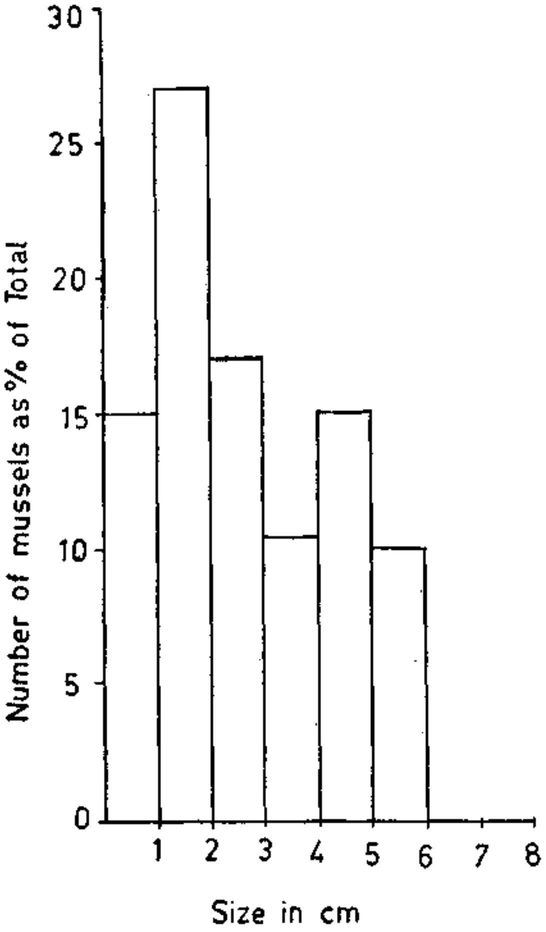

Fig. 7. Size distribution of green mussel on a trash rack at the intake.

Ecology

Marine mussels are generally found in shallow sublittoral waters. On the Indian Coast they have been observed upto a depth of 15 m, although more abundant at shallow depths (Appukuttan and Nair, Per. Comm.). In the present study they have been collected from a depth of upto 42 m. They were found in association with brown mussels, clams, barnacles and sea anemones. Since the seawater tunnel at Kalpakkam is an artificial habitat wherein a depth of 50 m is encountered on the shoreline and velocities of 3 m/sec. exists in the tunnel, the occurrence of mussels at this depth cannot be considered as their natural distribution. However, it is of scientific interest to note that not only green mussels, but brown mussels and several other groups of marine life have colonised this unique, deep habitat.

Discussion

Observation on the type, intensity and seasonal distribution of macrofoulants have been carried out at Kalpakkam during the preoperational phase of the power plant (Karande *et al.*, 1983). These studies have succeeded in identifying the major groups and their seasonal abundance. These studies have also indicated that barnacles [*Balanus* sp. would be the dominant organism to be reckoned with in the cooling system. However, as the power station started drawing water through the seawater tunnel, it was marine mussel (*Perna viridis*) which was found coming increasingly on the travelling screens. The present data on the samples collected from the diving inspections as well as from the trash racks at the intake, clearly demonstrate that tunnel fouling is dominated by *Perna viridis*. This is understandable as mussels are some of the very few animals among the macrofoulants which can withstand a water velocity ranging from 2 to 3 m/sec (Perkins, 1974) which occur in the tunnel during different modes of operation. Moreover, intermittent chlorination which has been practiced at the station has very little impact on these bivalves which close their valves to tide over the periods of chlorination. From the size-distribution of mussels on the trash racks and at various depths, it appears, juvenile mussels are entering the tunnel from seawater end and slowly moving along the tunnel length in the direction of flow, growing up in the process and ending up at intake shaft bell mouth as large size mussels. It is observed that the productivity of mussels is very high in the tunnel, possibly due to the increased food availability as a result of the flow of water. There is also a hint that the rate of growth is higher than the pre-operational period. In addition to the increased availability of food brought by flowing water, an increase in mean temperature could have contributed to their increase in growth rate.

In view of the preponderance of mussels among the fouling community in the tunnel and in view of the well known practice of low level continuous chlorination (exomotive chlorination) for mussel fouling control, this practice has now been adopted as an experimental measure for fouling control in the MAPS tunnel. However, many questions relating to the problem remains to be answered before a viable solution can be worked out. Some of these are (i) continuous chlorination at what level could deter the settlement of mussels? (ii) since mussels predominate the fouling community, would it not be sufficient to chlorinate only during the mussel spawning season? (iii) if mussels are displaced, is there a possibility that some other species would enter the scene? (iv) is low dose chlorination adequate to control condenser slime formation?

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PERIOSTRACUM OF THE GASTROPOD *HEMIFUSUS PUGILINUS* : NATURAL INHIBITOR OF BORING AND ENCRUSTING ORGANISMS

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ABSTRACT

The gastropod *H. pugilinus* has a thick pale greenish brown coloured periostracum which inhibits settling and growth of many borers and epizoans. The inhibitory effect of periostracum to borers and epizoans contributes to the snail's energetic efficiency by reducing the energy utilised for shell repair caused by borers and reduces the weight of encrusters and other epizoans carried during the snail's movement. Moreover, the periostracum forms an obstacle to borers and hence to shell damage. Further, it acts to protect the snail from its predators by way of camouflage by trapping mud and sand in between the hairs. Thus in the molluscs a superior antifouling system can be established through a clear understanding of encruster inhibitor properties. In the present study the morphology of the periostracum of *H. pugilinus* was observed with SEM and had been discussed. It's functional significance was correlated with occurrence and abundance of various epizoans, encrusters and borers found associated with *H. pugilinus*.

INTRODUCTION

THE PERIOSTRACUM is the outermost uncalcified coating of molluscan shell, the primary function of which is the deposition of inorganic phase to the shell. It is secreted by the mantle at the growing edge of the shell. These structures are commonly found in the Hipponicidae Capulidae, Trichotrophidae, and Cymatidae. It is present in archegastropod Neogastropod and Opisthobranchs also (Clarke, 1976). Clarke (1976) suggested the involvement of the periostracum in the secretion of gastropod shells. Gastropod periostracal structures have in general, been little analysed for their functional significance other than in relation to shell calcification (Bovelander and Nakahara, 1970). Bottjer (1977) attributed secondary functions rather than calcification process to the periostracum owing to its great structural variety. The mostly accepted one is that the periostracum protects the calcified gastropod shells against dissolution by acidic waters and boring organisms (Clarke, 1976 ; Abbott, 1968). This paper summarizes the structural and functional significance of periostracum in the species *H. pugilinus*. Preliminary observations made with the specimens collected from dredge hauls showed that a number of specimens lost at least some of their periostracum and that shell portion without periostracum seemed to be occupied by a greater number of borers and epizoans, than those with intact periostracum (Pl. I A). Subsequent investigations led to the conclusions given in this report. These investigations clearly show that the thick periostracum of *H. pugilinus* functions so as to significantly inhibit the settling and growth of many epizoans with relatively large calcareous skeletons like barnacles and oysters as well as many borers that penetrate into the calcareous shell causing damage to the latter. This inhibitory property

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may contribute to increased energetic efficiency and increased resistance to predators for *H. pugilinus*.

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MATERIALS AND METHODS

The specimens of *Hemifusus pugilinus* for the present investigations were collected along the Porto Novo Coast using trawl net. The distribution of this species in this coast is confined between three and thirteen fathom lines. The periostracum in this species is quite thick and can be readily peeled off the shells with forceps. For scanning electron microscopy, small strips of periostracum were mounted in various orientation on Aluminium stubs, thinly coated with gold to prevent charging effects and observed in S-180 stereoscan. Investigations on periostracal inhibition of epizoans and borers are based on specimens of *H. pugilinus* dredged from the coast of Porto Novo during October 1984-September 1985.

RESULTS

Gastropod periostraca show great variations from species to species in thickness, colour, flexibility and strength. The colour is usually brown, but may show variations depending upon the habitat. In the present collection the colour is greenish brown owing to the presence of algae in between the hairs of the periostracum of the shell. The periostracum tends to tear readily along the line of transpiral ridges of the shell, conforming to the contours of the underlying shell which in *H. pugilinus* is more or less smooth. The surface of the periostracum is covered externally by numerous papillae (Pl. I B) which makes it velvety both in appearance and to touch. These papillae appear to consist of layers drawn out from the major body of the periostracum. Projecting periostracal structures include shingles, hairs, hairlets and raised lamellae (Bottjer, 1982). The periostracum in many gastropods is secreted as thin strips which overlap towards the aperture and are commonly appressed to the shell, but in some families such as Tubinidae, Hipponicidae, Capulidae, Trichotropidae and Cymatidae, these strips do not lie flat, but project at lesser angle so as to resemble shingles.

The periostracal hair which are the drawn out structures from the major body of the periostracum range in shape from rectangular strips to structures which taper from a triangular base to a point (Pl. I C). Hair may be attached to periostracal strips. Hairs are found in the Coculinidae, Hipponicidae, Capulidae, Trichotropidae, Cymatidae and Melongenidae (Bottjer, 1982). Hairlets can be stated as hair-like structures less than 1 mm long. Hairlets have a wide taxonomic distribution with occurrence in Vitrinellidae, Cerithidae, Columbellidae, Buccinidae, Melongenidae, Fasciolaridae, Capulidae, Strombidae, Cymatidae, Cancellaridae, Conidae and Tylodinidae. Hairlets are found attached to appressed periostracal strips.

Functional aspect

The percentage occurrence of borers and epizoans on different shell surface has been given in Table 1. The boring and epizoan fauna can be divided into three categories. 1. Organisms that become less common as the periostracum deteriorates. 2. Organisms that are limited to bare shell surfaces or become more common as the periostracum deteriorates. 3. Organisms which show no change in occurrence between shell surface types. Group A (Fig. 1) comprises the epizoans with either non-mineralized, lightly mineralized or completely mineralized skeletons as well as skeletons composed of sandgrains and shell fragments held together by organic cement.

Group B contains relatively large epizoans with calcified skeleton and borers that penetrate into calcareous substrates (barnacles, hydroids, serpulid worm tube, spinoid wormborings). The encrusting bryozoans and brachiopods come under the group C and attach regardless of the shell surface.

The presence of borings under the periostracum was examined by removing it (non-eroded) by immersing the shell in either potassium hydroxide or sodium hydroxide solution. The observation showed the presence of boring branches about 0.5 to 1 mm in diameter that appeared to be fungal (Colubic *et al.*, 1975). They probably get into the shell through the periostracum. However their destructive role was lesser than by spionid worms or algal grooves and borings.

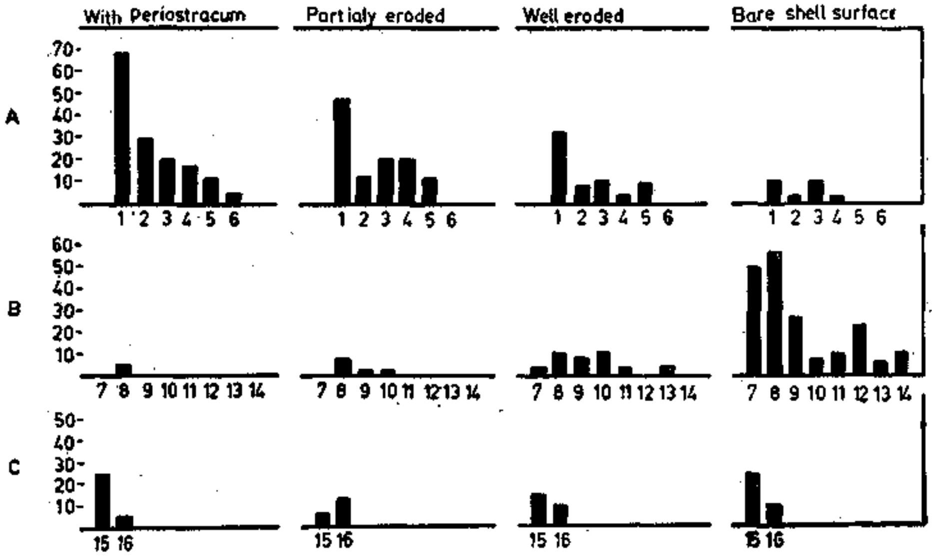

Fig. 1. Percentage occurrence of borers and epizoans on different shell surface of *H. pugilinus.*

Many *H. pugilinus* were found naturally with partially eroded periostracum. Sometimes even the entire periostracum had been eroded off, which appears to have been caused by abrasion during movement as well as by erosion by the growth of barnacles and oysters. The barnacles and oysters will grow only if they find at least some portion of the shell without periostracum. Their growth will be continued by intruding under the surrounding periostracum which initiates its removal further.

DISCUSSION

The investigation with this species showed that many specimens of these gastropods had lost much of their periostracum and that shell portion without periostracum apparently had a greater number of borings and epizoans than those with intact periostracum. 135 specimens were examined for shell surface type as well as boring and encrusting organisms. These data were then normalized as percentage occurrence of the organisms for each shell surface type and were given in the Fig. 1. Observations made in the present investigation clearly show that these epizoans use periostracal hairs for attachment and for protection from mechanical disruption, and become less common as hair is eroded off.

Group C (Fig. 1) includes epizoans which show no change in occurrence between the shell types of *H. pugilinus.*

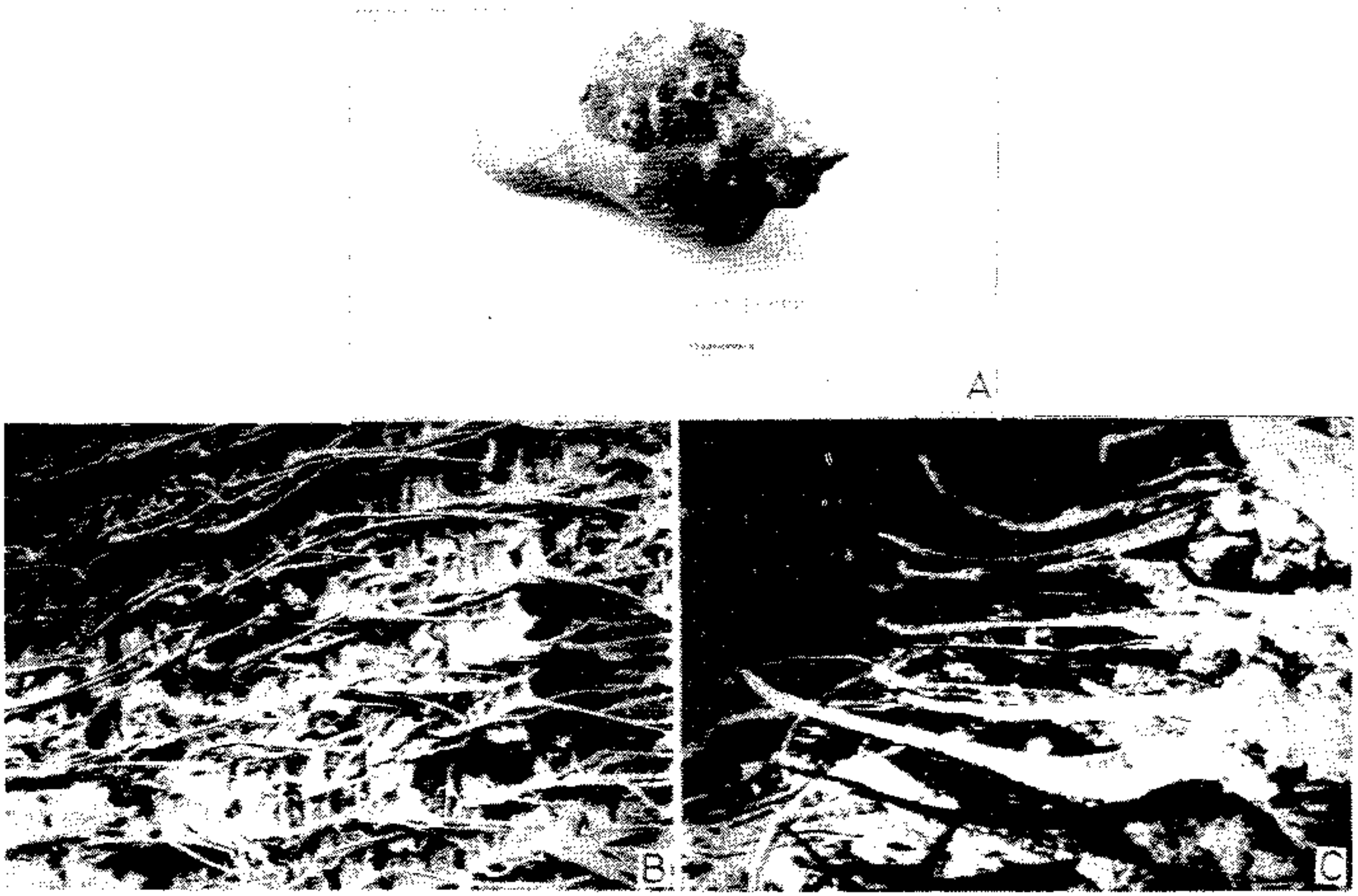

PLATE I. A. *Balanus* attached shell with eroded periostracum. B. Structure of periostracum (low magnification) and C. Structure of periostracal hair (high magnification).

TABLE 1. *Percentage occurrence of borers and epizoans on different shell surfaces of* Hemifusus pugilinus (1) Shells with non-eroded periostracum (2) Shells with partially eroded periostracum (3) Shells with well eroded periostracum (4) Bare shell surface.

Group A	(1)	(2)	(3)	(4)
Seccamminid Foraminifera	67.5	48.1	32.5	10.0
Terebellid worm tubes ..	29.7	11.8	7.5	2.5
Sabellid worm tubes ..	20.0	20.0	10.0	5.0
Ascidians ..	17.0	20.0	3.75	1.8
Calcareous bryozoans ..	10.4	15.5	10.0	0
Juvenile bivalves ..	3.7	—	—	—
Group B				
Spionid worm borings ..	—	—	2.5	50'0
Algal borings and grooves	5	8	10.0	56.3
Barnacles ..	—	1.8	7.5	26.3
Hydroids ..	—	1.8	10.0	6.9
Spirorbis worm tubes ..	—	—	2.5	10.0
Polydora worm borings ..	—	—	—	23.1
Crepidula spp. ..	—	—	3.8	5.6
Oysters ..	—	—	—	8.1
Group C				
Encrusting bryozoans ..	25.2	5.5	15.0	23.8
Brachiopods ..	5.2	12.7	5.0	10.0

Group A. Organisms which become less abundant as the periostracum deteriorates.

Group B. Organisms which become more abundant as the periostracum deteriorates.

Group C. Organisms which show no change in the occurrence between various shell types.

Freshly collected specimens of *H. pugilinus* are commonly found covered with a thin layer of sediment that is trapped by the triangular periostracal hairs. This may inturn, inhibit the settlement of borers and epizoans which need hard substrate for their growth (Grant, 1966). Further, these projecting periostracal hairs may aid the possessor to escape from its predator (Bottjer, 1981) which rely upon visual perception, by way of camouflage in which process mud and sand particles are trapped in between the hairs. The fishes feeding on gastropods are cheated by the periostracum and raised lamellae which give a false appearence to the shell with great external sculptures (Palmer, 1977). The larger size of the shell owing to the presence of periostracum helps the snail to escape from its predator, which swallow their catches whole (Vermeioj, 1978). The flexible margin formed by the hairs and hairlets in Hipponicids and Capulids aid in adherence with regular hard substrates. The main function of periostracum is to inhibit the settlement and growth of epizoans.

Projecting periostracal structures are well developed in the mesogastropod families, even though they widely distributed among the families of archaegastropods (Turbinidae, Cocculinidae only) and neogastropods. The mesogastropods and neogastropods show more variation in shell sculpture than archaegastropods (Mortan, 1967). Among opisthobranchs the Tylodinidae alone has projecting periostracal structure. The property to inhibit the settlement and growth of epizoans had already been well documented (Scanland, 1979 ; Bottjer and Carter, 1980). In the same way Heptonstall (1970) suggested the functional significance of the periostracum of the cephalopod *Nautilus*. Jackson (1977) enumerated that the tentacles and nematocysts of cnidarians, avicularia of ectoprocta and toxicity of ascidians, cnidarians and sponges take place the role molluscan periostracum. As the epizoans and borers need a stable substratum (Grant, 1966), they usually do not get attacked on the shell, because of the presence of liable sandy coating which inturn is held in between the hair of periostracum. The periostracal hairs much like the artificial surface directly inhibit the settling and growth of epizoan and borers (Barnes and Powell, 1950). The presence of periostracum avoid the occurrence of *Balanus* as they preferentially avoid growing on a substratum densely covered with 1 mm long hairs (Warme, 1975). The occurrence of polychaete worms, clionid sponges and algal borers below the periostracum may be attributed to their ability to penetrate into the periostracum and other organic materials (Warme, 1975). It is possible that the relatively thick periostracum of *H. pugilinus* might inhibit these borers which are more adopt at penetrating calcareous substrates. The present study shows that the periostracum of *H. pugilinus* functions to inhibit settling and growth of borers and epizoans. Rittschoff *et al.* (1985) observed that neither seafish nor algae settle on corals such as the *Leptagiorgia virgulata* and *Renilla reniformis*. Latter it has been identified that the presence of three deterpenes was responsible for the inhibition. A very small quantity of these molecules (20.2 μg/ml) is enough to produce a repulsion of more than 50% of shellfish. This discovery opened the way for the development of antifouling paints. Hence the study of encrustor inhibition property as well as other functional and biochemical significance of gastropod periostraca will lead to the development of superior antifouling system.

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PHOTOSYNTHESIS, RESPIRATION AND EXUDATION OF ORGANIC MATTER BY SOME MARINE MACRO-ALGAE

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ABSTRACT

Photosynthesis, respiration and exudation of organic matter in three common benthic marine macro-algae *Chaetomorpha linum* (Mull.) kutz., *Hypnea musciformis* (Wulfen) Lamouroux and *Padina gymnospora* (Kutz.) Vickers were studied. Net photosynthetic rates of 3.46 mg C g^{-1} dry wt. h^{-1} for *C. linum*, 3.89 mg C g^{-1} dry wt. h^{-1} for *H. musciformis* and 3.25 mg C g^{-1} dry wt. h^{-1} for *P. gymnospora* were observed. All the three algae excreted extracellular organic matter both in light and dark. The exudation of carbon in the dark ranged from 33% to 44% of that during photosynthesis (light). The loss of fixed carbon due to exudation in the light was greater than that due to respiration in all three algae. The estimated daily organic matter flux (g C $m^{-2}d^{-1}$) by these algae were gross production 4.4, net production 2.7, exudation 1.4, respiration 1.3 and assimilation 1.7. The excreted organic nitrogen and phosphorus fractions were very less compared to carbon.

INTRODUCTION

BENTHIC macro-algae contribute significantly to marine productivity primarily through their greater biomass in shallow littoral waters (Ryther, 1963). The primary productivity of the littoral macrophytes has been documented extensively elsewhere (Johnston, 1969 ; John, 1971 ; Littler and Murray, 1974 ; Johnston *et al.*, 1977 ; Wallentinus, 1978 ; Littler and Arnold, 1980), but data from tropical marine environments, especially from Indian waters are scarce. The method of estimation of organic matter production by macro-algae has also been criticised, because of the possible errors (Littler, 1979 ; Littler and Arnold, 1980) and omissions. One of the major omissions in previous productivity studies is the excretion of organic matter by macro-algae. Although, this has long been a subject of controversy, the evidence for existence of such a phenomenon has been documented by Fogg (1983) for phytoplankton and demonstrated in macro-algae by Hanson (1977), Hatcher *et al.* (1977) and Johnston *et al.* (1977).

The excreted extracellular products of photosynthesizing organisms exert a significant influence on the productivity of natural waters due to their utilization by other organism in both autotrophic and heterotrophic processes (Sieburth, 1969 ; Sieburth and Jensen, 1970 ; Hellebust, 1974 ; Wangersky, 1978 ; Fogg, 1983). This signifies the importance of qualitative and quantitative information about these compounds to the study of ecology and estimation of primary production. In the present study, photosynthesis, respiration and exudation of organic matter by three common benthic marine macro-algae *viz. Chaetomorpha linum* (Mull.) Kutz., *Hypnea musciformis*

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(Wulfen) Lamouroux and *Padina gymnospora* (kutz.) Vickers were estimated. The difference in excreted fractions during dark and light incubation were measured. A daily organic matter flux based on the standing crop of these algae was also formulated.

MATERIAL AND METHODS

Algal samples : Chaetomorpha linum, Hypnea musciformis and *Padina gymnospora* were carefully collected from the littoral region of the marine zone of the Vellar Estuary, Porto Novo, India (11° 30′ N ; 79° 49′ E). The collected samples were washed thoroughly in filtered seawater to remove the associated fauna and flora before subjected to experiment.

Incubation : The experiments were designed to have optimum conditions so as to avoid any possible error due to the sample weight, incubation time and volume, initial oxygen concentration, attached epiphytes, bacterial breeding population in incubation medium and variations in incubation light and temperature from *in situ* conditions. About 3 gm (wet weight) of algae was introduced into light and dark bottles of 3 l capacity containing filtered and autoclaved (120°C, 15 lb/in, 20 min) seawater. The bottles were attached to anchored buoys and suspended in the estuary at 1 m depth. The incubation was carried out between 0600 hrs and 1800 hrs. Water samples were siphoned out at the end of the 6th hour for the estimation of oxygen and carbon and 12th hour for the estimation of organic phosphorus and nitrogen. The incubation seawater quality was as follows : Salinity 34.6‰, pH 7.8, dissolved oxygen 3.2 ml l^{-1}, inorganic nitrogen-nitrate 3.4 μg at l^{-1}, nitrite 2.1 μg at l^{-1} and ammonia 1.7 μg at l^{-1}, phosphate 1.8 μg at l^{-1}. The water temperature during incubation was 28 ± 2°C.

Standing crop measurements : The algal standing crop was measured by quadrate sampling method.

Analytical procedure : The total dissolved oxidizable organic matter was determined by the permanganate oxidation method (Golterman, 1970) and from these the dissolved organic carbon concentration was calculated by multiplying the COD values by a factor of 0.588 (proposed by Duursma, per. Comm.). Organic phosphate was estimated by the method of Menzel and Vaccaro (1965). Dissolved organic nitrogen was analyzed by the alkaline persulphate oxidation method of Dahl (1972). Photosynthesis and respiration were estimated by light and dark bottle method (Strickland and Parsons, 1968). The carbon values were calculated from oxygen using a conversion factor of 0.536 and a P.Q. of 1.2. The algae were dried in an oven at 60-70°C to constant weight and the results expressed on dry weight basis. The experiments were conducted in triplicate and the results are means of three estimates.

Background concentration of organic fractions : The concentrations of different organic fractions in the incubation water were as follows : dissolved organic carbon 2.04 mg l^{-1} total organic nitrogen 13.2 μg at nitrate N l^{-1} and total organic phosphorus 0.71 μg at phosphate P l^{-1}.

RESULTS AND DISCUSSION

The average rate of net photosynthesis for the three macro-algae studied were *C. linum* 3.46 mg C g^{-1} dry wt. h^{-1} ; *H. musciformis* —3.89 mg C g^{-1} dry wt. h^{-1} and *P. gymnospora* 3.25 mgC g^{-1} dry wt. h^{-1} (Fig.1). The reported rates of net photosynthesis among macro-algae vary considerably. Even intraspecific variation greatly exceeds inter-specific variation (Wallentinus, 1978). However, rates of 2 to 4 mg C g^{-1} dry wt. h^{-1} were frequently reported (King and Schramm, 1976 ; Wallentinus, 1978 ; Littler and Arnold, 1980). The respiration rates were 0.78 mg C g^{-1} dry wt. h^{-1} for *C. linum*, 0.74 mg C g^{-1} dry wt. h^{-1} for *H. musciformis* and 1.07 mg C g^{-1} dry wt. h^{-1}

for *P. gymnospora*. The P : R ratios were 4.4, 5.3 and 3.0 for *C. linum*, *H. musciformis* and *P. gymnospora* respectively.

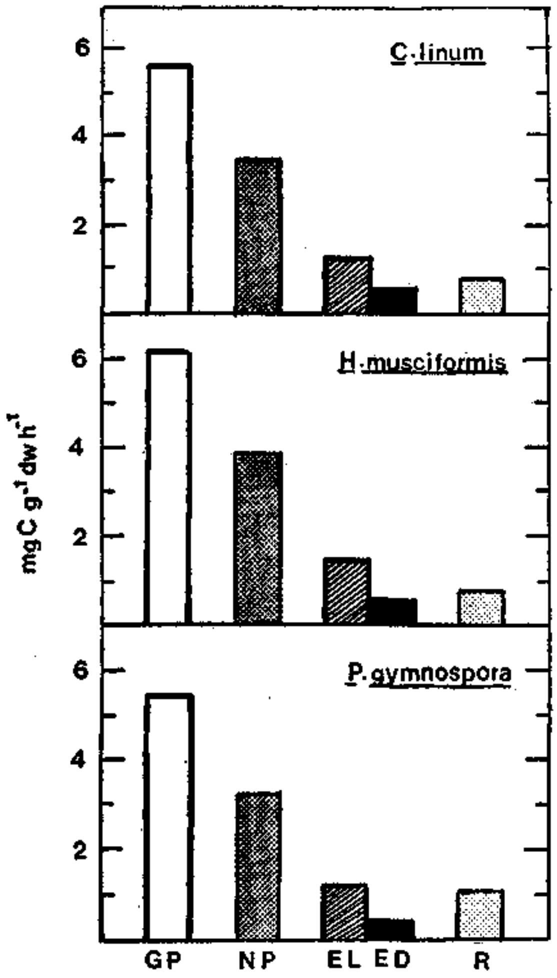

Fig. 1. Rates of photosynthesis, respiration and exudation of the benthic macro-algae. GP—Gross production = Net photosynthesis +Respiration + Exudation in light; NP—Net production; EL—Exudation in light; ED—Exudation in dark; R—Respiration.

As for as the exudation is concerned, all the three algal species were found to exude dissolved organic matter both in the light and in the dark, with greater exudation in the light. The exudation of carbon during the dark period ranged from 33% to 44% of that excreted during photosynthesis (light). Sieburth and Jensen (1970) found that the exudation rate in the dark was about 60 % of that in light. Hellebust (1965) also pointed out differences in exudation due to differences in light intensity. Exudation in the range of 20 to 37% of net photosynthesis has been reported by Khailov and Burlakova (1969), Sieburth (1969), Hanson (1977), Hatcher *et al.* (1977) and Johnston *et al.* (1977). In the present study the exudation in the light amounted to 37 to 38% of net photosynthesis or 22 to 24% of gross photosynthesis (Fig. 1).

The loss of fixed carbon due to exudation in the light was greater than that due to respiration in all three algae (Fig. 1). Sieburth (1969) and Sieburth and Jensen (1970) have also reported similar greater losses due to excretion rather than respiration. However, in the daily budget of organic matter flux, the loss by respiration is greater (38.6%) than that by exudation (29.6%) in *P. gymnospora* (Table 3).

Studies with phytoplankton both *in situ* and in laboratory conditions (Anita *et al.*, 1963; Hellebust, 1965; Fogg, 1977) also clearly demonstrated the release of extracellular organic matter. The few studies which contradicted the amount of extracellular exudation have admittedly differred in experimental design and conditions *e.g.* Moebus and Johnson (1974). Variations in the amount of excretion among the species are also common (Hellebust, 1965). The general consensus regarding the exudation is that it is an overflow mechanism (Fogg, 1983) and occurs when the supply is in excess of requirement. Exudation could also be a reflection of a poor mechanism of conservation (Sieburth and Jensen, 1970). The increased rate of exudation with the increased rate of photosynthesis (Sorensen and Halldall, 1977) could also substantiate this notion. As

Wangersky (1978) pointed out exudation may be energetically advantages over storage.

Based on the observed rates of photosynthesis, respiration and exudation, a daily balance sheet of organic matter productivity per square meter area for the total standing crop is presented in Table 3. The values presented for m^{-2} area are computed by multiplying the values of photosynthesis, respiration and exudation of each species by their respective standing crop (Table 1) and the average values thus obtained for g dry wt. were assumed for the other species also. This average value for g dry wt. was then multiplied by 63, the total standing crop per square metre area. The total standing crop per square metre area could fix about 4.4 g C d^{-1}, exude 1.4 g C d^{-1} and assimilate 1.7 g C d^{-1}. The theoretical maximum production rate for phytoplankton has been calculated to be 20 g C m^{-2} d^{-1} (Sieburth and Jensen, 1970), while yields of 10 g C m^{-2} d^{-1} have been obtained in *Chlorella* culture. The maximum rates observed in nature have been 3 to 6 g C m^{-2} d^{-1}. Macro-algal production (net) rates similar to the present study were reported by Johnston (1969), John (1971) and Littler and Murray (1974).

TABLE 1. *Distribution of macro-algae in the littoral area of the marine zone of Vellar Estuary*

Species		Distribution g wet wt m^{-2}	Water content %
Chaetomorpha linum	..	155±10	90.5
Hypnea musciformis	..	180± 8	90.8
Padina gymnospora	..	97± 4	91.0
Others	..	201± 5	90.5
Total	..	633	

Analyses of different fractions of the excreted matter also revealed interesting results. Excretion of nitrogenous matter was observed only in the light and amounted to 113 to 187 μg N g^{-1} dry wt. in 12 hours. Excretion of organic nitrogen compounds by macro-algae was reported earlier by Newell *et al.* (1972). Generally excretion of nitrogenous matter has been studied more frequently in blue-green algae than in other organisms. Stewart (1963) reported that the extent of nitrogen excretion could be upto 45% nitrogen fixed in blue-green algae. About 30% of fixed nitrogen was found to be excreted in cultures of two marine nitrogen fixing blue-green algae by Ramachandran (1982). Fogg (1966), Sieburth (1969) and Sieburth and Jensen (1970) also showed that exudation of nitrogenous matter occurred only to a lesser extent when compared to carbon. Exudation of organic phosphorus was not significant in either light or dark (Table 2).

TABLE 2. *Excretion of organic nitrogen and phosphorus by macro-algae*

Species	Incubation period hrs	μg P g^{-1} dry wt.		μg N g^{-1} dry wt	
		light	dark	light	dark
Chaetomorpha linum	6	2.2	2.5	101	no production
	12	1.7	1.7	187	,,
Hypnea musciformis	6	4.5	4.6	107	,,
	12	5.5	2.8	186	,,
Padina gymnospora	6	1.6	2.3	74	,,
	12	5.8	7.4	113	,,

The biological and biochemical advantages of extracellular excretion to algae are not yet evident, however, the ecological significance has been well documented (Williams and Yentsch, 1976; Dawson and Duursma, 1981). From the present study it is clear that benthic macro-algae, by virtue of their high photosynthetic efficiency and significant production of extracellular organic matter form a primary source of utilizable organic matter which enhances the productivity in shallow littoral waters.

TABLE 3. *Daily budget for organic matter flux in benthic marine macro-algae* (mg C g^{-1} dry wt. d^{-1})

Species	NP	R	Exudation L	Exudation D	GP[a]	Assimilation[b]	Loss by R% of GP	Loss by E% of GP
Chaetomorpha linum ..	41.5	18.6	15.4	6.7	66.2	25.5	28	33
Hypnea musciformis ..	46.7	17.9	17.4	7.4	74.0	31.3	24	34
Padina gymnospora ..	39.0	25.8	14.9	4.9	66.8	21.2	39	30
g C m^{-2} d^{-1} (for a total Standing crop of 63 g dry wt.) ..	2.7	1.3	1.4		4.4	1.7	30	32

NP—Net Production; R—Respiration; L—Light; D—Dark; GP—Gross Production; E—Exudation.

[a] Gross Production — Photosynthesis in light (Net production—12 hrs)+Respiration (12 hrs)+Exudation (12 hrs in light).

[b] Assimilation — Gross Production — Respiration (24 hrs)+Exudation (24 hrs—12 hrs in Light and 12 hrs in Dark).

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POTAMIDID SNAILS OF VELLAR-COLEROON ESTUARINE AREA, SOUTHEAST COAST OF INDIA

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Abstract

Shell sculpture, external morphology of the body and pallial organs, digestive system, reproductive organs and types of sperms of three species of potamidids, *Cerithidea (Cerithideopsilla) cingulata, C. (Cerithidea) obtusa* and *Telescopium telescopium* collected from Vellar-Coleroon estuarine complex are studied, described, illustrated and discussed in this account.

Electrophoretic analyses showed that the pattern of protein fractions indicated closer association between *C. (C.) cingulata* and *C. (C.) obtusa* at interspecific level and both differ from *T. telescopium.* Of the three species, *C. (C.) obtusa* appears to be more advanced and evolving gradually towards terrestrial mode of life.

Introduction

In the Vellar-Coleroon estuarine area, snails of the family Potamididae are represented by three species, namely, *Cerithidea (Cerithideopsilla) cingulata* (Gmelin), *Cerithidea (Cerithidea) obtusa* (Lamark) and *Telescopium telescopium* (Linnaeus) under the subfamily Potamididinae. So far no detailed study has been carried out on these snails from this area. Therefore, detailed investigations were carried out on the organisation, habit and habitats, and biochemical systematics of these snails and results are presented here.

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Material and Methods

Cerithidea (C.) cingulata was collected from the Vellar Estuary and Killai Backwater. *C. (C.) obtusa* from the mangrove of Pichavaram and *T. telescopium* from both the areas.

Terminology used in the description were those employed by Van Bentham Jutting (1956) and Houbrick (1978).

For electrophoresis, the three layered polyacrylamide gel electrophoresis (Ornstein, 1964, Davis and Lindsay, 1967 ; Smith, 1976) was used in the present investigations. Chemical formulations described by Canalco Bulletin (1968) were used for the preparation of various stock solutions and combination of them, in actual processing of electrophoresis. The separating gel was the standard 7.5% polyacrylamide gel. Extracts of foot and gonadal tissues from the three species were used for the analyses and electrophorased simultaneously. Comassie Brilliant Blue for general proteins and PAS reaction for glycoproteins, were the stains used.

Relative mobility (Rm) of the individual fraction of the proteins was calculated taking

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the distance from origin to the front as 1.0 unit. For convenience, the fractions were grouped into three, based upon their Rm values : (1) slow moving (upto 0.33), (2) intermediate (0.34 to 0.66) and (3) fast moving (0.67 to 1.00). The Rm values were calculated for each gel and the average for 20 runs were used for final analyses.

Observations

Shell

Shells of potamidids are characteristically elongate, turrated and fairly thick. The aperture is ovate with a short anterior siphonal canal. The outer lip is flared and grows beyond the columellar base. The outer lip is thickened in older specimens. The shell is strongly sculptured in both *Cerithidea* and *Telescopium*. In the former, both the axial and spiral sculptures are evident, while in the latter only spiral ridges are present. Periostracum is colourless. Shells of *C.* (*C.*) *cingulata* (Pl. I A-C) are uniformly dark coloured or mottled with brownish yellow spots, particularly on the lower row of nodules in each whorl of the shell. *C.* (*C.*) *obtusa* (Pl. I D-F) is pale pinkish without any mottling. Protoconchs are small and normally lacking in older specimens, especially in *C.* (*C.*) *obtusa*. In *T. telescopium* (Pl. II A-C) the shell is dark in young specimens but greyish in older ones. Operculum is ovate with a central nucleus and concentric lines of growth. It is generally thin, chitinous and brown or dark.

External features (Fig. 1)

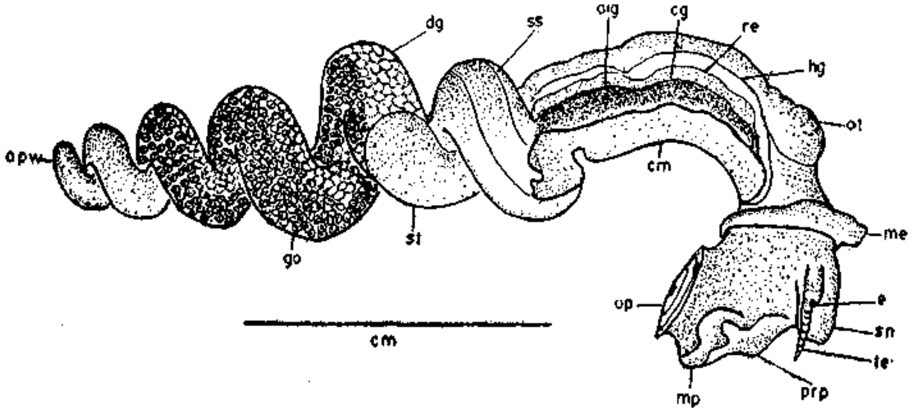

Fig. 1. *C.* (*C.*) *cingulata*. Female with shell removed exposing mantle, visceral mass and associated organs. (alg : albumen gland, an : anus, apw : apical whorl, blsi : blood sinus, cg : capsular gland, chc : cephalic haemocoel, cm : columellar muscle, cpg, : cerebro-pleural ganglion, cs : crystalline style, ct : ctenidium, dg : digestive gland, e : eye, go : gonad, he : heart, hg : hypobranchial gland, in : intestine, inh : inhalent siphon, k : kidney, la : lateral tooth, ll : lateral laminae, ma_1 and ma_2 : marginal teeth, mc : mantle cavity, md : median tooth, me : mantle edge, ml : median laminae, mp : metapodium, ng : pallial siphonal eye, o : oviduct, oc : oral cavity, od : odontophore, odg : oviducal groove, oe : oesophagus, op : operculum, osp : osphradium, ov : ovary, pdg : pedal ganglion, pgd : pallial gonoduct, prg : prostate gland, prp : propodium, rd : radula, re : rectum, rs : radular sac, ser : seminal receptacle, sg : seminal groove, sn : snout, spg : sperm collecting gutter, ss : style sac, t : testis: te : tentacle, vd : vas deferens).

The visceral organs in general are greyish, but individual organs show different colouration. Foot is dark in *C.* (*C.*) *cingulata* and *T. telescopium* while it is red in *C.* (*C.*) *obtusa*. The head is dark in the former two species while in the latter, it is red and black banded alternately. The stomach region is bluish-green while the gonads appear creamy (mature female) or bright yellow (mature male). Columellar muscle is invariably white. The region near the kidney is iridiscent.

The foot is massive, highly contractile and capable of considerable expansion during locomotion. The propodium, invested with mucus secreting cells, has a network of connective tissue and muscle fibres. The chitinous operculum is attached to the metapodium. The foot is innervated from the paired pedal ganglia situated at the juncture of head-foot region.

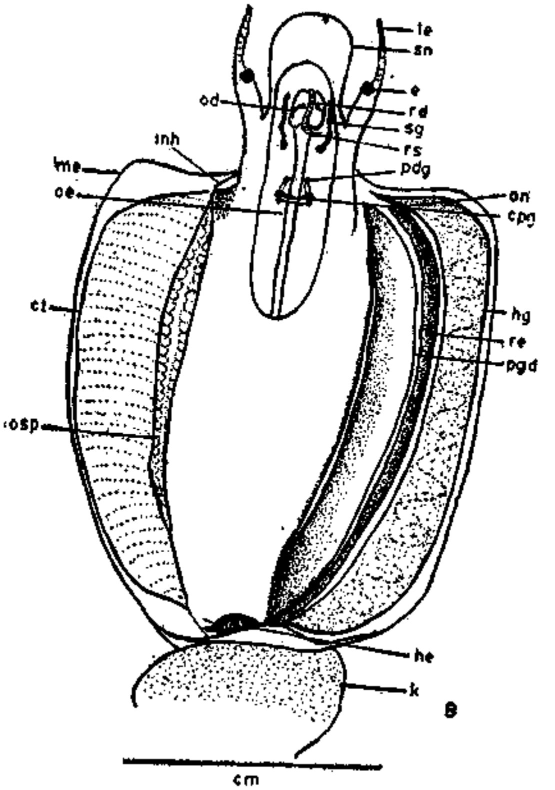

Fig. 2. *C. (C.) cingulata.* Mantle skirt medially cut; two halves deflected laterally. Buccal cavity opened mid-dorsally exposing anterior alimentary tract and nerve ring. (for abbreviations, see Fig. 1).

The head is broad with a prominent snout which is wrinkled and highly contractile. The mouth is crescentic and situated at the anterior tip of the snout. The tentacles project from the neck, are stumpy at the base, but from the position of eye, somewhat thinner. The tentacles are spotted with black in *C. (C.) cingulata* and *T. telescopium*, but are banded in *C. (C.) obtusa* with red and black.

Mantle cavity and associated organs (Figs. 2 & 3)

The organs of the pallial complex are the ospharadium, ctenidium, hypobranchial gland, intestine, rectum and the genital tracts. The surrounding mantle is thick and muscular at its free edge. The dorsal and lateral edges of the mantle are smooth and without crenulation. In the inhalent siphon area, the mantle edge is modified into muscular fold, but not so distinctly in the exhalent siphon area. There is a very narrow groove leading from the exhalent siphon area to the foot in the females. The mantle cavity is very deep.

The osphradium is elongate and prominent extending from kidney-heart region anteriorly to the inhalent siphon. It is bifurcated and each part is triangular in shape. A thick nerve runs beneath the osphradium.

The well developed ctenidium is large and occupies a considerable portion of the mantle cavity, but it narrows down posteriorly. The ctenidium is separated from the osphradium by a narrow space. It is highly vascularised at the posterior region as an adaptation to partial aerial breathing.

In *C. (C.) cingulata*, the hypobranchial gland covers the entire region from the exhalent canal to the ctenidium anteriorly. It is traversed and bifurcated by the rectum anteriorly and the intestine posteriorly. The hypobranchial gland secretes copious mucus to bind the extruded faecal matter from the rectum so as to keep them away from the ctenidium to avoid contamination.

The intestinal and rectal portions of the digestive tract lie in the visceral complex between the hypobranchial gland and the gonoduct.

The anus is located slightly behind the mantle edge, near the exhalent siphon.

The genital ducts appear as folds and grooves and are coloured pale yellowish. They extend almost the full length of the mantle cavity from the anterior to the posterior end.

Digestive system (Fig. 4)

The terminal crescentic mouth opens into the buccal cavity. At the anterior end, the buccal cavity lodges a pair of triangular chitinous jaws embedded in the dorsal wall of the cavity. The buccal mass or odontophore is muscular, red in colour and anchored dorsally to the body wall by strong muscles. The radula is typically taenioglossate *viz.*, one median, one lateral and two marginals (2-1-1-1-2) (Fig. 5 a, b; Fig. 6). The median tooth, smaller than others, has a upper broader edge which bears a middle cusp and three lateral cusps on each side. The ventral triangular portion is smooth near the base. The lateral tooth bears about 5 to 6 cusps. The marginals are narrow and elongate and appear hook-like and bear strongly curved cusps. The number of rows of teeth varied from 65 to 71 in *C.* (*C.*) *cingulata*, 142 to 160 in *C.* (*C.*) *obtusa* and from 80 to 87 in *T. telescopium*. At its rear end, the radula confluences with radular sac which secretes the radula. This region is provided with strong musculature for the movement of the radula.

The salivary glands are thin and elongated. The dorsal food channel of the anterior oesophagus shows a characteristic twist at the region of torsion, posterior to the nerve ring and comes to lie ventrally in the posterior oesophagus.

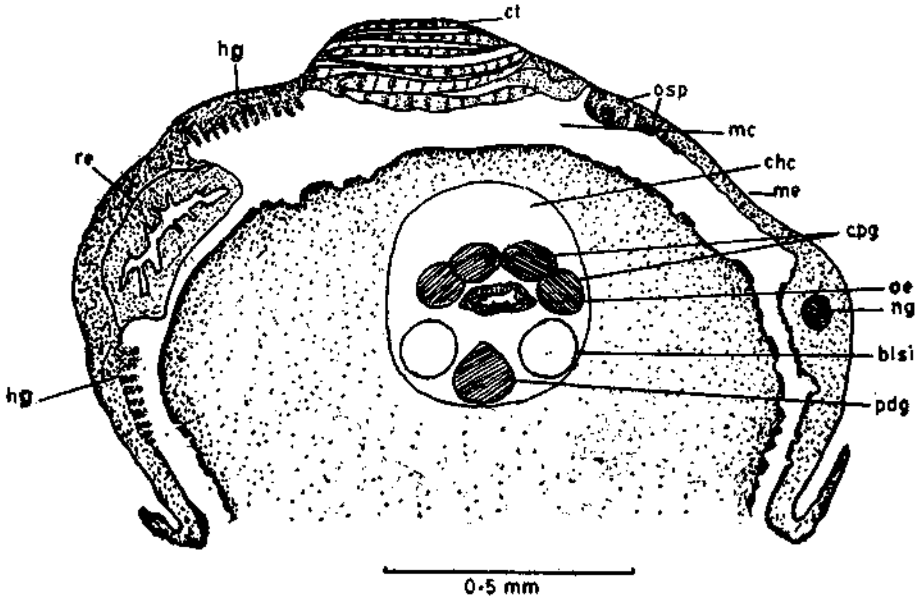

Fig. 3. *C.* (*C.*) *cingulata*. T.S. through anterior edge of the mantle cavity. (For abbreviations, see Fig. 1).

The stomach is quite large, with many muscular folds and ridges. Oesophagus opens into the stomach midventrally. Digestive gland opens by a pair of openings closer to that of the oesophagus. Style sac is well developed and secretes the proteinecieous crystalline style, which dissolves to release the digestive enzymes. The hindgut includes the intestine and the dilated rectum, which opens into the mantle cavity by the anus. The digestive gland is an elaborate structure lying posteriorly to the stomach extending up to the apical whorls.

The entire alimentary tract is provided with thick cilia for transportation of food particles. Extensive mucus secreting cells are found in the foregut for binding the food particles and in the hindgut for binding the faecal matter.

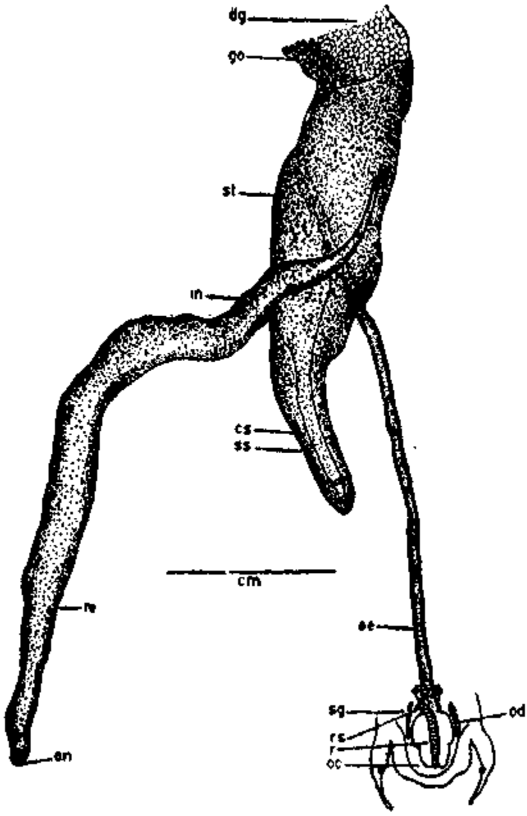

Fig. 4. Digestive system of *C.* (*C.*) *cingulata*. (For abbreviations, see Fig. 1).

Food of potamidids consists generally of fine organic, particulate detrital matter settled on the substratum. The snails scrap off the food matter with the help of the radula and swallow along with it, a lot of sand particles. Benthic as well as the settled diatoms on the bottom are also found in the stomach contents. Algal bits are also quite common.

Reproductive system

Potamidids are dioecious and aphallic, rendering external sexual determination difficult. However, in adults, the colour of the gonads varies with sex—creamy colour in female and yellow in male. The female of *C.* (*C.*) *cingulata* possesses modified metapodium which is swollen and bright yellow and can be easily recognised.

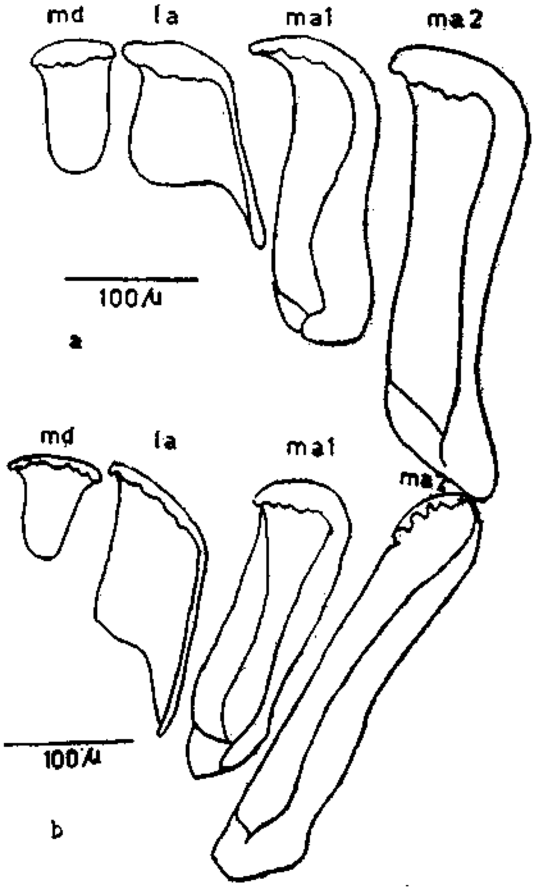

Fig. 5. Radular teeth of *C.* (*C.*) *obtusa* and *T. telescopium*. (for abbreviations, see Fig. 1.)

Gonads are closely associated with the digestive gland making it difficult to separate them from each other. The testis is follicular in nature and each follicle leads into a tiny tubule, which in turn leads into a vas deferens, running along the columellar side of the visceral coil. The vas deferens enters the open pallial gonoduct near the stomach (Fig. 7 a). The pallial gonoduct possesses two laminae—lateral and median, which are fused dorsally to each other and to the mantle. The ventral margins are free and open into the mantle cavity. The proximal portion of the genital groove is glandular and acts as prostate. The epithelial lining of the inner walls of the laminae, thrown into folds, appear smooth.

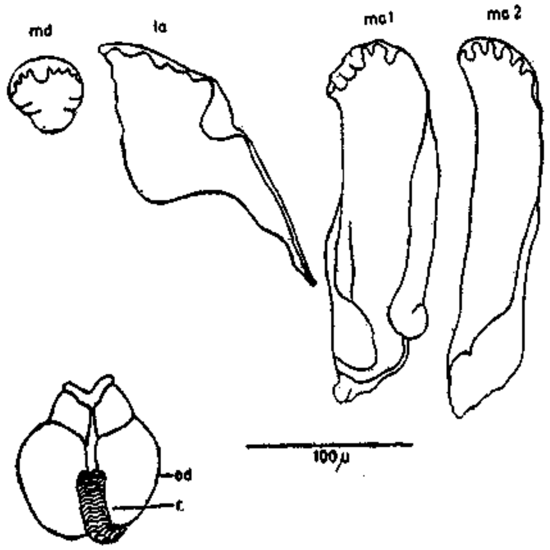

Fig. 6. Radular teeth of *C.* (*C.*) *cingulata*. (For abbreviations, see Fig. 1).

Sperms are of two types, eupyrene and apyrene (Figs. 7 c, d) as found in other cerithiaceans. A spermatophore (Fig. 7 e) is formed to aid sperm transfer from the male to the female. Wall of the spermatophore is produced by the pallial gonoduct.

The ovaries are follicular and superficially interspersed over the digestive gland. The oviduct runs along the columella similar to that of vas deferens. The open pallial oviduct is similar to that of male in general appearance (Fig. 7 b). The median lamina is non-glandular upto anterior—middle region and glandular from thereon. The posterior portion of this glandular region secretes the albumen and the anterior, the capsule of the egg. Anteriorly, a long slit, the sperm collecting gutter is present and leads into a ciliated tube-like channel, which runs posteriorly to the sperm collecting pouch. The latter has a fine opening into the lumen near the opening of the closed oviduct. This area is the site of fertilization from which egg moves anteriorly, via albuminous and capsular regions by ciliary currents. The eggs leave the mantle cavity and reach the exterior along the groove in the neck, to the pedal groove formed by the foot.

Other systems

The excretory organ in the potamidids is the kidney which is large, flat and spongy, appearing grey to brown in colour. It is located at the left side of the visceral hump. The elliptical slit-like renal opening is situated on the ventro-lateral part of the ascending portion of the kidney, close to the intestine. The opening is surrounded by cilia.

The vascular system of the potamidids is similar to that of the related cerithiids (Houbrick, 1978) and other mesogastropods. A two chambered heart is located in a pericardial cavity. The anterior aorta runs forward under the floor of the pericardial cavity, dorsally to the left of the posterior region of the oesophagus and ends in a series of sinuses in the head-foot region. The posterior aorta buds off from the anterior aorta and runs along outside of visceral mass and ends in visceral sinuses. The blood vessels and sinuses are open and poorly defined.

The nervous system of the potamidids is similar to that of *Littorina* (Fretter and Graham, 1962). The ganglia of nerve ring, the dorsally located cerebral and pleural and the ventrally located pedal ganglia are all distinct. Commissures connecting the right and left ganglia to pedal ganglia are thin. Fine nerves branch off from the ganglia and run to various regions. There is a tiny ganglion in the inhalent siphon region in the mantle edge. The chief sensory organs of the potamidids are the eyes, osphradium and statocyst.

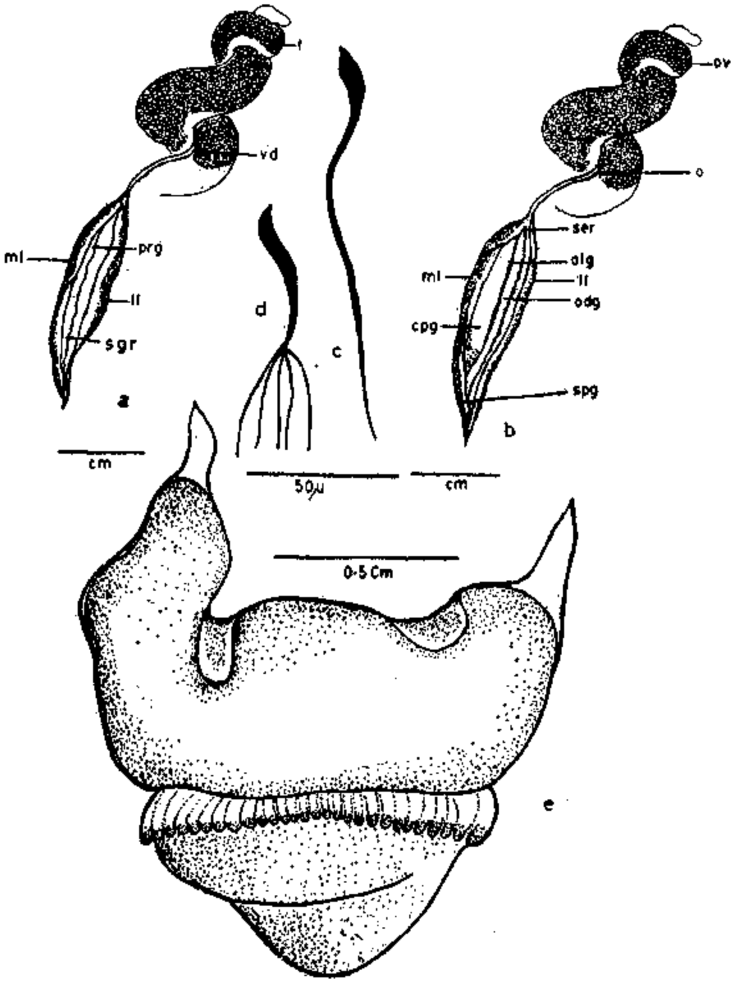

Fig. 7. *C. (C.) obtusa* : a. male reproductive system, b. female reproductive system, c. eupyrene sperm, d. apyrene sperm and e. spermatophore. (For abbreviations, see Fig. 1).

Habit and habitats

C. (C.) cingulata occupies the intertidal area of the Vellar-Coleroon area mainly between MTL and LTL. The snail prefers sand mixed with clay substratum. Most dense populations are found near river mouth, dwindling gradually towards the upper reaches. The snail feeds on the detrital matter settled on the substratum. It is totally absent inside the mangrove proper.

C. (C.) obtusa is found only within the mangrove forest and endemic to that area. The snail climbs the *Rhizophora* tree upto one meter height and often found in the branches attached by a thin film of mucus. It prefers shady areas indicating its adaptation to humid cool atmosphere. Aerial respiration appears to be dominant over aquatic respiration in this species. The snail subsists on detritus of decomposing leaves, rich in organic matter.

T. telescopium is found in the gradient and tidal zones of the Vellar Estuary as well as inside and out of the mangrove forest. *T. telescopium* is found mainly between HTL and MTL. The snail takes submersion and exposure with ease, indicating that the respiration is both by aerial and aquatic modes. It also prefers a substratum of fine sand mixed with clay. The snail feeds on the detrital matter and diatoms settled on the substratum, similar to that of *C.* (*C.*) *cingulata*.

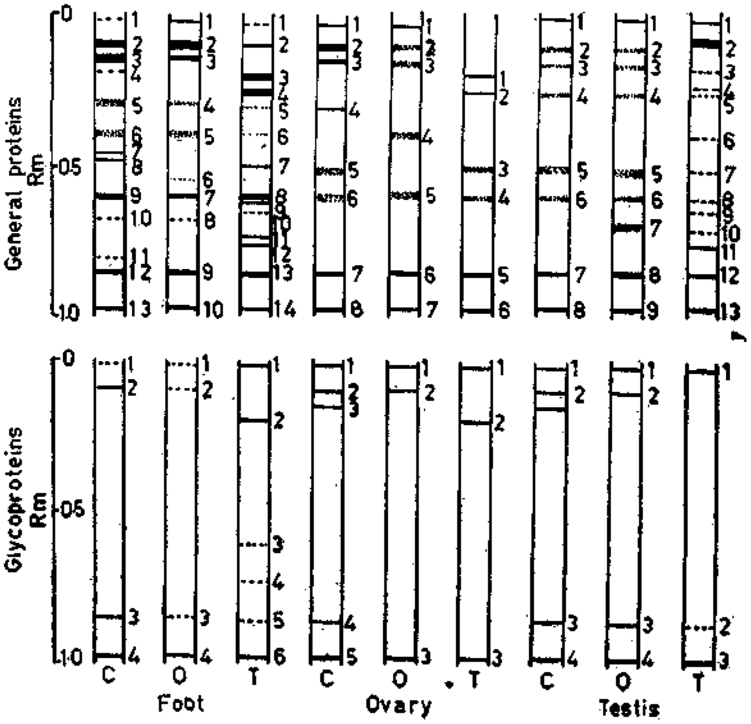

Fig. 8. Electrophorograms of general proteins and glycoproteins in the foot muscle, ovary and testis — C : *C.* (*C.*) *cingulata*, O : *C.* (*C.*) *obtusa* and T : *T. telescopium*. Rm : Relative mobility.

Electrophoretic studies

The pattern of the protein fractions stained by Comassie Brilliant Blue from the foot muscle, ovarian and testicular tissues of *C.* (*C.*) *cingulata*, *C.* (*C.*) *obtusa* and *T. telescopium* are given in Plate IV. There are 13, 10 and 14 fractions in the foot muscle of *C.* (*C.*) *cingulata*, *C.* (*C.*) *obtusa* and *T. telescopium* respectively. Of them, 5 fractions in *C.* (*C.*) *cingulata* and *C.* (*C.*) *obtusa* and 4 in *T. telescopium* are dense. Fast moving fractions are 4 in *C.* (*C.*) *cingulata*, 3 in *C.* (*C.*) *obtusa* and 4 in *T. telescopium*, while intermediate fractions number 4, 4 and 5 respectively. Between *C.* (*C.*) *cingulata* and *C.* (*C.*) *obtusa* there are 8 common fractions while between the three species there are only 5 common fractions.

In the ovarian tissue, there are 8, 7 and 6 fractions respectively in *C.* (*C.*) *cingulata*, *C.* (*C.*) *obtusa* and *T. telescopium*. The fractions recorded in the ovary are all represented in

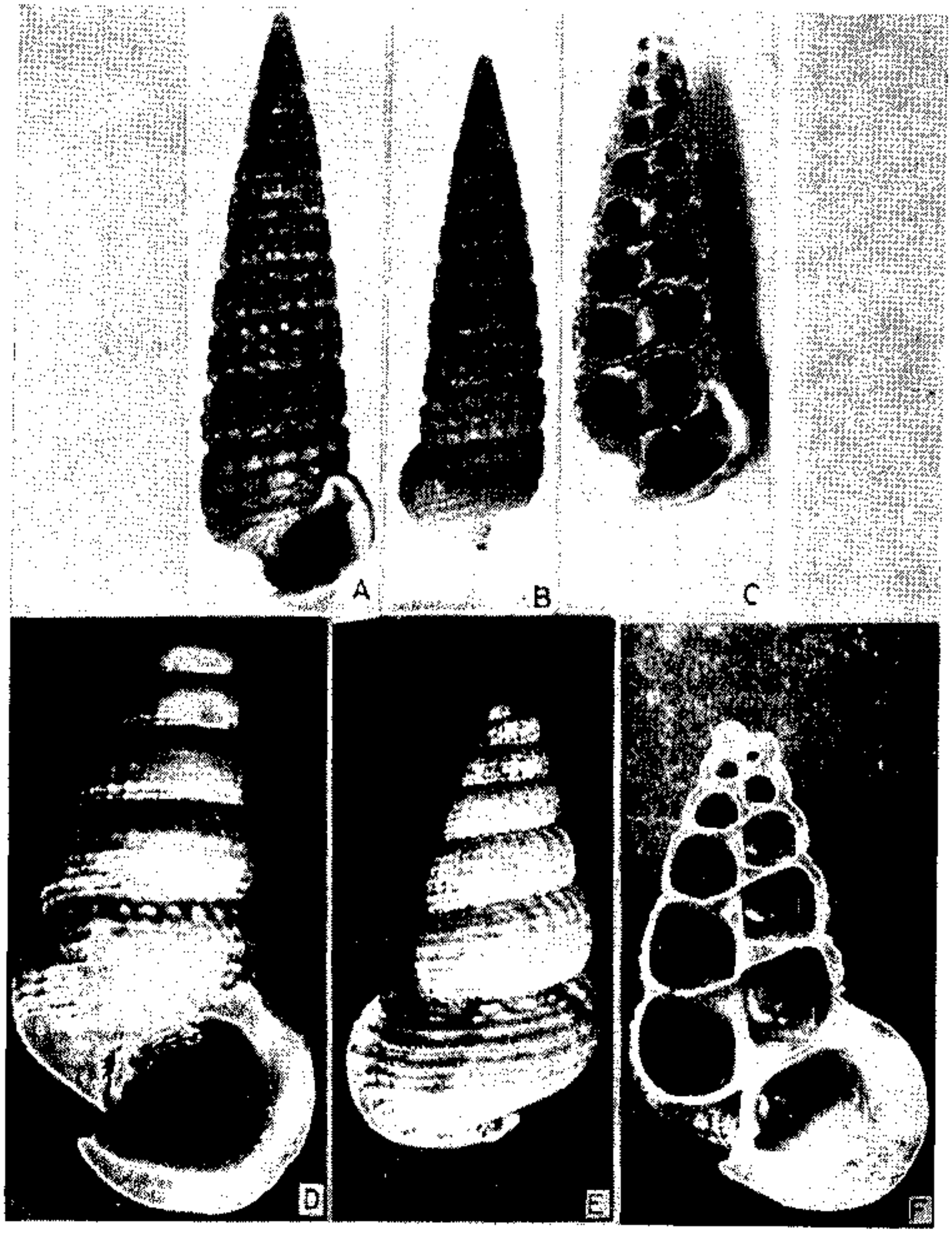

PLATE I. C. (C.) *cingulata* — A. Apertural view, B. Abapertural view, C. Longitudinally cut exposing columella ; C. (C.) *obtusa* — D. Apertural view, E. Abapertural view and F. Longitudinally cut to expose columella.

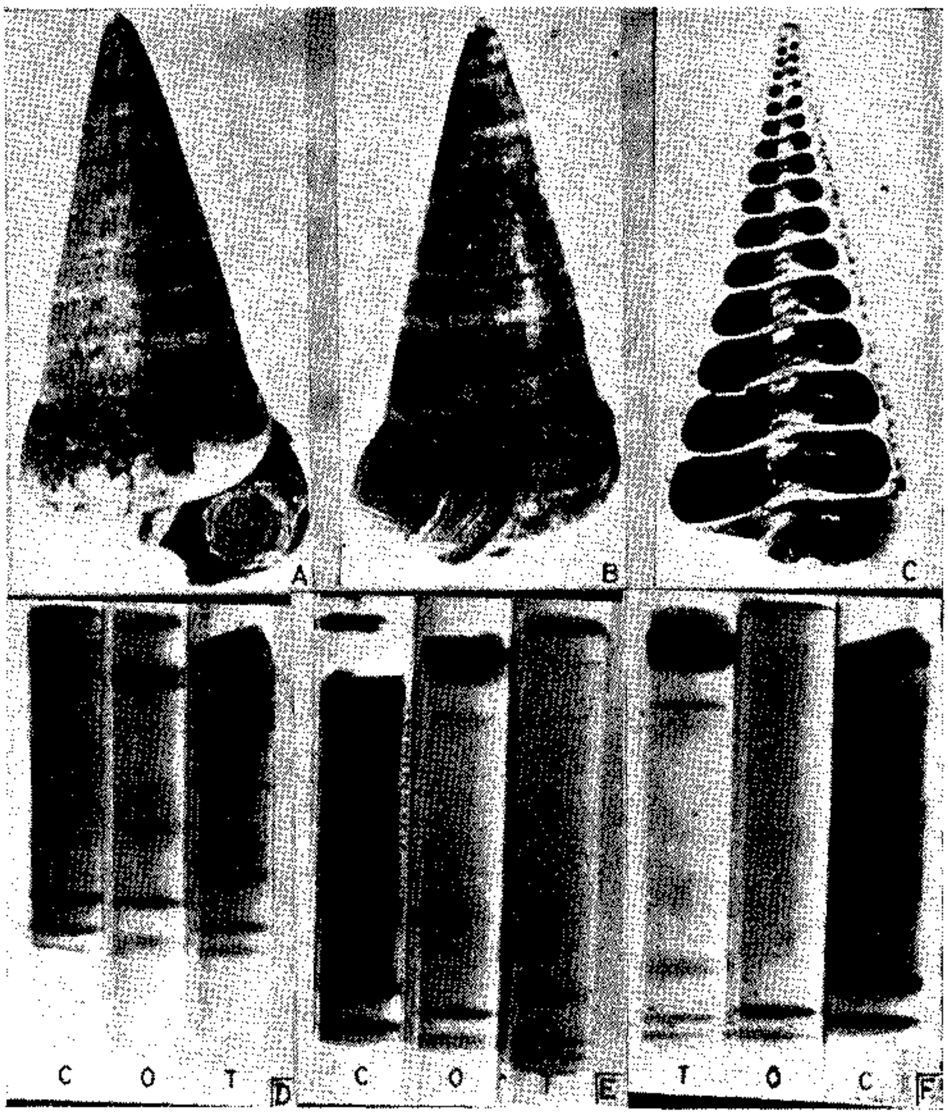

PLATE II. *T. telescopium* — A. Apertural view, B. Abapertural view, C. Longitudinally cut exposing columella ; General protein fractions in — D. foot muscle, E. ovary and F. testis. C : *C. (C.) cingulata* O : *C. (C.) obtusa* and T : *T. telescopium*.

the foot muscle except in *C.* (*C.*) *cingulata*. Of these fractions, there are 2 fast moving and 2 intermediate fractions in all the three species. Five fractions of *C.* (*C.*) *cingulata*, 3 of *C.* (*C.*) *obtusa* and 2 of *T. telescopium* are dense. There are 3 common fractions between the three species.

In the testis, the number of fractions are similar to the female gonad in the case of *C.* (*C.*) *cingulata* (8), while they are more in *C.* (*C.*) *obtusa* and *T. telescopium*. Fast moving fractions are 2, 3 and 4 and intermediate moving are 2, 2 and 4 respectively in the three species. High density fractions are 2, 2 and 3 in *C.* (*C.*) *cingulata*, *C.* (*C.*) *obtusa* and *T. telescopium* respectively. Four fractions are common between the three species.

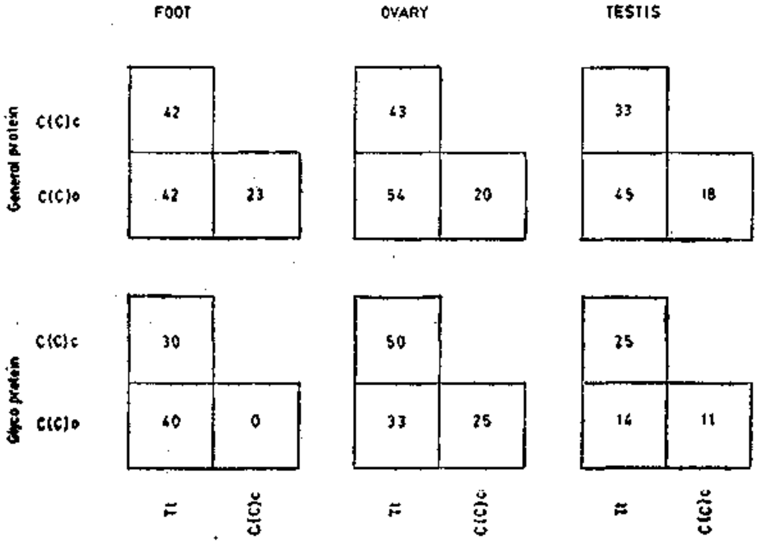

Fig. 9. Trelli's diagram showing the differences (in percentage) in general proteins and glycoproteins among the potamidids — C.C.C. : *C.* (*C.*) *cingulata*, C.C.O. : *C.* (*C.*) *obtusa* and T.t. : *T. telescopium*.

Davis and Lindsay (1967) suggested that for taxonomic purposes , the band pattern between midway and front (Rm 0.5 to 1.0) are more reliable. Three to eight such fractions were observed among the three species, of which 3 are common in the foot muscle and 2 in the gonadial tissues.

The pattern of glycoproteins was much simpler in all the three species studied. In the foot muscle, there are 4 fractions in *C.* (*C.*) *cingulata* and *C.* (*C.*) *obtusa*, while there are 6 in *T. telescopium*. Of them, 2 are slow moving and the rest fast moving. There are no intermediate fractions.

In the ovarian tissue the total number of fractions varied from 3 to 5. Fast moving fractions are 2 in *C.* (*C.*) *cingulata*, and one each in *C.* (*C.*) *obtusa* and *T. telescopium*. In the testis, the total number of fractions varied from 3 to 5 and the fast moving fractions are 2 in all the three species. In the case of glycoproteins, the total number of fractions from midway to front are 2 except in the foot and ovary of *T. telescopium* and also in the ovary of *C.* (*C.*) *obtusa*.

The electrophorograms of the general proteins are glycoproteins in the foot muscle, ovary and testis of *C.* (*C.*) *cingulata*, *C.* (*C.*) *obtusa* and *T. telescopium* are given in Fig. 8.

To quantify the systematic affiliation between the three species, an attempt has been made based on the number of protein fractions encountered in any of the two species following Bedford and Reid (1969). The number of fractions differed between any two species was scored. The percentage difference between them was found out from the formula :

$$\frac{\text{Number of fractions differed between each pair}}{\text{Total number of fractions present in each pair}} \times 100$$

The percentage obtained was plotted in Trelli's diagram (Fig. 9).

It was observed from the figure, that in general, the difference between *C.* (*C.*) *cingulata* and *C.* (*C.*) *obtusa*, is from 18 to 23%, while with *T. telescopium*, it is between 33 and 54%. In the glycoproteins also, interspecific differences in the genus *Cerithidea* is only 0 to 25%, while the intergeneric difference is 25 to 50%.

The electrophoretic studies reveal without any doubt a strong affiliation between the three species at the family level ; *C.* (*C.*) *cingulata* and *C.* (*C.*) *obtusa* appear to be closely related and justify their inclusion in the same genus ; between the two species of *Cerithidea* and *T. telescopium*, affinity to *C.* (*C.*) *cingulata* is more than to that of *C.* (*C.*) *obtusa*.

DISCUSSION

An anatomical study of three species of potamidids shows many similarities. Difference in shell size and sculpture between the members of potamidids, was observed by Vermeij (1973) who stated that higher shore forms have slender and larger shells, an adaptation to extreme desiccation and temperature. *T. telescopium* and *C.* (*C.*) *obtusa* have larger shells than their counterpart *C.* (*C.*) *cingulata*, which inhabits the low levels, confirming the above view. Dissolution of the shell at the apex and erosion of axial rib found in *C.* (*C.*) *obtusa* was attributed to high acidic conditions found in the sediment of mangrove and as a means of calcium carbonate conserving mechanism (Vermeij, 1973).

The external morphology, pallial organs, digestive system and reproductive system are all similar in all the three species. The organisation resembles that of lower mesogastropods and corresponds with the description of *Littorina* by Fretter and Graham (1962). Potamidids bear common characters to the super family Cerithiacea in having a crystalline style, ciliary mode of feeding and open pallial gonoduct. These are considered as primitive characters and the potamidids are positioned in the lower level of evolutionary ladder.

Driscoll (1971) ascribed the difference in the radular length to the nature of substratum on which the snails live and feed on. More number of teeth and lengthy radula in *C.* (*C.*) *obtusa* indicate that it can feed on coarser particles too.

Regarding the presence of open pallial gonoducts of Cerithiacea, Johansson (1956) pointed out that open glandular grooves with sperm collecting gutter along the edge of the oviducal folds occur in several families with different habits of life *e.g.* Turtitellidae, Cerithiidae, Melaniidae, Pleuroceridae and Potamididae. He opined that such pallial gonoducts were primary characteristics of the group Cerithiacea and were ancestral recurrences of primitive grooves. Fretter (1951) and Fretter and Graham (1962) did not agree with the opinion of Johansson. They suggested that the open condition of the duct and absence of penis in these mesogastropods were correlated with a long, narrow mantle cavity. In such closely coiled visceral spires there is less space for the right half of the pallial complex. During the breeding season, the presence of a penis and its insertion into the pallial oviduct during copulation would interefere with the efficient functioning of the mantle cavity. Therefore, they concluded that the penis was lost and the spermatophore was transferred to the female through open ducts and that the open condition of the duct in such mesogastropods is probably secondary and advantageous.

Differences in the protein fractions bring out the taxonomic relation between the three species. Being placed in the same genus, *C.* (*C.*) *cingulata* and *C.* (*C.*) *obtusa* show a closer alliance. They differ significantly from *T. telescopium*. The interesting point is about the relationship between *C.* (*C.*) *cingulata* and *T. telescopium* on one hand and *C.* (*C.*) *obtusa* and *T. telescopium* on the other. The former two show close affiliation than the latter two. A perusal of the shell morphology itself brings out this striking similarity between these species. Both *C.* (*C.*) *cingulata* and *T. telescopium* have more than 10 whorls and more conical than *C.* (*C.*) *obtusa*. Decollation of the apical whorls is minimum in those two species. They also share a common habitat of intertidal substratum, while *C.* (*C.*) *obtusa* is a tree-associated form. *C.* (*C.*) *obtusa* is more adapted to air-breathing than aquatic respiration as evidenced by the behaviour of avoiding submersion. On the other hand, *C.*(*C.*) *cingulata* and *T. telescopium* need periodical submersion and are adapted to aquatic respiration rather than to aerial respiration. So it can be concluded that among the three, *C.* (*C.*) *obtusa* is probably highly evolved than the other two species. It is more appropriate to quote the words of Morton (1967) here : ' Most terrestrial molluscs have early relationships with estuarine or freshwater species and they may share similar adaptations, especially in respiration and reproduction. Thus, lack of oxygen in estuarine waters may first lead to aerial respiration. Air breathing in aquatic snails in turn allows eastivation in response to occasional draught. This leads to further adaptations against desiccation and fully amphibious habit develops. With this comes changes in the mode of excretion, leading finally to a complete terrestrial life '. This seems to be most true in the case of *C.* (*C.*) *obtusa*, which appears to be evolving for terrestrial mode of life.

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OBSERVATIONS ON SOME ASPECTS OF BIOLOGY AND POPULATION DYNAMICS OF THE SCAD *DECAPTERUS RUSSELLI* (RUPPELL) (CARANGIDAE) IN THE TRAWLING GROUNDS OFF KAKINADA*

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ABSTRACT

Decapterus russelli (Ruppell)[2] is abundant in relatively deeper waters and forms 80-90% of carangid catches by trawlers. The von Bertalanffy growth parameters are estimated as L_∞ = 232.3 mm, K = 1.08 per year and t_0 = —0.08 year. The length-weight relationship can be described by the equation log W (g) = —5.93433+3.40764 log L (mm). The length and age at first maturity are estimated as 150 mm and 0.88 year respectively. This species spawns off Kakinada during December-August. The different mortality rates are estimated as Z = 6.65, M = 1.90 and F = 4.75 and the length and age at first capture as 158 mm and 0.98 year respectively. The yield per recruit analysis shows that : with t_c above 0.6 the Y_w/R increases with increased F without reaching maximum. The highest Yw/R, however, is obtained with tc at 0.6 only.

INTRODUCTION

THE FISHES of the family carangidae are an important group of exploited pelagic resources of India; an estimated average annual carangid catch of 38,685 tonnes was landed during 1981 and 1982 (CMFRI, 1982 ; 1983) forming 2.8% of the total marine landings of the country. Though this family is represented by about 50 species in Indian seas, only a few contribute to the fisheries at different places and *D. russelli* is the most dominant carangid landed by trawlers at Kakinada : an estimated annual average of 1229 t were landed during July 1979-June 1983 forming 83% of all carangids landed. Excepting the work of Sreenivasan (1982, 1983, 1984) from Vizhinjam, there is no information on the biology of *D. russelli* from India. The present paper deals with some aspects of biology and population dynamics of *D. russelli* on the basis of data obtained from commercial shrimp trawlers at Kakinada during July 1979-June 1983.

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MATERIAL AND METHODS

Data on effort and catch were collected for about 18 days each month and samples for biological study were obtained at weekly intervals. The data obtained on each observation day were weighted to get the

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[2] Smith-Vaniz (1984) considered *Decapterus dayi* Wakiya as a junior synonym of *D. russelli* (Ruppell).

estimates for that day and the pooled days' estimates were weighted to get monthly estimated effort, catch and length composition of catch. The length data were grouped into 5 mm class intervals and the mid points of these groups were considered for estimation of growth. The parameters of von Bertalanffy growth equation were estimated using the monthly length frequency data obtained during March 1979-February 1983 and following the integrated method of Pauly (1980 a). The length-weight relationship was calculated following Le Cren (1951) using the formula log W = log a + b log L, where W = weight in grams, L = total length in mm, 'a' a constant and 'b' the exponent, The specimens were examined in fresh condition; each fish was measured and weighed to an accuracy of 1 mm and 0.5 g respectively. The stages of maturation were fixed following Kagwade (1971) and Sreenivasan (1981). Ova diameter measurements were taken from ovaries fixed in 4% formalin following the procedure of Clark (1934). From each ovary about 300 ova were measured using an ocular micrometer at a magnification where each micrometer division (md) was equal to 0.017 mm. The instantaneous rate of total mortality (Z) was estimated following the length-converted catch curve method of Pauly (1982). The natural mortality rate (M) was estimated assuming that 99% of fish by numbers would die if there was no exploitation by the time they attained t_{max} and by taking t_{max} as corresponding to L_{max} in the catch (Sekharan, 1975), or to L_∞ - 0.50 cm (Alagaraja, 1984) or to 95% of L_∞ (Pauly, 1983). The value of M was also obtained using the equation of Pauly (1980 b), taking the average water temperature as 27.2°C following Ganapati and Murthy (1954) and LaFond (1958). The length at first capture was estimated following Pauly (1984 a) and the yield in weight per recruit by following Beverton and Holt (1957) method.

TABLE 1. *Estimated annual effort and catches (t) of all carangids and* Decapterus russelli *by private trawlers at Kakinada (Values in parantheses show % increase or decrease over each previous year)*

Years		Effort		All carangid catch	Catch of *D. russelli*	% of *D. russelli* in all carangid catch
		Units	Tr. Hrs.			
1979-80	..	47,948	3,41,997	442	350	79.2
1980-81	..	40,294 (—16.0)	3,29,179 (—3.7)	1,003 (+126.9)	900 (+157.1)	89.7
1981-82	..	50,462 (+25.2)	4,45,794 (+35.4)	1,652 (+64.7)	1,360 (+51.1)	82.3
1982-83	..	48,550 (—3.8)	3,19,864 (—28.2)	2,823 (+70.9)	2,305 (+69.5)	81.7

CATCHES AND EFFORT

The estimated annual catches of carangids by trawlers at Kakinada varied from 442 t in 1979-80 to 2,823 t in 1982-83 (Table 1); though there were fluctuations in the effort in different years, the catches showed considerable increase in succeeding years. The seasonal variations in the catches of carangids showed (Fig. 1) that peak periods of abundance varied during different years: there were major peaks during February 1982, 1983;

April 1980 or May 1981. A minor peak in abundance was observed during September 1979 and 1980. *Decapterus russelli* was the most dominant species in the catches and formed about 80-90% of carangid catches during different years (Table 1), though it contributed to the fishery significantly only during certain months particularly during January-April (Fig. 2).

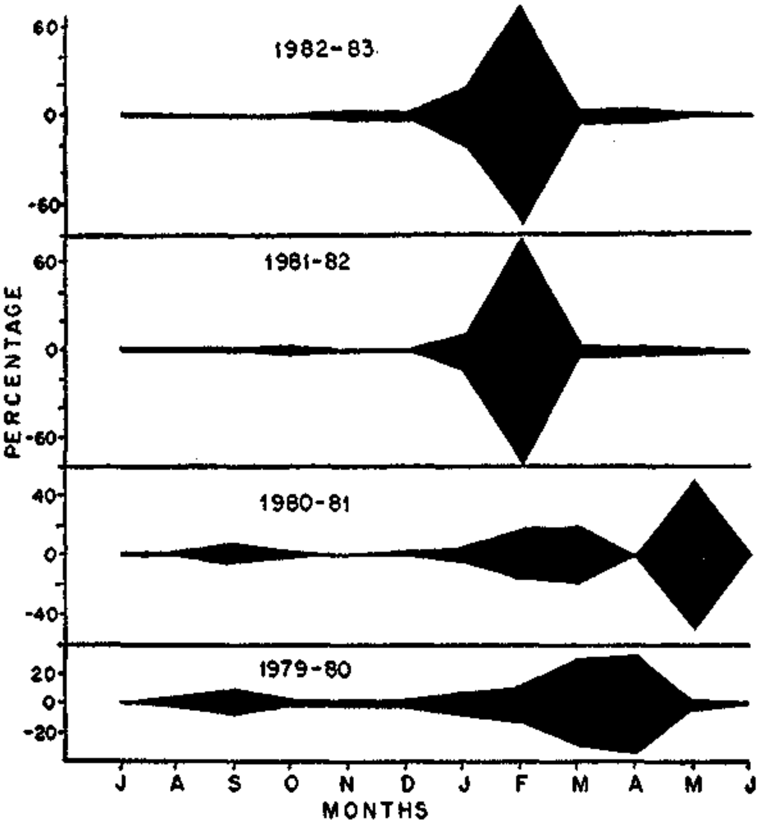

Fig. 1. Estimated monthly percentage of carangids in the total catch of each year.

GROWTH PARAMETERS

A total of 8,984 specimens of the length range 52-217 mm were measured. The monthly modal lengths and growth curves drawn through majority of them are shown in Fig. 3; it may be seen that the curves are more or less parallel. The lengths attained at intervals of six months starting from the smallest modal length in each curve were read off these curves: in each curve, only the portion between the smallest and largest modal lengths was taken; sometimes to enable reading the growth for 6 month period the portion of the curve slightly beyond the largest modal length was also taken. The values thus taken from all the curves were used to estimate the parameters of von Bertalanffy equation.

A plot of L_{t+1} against L_t (similar to that of Manzer and Taylor, 1947) shows that the observed points are well represented (Fig. 4) by the straight line ($r^2 = 0.89$). From this relation, the values of $L\infty$ and K were estimated as 232.3 mm and 1.08 per year respectively.

From the origin of the curve D (Fig. 3), the age of the smallest modal length at 67 mm was read as three months and taking this into account, the lengths at successive half years were estimated using the constants of the above regression for estimating t_0 (Fig. 5) ; the value was estimated as -0.08 year.

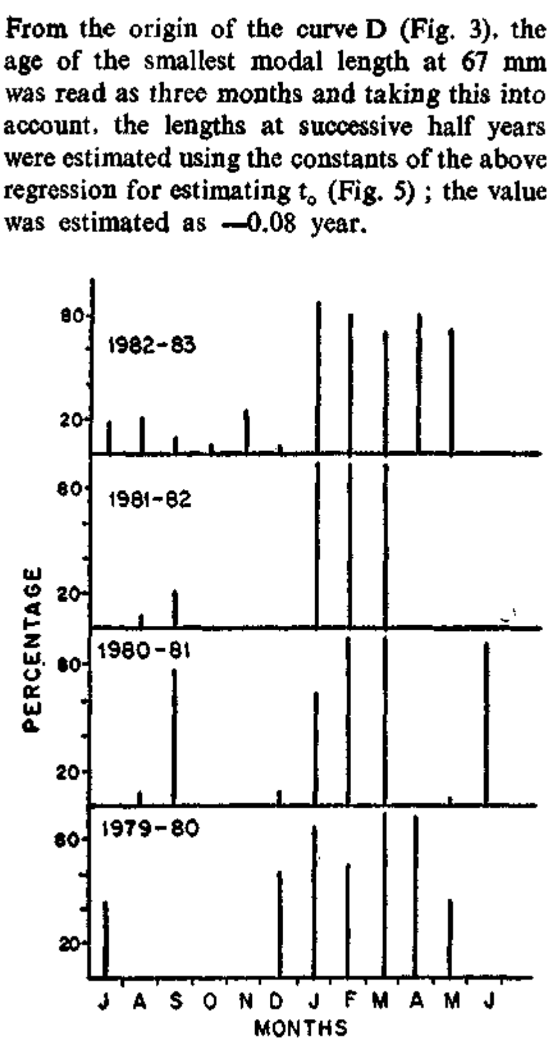

Fig. 2. Monthly percentage composition of *D. russelli* in the carangid catches of each month.

The estimated lengths at the completion of I, II and III years are 160, 208 and 224 mm respectively (Fig. 3). The maximum recorded length at Kakinada was 217 mm (age 2.4 years)

LENGTH-WEIGHT RELATIONSHIP

Data of 267 females ranging from 132 to 201 mm in total length and from 19 to 87 g weight and 325 males ranging from 120 to 205 mm and 15 to 89 g were considered. The equations obtained for each sex were :

Females : $\log W = -5.97804 + 3.42534 \log L$ ($r^2 = 0.92$)

Males : $\log W = -5.88927 + 3.38898 \log L$ ($r^2 = 0.86$)

The analysis of covariance (Snedecor and Cochran, 1967) showed that the differences between regression coefficients and Y-intercepts of sexes were not significant at 5% level. Hence the data of sexes were pooled and the relationship for the species was calculated as :

$$\log W = -5.93433 + 3.40764 \log L \ (r^2 = 0.90)$$

The value of regression coefficient was tested against the theoretical value of 3 by the t-test ; it was significantly different from 3.

MATURATION AND SPAWNING

Length and age at first maturity : Only females were considered and individuals in stages III-VII of maturation were taken as mature. Fishes of 135 mm and above showed mature ovaries. On the basis of the percentage of mature fishes in each length group, length at first maturity could be taken as 150 mm (Fig. 6) whose age could be calculated as 0.88 year.

Spawning habits : Three specimens each of stages IV and V and one each of stages VI and VII were examined for ova diameter frequency distribution. Three types of ova were recognised in ovaries in stages IV and V, the first one representing immature ova with the diameter extending upto 4 md and the second one representing maturing ova with the diameters ranging from 5 to 18 md. The former were transparent and irregularly-shaped with the nucleus clearly visible and the latter were more or less spherical, yolked, translucent and the nucleus was not clearly visible. For the present study, ova upto 6 md were not considered as they were of no consequence in interpreting the periodicity of spawning. The third group Fig. 7) represented the mature ova with the diameters ranging from 19 to 32 md; these ova were spherical and opaque. In stage VI, in addition to the above, there was another group (Fig. 7) which represented the ripe translucent ova with a distinct oil globule; these ova were spherical and ranged from 33 to 48 md and the diameter of the oil globule ranged from 9 to 11 md.

The ova diameter frequency distribution in ovaries of different stages of maturation (Fig. 7) showed that the mode at 11-12 md in stage IV remained stationery in stage V, but in stage VI it had shifted to 17-18 md; the ova in this group were mature opaque and maturing. The mode at 23-24 md in stage IV had shifted to 27-28 md in stage V and then to 39-40 md in stage VI. In stage VII, in addition to the modes in maturing ova, there were two minor modes one each in mature opaque ova and ripe translucent ova. The situation therefore, indicates that the species probably spawns twice in a season in the sea off Kakinada.

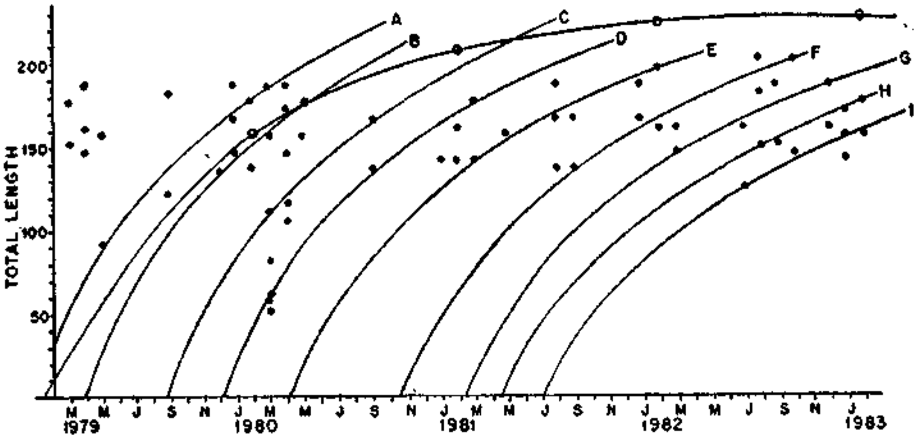

Fig. 3. Growth curves in *D. russelli* to estimate growth. The VBG curve is also shown.

Spawning season: Only females of and above the length at first maturity were considered. The frequency distribution of females in different stages of maturation (Table 2) suggests that *D. russelli* in the sea off Kakinada spawns during December-June the period sometimes extending upto August.

MORTALITY RATES

Total mortality rate: During 1982-83 the data were not available for several months, hence the data of this year were not used. Through the length-converted catch curves (Fig. 8), the values of Z were estimated to range from 4.78 to 8.75 with the average at 6.65.

Natural and fishing mortality rates: The values of M estimated by following different approaches are shown in Table 3. In the present study, however, the M value obtained by Sekharan's (1975) method at 1.90 was considered. Since the average total mortality during the period was estimated as 6.65, the present F value became 4.75.

ESTIMATION OF LENGTH AT FIRST CAPTURE

Since the gear operated was the same with the same cod end mesh size in all the three years, the data of these three years were pooled and a length converted catch curve was obtained to estimate the number of fish in the first length class that was fully selected (*i.e.*) the estimated number of fish corresponding to the first point in the straight descending portion of the length-converted catch curve. Taking this value, and the M value at 1.90, the length at first capture (L_c) was estimated as 158 mm (Fig. 9); the t_c could therefore be calculated as 0.98 year.

YIELD PER RECRUIT

The smallest length in the catch (52 mm) was taken as the length at recruitment (L_r) and its age at 0.15 year as t_r. The value of $W\infty$ was calculated as 134.4 g taking the value of $L\infty$ and the length-weight relationship.

The yield in weight per recruit (Y_w/R), at $M=1.9$ and five values of t_c corresponding to L_c values of 108, 118, 128, 148 and 158 mm (Fig. 10) against F showed that, within the range of F values considered :

1. With t_c ranging from 0.50 to 0.66, the Y_w/R was greater if t_c was greater and attained maximum at greater values of F if t_c was greater ; there was however no maximum if t_c was 0.66.
2. With t_c above 0.66, the Y_w/R increased with increased F without attaining a maximum.

The Y_w/R as a function of t_c with the present F (Fig. 11) showed that maximum Y_w/R was obtained with t_c at only 0.6, whereas the present t_c was 0.98.

It is thus clear that highest yield of *D. russelli*, with the present F or by increasing the same, can be obtained only if the t_c is 0.6. It is also clear, however, that yield can still be increased from the present level, without decreasing t_c, but by increasing the effort, though the yield will be less than when t_c is 0.6.

DISCUSSION

The trawling experiments in the sea off Kakinada in the depth range 5-100 m by Narayanappa *et al.* (1968), Satyanarayana *et al.* (1972) and Satyanarayana and Narayanappa (1972) have shown that *Decapterus* spp. are abundant beyond 50 m depth. According to Muthu *et al.* (1977), the abundance of these fishes during February-April off Kakinada

TABLE 2. *Gonadal condition of adult females of* D. russelli *in different months (data of all years pooled)*

Months	Females examined (No)	% of maturation stages II	III+IV	V+VI	VII
July	—	—	—	—	—
August	22	86.4	4.5	4.5	4.5
September	6	100.0	—	—	—
October	13	100.0	—	—	—
November	—	—	—	—	—
December	41	80.5	14.6	4.9	—
January	157	44.6	32.5	20.3	2.5
February	198	1.0	40.9	54.5	3.5
March	46	15.2	69.6	13.0	2.2
April	9	55.5	45.5	—	—
May	19	63.1	36.9	—	—
June	—	—	—	—	—

may be due to possible upwelling in the region. On the basis of data of 10 year period (1969-'79) it was shown (CMFRI, 1981) that *Decapterus* spp. are abundant in the catches during January-March at Kakinada. The greater returns of *D. russelli* during January-April, as observed in the present study, may be because the boats conduct fishing in the relatively deeper waters during this period.

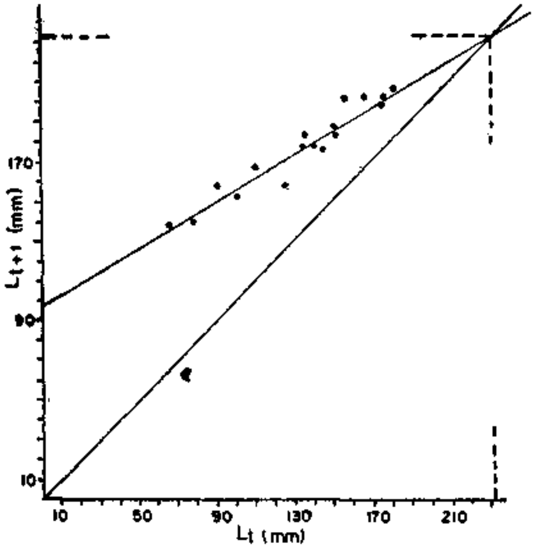

Fig. 4. Plot of L_{t+1} against L_t in *D. russelli* a intervals of 6 months.

It is known (Qasim, 1973) that spawning in majority of Indian marine fishes is prolonged lasting 7-9 months in a year and the present observation on *D. russelli* are in agreement with this. The conclusion on spawning period as December-August is in conformity with the observations of Rao *et al.* (1977) along the Indian west coast: they observed scads with ripe and running ovaries during October-August. The ova diameter frequency distribution in mature and ripe ovaries (Fig. 7) indicates that spawning takes place in two batches during a season. The growth curves (Fig. 3) show that 2-3 broods are recruited to the fishery in different years indicating tha. ova are also released in 2-3 spawnings a yeart Though the data on hand do not give evidence of spawning in three batches in a year, the observations of Rao *et al.* (1977) show that the scad spawns over an 'extended period with two or three peaks in an year'.

TABLE 3. *Estimated values of M obtained by different methods along with the values of* L_{max} *and* t_{max} *in* D. russelli *at Kakinada*

Method adopted		L_{max} (mm)	t_{max} (years)	M
Sekharan (1975)	In the catch:	217	2.4	1.9
Alagaraja (1984)	L_∞-5 mm:	227.3	3.5	1.3
Pauly (1983)	95% L_∞:	220.7	2.7	1.7
Pauly (1980 b)	—		—	2.0

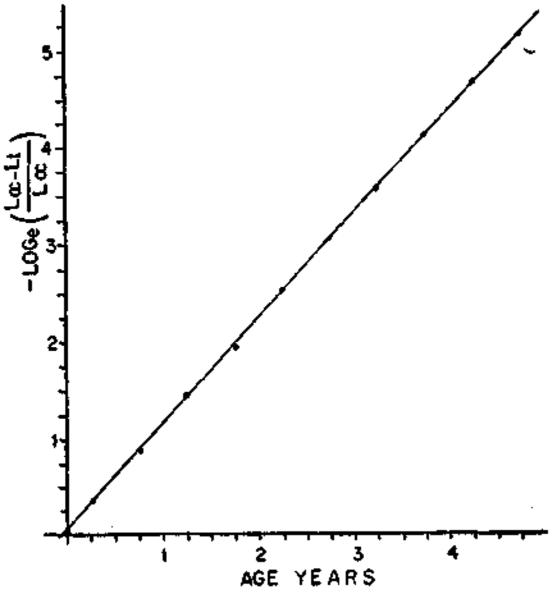

Fig. 5. Estimation of t_0 in *D. russelli*.

From Vizhinjam along the southwest coast, Sreenivasan (1983) estimated the growth parameters of *D. dayi* (=*D. russelli*) as $L\infty = 260$ mm fork length (288 mm TL[*]), $K = 0.74$ per year and $t_0 = -0.13$ year whereas the same

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[*] Sreenivasan (1983) considered fork length only; the total length was calculated from TL-FL relationship given by him.

from Kakinada were estimated as 232.3 mm TL, 1.08 per year and -0.08 year respectively. The length range and maximum length at Vizhinjam (20-219 mm FL or 21-243 mm TL and 271 mm FL or 300 mm TL) are greater than those at Kakinada (52-217 mm TL and 217 mm TL); these differences appear to be responsible for the differences in the estimated values of growth parameters though such differences in growth parameter estimates can also occur (for various reasons) in different stocks of the same species and during different periods in the same stock. Further, the non availability of data in some months (Fig. 2, 3) and the narrow length range in the catch in most months (probably because of size specific shoaling behaviour) which resulted in the data having over 90% of the modal values between 100 and 200 mm (Fig. 3) only, could also possibly have lead to the differences in the growth parameter values.

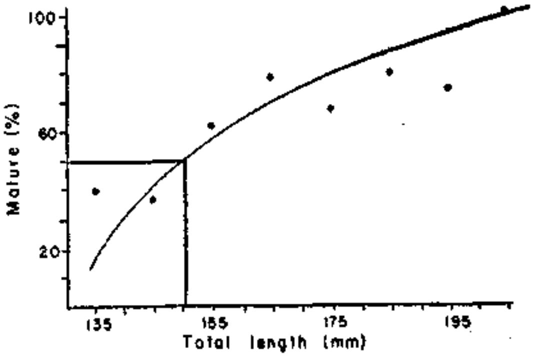

Fig. 6. Percentage of matured individuals of *D. russelli* in each length group.

According to Munro and Pauly (1983) the frequency distribution of the values of ϕ ($\phi = \log K + 0.67 \log W_\infty$) of a particular species from different areas produces normal distribution and that the growth parameter estimates pertaining to a species of a particular area have to be checked, if the ϕ value from that region does not fit into the already known range of normal distribution (obviously assuming that the ϕ values producing the normal distribution have *indeed* resulted from reliable growth estimates). In the case of *D. dayi* (=*D. russelli*) from Vizhinjam, the ϕ value can be calculated as 1.6 (taking different parameter values from Sreenivasan 1982, 1983) and the one from Kakinada as 1.5 which are close to each other.

It is well-known that estimation of natural mortality rate in exploited fish populations is difficult (Cushing, 1981; Alagaraja, 1984). In the absence of knowledge of effective effort pertaining to a particular species in a multispecies fishery, it is not possible to estimate M with the help of the regression of Z against effort. It is also clear (Fig. 8) that Z showed an increasing trend over different years though such a trend is not present in the effort (Table 1) which is due to the fact that the effort is not effective effort for the species. In the present study, the M value was estimated following different approaches (Table 3). In the Sekharan's (1975) method, the value of t_{max} in a virgin stock is required (Sekharan, 1975; however, considered t_{max} in the catch) and this value is not available for the stock of *D. russelli* at Kakinada. Though Alagaraja (1984) suggested that maximum length in a population (to calculate t_{max} value in a 'virgin stock, and to estimate M) could be taken as L_∞ —0.50 cm, the reasons for doing so were not mentioned; it is also not known whether this can be done uniformly for all species having widely varying L_∞ values. Pauly (1983) suggested that L_{max} could be taken as 95% of L_∞ following Taylor (1962). It is, therefore, clear that all these approaches are subjective. Recently Alagaraja *et al.* (1986) estimated M in shrimps 'Assuming that when X% of L_∞ is reached by fish X% of mortality takes place, one gets M/K=1 for all X'. Though these authors have not stated, it is also necessary to assume $t_0 = 0$, as otherwise M/K is not always equal to 1. This approach however, presupposes M/K=1 (which means M=K) whereas the M/K in fishes is known to range from 1 to 2.5 (Beverton and Holt, 1959). The equation of Pauly (1980 b) does not require assumptions or adjustments as above, but according to Pauly (1984 b), the value obtained by this equation 'may be biassed upward in the case of strongly schooling fishes' and therefore this approach cannot be followed in *D. russelli* which is known to form schools. Under the circumstances it is not possible to state which of the methods considered here gives the most satisfactory estimate of M for the species under consideration. The M value obtained by Sekharan's method (Table 3) was taken into account in this study, because the maximum length in the catch was considered as L_{max} without any adjustment; the value obtained this way is only slightly less than that obtained by Pauly's (1980 b) equation and slightly more than that obtained by Pauly's (1983) method (Table 3). The value obtained by Alagaraja's method is, however much smaller than those obtained by other methods.

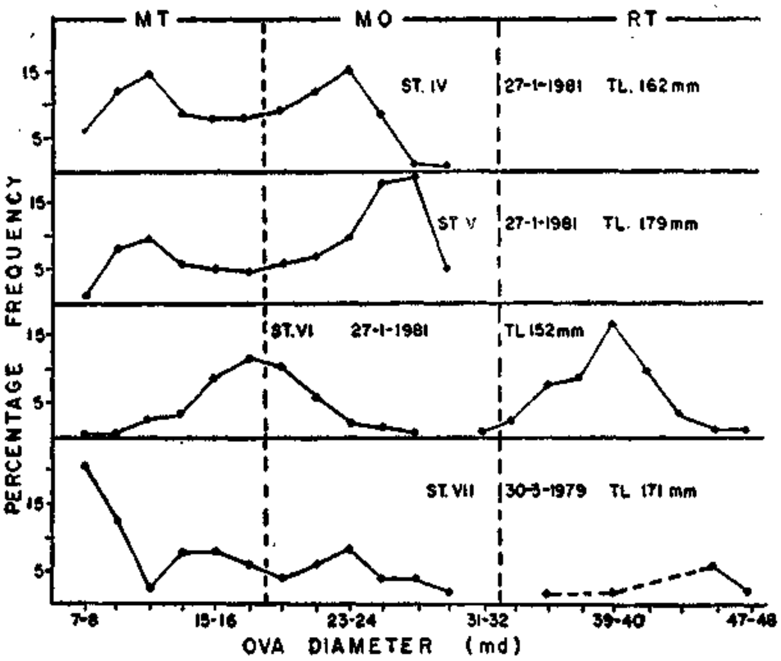

Fig. 7. Ova diameter frequency distribution in ovaries of different stages of maturation. MT, MO and RT indicate the diameter range of maturing translucent ova, mature opaque ova and ripe translucent ova respectively.

The value of L_c at 158 mm as obtained by following Pauly's (1984) method was used in the present study. Taking the depth ratio (standard length/maximum body depth) of this species from Kakinada (as 4.2) and using the nomogram given by Pauly (1983), the selection factor of *D. russelli* can be read as 2.5. Using the cod end mesh size of the gear under use (average 15.6 mm), the L_c value can be calculated as 39 mm which is less than even the length of the smallest fish caught (52 mm). The L_c obtained by the Pauly's (1984) method is therefore much greater than the theoretically possible value. It may be mentioned in this connection, that fishing being prawn-biassed, the effort is not uniformly distributed in the fishing grounds and this can result in the non-representativeness in the catches, of the lengths in the populations of finfishes *i.e.* fishes of certain smaller lengths are not available in areas where fishing activity is concentrated, as otherwise one would expect smaller fishes (smaller than the smallest fish caught) to be retained in the gear in large numbers since the cod end mesh size is very small. This could probably be the reason for the wide difference in the Lc values shown above. It may be argued that since *Decapterus* spp. are pelagic, catches by bottom trawl are not representative of the population. It may not hold good, because the resources surveys conducted by Rao *et al.* (1977) clearly show that the scads are distributed in dense vertically extended schools at or near the bottom during day and ascend to surface layers at night ; according to Lowe-McConnel (1977) also, the neritic pelagic fishes like the scad, have the habit of forming demersal shoals congregating near bottom

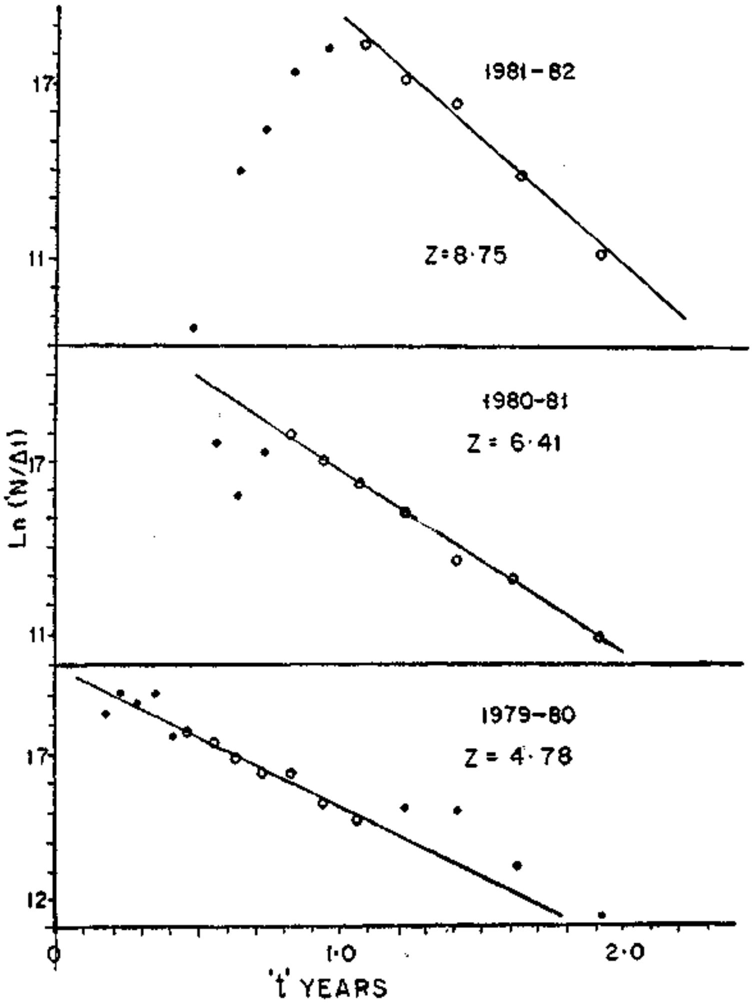

Fig. 8. Length-converted catch curves in *D. russelli* during different years.

depressions by day and moving up to feed at night. It may noted that the trawlers at Kakinada conduct fishing during day time.

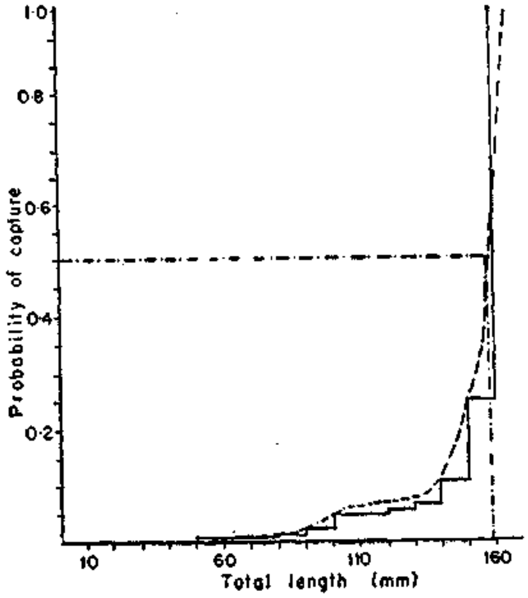

Fig. 9. Estimation of length at first capture (L_c) in *D. russelli* by trawlers at Kakinada.

The non availability of smaller fishes in the presently fished areas could probably be due to the fact that *Decapterus* spp. are more abundant beyond 50 m depth (*Vide* supra) or, as already observed by Rao *et al.* (1977), the current system is such that young scad probably cannot enter the fishing grounds to be captured. The data of different years also show that fishes of the length range 52-89 mm were caught only during 1979-80 and not in other years. Since it is known (Fig. 10) that t_c determines the shape of the yield curve, there is need to determine L_c of *D. russelli* by experimental fishing using commercial gear in areas where it occurs in abundance for any realistic advice on optimum mesh size.

The yield per recruit analysis shows that there is need to decrease the present cod end mesh size and then to increase effort to get increased Yw/R (Fig. 10, 11). In view of the uncertainty, as shown above in the estimated

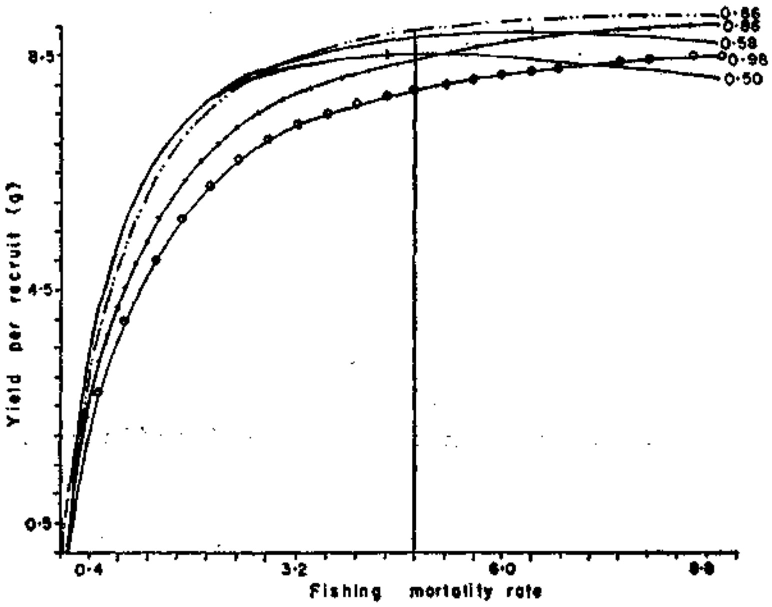

Fig. 10. Yield in weight per recruit as a function of fishing mortality rate in *D. russelli*. The numerals pertain to ages at first capture and the vertical line the present F.

value of L_c in the present study, this regulation should not be implemented. The data of different years show that the smallest modal lengths (excluding the fishes of the length range 52-89 mm caught only during 1979-80) are at 102 and 107 mm. If the average of these two values at 105 mm is taken as the present L_c the present t_c works out to 0.48 year which is almost the same as one of the t_c values (=0.50) considered (Fig. 10). In this case the Y_w/R reaches the maximum at F=4.4 and then declines slowly with increased F, thus indicating that the effort has to be decreased (present F=4.75). The Y_w/R as a function of t_c (Fig. 11) shows that maximum Y_w/R is obtained at t_c=0.6. If the present t_c is indeed 0.5 (as mentioned above) there is scope to increase the cod end mesh size to get increased and sustained yield. Further, (1) since the length at first maturity and L_c are at 150 mm and 158 mm respectively, reduction in mesh size will affect the recruitment adversely and should not be recommended; (2) since the Y_w/R does not attain maximum with increased F at higher levels of t_c (Fig. 10), there is no harm to the stock even if the mesh size is increased. Finally it may be pointed out that whichever may be the optimum mesh size for *D. russelli*, any regulation of mesh size or effort has to take into consideration the possible effect of such regulation on other species since the trawl fishery is a multispecies one.

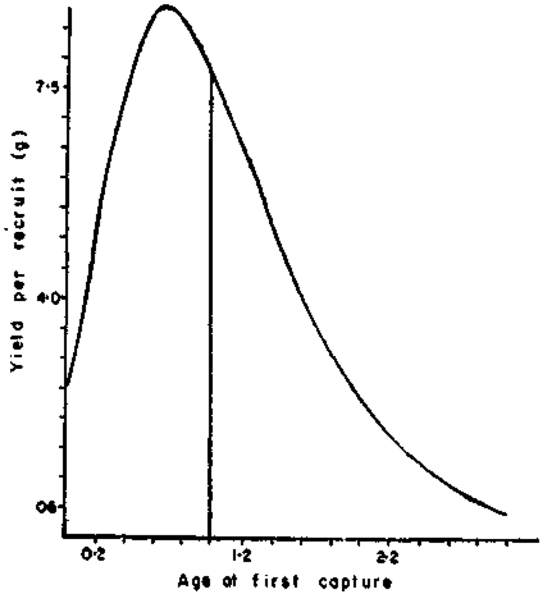

Fig. 11. Yield in weight per recruit as a function of age at first capture. The vertical line indicates the present age at first capture.

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SOME OBSERVATIONS ON THE BIOLOGY AND FISHERY OF THE BANANA PRAWN *PENAEUS MERGUIENSIS* DE MAN OFF ORISSA COAST*

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ABSTRACT

In the context of a hatchery programme for the penaeid prawns, some aspects of the biology of *Penaeus merguiensis* along the Orissa Coast were studied over a three year period (1983-1985) and are presented in this paper. This species is caught both by mechanised boats (trawlers) and the artisanal craft, the catamarans. Postlarval or juvenile population of this prawn were not recorded so far in any of the estuarine creeks or even in the outer channel of the Chilka Lake. Length frequency distribution of the adult prawns sampled from offshore catches showed that generally females exhibited two modes and males one mode in most of the months, during August 1984 to July 1985. The length-weight relationship calculated for females was found to be $\log W = -4.6612 + 2.8239 \log L$. This prawn was found to exhibit strong schooling movements and was active during day and night as exemplified by its catch in trawlers as well as catamarans. The size of the smallest observed mature female was 132 mm. The mean sex ratio of males to famales was 1 : 1.5. Fully mature females were available from May/June to February/March with peak during July-August and November. Successful attempts have been made in developing hatchery techniques for this species based on the knowledge of its biology.

INTRODUCTION

THE BANANA PRAWN *Penaeus merguiensis* De Man, originally considered as a variety of *Penaeus indicus* (Alcock, 1906), is a species of considerable importance in the penaeid prawn fishery off Orissa Coast, India. This species is of commercial importance along the Indian coastline only off Orissa (East coast) and Karwar (West coast). In the general world-wide distribution it is confined to the Indo-Pacific area between longitude 67°E to 166°E and latitude between 25°N to 29°S (Holthuis and Rosa, 1965 ; Kirkega ard *et al.*, 1970).

Elsewhere in the world, the major fishery occurs off the Australian waters in the Gulf of Carpentaria where extensive studies have been made (Dall, 1957 ; Tuma, 1967 ; Hindley, 1975 ; Kirkegaard, 1975 ; Munro, 1975 ; Gwyther, 1980 ; Staples, 1980).

Because of the high contribution (60-70%) of this species to the penaeid prawn fishery off the Orissa Coast and lack of any prior study on this species in India, an attempt is made to study the population, its biology and fisheries. This study is also useful in the context of developing a suitable hatchery technology for this species.

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Fisheries Research Institute, Barrackpore and Dr. K. Alagarswami, Director, Central Institute of Brackishwater Aquaculture, Madras for their interest in this study.

MATERIAL AND METHODS

The basic characters measured for studying the biology were carapace length (CL) (from eye-notch to mid-dorsal carapace edge), total length (TL) (from tip of rostrum to tip of telson) and total weight (measured to the nearest 0.1 g). These data were taken from samples obtained from trawlers as well as catamarans during 1983-1985. Observations on seasonal distribution, sex-ratio, maturity and spawning and fishery were made simultaneously when length-weight data were obtained from samples of trawler and catamaran catches. However, for length frequency distribution data from trawl catches alone were used. Maturity was recorded on the basis of stages already delineated by earlier workers (Rajyalakshmi, 1961 ; Rao, 1968). The catch effort statistics in general were not obtained in this study, because they are being regularly recorded by the concerned organisations. The data given in the reports (Anon., 1982 ; 1983 ; 1986) are however, used to support or interpret the other observations in this study.

For the study on juvenile distribution, commercial drag-net samples from the outer channel of the Chilka Lagoon and the catches received at ice plants were regularly scrutinized. The standard fry collection net (shooting net) operations were conducted during October-January at the mouth of the Chilka Lagoon during 1983-1985 at one place *i.e.* at the 1 m depth zone near the shore line during rising high and receding low tides and once in a continuous 24 hour operation to study the postlarval recruitment and distribution.

The sampling places in general are as follows :

Estuarine phase

Chilka Lagoon, Ramachandi Lagoon, Mahanadi estuarine complex, Rushikulya Estuary, Bahuda Estuary, Bado Noi Estuary (Fig. 1).

Inshore and offshore phase

(5 m - 40 m depth) Catamaran catches at Puri and Paradip. Trawler catches off Paradip, Astharang and Ramachandi (Fig. 1).

Hydrological conditions off the Orissa Coast

The Orissa coastline (480 km in length) extends from 19°06'N to 21°36'N latitude and 84°36'E to 87°30'E longitude. The coast is bisected with a number of creeks connected to the Mahanadi and the Brahmani River systems (Fig. 1).

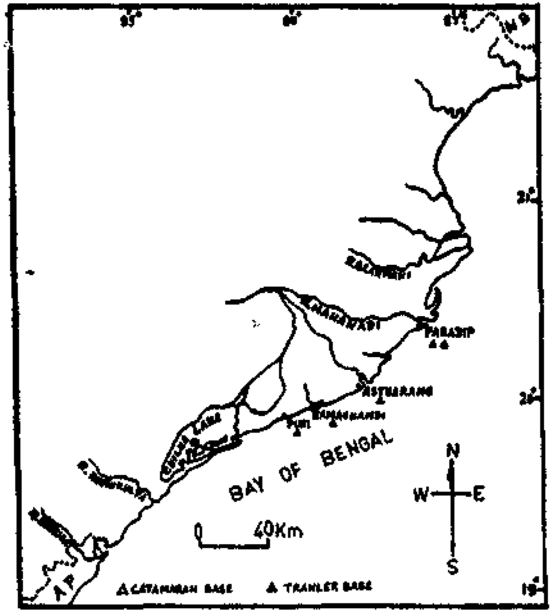

Fig. 1. Coastline of Orissa showing survey and sampling areas.

The waters of the Bay of Bengal are subjected to two important influences. Firstly, several major rivers carrying large amounts of siltladen waters empty into the Bay of Bengal. Secondly, the northeast and southwest monsoon set up 4 distinct patterns in the movements of the surface waters of the Bay during different months of the year (LaFond, 1954). Orissa Coast lies mid-way in this opposing current systems and carries the maximum amount of turbid waters that emanate from the Hooghly Estuary and the Mahanadi complex. It was shown (Rao, 1958) that during the months of November-December the waters are uniformly transparent along the east coast of India. This period also corresponds to the season of maximum prawn landings off Orissa Coast.

RESULTS

Population study

P. merguiensis is caught both by trawling and non-mechanised gill-netting, sometimes in the shallow 10 m zone and extending to a depth of 40 m. Both types of fishing are discontinued when strong winds start blowing from March with strong wave causing entanglement of nets. This suspension of operation extends upto June for trawlers. Therefore for this period there is no exploratory or other type of study to prove if there are any deeper water concentrations of the species in the offshore waters.

Operations of the shooting net revealed the absence of postlarvae in the backwaters or in the outer channel of Chilka Lagoon. Even juveniles below 80 mm were rarely encountered. This fact is further confirmed by the absence of any commercial fishery for marketable sized prawns of this species in the Chilka Lagoon.

Length frequency distribution

The length frequency distribution of females of *P. merguiensis* is shown in Fig. 2 a, for the period from August 1984 to July 1985. The female prawns showed two modes in most of the months. In August 1984, the mode was at 165 mm and this mode remained in most of the succeeding months in 1984 and 1985 (Fig. 2 a). The mode shifted to 225 mm in September and in October it reverted to 175 mm and reached 165 mm in November and remained stable in January 1985 indicating entry of new recruits into the fishery. Sampling could not be done in December. The mode once again moved to 175 mm in February and 185 mm in March. Once again new recruits entered the fishery when the length frequency distribution showed a mode at a

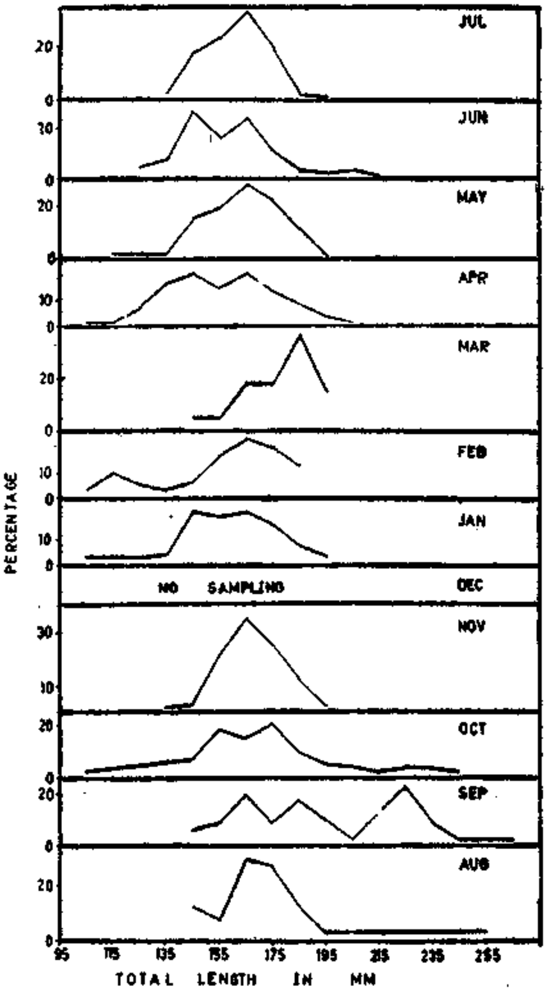

Fig. 2 a. Length frequency distribution of *Penaeus merguiensis* during August 1984 to July 1985 : Female.

smaller length of 165 mm in April and this mode was maintained in May and July. However, in June the length frequency polygon showed a mode at 145 mm.

The length frequency distribution of males is shown in Fig. 2 b. The male prawns showed one conspicuous mode in most of the months except in February and March 1985 when two modes were seen and in April three modes were noticed. The mode at 145 mm in August 1984 progressed to 155 mm in September and remained at that size in October. This further moved to 165 mm in November. The single mode at 145 mm seen in January 1985 was also seen in February in addition to another mode at 165 mm. These two modal sizes remained unchanged in March, but advanced to 155 mm and 175 mm in April. The mode at 155 mm remained in May and shifted to 165 mm in June. In July the modal value was 145 mm as in August of the previous year indicating entry of new recruits into the fishery.

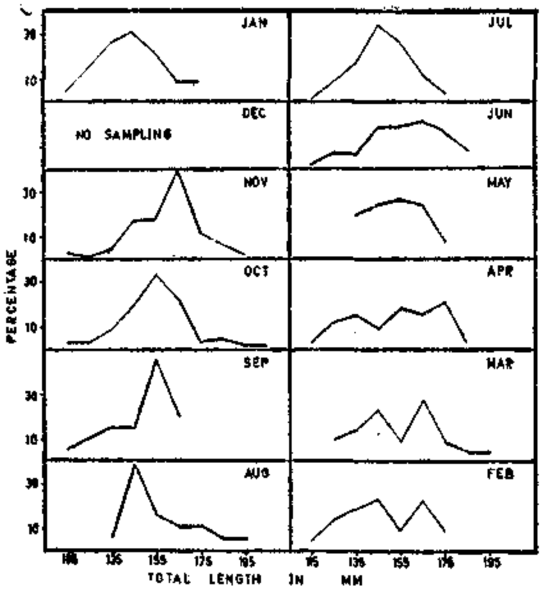

Fig. 2 b. Length frequency distribution of P. *merguiensis* during August 1984 to July 1915 : Male.

Growth rate and life span

The total length recorded from sampling of both trawler and catamaran catches (Fig. 2 a, b) indicated a single peak at 165 mm/45g throughout the season of peak capture. However, the length frequency distribution shows a peak at 180 mm at the maximum length. This picture indicates a short life span of the species.

Basically then, the small size group at 95 mm to 110 mm enter the capture fishery from April onwards and dwindle by July-August. The larger size groups take over from July and continue to dominate the fishery till March of the following year *i.e.*, through summer to monsoon and winter the size group distinction is of the order of ± 10 mm indicating every little variation in the rate of growth. But the maximum difference in size occurs in March entry into the population and constant migration as well. But the population as a whole retains this structure.

The juvenile phase

A distinct *P. merguiensis* juvenile population has not been identified or detected in any of the adjacent nursery areas along the coast of Orissa so far. Dall (1957) has shown that there is a distinctively long rostrum in juvenile phase which progressively shortens with age. Because a similar elongated rostrum occurs in *P. indicus* as well at this phase, it is possible that this phase has not been recorded properly in the collections made from tow nets or drag nets. Alternately, there is also the possibility of the species having no inland nursery areas along this coast line due to the type of hydrological environment of the Orissa Coast.

The immature groups

Commencing from March-April onwards the immature size groups are captured in the inshore coastal waters in the gill nets operated by the catamarans. The size groups vary from 80 mm to 120 mm. This operation is confined to a shallow zone of 5-10 m during day time.

These size groups are rarely seen to have any mature ovaries. The smallest size where a greenish ovary was recorded is at 132 mm, in the shallow region. Later, by July and progressively through winter, those that go into deeper waters at 30-40 m and are captured by the trawlers as well as catamarans, the percentage of females with ovaries in different maturity stages increases as also that of spent females.

Length-weight relationship

The length-weight relationship of the female *P. merguiensis* confirms to the general formula,

$W = aL^n$ or Log $W = \log a + n \log L$

The logirithmic values of observed lengths and corresponding weight were plotted and the straight line fitted (Fig. 3). The equation obtained was as follows :

Females : $\log W = -4.6612 + 2.8239 \log L$

Behavioural characteristics and schooling

Comparing the catches taken during day and night operations of trawlers and the early morning to mid-day operation of catamarans, it is evident that the immature adults and mature adults as well are equally active during day or night. This is in distinct contrast to the tiger prawns *Penaeus monodon*, *Penaeus semisulcatus* and *Penaeus japonicus*, the larger sizes of which are predominantly captured from night operations, from depths greater than 25 m whereas immature adults occurred inshore in 10-15 m probably on their migration towards deeper waters.

The study of catch compositions throughout the season suggested a strong schooling movement of adult *P. merguiensis*. While immature adults appear to be much dispersed along the shoreline as seen from the too few a number captured in each catamaran gear in the near shore waters, the deep water trawls brought in dense quantities of either *P. indicus* or *P. merguiensis*. This suggests segregation of species and schooling in the same fishing ground.

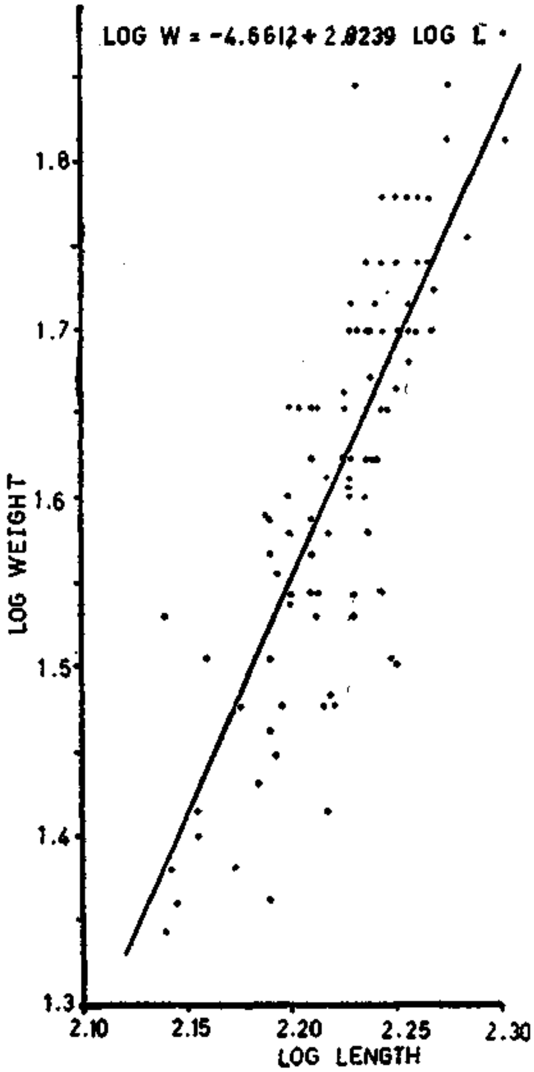

Fig. 3. Length-weight relationship of *Penaeus merguiensis* (female).

However the type of schooling denoted as 'boils' in the Gulf of Carpentaria (Lucas *et al.*, 1979) has not been reported by the fishermen in the Indian waters.

Sex-ratio

In the immature adults and mature ones the sex-ratio showed increasing numbers of females as the size increased. The mean ratio of males to females was 1 : 1.5 combining the data from all the months of occurrence. Monthwise (Table 1) in the mature size groups, the male to female ratio was 1 : 2. This is in distinct contrast to observations made in the Gulf of Carpentaria by Munro (1975) where males were found to be relatively more numerous than females in all the months except January and September. Even when the proportion of females in spent condition increased in the later part of the season (winter to summer), the females continued to be higher in proportion to males.

Table 1. *Sex ratio of* P. merguiensis *in artisanal catches off Puri Coast in* 1984-85

Year and Month		Male (%)	Female (%)
1984			
August	..	31	69
September	..	36	64
October	..	49	51
November	..	63	37
December	..	—	—
1985			
January	..	26	74
February	..	42	58
March	..	37	63
April	..	31	69
May	..	31	69
June	..	37	63
July	..	50	50

This type of distribution suggests either (1) differential growth in sexes, (2) early mortality of males (3) migration of males as compared to females to a different zone after mating, or (4) differential capture by the gear. From the three year study it appears that there is a differential growth in sexes but it is of a small order; maximum-sized males and females differing in length by 30 mm. The third alternative of males migrating away from the fishing zone is deemed not possible because the trawl sweeps across several depth zones. The second and fourth points might have some basis and need further study.

Maturity

A slight variation in the onset and ending of maturity season was observed in this species during each year (1983-1985). A high density of spent females occurred in September 1983 in the nearshore waters. There were smaller size groups in full maturity starting from February to August. The larger sizes overlapped from August onwards and one mass spawning occurred in September. Following this, during the winter months of October-January recovering (I). II and III stages were available together with a large number of spent females. The trend differed in 1984 in that the catches were very poor in February-May period and the incidence of mature females was also poor. Recovery occurred in July/August and continued to be good upto February 1985. During March to July, the catch was poor, but spent recovering and maturing ones were observed in the catches. From August onwards the percentage of mature females increased in the catches and fully mature ones dominated in winter months of October-November. The catch was once again poor in December.

The percentage of females in different stage of maturity from August 1984 to July 1985 is shown in Fig. 4. Except for April to July 1985, in all the preceding months more than 50% of the females were either in immature (I) or spent recovering (V) stages. The stage II and III females increased in the samples during January to April 1985. The percentage of mature females (IV) was greater in catches from May to August.

FISHERY

Vessels and gear

Two types of vessels operate in this area. (i) The mechanised trawler (45-75 hp) and (ii) The artisanal (non-mechanized) craft termed as catamaran. About 200 trawlers operate from the Paradip Port as permanent base and around 30-50 trawlers are 'migratory' and come from other states during the fishing season. These operate from Astharang and recently (1984) from Ramachandi. Trawler operations are primarily for prawns and operate for about 12-72 hours.

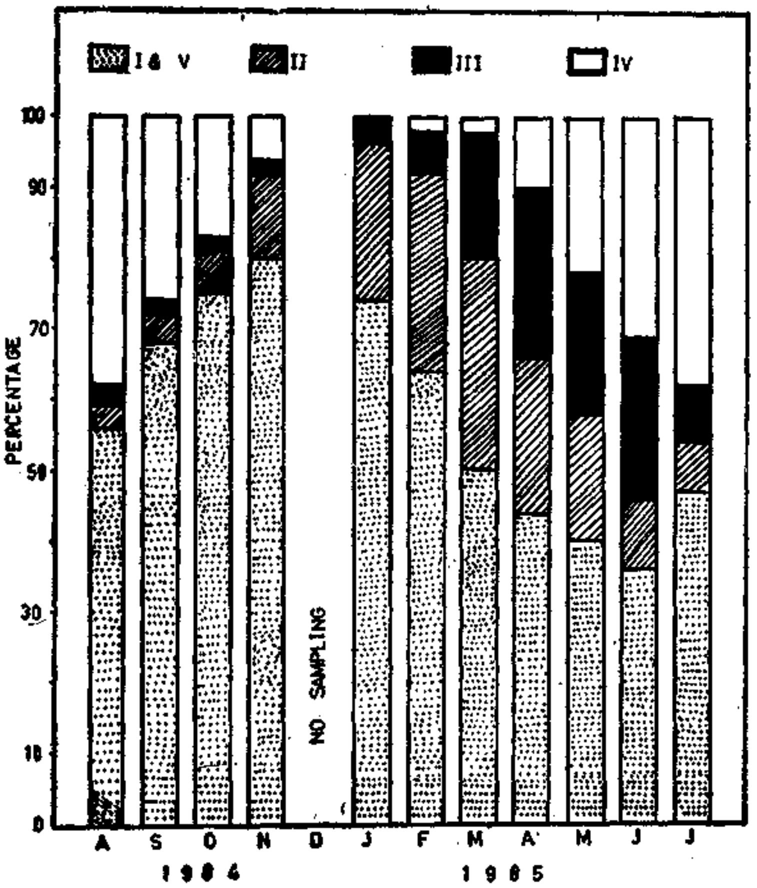

Fig. 4. Monthwise distribution of maturity stages in *Penaeus merguiensis*.

The catamaran is the principal craft of the fishing villages operated by 2-5 men. For prawn fishing, drift gill nets of 5 cm mesh size, 150′ long are operated at a depth of 20-50 m (12-13 km from shore) for the larger prawns and for smaller prawns the depth zone is 15-20 m (6-7 km from shore).

Landings

The total catches of prawns off Orissa Coast was recorded as 2031 tonnes (1982-83), 35% of which was from mechanised vessels (Anon 1983). Species-wise break up of the 1981 prawn catches from both coasts of India gave the landings of *P. merguiensis* as 1096 t which formed 0.8% of total penaeid landings and the other white prawn *P. indicus* at 7,537 t being 5.2% of total prawn landings (Anon., 1982).

Since as shown earlier, abundant capture of *P. merguiensis* is off the coast of Orissa, the landing figure show that a total of 1,328 t of penaeid prawns were landed in Orissa (Anon., 1982). Of these around 60% was *P. merguiensis*, followed by *P. monodon* and *M. affinis*, the smaller quantities of *P. semisulcatus*, *P. iaponicus*, *M. monoceros* and *Parapenaeopsis sp*. This trend was observed during 1983 and 1984 also. During 1983-'84 and 1984-'85 the total penaeid landings off Orissa Coast were 1,940 and 2,519 t respectively (Anon., 1986).

DISCUSSION

The informations available on *P. merguiensis* are from the waters of Australia and Papua New Guinea (Tuma, 1967 ; Munro, 1975 ; Lucas *et al.*, 1979 ; Gwyther, 1980 ; Staples, 1980). In the Gulf of Carpentaria most of the impregnated females were found in waters deeper than 13 m (Munro, 1975) and the greatest number of them were found between the months of March and September (Tuma, 1967). Mating was found to take place in winter and the main spawning season during late winter and early summer (Munro, 1975). In the present studies also maximum number of mature/spent females occurred during winter months of October/November and upto early summer, the first batch of mature females appearing by late monsoon *i.e.* August and late spawners continuing to occur upto early summer *i.e.*, March so that an almost 10 months spawning is indicated as in Australian waters.

Studies from Australian waters (Hynd, 1974 ; Hindley, 1975 ; Munro, 1975 ; Staples, 1979) showed a high correlation in the distribution of this species in juvenile and adult stages between rivers to offshore areas. Juveniles have been found in the estuarine areas of rivers in eastern Australia although much variabiltyi was reported (Hynd, 1974) on their occurrence. In the present studies, however no such relationship of juvenile population to estuarine areas or rivers could be found. Similarly postlarval or juvenile population was not observed even in the outer channel or the mouth of the Chilka Lake which are the high saline areas of the lake water body. However further sampling is very much needed because of factors such as day-night variations, tidal rythms etc., which may obscure their catchability (Staples and Vance, 1979).

Kirkegaard (1975) included this species in what he termed as the mixed cycle species ' with postlarvae and juveniles inshore in waters less than oceanic salinity and adolescents and adults offshore, but there is a particular type in which postlarvae settle in approximately oceanic salinity and juveniles migrate into the lower salinities '. It is also further shown that in this species that one of the explanations for observed fluctuations in the size distribution is the difference in the extent of coastal swamps available during successive monsoon periods. This explanation seems to be applicable to the absence of postlarval juvenile phase in the inshore areas of Orissa which are vastly influenced by the specific hydrological regime of this coast. Regarding the management of prawn fisheries in India, in the recent times a limited ruling has been given on the depth of trawler operations such that the trawlers have been limited to areas beyond 20 m or so where it is supposed that catamarans or other non-mechanised craft do not venture. In fact, the present studies indicate that catamarans at Puri have recently been venturing further and further out, to depths of 30 to 50 m.

With this system which operates on the basis of unlimited entry, the number of trawlers increase overnight by steaming in from the bordering states. It is thus quite impossible to arrive at total capture or capture per unit of effort. Management measures for this type of open entry and unlimited fishing is next to impossibility particularly when it is a multispecies fishery.

In future, a method of monthly returns of catch and effort should be made compulsory from all professional trawlers in operation. Possibly the processing factories also can help in this regard by filing returns by categories which can help to a certain extent in laying down policies.

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A NEW SPECIES OF SCYLLARID LOBSTER *SCYLLARUS TUTIENSIS* (SCYLLARIDAE : DECAPODA) FROM THE TUTICORIN BAY IN THE GULF OF MANNAR

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Abstract

A new lobster *Scyllarus tutiensis* from Tuticorin Bay, Gulf of Mannar is described. The salient characters of the new species are: absence of median tubercles on last thoracic sternum; anterior tooth of inner margin of orbit small and straight; median carina of abdomen not rised; a conspicuous colour spot on mid dorsal line of first abdominal segment partially hidden under carapace.

Introduction

The Family Scyllaridae comprises of sand and mud lobsters commonly known as slipper lobsters. The body is dorsoventrally flat and varies in size between 2 and 40 cm. The broad plate antennae are characteristically short, while the antennules are short and slender. The Scyllaridae consists of six genera widely distributed in the tropical and temperate waters. They occupy different habitats extending from shallow to the deep seas where the bottom is sandy or muddy. The genus *Scyllarus* comprises of small lobsters (Holthuis, 1984), all characterised by less than 10 teeth on the distal segments of the antennae. These teeth are very distinct and wide. Abdominal segments marked by a transverse groove or arborescent narrow grooves without elevated crenulated structures. The adults reach a maximum size of 10 cm.

Thirtyfive species of *Scyllarus* lobsters have been found distributed in the world oceans (Burukovskii, 1974; Williams, 1988). Among that, seven species have been recorded from Indian waters (George, 1967; Prasad and Tampi, 1957, 1969). Out of these, four species have been found distributed in the Bay of Bengal; *Scyllarus sordidus* and *S. rubens* particularly from the Gulf of Mannar. Prasad and Tampi (1967, 1969), Tampi (1973) Prasad *et al.* (1975) have reported the distribution of the phyllosoma larvae of eight species of the genus *Scyllarus* from the Indian Ocean. During our routine cruises of the college research vessel 'Dolphin' a new species of the genus *Syllarus* was encountered off Tuticorin (Lat. 08° 44′ 18″ N; Long. 78° 12′ 54″ E) in the Tuticorin Bay at 10 m depth. This species, hitherto unknown, is described here as *Scyllarus tutiensis* and comparison made with the other two related species of this genus.

Etymology

Tuticorin is a place of fisheries importance for both finfish and shellfish. Spiny lobsters of the genus *Panulirus* form one of the major components of the fishery resources in Tuticorin. The common species are *Panulirus ornatus* and *P. homarus* which inhabit the coral rocky bottom. In between the coral beds there are areas of sand and mud. The occurrence of this new species in Tuticorin Bay is of significance in terms of species diversity in the Tuticorin waters. Hence the new species has been named after Tuticorin. Suggested common name is Tuticorin lobster.

SPECIES DESCRIPTION

Scyllarus tutiensis sp. nov. (Fig. 1 a)

Holotype: Lob. 9. Total length 40 mm. Carapace length 16 mm. female — berried, deposited at the Fisheries College Reference Museum (FCRM) Tuticorin, Tamil Nadu, India, May 1990.

Paratypes: (1) 8 specimens. Total length 30 mm to 58 mm. (2) 2 specimens. Total length 46 mm to 52 mm. deposited in the Marine Biological Station Reference Museum (BSRM) at PortoNovo, Annamalai University in Sonth India.

This description is based on 14 specimens including 8 females and 6 males of total length 30 mm to 58 mm.

Carapace almost rectangular. Eyes not on lateral margin. Dorosmedian ridge (Carina) of carapace with three short blunt spines. Posterior two spines with tuberculate short

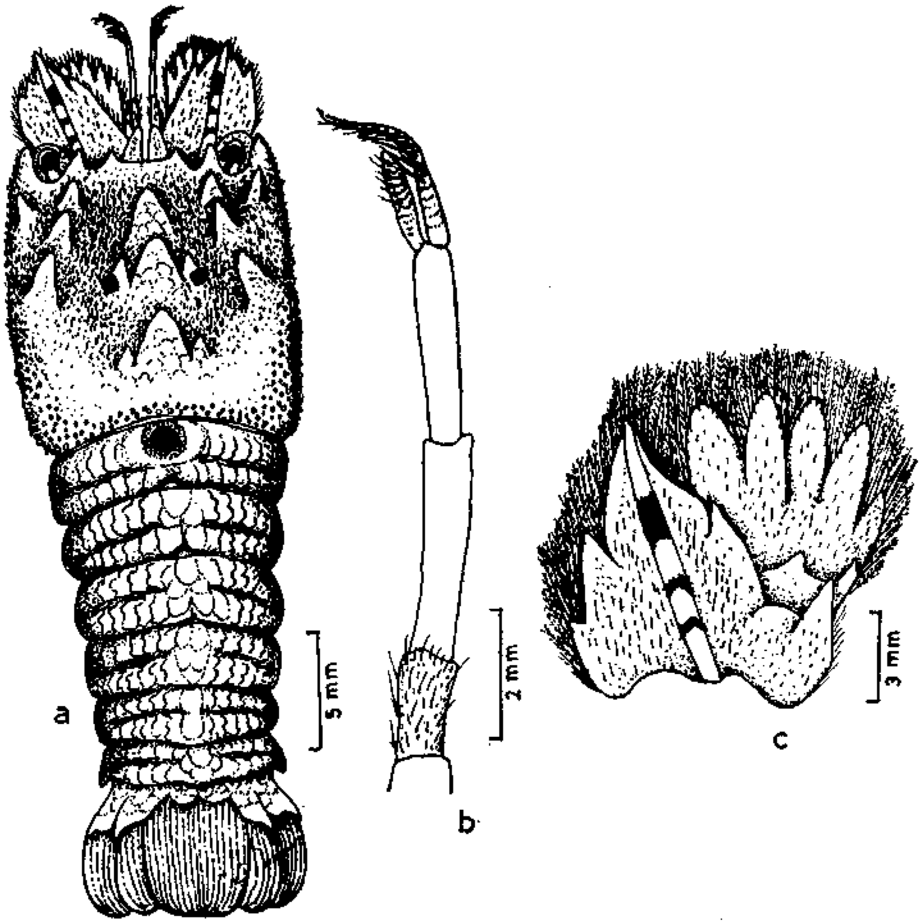

Fig. 1 a. *Scyllarus tutiensis* sp. nov. - Dorsal view, b. left antennule and c. left antenna.

spines on either side. Diagonal row of short blunt spines on anterior half of carapace. Inner anterior orbital spine small and straight. Prominent patches of tubercles on posterior and postero-lateral margins of carapace.

Antennules (Fig. 1 b) short with three elongated basal segments, proximal segment with setae and others smooth. Two short processes one shorter (exopodite) and other somewhat longer (endopodite) and bent outwards, both with long setae. Antennal plates (Fig. 1 c) broad, distal plate with 5 distinct teeth. Margin with plumose setae. Legs without pincers. No tubercle on last thoracic sternum. Short brownish hairs among spines on carapace. Abdomen without distinct carina. Abdominal segments with transverse grooves interrupted at mid dorsal region. Tubercles flat and scale-like on abdominal segments. Short brownish hairs on margins of tubercles and transverse grooves.

Overall colour of carapace and abdomen light brown to dark brown. Distinct colour marking on antennal plates, carapace and abdomen. Carina of proximal antennal plate with one large and two small bluishblack colour bands. A bluishblack colour spot on either side (at base of lateral spines) of middle spine of median carina on carapace. A conspicuous purple round spot encircled by bluishblack and white rings on mid dorsal line of first abdominal segment, partially hidden under carapace. In older specimen, entire spot bluishblack. Legs with alternate brown and white bands.

Distribution : Tuticorin Bay — Gulf of Mannar — Bay of Bengal.

RELATIONSHIP WITH OTHER SPECIES

This species is closely related to *Scyllarus paradoxus* and *S. posteli*, but differs from them in several characteristics.

Scyllarus tutiensis sp. nov. : No median tubercles on last thoracic sternum. Anterior tooth of inner margin of orbit small and straight. Median carina of abdomen not rised. A conspicuous colour spot on mid dorsal line of first abdominal segment, partially hidden under carapace.

A comparison of the characteristics of *S. paradoxus* and *S. posteli* with *S. tutiensis* shows *S. tutiensis* to be distinctly a new species.

Scyllarus paradoxus Miers, 1881 : Median tubercles of last thoracic sternum small. Anterior tooth of inner margin of orbit longer than posterior one. Median carina of abdomen slightly raised.

Scyllarus posteli Forest, 1963 : Median tubercle of last thoracic sternum sharp and curves backwards. In males additional pair of large lateral teeth present. Anterior tooth of inner margin of orbit shorter than posterior one ; median carina of abdomen slightly raised.

Scyllarus tutiensis sp. nov. differs from *S. rubens* (Alcock and Anderson), *S. batei* (Bate) and *S. sordidus* which were recorded from the Bay of Bengal.

Scyllarus rubens (Alcock and Anderson, 1894) : Anternal squmae divided by two oblique crests. Median carina present on abdominal somites II and V. Scaly sculpture on abdomen prominent only on somite VI and on pleura.

Scyllarus batei (Bate, 1888) : Anterior unsculptured part of terga of abdominal somite II smooth and without transverse groove. Propodus of pereopods II and III broad and laterally compressed.

Scyllarus sordidus (Stimpson, 1860) : Rostrum distinctly dentate. Propodus of pereopods II and III slightly compressed. Typical dendroid pattern found on abdominal somites II to IV. Additional transverse groove present between posterior marginal groove of carapace and its posterior margin.

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NOTES

A SIMPLE METHOD OF ESTIMATING TOTAL MORTALITY RATE

Pauly (1983) and Alagaraja (1984) have proposed a variety of approaches for estimating the total mortality rate (Z) using the length frequency data. Ssentogo and Larkin (1973) have estimated Z making use of the probability distribution (*p.d.f.*) of age.

The p.d.f. of t (age) is given by

$$p(t) = Z e^{-Z(t-t_c)} \text{ for } t >= t_c$$

where p (t) is the probability of t

Z = the total instantaneous rate of mortality

t_c = age at first capture

From this, we obtain,

$$V(t) = 1/Z^2 \text{ for } t >= t_c \qquad (1)$$

where V(t) is variance of t

Assuming the growth in length follows von Bertallanfy's Growth Formula (VBGF), we get,

$$t = t_o - 1/K \ln(1 - l_t / l\infty)$$

where, $l\infty$, K and t_o have their usual meaning. Thus,

$$V(t) = (1/K^2)\ V(y) \qquad (2)$$

where V(y) is the variance of $\ln(t\infty\, l_t)$

Substituting (2) in (1) we get,

$$Z^2 / K^2 = 1 / V(y) \text{ for } l >= l_c$$

where l_c is the length at first capture.

Hence $Z/K = 1/s.d(y)$

where, s.d(y) is the standard deviation of y.

The method is illustrated with the following example which is generated with $l\infty = 100$, K=0.5 and $Z = 1$.

Example

Length	Catch
30-35	250
35-40	309
40-45	320
45-50	389
50-55	352
55-60	315
60-65	278
65-70	241
70-75	203
75-80	167
80-85	130
85-90	93
90-95	55

Taking $l_c = 45$ we obtain, s.d(y) = 0.5059 for $l > l_c$ and $Z/K = 1/0.5059 = 1.9765$.

Since K=0.5 we have $Z = 0.5 \times 1.9765 = 0.988$

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ON A NEW RECORD OF *METAPENAEOPSIS TOLOENSIS* HALL (CRUSTACEA : DECAPODA) FROM INDIAN WATERS, OFF THE COROMANDEL COAST

ABSTRACT

The penaeid prawn *Metapenaeopsis toloensis* Hall, 1962 is recorded for the first time from Indian waters and reported in this note. The material has been compared with the previous descriptions and additional characters are described for distinguishing the species from *M. barbata*.

THE PRESENT note is based on the material collected from trawl catches landed at Madras fishing harbour and gives the new known geographic distribution of the species, being recorded for the first time from Indian waters.

The authors are thankful to CSIR, New Delhi for financial assistance and to Prof. K. V. R. Murthy, Department of Marine Living Resources, Andhra University for encouragement and facilities.

Metapenaeopsis toloensis Hall, 1962

Material : Two females with broken rostrum (20 to 21 mm carapace length) and 4 male

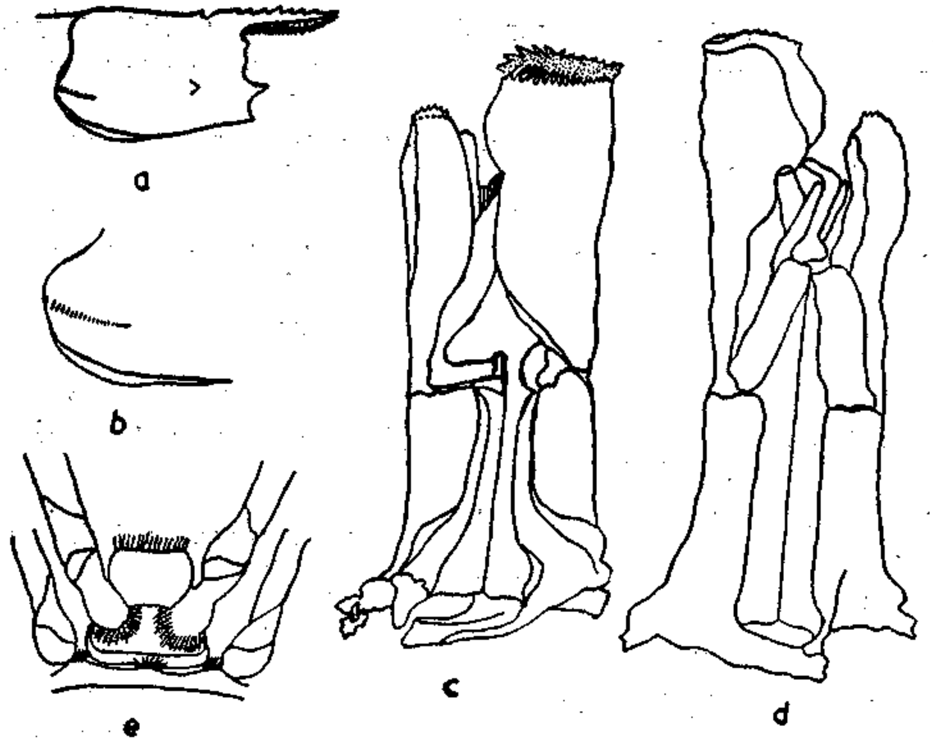

Fig. 1. *Metapenaeopsis toloensis* Hall : a. Carapace in lateral view ; b. stridulating organ ; c. petasma in ventral view ; d. petasma in dorsal view and e. thelycum.

ranging from 88 to 91 mm total length (18 to 18.5 mm carapace length) collected from Madras fishing harbour on 2 December, 1988.

Distribution : *M. toloensis* has been recorded from Sri Lanka and Malaya (Holthuis, 1980), Thailand (Chaitiamvong and Ratana-Ananta, 1974), Sarawak, north coast of Borneo (Bruce, 1965), Hong Kong (Wear and Stirling, 1974) and Cebu, Philippines (Miquel, 1984 a). The present record from Madras fills the gap in the known geographic range of the species from Sri Lanka to Philippines.

Remarks : The specimens agree with the original description given by Hall (1962) and the recent description given by Miquel (1984 b). The carapace, the stridulating organ, the petasma and the thelycum are presented in Fig. 1. The number of rostral teeth and the total length are available only for males as the two females on hand have broken rostrum. All the males possess one epigastric tooth and seven arostral teeth on the dorsal side of the rostrum.

Miquel (1984 b) distinguished *M. toloensis* Hall from *M. barbata* (De Haan) on the basis of differences in the carination of third abdominal somite, in the position of penultimate rostral tooth and in the configuration of petasma and thelycum. The following additional characters have also been found to vary in the two species :

Character	*M. toloensis*	*M. barbata*
Rostrum	Wider in profile ; hardly reaching middle of 2nd segment of antennular peduncle.	Narrow in profile ; reaching tip of 2nd segment of antennular peduncle.
Stridulating ridges	At ¼ depth carapace.	At more than 1/5 depth carapace.
Pereopods	Shorter.	Longer.
1st pereopod	Reaches upto base of carpocerite.	Reaches upto middle of carpocerite.
2nd pereopod	Reaches tip of carpocerite.	Exceeds carpocerite by half the length of chela.
3rd pereopod	Reaches base of first segment of antennular peduncle.	Reaches upto second segment of antennular peduncle.
4th pereopod	Extends upto base of scaphocerite.	Extends upto tip of carpocerite.
5th pereopod	Reaches tip of carpocerite.	Exceeds carpocerite by half the length of dactylus.
Terminal spine of sixth abdominal somite	Blunt.	Acute.

The colour pattern in fresh specimens of *M. toloensis* agrees with the description given by Miquel (1984 b).

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LENGTH-WEIGHT RELATIONSHIP IN THE BIVALVE *ANADARA ANTIQUATA* (LINNAEUS 1758)

ABSTRACT

Investigations were conducted on the hinge length meat weight relationship in *Anadara antiquata* (Linnaeus 1758) collected from the mud flats of Zanzibar, between July 1987 and February 1988. A hinge length frequency distribution with a clear mode at 2.4 cm was observed in a total sample of 980 bivalves used in the investigation. The meat weight frequency distribution was positively skewed and had a peak at 2.2 g. Meat weight and hinge length had a correlation coefficient of 0.9852 and were related by the exponential curve equation : $W=0.23676\ L^{3.1661}$ where W=meat weight, L= hinge length. Meat weight was also found to vary with time.

THE BIVALVE *Anadara antiquata* occurs abundantly in the sheltered coastal mud flats of Tanzania (Matthes, 1974 ; Mwaiseje, 1982 ; Kayombo and Mainoya, 1985). it is an important non-conventional fishery item, constituting over seventy per cent of the bivalves collected (Per. obser.) and has a high potential for aquaculture development (Panikkar, 1966 ; 1976).

In Tanzania, coastal dwellers especially women and children engage in *Anadara* collection particularly during spring low tides. Groups of up to 30 collectors can often be seen along the beaches at low ebb tide. The bivalve is collected mainly to meet family consumption, but occasionally some is sold either fresh or after boiling and sun drying the meat, usually pierced and arranged on wooden spokes.

Studies on *Anadara antiquata* in Tanzania have to-date concentrated on aspects of the ecology and reproduction of the species (Kayombo, 1985). Another study related to this species has been that by Kudoja (1987), who reported coliform bacteria counts in the meat of *Anadara* spp. from Dar es Salaam coastal waters. His studies revealed high coliform bacteria count to the extent that he was of the opinion that bivalves collected from Dar es Salaam beaches should be declared unfit for human consumption as they could easily be a source of diseases.

Yield related studies on the bivalves currently being collected have not been undertaken. Information regarding the sizes and meat content of the bivalves cropped is essential for the determination of current human predation pressure on the bivalve populations, as well as for estimating the molluscan contribution to the annual yield of fish. Such information could indeed also help in the formulation of recommendations regarding appropriate harvestable cockle size for the realisation of optimum yeilds, especially when the fishery becomes conventional, in addition to serving as baseline data for future studies on the growth and sizes of the molluscs.

The author is thankful to Dr. M. A. K. Ngoile for his critical and useful suggestions on the layout of the manuscript and for the technical assistance of Mr. Idrissa A. Omar who patiently assisted in getting the samples; and to Mr. Doudi S. Mukaka for working out the calculations as well as the graphical work.

for eight months (July 1987-February 1988). Effort was made to get the samples as random as possible by buying from a different collector and at a different place everytime, without the collectors having any prior information. This was an attempt to ensure that the samples represented what the collectors naturally collected.

In the laboratory, *Anadara antiquata* was sorted from the rest
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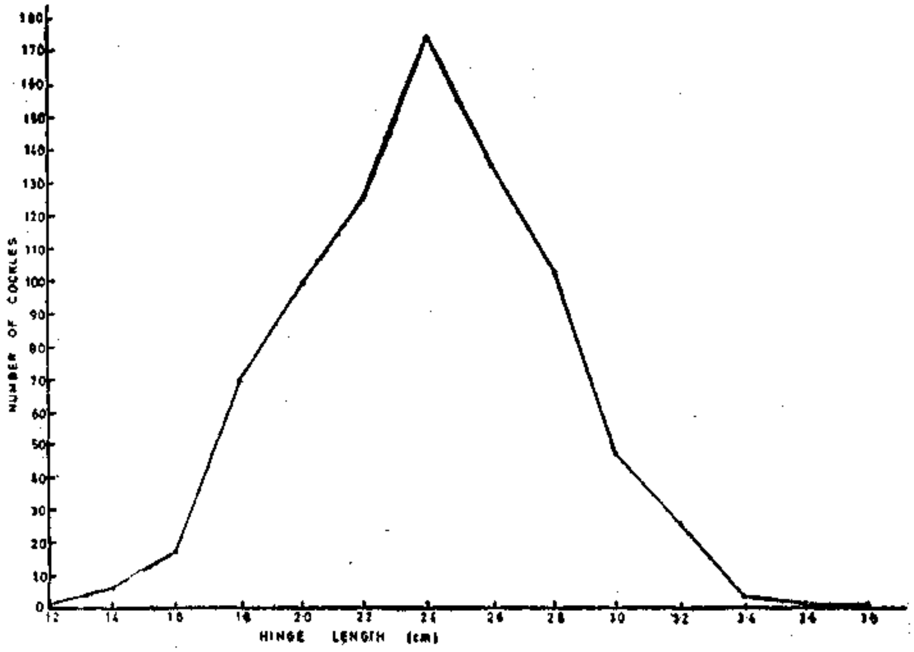

Fig. 1. Size distribution of the cockles.

Material and methods

Samples of *Anadara antiquata* were bought from collectors operating on the beach extending from Zanzibar town southwards to Mbwenj village. Samples were taken twice per month

total wet weight (including the shells); weight of meat (after removing it from the shells and blot drying it); hinge length (the hinge length being the length of the straight edge of the shells on one side of the Umbo).

All the weights were in grams and recorded to one decimal place and were taken using a sensitive electronic balance (Sartorius model). The hinge lengths, taken by means of a vernier caliper were recorded in centimetres to one decimal place. A total of 980 bivalves were examined. From these data, hinge length, meat weight frequency and the length weight relationship were determined.

Results

The hinge length frequency distribution curve was unimodal and more or less normal. The meat weight frequency curve was unimodal, but was also positively skewed. The correlation coefficient between meat weight and hinge length was very significant at 0.9852. Meat weight increased exponentially with hinge length. A time related variation in the weight of meat was also revealed (Fig. 1-4).

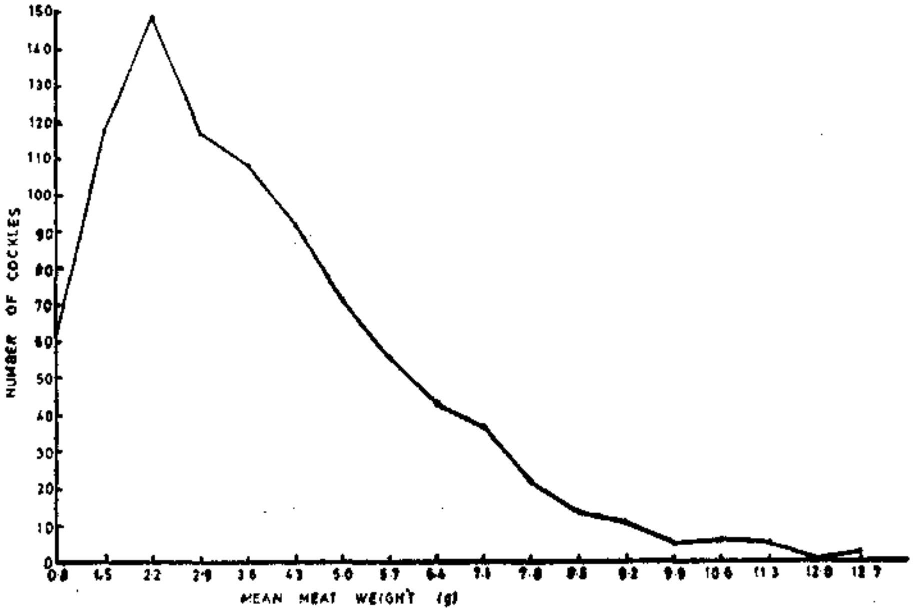

Fig. 2. Mean meat weight of cockles.

Discussion

It can be seen from the results of this investigation that the majority of the *Anadara* collected from this beach have a shell hinge length of 2.4 cm each and it appears (Fig. 1) that exploitation of these bivalves on this beach is not biased with regard to size.

From the meat weight frequency distribution curve it is seen that the majority of the cockles collected have a meat weight of 2.2 g each. This is a small amount of meat compared to the maximum amount of 12.7 g which was observed in few animals (Fig. 2). The positive skew of the curve (Fig. 2) reflects the influence on the mean meat weight of the few large meat weight values observed in the samples. As is shown in Fig. 3, bigger meat weights are obtained by collecting bivalves with a hinge length exceeding 2.4 cm. It can be said however that there were few animals with large meat weights on this beach. Since collectors would naturally not leave large sized cockles, hence bigger meat weights, in preference for small ones, the present collection of cockles with an average hinge length of 2.4 cm (Fig. 1) appears to represent the exploitation of the best available size from the beach. This can also be taken to indicate the low availability of cockles with hinge lengths exceeding 2.4 cm.

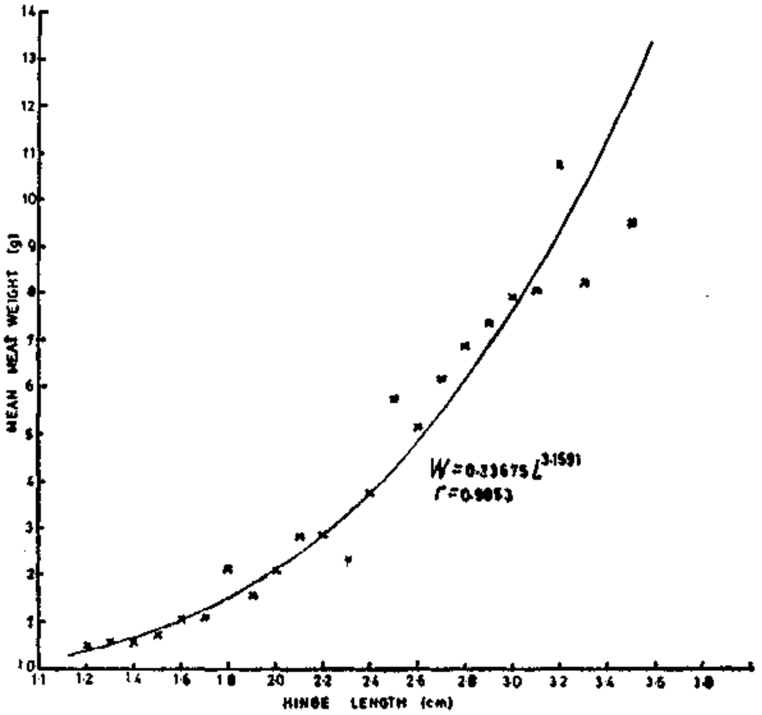

Fig. 3. Length-weight relationship in *Anadara antiquata*.

The scarcity of large cockles was also reflected by the fact that in the whole sample of 980 animals collected and examined during the eight month period of investigation, only about forty cockles had a hinge length of 3.0 cm. The frequency of cockles with a higher hinge length was even lower. It is difficult to explain or point out the reasons for this paucity for large cockles in the area. It is likely that there are factors other than man that operate selectively on the cockles such that certain size groups are removed from the populations. However, neither direct evidence for this was found nor was the search for such evidence part of the current work.

The present work has also revealed that the meat weight of the cockles fluctuates with time. It was seen for instance that bivalve within one hinge length category had low meat weight values during November, but had higher meat weights in January (Fig. 4). It is further seen from Fig. 4, that the months of July to September and December to January represent periods of high average meat weight per cockle. These observations tally with those by Kayombo and aiMnoya (1986), who suggested the periods December, February and May to September as ideal for cockle harvesting, because then the condition index, C.I. (which also reflects the weight of meat per animal) is high.

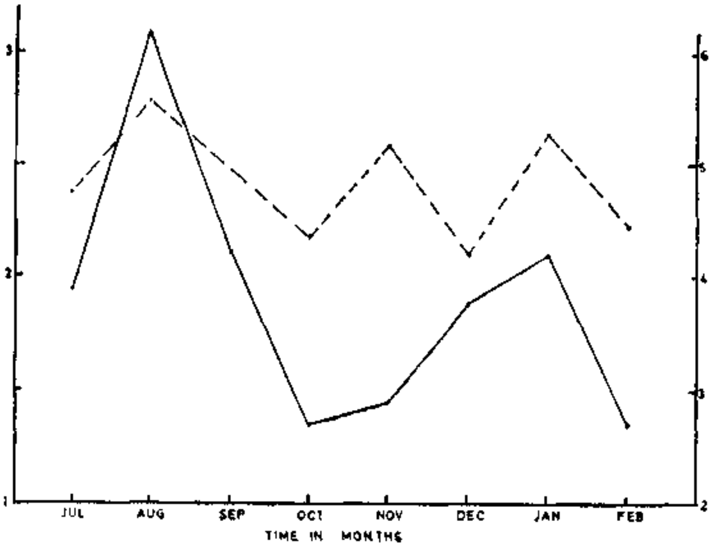

Fig. 4. Relationship between mean meat weight and mean hinge length during different months.

The low meat weight values observed are probably associated with spawning. Mainoya and Kayombo (1986) observed low C.I. in the same species during November and March and which they associated with spawning. Algarswami (1966) suggested that spawning was responsible for marked decreases in percentage edibility in clams and Gonor (1972) also reported losses in body weight of up to 15 g at spawning in marine invertebrates.

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HYDROZOA — AN ECTOCOMMENSAL IN A PENAEID PRAWN

ABSTRACT

Occurrence of an ectocommensal hydroid *Hydractinia* sp. on the carapace of the penaeid prawn *Parapenaeopsis maxillipedo* is reported. The mechanism of relationship between the host and commensal is also explained.

DOCUMENTED reports on parasites and diseases in prawns are limited. With the emerging interest in culture of prawns, greater attention is now being given to the above aspects as infestations due to parasites and diseases affect the growth of prawns in culture systems. Overstreet (1973), who dealt elaborately with the parasites and diseases of prawns, reported the occurrence of a few epizoic forms such as barnacles and hydroids (*Obelia bicuspidata*) on the carapace and abdominal regions of prawns. But the mechanism of relationship between the host and commensals was not explained. The present report explains the ectocommensalic relationship between a commercially important prawn *Parapenaeopsis maxillipedo* (T.L. : 116 mm ; C.L. : 135 mm ; sex : female) collected from the landing centre of Porto Novo (Lat. 11°29′ N and Long. 79° 46′E) and a hydroid *Hydractinia* sp. This commensal was found attached as a cluster on the middorsal line of the carapace of prawn (Fig. 1) which hitherto has not been reported in prawns. Such hydroid colonies may benefit their hosts by protecting them from the predators with their zooids. *Hydractinia* sp. feeds on a variety of organisms (Christensen, 1967) and it drains water to catch organisms

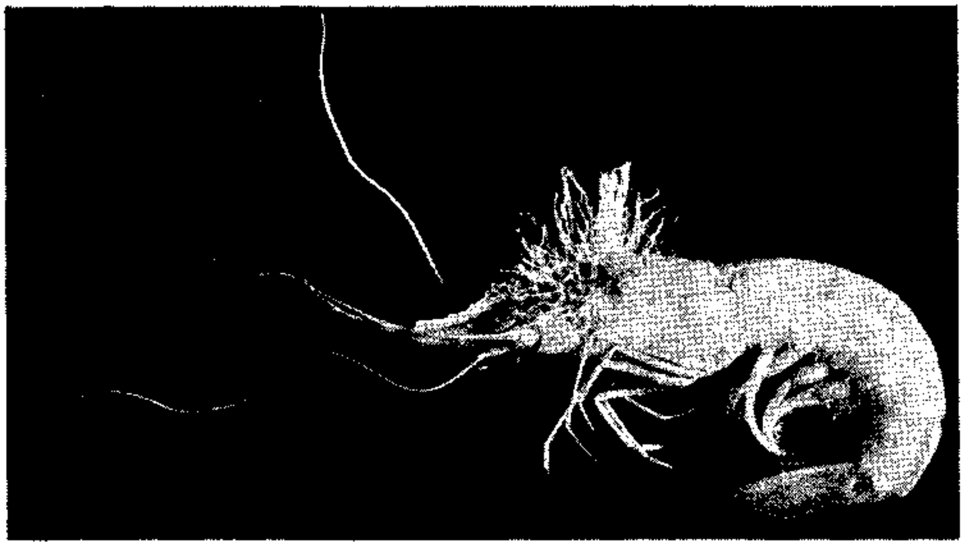

FIG. 1. *Parapenaeopsis maxillipedo* with the ectocommensal hydrozoa *Hydractinia* sp.

from plankton. This may perhaps be shared with the prawn. In turn the hydroid colony which will get smothered by sediments, if it grows in a stationary place, is kept intact by the locomotor activity of prawns. Prawns are omnivorous detritus feeders. They scoop up the bottom with the maxillipeds and legs and select their food. The unwanted materials are sifted above from which the hydroids can collect their food. Ectocommensalic relationship between the hydroid *Hydractinia* sp. and the hermit crab has been reported (Wright, 1973). The basal plate of hydroid was found to be helpful in enlarging the shell. In the same way the basal plate of hydroid colony may induce growth in prawns also. Thus the association between the hydroid and the prawn is of advantage to both the partners, a clear case of true mutualism.

The authors are thankful to late Prof. K. Ramamoorthi, Centre of Advanced Study in Marine Biology, Parangipettai for confirming the identity of the hydroid and to Prof. V. K. Venugopalan, Director of the above institute and authorities of Annamalai University for the facilities.

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PRELIMINARY STUDY ON THE TOXICITY OF FISHES OF CUDDALORE AND PARANGIPETTAI WATERS

ABSTRACT

Among the eight fishes collected from Cuddalore and Parangipettai waters and screened for toxicity tests, three tetrodontiformes exhibited positive results and other fishes belonging to Flat-head, sole fish and another three tetrodontiformes showed negative results. The results obtained from the analyses of different tissues of different fishes are discussed in the present note.

MARINE toxins have been extensively studied in Japan and other developed countries (Tani, 1945 ; Tsuda and Kawamura, 1962 ; Goto, 1964 ; Russell, 1965 ; Halstead, 1967 ; Hashimoto, 1969; 1979; Clarke and George, 1979 ; 500 species of marine fishes are known to be toxic. Studies on marine toxins are very limited from Indian waters. Such studies are immediately warranted as they would pose problems to fishing industry and public health. The present work was carried out to find out the toxic fishes from Cuddalore and Parangipettai waters.

The authors are thankful to the Director, CAS in Marine Biology for providing the facilities and the second author (R.J.) thanks the UGC for the award of Research Associateship.

Material and methods

The fishes were collected from Cuddalore and Parangipettai waters for toxicity tests. The method described by Hashimoto (1979) was followed with slight modifications to prepare the test solutions for toxicity studies. The skin, gonad and liver of the experimental fishes were dissected and minced with 70% ethanol. To this minced tissues 50 ml of 70% ethanol was added and kept in waterbath for 30 minutes at 60 to 65°C. The supernatant was filtered and again 50 ml of 70% ethanol was added to the residue. This process was repeated three times. The pooled supernatant (150 ml) was concentrated to 10 ml in vacuum rotary evaporator. Equal volume of this crude extract and 1% Tween 60 solutions were mixed for emulsification. From this test solution 0.5 ml was injected interperitoneally into male mice weighing 20 gms. A control was maintained by injecting 0.5 ml of 1% Tween 60 without extract. The time of death after injection was noted. Death within 24 hrs, was followed as criteria for toxicity.

Results

The results of the bioassay were given in Table 1. Among the eight fishes screened for toxicity tests, three tetrodontiformes exhibited positive results, other five species including three tetrodontiformes, one flat head and one sole fish showed negative results. Whenever a toxic extract was injected into mice they suffered from suffocation, paralysis of limbs and they urinated and defaecated frequently before they become inactive, probably due to inhibition of nerve conduction (Halstead, 1967). Many species of tetrodontid fishes have been reported to contain tetrodotoxins in their gonads, skin, liver, muscle and intestine. During spawning period the ovaries become more toxic than the liver (Tani, 1945). The appearance and amounts of toxin in the fishes is related to reproductive cycle. The absence of toxins in the ovary extracts of *Arothron stellatus* and *Amblyrhynchotes hypselogenion* may be due to the fact that they were caught during non-spawning season. But the ovary extract of *Gastrophysis lunaris* inactivated the mouse within 20 minutes indicating the presence of more potent toxin in the ovary than in skin. In *Arothron stellatus* and *Amblyrhynchotes hypselogenion*, the skin extracts inactivated the mice within a very short period (16, 22 minutes respectively) than that of the liver extracts. This indicates that the concentration of toxins is more in the skin than in the liver. A detailed study on purification and pharmacological action of tetrodotoxin are in progress.

TABLE 1. *Toxicity of fishes*

Fishes	Skin	Ovary	Liver
Thysanophrys carbunculus (flat head)	—	—	—
Euryglossa orientalis (sole fish)	—	—	—
Lagocephalus inermis (tetrodon)	—	—	—
Arothron immaculatus (tetrodon)	—	—	—
Arothron leoparadus (tetrodon)	—	—	—
Arothron stellatus (tetrodon)	+	—	+
Amblyrhynchotes hypselogenion (tetrodon)	+	—	+
Gastrophysis lunaris (tetrodon)	+	+	—

+ : Positive (lethal)
— : Negative (non-lethal)

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SOME ASPECTS ON BIOLOGY OF *TRACHNOCEPHALUS MYOPS*

ABSTRACT

Size frequency distribution of *Trachinocephalus myops* (Schneider) showed that the species grows 10 mm per month in specimens measuring 70-240 mm. Analysis of stomach contents revealed that teleosts and crustaceans are chief constituents of food, *Leiognathus* sp., *Stolephorus* sp., *Penaeus* sp., *Metapenaeus* sp. and *Solenocera* sp. being the important food items. From the frequency distribution of intra-ovarian eggs, spawning period is taken to be April to June. Generally females dominated over the males in percentage contribution. The ovaries of mature females contained an average of 18,545 eggs.

THE GENUS *Trachinocephalus* belonging to the family Synodidae, is represented by a single species namely *Trachinocephalus myops* (Schneider). Even though the species does not form a fishery of any considerable importance along the coast of Visakhapatnam, it is quite acceptable, both in dry and fresh condition, along with other lizard fishes which comprise 12-13% of total demersal catches. *T. myops* itself contributes 5% of the lizard fishes. A study on of the biology of this species with reference to growth, food and feeding habits, maturity, sex ratio, fecundity was carried out during the period 1986-87 and the results are presented in this paper.

The author is thankful to Shri C. Mukundan for going through the manuscript and also to Shri K. Narayana Rao and Shri M. Chandrasekhar for the technical help rendered during the period.

Material and methods

The material was collected from the catches of private trawlers at the fishing harbour. A total of 2,304 specimens ranging in size from 70 to 240 mm was examined.

Results and discussion

The percentage frequency of various size groups of *T. myops* that contributed to the fishery during the period of April 1986 to August 1987 is given in Fig. 1. It is seen that in April 1986 mode 'a' which is formed at 120 mm could be traced to 170 mm in September thus showing a growth 50 mm during the interval of five months or a growth of 10 mm per month. Further the mode 'b' at 150 mm in May had shifted to 160 mm in June showing the growth of 10 mm in one month. Similarly mode 'c' at 130 mm in August has progressed to 160 mm in November giving the growth of 30 mm during the time interval of three months, thus exhibiting a growth rate of 10 mm per month. In 1987, principally there are two modes, *viz.*, 'a 1' and 'b 1'. The progression of the mode 'a 1' could be followed from 90 mm in January to 110 mm in March. This mode 'a 1' could further be traced at 120, 130, 150 and 160 mm in April, May, July and August respectively thus showing the total growth of 40 mm during the period of four months. Similarly, the mode 'b 1' at 110 mm in February progressed to 130 mm in April and 150 mm in June thus giving a growth of 40 mm in four months or showing a growth rate of 10 mm per month. Thus it could be concluded that in *T. myops*, a growth rate of 10 mm per month could be seen in fishes measuring 70-240 mm.

Qualitative and quantitative analysis of stomach contents of *T. myops* showed that the intensity of feeding was low during June-August and the fish fed mainly on teleost fishes and crustaceans. Among the teleosts *Leiognathus* sp. and *Stolephorus* sp. were dominant and among the crustaceans *Penaeus* sp. *Metapeneus* sp., *Solenocera* sp. and *Squilla* sp. were predominant.

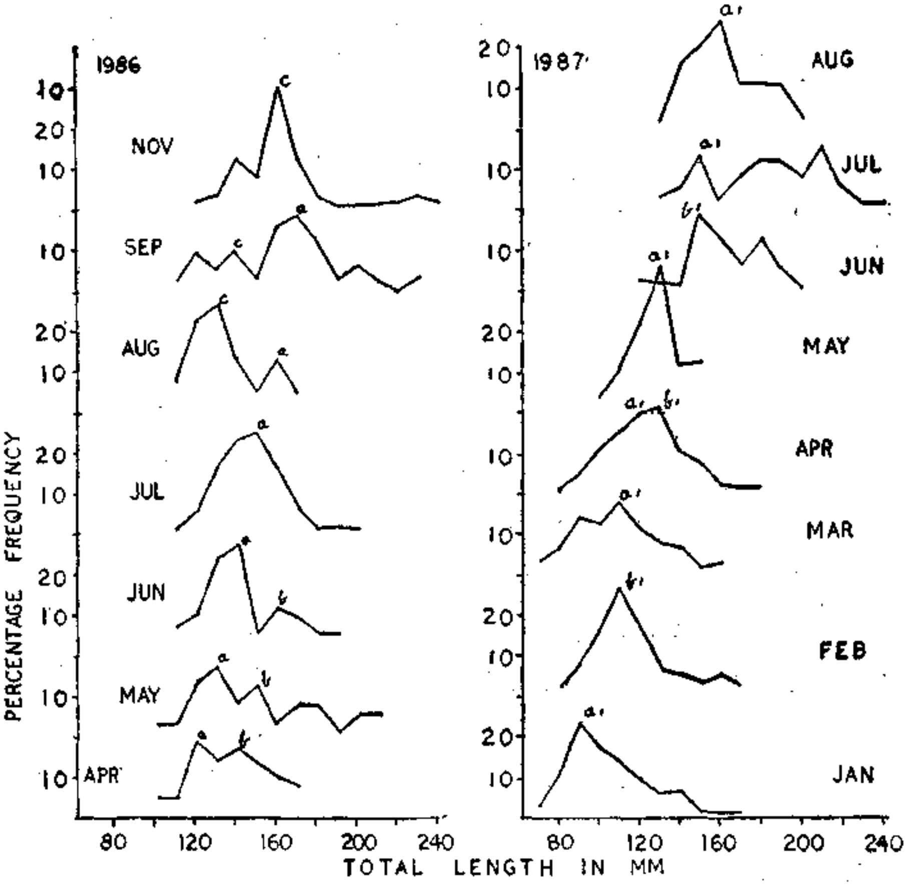

Fig. 1. Size frequency distribution of *T. myops*.

For studying the length weight relationship, 389 specimens of males and females of *T. myops* of length range 100-255 mm were taken for analysis and relationship was estimated by the method of least squares by making use of the formula $W = a\ L^b$ or log a + log L, when W = weight, L = length and a and b constants. The relationship for males and females were studied separately and the equations respectively were :

$$\text{Males}: \quad W = 0.01076\ L^{2.9583}$$
$$\text{or } \log W = -1.9683 + 2.9583$$
$$\text{Females}: W = 0.00779\ L^{3.0633}$$
$$\text{or } \log W = -2.1077 + 3.0633$$

Since there is no significant difference between 'b' values for males and females, a single equation to describe the length weight relationship is derived and it is as follows :

$$W = 0.00104\ L^{3.0662}$$
$$\text{or } \log W = -2.1195 + 3.0662$$

Among females with maturing and mature gonads, it was observed that 50% of fish were mature at 160 mm and above 190 mm all were mature.

Ovaries of mature and spawning fish whose total length ranged from 165 to 244 mm were examined for ova diameter frequency studies and modal progression of ova shown in Fig. 2. The mode 'a' which was formed by maturing ova at 0.3 mm had shifted first to 0.35 and later to 0.4 mm as shown in Fig. 2 b, c, thus showing the growth in size of ova. Similar increase in size of maturing ova is also depicted by the ova falling under 'b' from 0.34 mm to 0.4 mm (Fig. 2 a, b).

In Fig. 2 c is shown the frequency polygon of maturing and fully ripe ova from the ovary of fish of total length 202 mm, which was obtained in May 1986. The mode 'b' formed by the maturing ova at 0.35 and 0.4 mm (Fig. 2 b) had shifted to 0.40 and 0.45 mm and ova falling under mode 'C' at 0.45 mm had also progressed to 0.5 mm. The ova falling under this mode are fully ripe and transparent with distinct oil globules. These are separated from the rest of eggs and are under process of spawning. Since mature and spawning fish are available during the period of April to June and spent fish during July, it could be concluded that the spawning period of *T. myops* is not prolonged and extended from April-June.

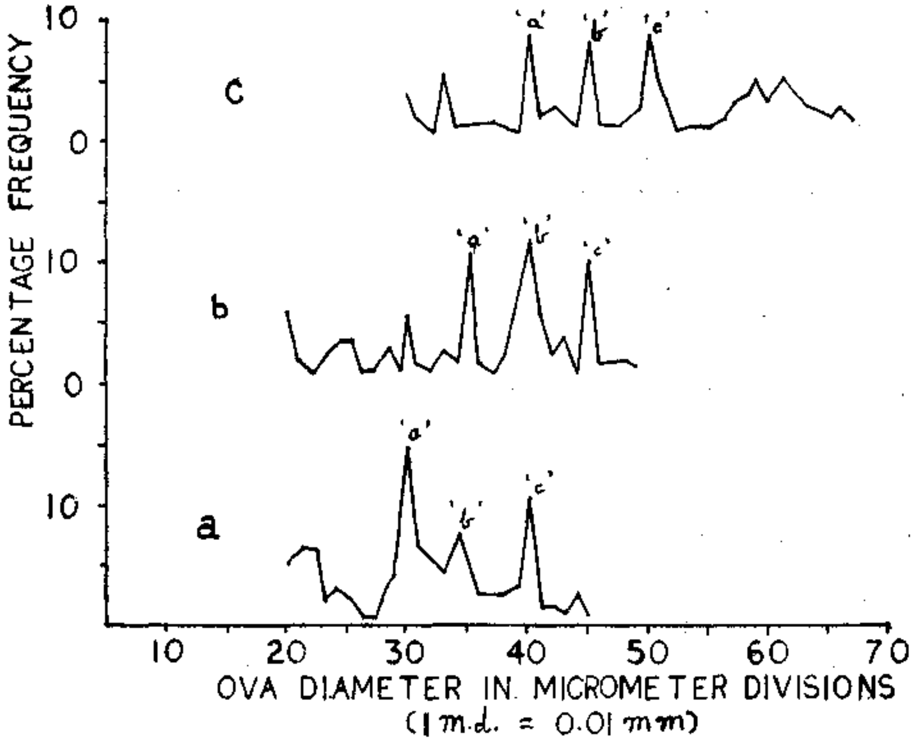

FIG. 2. Frequency polygons of ova diameter in *T. myops*.

Studies on sex ratio showed that during the period April 1986-March 1987 excepting in

May 1986, November 1986, January 1987 and February 1987 females dominated over the males in percentage contribution.

Mature specimens whose total length ranged from 165-244 mm were examined to study the facundity. It was estimated that the mature ovary contained an average of 18,545 eggs.

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EYE OPACITY AND FIN EROSION AMONG FISHES FROM VISAKHAPATNAM HARBOUR WATERS

Abstract

Opacity of eye was confined to *Mugil cephalus* only (23.2%) while fin erosion was observed in several species — *Liza macrolepis* (36.1%), *Rastrelliger kanagurta* (39.1%) and *Sardinella longiceps* (63.4%) including *M. cephalus* (20.3%) from harbour waters of Visakhapatnam. The presence of pollutants in form of heavy metals, and oil and grease at toxic concentrations might be the cause for these abnormalities.

Pollution arising from domestic and industrial wastes is known to impair and debilitate the biota in any water system. In fish populations not only debility but physical deformities of different kinds also seem to be manifested with species specific variations. In the case of other organisms which are lowly organised the physical deformities are not likely to be so manifest as in fishes. Thus, the physical deformities in fishes serve as biological indicators of the degree of pollution of a water system. Various substances enter the natural waters at seemingly sublethal levels and the usual *in vivo* toxicity tests may not reveal the harmful effects of pollution at these sublethal levles. Occasional fish kills and disease prevalence are found under conditions of extreme deterioration in addition to the presence of pollutants at sublethal levels. Such observations act as a late eye opener to the degree of deterioration of a water systems. The present report deals with the frequency patterns of deformities in the fishes from the harbour waters of Visakhapatnam.

Visakhapatnam harbour is a receptacle of city's sewage and effluents from several industries (Satyanarayana *et al.*, 1985). Since the growth of the industries has been on the increase for the past two decades, there is ever increasing accumulation of pollutants in Visakhapatnam harbour, which is more or less a closed system except for ineffective tidal flushings. Industrial effluents enter the harbour at station 2 (Satyanarayana *et al.*, 1985) (Northwestern arm of Visakhapatnam harbour), where fish were collected by doing experimental fishing with boat seine. Species specific deformities or abnormalities were often encountered in these fish collections.

Opacity of the iris and adipose covering of the eyes of grey mullet *Mugil cephalus* (Pl. I A) was observed in 13 out of 56 fish (23.2%). This was predominant in fishes of larger size group (>30 cm). This abnormality, which was reported earlier (Steucke *et al.*, 1968; Dukes *et al.*, 1975) in culture fish was attributed to nutritional deficiency. Since there is

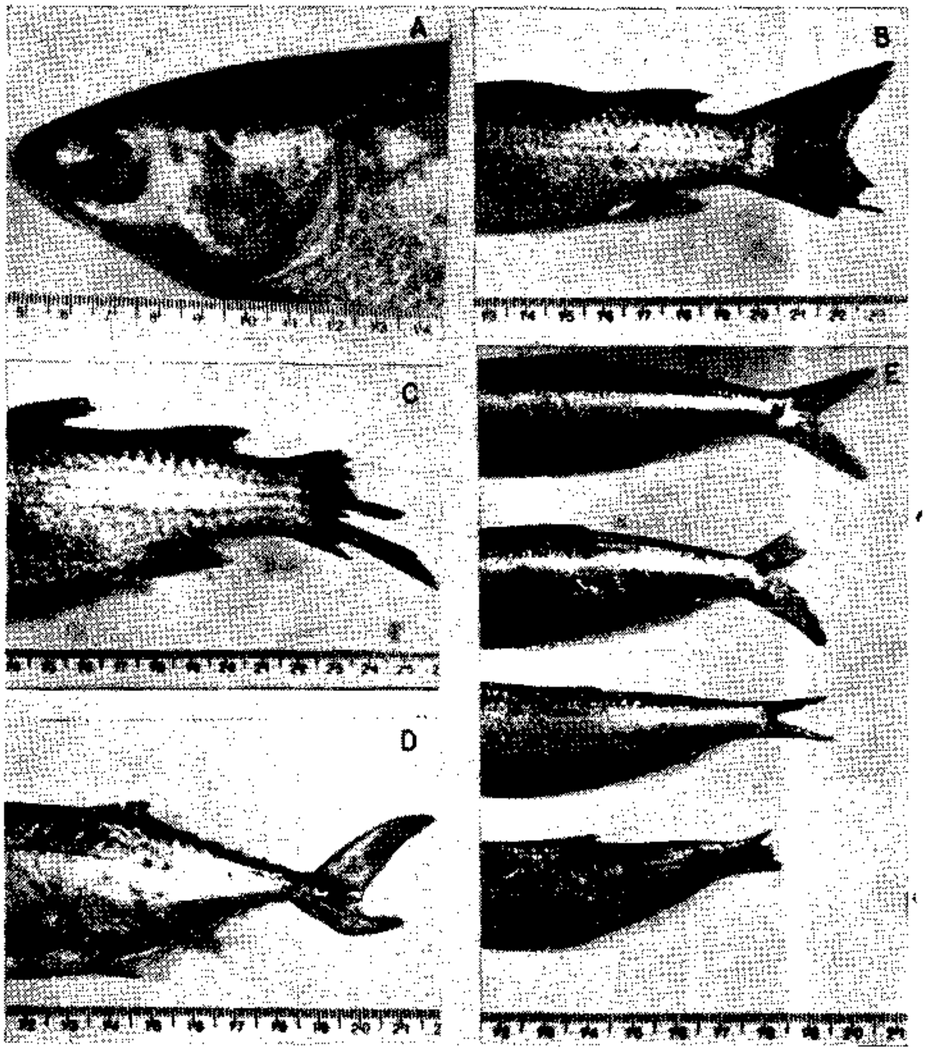

PLATE I A. Opacity of the iris and adipose covering of the left eye of *M. cephalus*. Tail fin erosion : in B. *M. cephalus*, C. *L. macrolepsis*. D. *R. kanagurta* and E. *S. longiceps*. N - Normal fish.

no dearth of food for *M. cephalus* (detritus feeder) in the harbour, the abnormality may be attributed to insidious biochemical changes due to pollution of the medium in which they live.

The abnormality that dominated among many species was tail fin erosion. This occurred in *M. cephalus* (Pl. I B) in 12 out of 56 fish (20.3%) and *Liza macrolepis* in 13 out of 36 fish (36.1%). In one *L. macrolepis* (Pl. I C) almost the whole of the tail fin was eroded. In 18 out of 46 (39.1%) mackeral *Rastrelliger kanagurta* caudal fin erosion was observed. Regeneration of the eroded tail fin was seen in one mackeral (Pl. I D). Maximum incidence (63.4%) of caudal fin erosion was recorded in oil sardine *Sardinella longiceps* (in 1,350 out of 2,130 fish), showing a size related degree of erosion (Pl. I E). In the small size group (9 cm) the erosion was at its maximum, with a gradual decrease of erosion in relation to increase in size, until in the largest size (13 cm) collected from harbour, the caudal fins of all fish were normal (Pl.I E). Nevertheless, schools of *S. longiceps* inhabit the polluted harbour waters of Visakhapatnam especially during the summer months (April to July).

A detailed study on fin erosion in different species was made by Cross (1985) near Southern California municipal waste-water outfalls. He observed fin erosion in about 24% of 122 species of fish and in 9% of more than 1,70,000 individuals collected over a period of 12 years. He states that the magnitude of contamination and incidence of fin erosion are directly related. In the present study, the contamination of the harbour waters of Visakhapatnam is found to be on the increase over the past two decades, but the fish abnormalities are found since 1986 only. The levels of concentration (ppb) of the toxic elements in the harbour surface waters at station 2 by 1986 are quite high (Cd : 20 ; Pb : 50 ; Cu : 20 ; Mn : 10 ; Ni : 20 ; Zn : 1,600 ; Fe : 11,000 ; Co : 10 ; Oil and grease : 43,000) according to Dr. N. Someswara Rao and T. N. V. Venkateswara Rao, Analytical Chemistry Section, School of Chemistry, Andhra University (Per. Comm.). As the concentrations of these elements in the harbour waters are likely to be on the increase, it is necessary to keep a watch not only on the harbour water fishes, but also on the coastal fishes in the vicinity of Visakhapatnam.

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STUDIES ON REGENERATION IN TWO SPECIES OF *RHIZOPHORA* UNDER LABORATORY CONDITIONS

Abstract

An attempt is made to study the Regeneration and growth performance in two species *Rhizophora mucronata* and *R. apiculata*. In this investigation on the *Rhizophora* plantation with propagule cutting was carried out and to decide the proper depth of plantation of propagule an experiment was designed.

Mangrove vegetation is a peculiarity of the estuaries in Maharashtra. In some of the mangroves seed germination takes place on the mother plant itself, this phenomenon is commonly known as viviparity. The seedlings thus formed are termed as propagules. The propagules after maturation drop down in the muddy soil and get established naturally. However, in present-day artificial regeneration of mangroves has become a need, because of lot of human pressures on the ecosystems. The mangroves all along the coastal line are degrading very fast due to human activities. It is observed that some species are disappearing because of over exploitation.

With this background an attempt is made to study the regeneration in two species of *Rhizophora* and plantation with cuttings obtained from propagules was carried out under laboratory conditions and to decide the proper depth of plantation of propagules, an experiment was designed.

Material and methods

The mature propagules of *Rhizophora mucronata* Lamk. and *R. apiculata* Blume were collected from Ratnagiri in April and May. Only the mature, healthy and unaffected propagules were selected and were carried to the laboratory. For the cultivation by cuttings, the cut was taken transversely as well as obliquely (Fig. 1 a). Both upper and lower, pieces were planted in separate polythene bags. To study the plantation depth. the propagules were planted with ¼ part of propagule burried in the soil and for deep plantation only narrow portion of propagule was kept on the soil. (Almost half the length) (Fig. 1 b).

Rooting of propagule was also observed under water culture. For this experiment, radicular end of propagule was dipped in the fresh water and rooting and other characters were studied. The water was changed once in a week.

Results and discussions

In India work on mangrove seed germination has been reported by Bharucha and Shirke (1947), Joshi *et al.* (1972), Jamale (1975) and others. It has been reported by Watson (1928) that members of Rhizophoraceae do not coppice when ordinary cutting practices are used. Therefore, according to him, forest regeneration became a matter of seed production and dispersal.

Table 1 gives the performance of the upper portion of the propagule which is having a plumule part, after 18 weeks of plantation in soil. The survival is cent per cent except for that of *R. apiculata* with transverse cut (80%). Though the two leaf condition is observed more frequently in the obliquely cut propagules the leaf length and breadth of *R. mucro* *nata* and *R. apiculata* is more in transverse cut propagules.

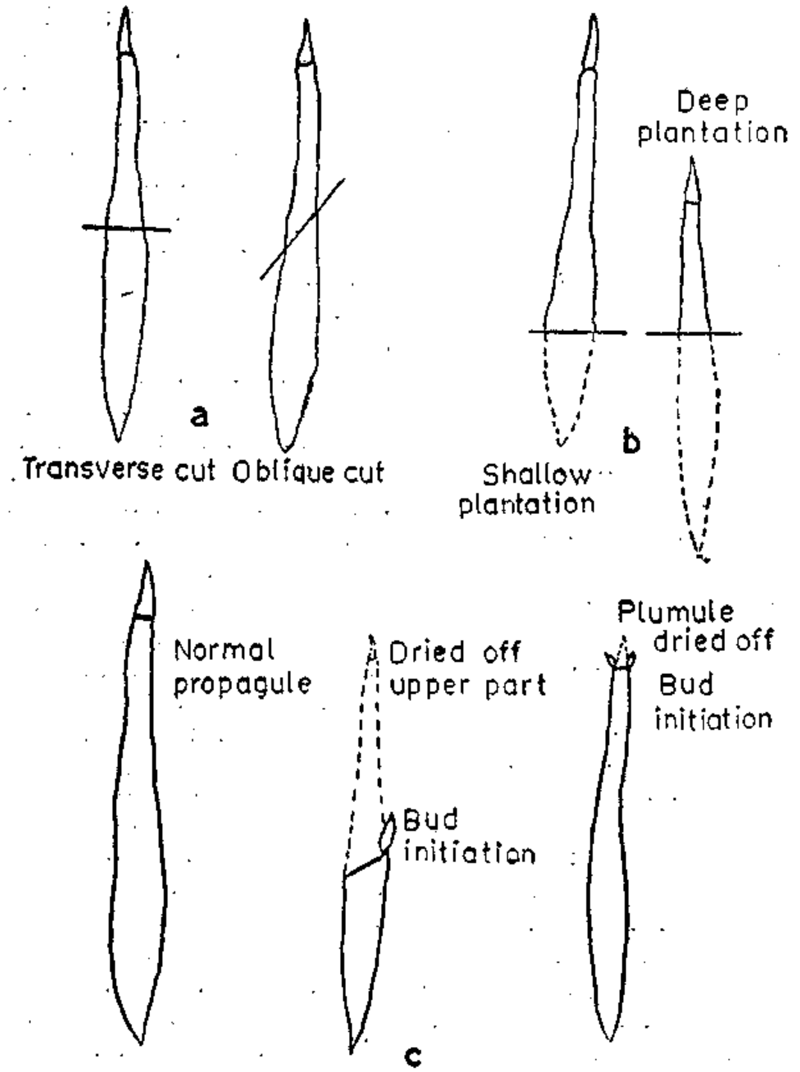

FIG. 1 a. Type and position of cut taken on the propagule, b. depth of plantation of the propagule and c. diagrammatic presentation of sprouting in *Rhizophora* propagule.

The second half of the cut propagule was separately planted in soil with cut surface exposed and tappering radicular end burried. These cuttings are alive and produce buds along the top edge of the propagule. This is observed in the oblique cut lower part of *R. apiculata* propagules within 19 weeks (Pl. I A). However, this type of sprouting is expected in *R. mucronata* bit later.

It is found in one year plants that even though the upper portion of propagule is dried due to some reason, sprouting still takes place from some point on the hypocotyle region. It is interesting to note that if some part from

Table 1. *Physical properties of* Rhizophora mucronata *and* R. apiculata *propagule cuttings after* 18 *weeks of growth*

		R. mucronata	*R.apiculata*
Living cuttings (%)	O	100	100
(Survival Tare)	T	100	80
Cuttings with 2 leaves (%)	O	80	100
	T	60	80
* Leaf length (cm)	O	3.92± 0.8	3.78± 1.3
	T	4.12± 0.6	4.26± 0.8
* Leaf breadth (cm)	O	1.68± 0.5	1.80± 0.45
	T	1.96± 0.3	2.06± 0.2
* Total height from collar (cm)	O	4.4 ± 1.6	4.98± 2.35
	T	5.16± 2.4	6.37± 2.8

O — Oblique cut
T — Transverse cut
* — Average of Five replicate

plumular end dries/dies when propagule is not still established into the seedling, hypocotyle acts as a stem (mature) and produces buds which sprout to give rise to shoot. This kind of sprouting is important because it shows potentiality of the species to coppice. Though Watson (1928) could not observe, coppicing a cutting of *Rhizophora, Bruguiera Kandelia* and *Ceriops*, present study shows coppicing is possible with cuttings from propagules. The Plate I B and C records that if the plumule part is dried off the bud initiation takes place from the collar region (Fig. 1 c). Some times more than one buds are developed. It is a common phenomenon in many angiosperms that if terminal bud is removed apical dominance is lost and axilary buds start developing. However, this kind of observation in very sensitive plants like mangrove is especially important from the point of view of establishment of the species.

Further the attempt was made to study hydroponic culture of *R. mucronata* propagules indicates that rooting occurs in intact (not cut) propagules as well as lower portion cut in both ways (transversely and obliquely). However, the upper portion with plumular end, shows late initiation of rooting. The root initiation is observed within 2 weeks. The secondary roots are initiated within 7 weeks and leaf unfolding is recorded in about 10 weeks. It should be noted here that the propagules of *R. mucronata* can be preserved for later use upto four-five months or even more. This is done by keeping the lower portion of the propagule in moist conditions (may be wrapped in moist gunny bag, etc.). The radicle produces small roots, but the terminal bud remains dormant. These can be planted. This experiment is conducted with fresh water. Davis (1940) reported that *R. mangle* propagules can be kept alive for a year by submerging in sea water. Nevertheless, Tease (1979) reported that in this type of experiment conditions became anaerobic within a few weeks. Further he pointed out that not roots developed in years time. From this point of view present finding is important. These experiments suggests that rooting potential is very high especially in *R. mucronata*. This shows very high reproductive capacity of the species, but the further growth of the seedling is affected due to some external ecological factors in natural environment.

Depth of plantation of propagule in the substratum is also an important character in the artificial regeneration technique. Depending upon the softness of the substratum the depth of penetration of propagule in the mud varies. So as to judge the effect of the depth of plantation on seedling growth an experiment was designed. Deep planted propagules of the *R. mucronata* and *R. apiculata* shows good performance (Table 2). First leaf pair unfolding is observed within a month, but the shallow planted propagules take more time for leaf unfolding. It appears that for better shoot development deep plantation is more suitable.

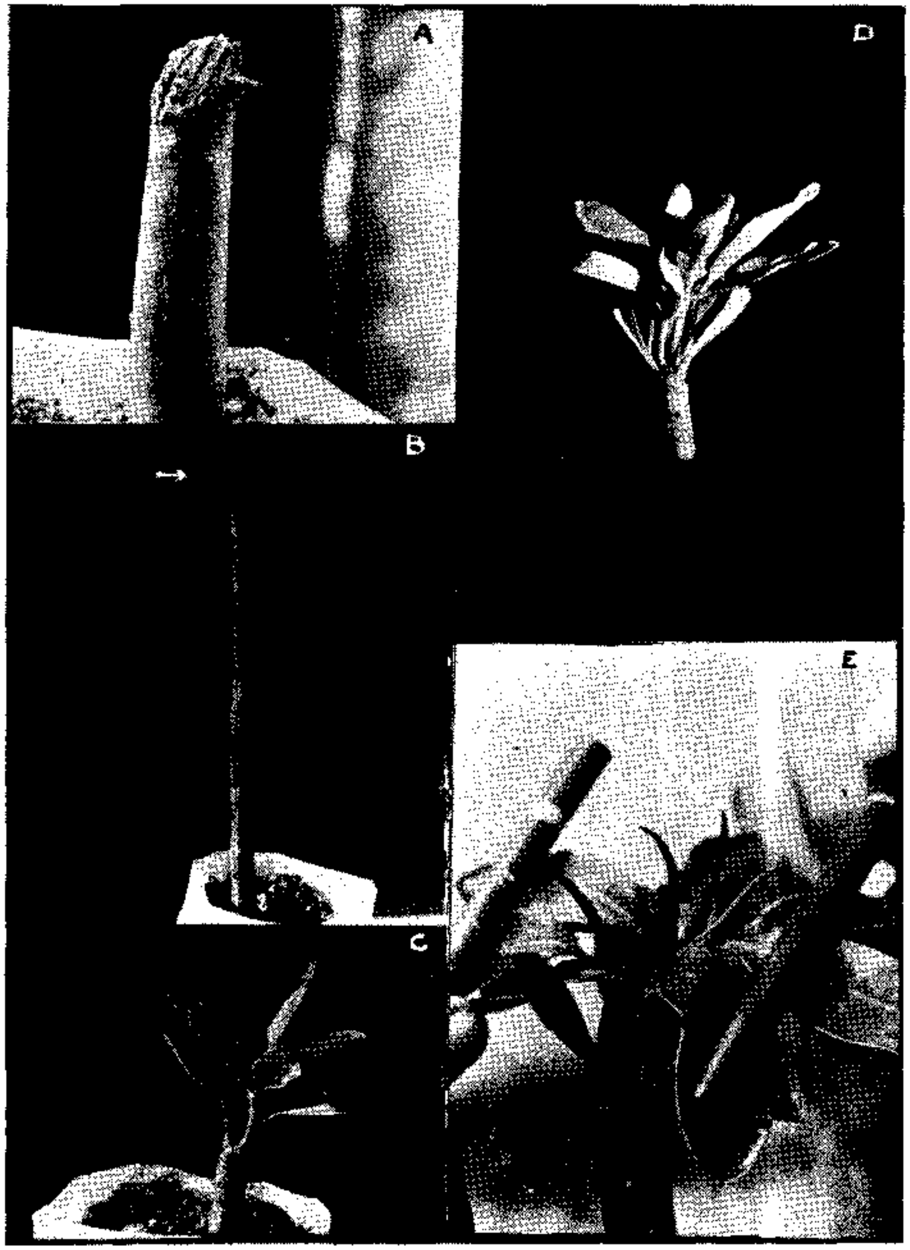

PLATE I A. propagule-cutting of *R. apiculata*, planted in soil (A bud is developed from cut surfaces), B. Propagules of *R. mucronata* and C. *R. apiculata* (After a part of propagule dries, sprouting takes place from alive part), and unique observation on the multishoot development in *R. mucronata* : D. Side view and E. Three shoots with six apical buds.

In *R. mucronata* the 1st two leaves are yellowish green in colour, the midrib is also yellowish in colour. The leaves are mucronate, pointed at apex. The unfolding of the leaves takes place pushing the scales downwards without elongation of 1st internode. In *R. apiculata* the 1st two unfolded leaves are having reddish tinge with prominent reddish mid rib. The leaves are ovate and rounded at the tip. The unfolding of leaves takes place outside the scale leaves, after the folded leaves are raised nearly by 1 cm above the scales.

TABLE 2. *Comparison between shallow and deep planted propagules of* R. mucronata *and* R. apiculata

		Shallow		Deep	
		April	May	April	May
Total propagules ..	Rm	30	30	15	30
	Ra	30	30	15	30
Average total length (cm) ..	Rm	42.38	40.21	41.28	40.34
	Ra	22.96	22.04	22.79	21.03
Sprouting (%) ..	Rm	96.66	100	100	100
	Ra	13.33	63.33	100	93.33
1st leaf pair unfolding (weeks) ..	Rm	8-12	8-12	4-11	4-12
	Ra	6-11	8-12	4-11	4-9
Seedlings with 2 leaves ..	Rm	26	30	8	30
	Ra	1	16	12	27
Seedlings with 4 leaves ..	Rm	3	—	7	—
	Ra	3	3	3	1
Initial length of plumule (cm) ..	Rm	2.46	2.48	2.54	2.51
	Ra	1.56	1.65	1.58	1.78
Seedling height above Collar (cm) ..	Rm	9.03	9.19	12.77	11.28
	Ra	17.17	18.28	15.96	21.19

Observations recorded after 13 weeks. Rm — *R. mucronata*; Ra — *R. apiculata.*

Unique observation is due to *R. mucroatna* propagule. Usually a single shoot emerges out of the scales. However, in one specimen it is found that three shoots are given out form single pair of scales. Further, each of these three has a peculiarity (Pl. I D and E). One of the shoot on one side shows three apices, the middle one has two whereas, the third has a single apex covered with scales. This development is possibly recorded for the first time. Poly-embryony or occurrence of twin propagule in Rhizophoraceae is already reported. In *Bruguiera cylindrica* the double seedling condition has been recorded by Rao *et al.* (1982). Twin propagule of *R. mucronata* was reported by Mulik (1987) from the areas near Ratnagiri. Further Rao *et al.* (1987) presented an account of twin propagules in Rhizophoraceae members. The twin propagule indicate two seeds fertilized, giving rise to two hypocotyle and two plumules in one fruit wall. In the present case there was no external indication of multi-shoot development of the propagule. It emerged after the plantation only.

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A PRELIMINARY SURVEY ON NEWLY RECORDED *SOLETELLINA VIOLACEA*

ABSTRACT

Soletellina violacea (Lam.) recorded for the first time, in India at Mithbav Creek (16° 20′ N 73° 25′ E), is highly nutritious and forms major resource in food chain. It is a good candidate species for aquaculture studies.

MOST of the publications have contained references to the growth, reproduction respiration and siphon regeneration of different species in Lamellibranchs. This study is important for three main reasons. *Soletellina* has food value and contains more than ten types of essential amino acids. It is one of the rare species around the west coast of India and the study on *Soletellina* may suggest general principles which could be applicable to other marine bivalves especially for aquaculture.

Material and methods

The specimens collected from Mithbav Creek in Sindhudurg District, over a period of 15 months, were examined for gut contents. The methods adopted here are mostly based on works of Hynes (1950) and Pillay (1952).

Results and discussions

Shell

Shell is fairly large, equivalve, more or less elongated and with a strong periostracum. Ligament pit is short and broad. The pallial sinus is very deep, narrowing anteriorly. Hinge has two teeth in each valve. The shell valves are moderately thick, covered by a dark brown periostracum and marked with concentric growth lines.

Burrowing habits

The foot is wedge shaped, muscular and very much active in burrowing especially during feeding. Distribution from intertidal down to a few metres below the low water mark. It burrows in the soft sandy-muddy ground upto a depth of about a metre beneath the surface, but maintains connection with the surface water through extraordinarily long siphons. They are found only in selected grounds, where the environmental conditions are suitable for survival. In burrowing position the shells lie mouth downward in the substratum. Burrowing depth (Table 1) varies according to the age and size group. Younger forms of 10-50 mm length always remain few cm below the surface of soil, while adults (51-120 mm) a metre below. During high tide, the functional activities of burrowing mechanism increases for rapid feeding and hence no stability in burrowing depths.

TABLE 1. *Relationship between depth of burrow and size groups in* S. violacea

Length of shell in mm	Depth in cm
10 — 25	10 — 12
26 — 50	20 — 40
51 — 70	60 — 70
71 — 100	80 — 90
101 — 120	92 — 105

Feeding

During high tides feeding activity seems to be quite high as can be seen by continuous siphonal activities. At this time, the animal gradually comes near the surface, but remains still burried in the mud. The circumference of rotation of the inhalent siphon goes on increasing as the animal comes nearer and nearer to the surface. From the analysis of the stomach contents, the species is considered as omnivorous and detritus feeder. The gut contents shows animals remains, algal fragments, sand and detritus. The food generally consisted of varying amounts of organic matter mixed with sand and mud.

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LABORATORY EXPERIMENTS ON GROWTH OF PENAEID PRAWNS FED WITH ARTIFICIAL PELLETS

ABSTRACT

Artificial feeds were compounded using wheat flour, tapioca powder, coconut cake, groundnut cake, fishmeal, prawnmeal and mineral supplement in different proportions, in pellet form, with agar-agar as binding agent. Feed numbers 1 to 19 were with protein contents ranging from 15.31% to 30.63%. Starch contents varied from 7.31 to 44.32% while fat contents were much less (0.04 to 4.35%). Feeding experiments of 60 days duration were conducted with postlarvae (TL=5.10 to 5.69 mm) and juveniles (TL=21.0 to 36.0 mm) of *Metapenaeus dobsoni* and *Penaeus indicus* (TL=10.10 to 14.60 mm) in aquarium tanks of 30 × 30 × 60 cm, containing 25 litres of sea water and plastic pools of 1 m diameter, containing 150 litres of seawater. The prawns exhibited average growth rates ranging from 0.225 to 0.574 mm per day. Feed number 15 containing 22.41% protein gave best results. The average growth rate per day in length and in weight were 0.505 mm and 0.015 g respectively. The cost of these feeds varied from Rs. 1.80 to 3.80 per kilogram.

SELECTION of appropriate feed is one of the major tasks in the culture of prawns, as it is directly responsible for the growth and survival. The feed should be cheap so as to make large scale intensive prawn culture economical. Usually, raw food materials such as minced meat of mussels and clams, rice bran, coconut cake, etc. are used individually or in combination for feeding the cultured prawns in countries like Japan, Taiwan, the Philippines, United Kingdom and the United States of America. Due to the shortage in the supply of these food items, their high cost and their deficiency in some of the nutrients, attempts were made to develop suitable artificial feed to meet the nutritional requirements of the cultivable species. Considerable research in this line has been carried out in Japan, United States of America and the United Kingdom (Kanazawa *et al.*, 1970, 1971 a, b; 1972; Kitabayashi *et al.*, 1971; Subramanyam and Oppenheimer, 1970; 1972; Deshimaru and Shigeno, 1971; Meyer and Zein-Eldin, 1972; Shigeno *et al.*, 1972; Sick *et al.*, 1972; Sick 1973; Forster and Beard, 1973). The present account deals with the preparation of different dry artificial feeds and the estimation of their efficiencies in promoting the growth of important cultivable species of penaeid prawns of India *viz. Metapenaeus dobsoni* and *Penaeus indicus* under laboratory conditions.

The help rendered by the Central Institute of Fisheries Technology, Cochin, in the analysis of the feeds is gratefully acknowledged.

Material and methods

The ingredients used for the preparation of the feeds were wheat flour, tapioca powder, coconut cake, groundnut cake, prawnmeal, fishmeal and mineral supplement (Starmin PS). Agar-agar was used as binding agent. The seived ingredients in different proportions were mixed thoroughly with sufficient quantity of hot 1% solution of agar-agar to make a soft dough and extruded through a meat mincing machine having a die with 3 mm holes. The strings were dried in a hot air oven at 70°C and crumbled into small pieces of 3-5 mm length with 5-10% moisture content and kept in air-tight polyethelene containers. Nineteen combinations of artificial feeds (No. 1-19) were prepared and the different proportions of the various ingredients are summarised in Table 1.

The chemical composition of these feeds were analysed and the results are given in Table 2.

Juveniles of *Metapenaeus dobsoni* of size range 21-36 mm in total length (length between the tip of the rostrum and tip of telson), collected from Cochin Backwater and postlarvae of the same species (TL = 5.1-5.6 mm) as well as those of *Penaeus indicus* (TL = 10.1-14.6 mm) obtained from Narakkal Prawn Farm of the Institute were used in the feeding experiments. Soon after collection they were acclimatised in the glass aquarium tanks for a day or two. They were weighed on an electric monopan balance to the nearest milligram. In each of the tanks (Size : 30 × 30 × 60 cm) 10 to 15 juveniles or 25 to 30 postlarvae were kept in 25 litres of seawater collected from the inshore areas of Cochin. In plastic pools of 1 m diameter, containing 150 litres of seawater 65 postlarvae of *P. indicus* measuring 10.1-14.6 mm in total length were kept. The experiments were conducted in duplicate, for a period of 60 days and the mean values of the lengths were taken. The prawns were fed once a day in sufficient quantities, *ad libidum* and the excess feed, dead animals and exuviae, if any, along with excreta were siphoned out the next day morning. Total lengths were taken at fortnightly intervals. The temperature and salinity ranges of the rearing medium were 26.9-30.0° C and 20.6-32.4 pp respectively. These experiments were carried out during the period October, 1972 to November, 1976.

TABLE 1. *Composition of artificial prawn feeds by percentage weight of ingredients*

Feed number	Wheat flour	Groundnut cake	Coconut cake	Tapioca powder	Rice bran	Fishmeal	Prawnmeal	Mineral supplement	Cost per kg
1	50.00	25.00	25.00	—	—	—	—	—	2.00
2	75.00	—	25.00	—	—	—	—	—	2.00
3	75.00	25.00	—	—	—	—	—	—	2.00
4	45.50	22.75	22.75	—	—	—	—	—	2.00
5	62.50	—	25.00	—	—	12.50	—	—	1.80
6	56.56	—	22.23	—	—	22.23	—	—	2.50
7	50.00	—	20.00	—	—	30.00	—	—	2.50
8	50.00	—	20.00	—	—	—	30.00	—	3.80
9	60.00	—	25.00	—	—	15.00	—	—	2.30
10	50.00	—	25.00	—	—	25.00	—	—	2.40
11	—	—	—	57.00	9.50	23.75	—	9.50	1.80
12	—	—	—	47.50	19.00	23.75	—	9.50	1.80
13	—	—	—	40.00	30.00	20.00	—	10.00	1.80
14	—	—	—	40.00	20.00	30.00	—	10.00	1.95
15	—	—	—	33.33	16.67	41.67	—	8.33	2.10
16	—	—	—	16.67	16.67	49.99	—	8.33	2.10
17	—	—	—	16.67	8.33	58.33	—	8.33	2.20
18	—	—	—	24.99	24.90	41.67	—	8.33	1.80
19	—	—	—	41.67	8.33	41.67	—	8.33	1.85

The increase in total length and weight were considered as indicators of efficiency of the feed during the present investigations.

Results

The growth attained by postlarvae and juveniles of *P. indicus* and *M. dobsoni* during 60 days of the experiment, when fed with different feeds (Nos. 1-19) are shown in Fig. 1 and Table 3. Among the first fifteen types of feeds, Feed No. 15 was found to be the best, giving an average growth rate of 0.505 mm per day for *M. dobsoni* and 0.565 mm per day for *P. indicus*. In order to find out whether the increase in protein content of the feed was directly proportional to the growth rate or not, feed No. 16 and 17 with 49.9% and 58.33% respectively, of fishmeal, by weight, were compounded and fed to the postlarave of *M. dobsoni*. Feed No. 16 gave 0.396 mm increase per day with a survival rate of 43.33% while the growth realised with feed No. 17 was only 0.342 mm per day, the survival rate being only 23.33%. Similarly, two more feeds (Nos. 18 & 19) were also prepared with 25% and 41.67% of tapioca powder, by weight, to determine the effect of increase of carbohydrate in the diet on the growth of these prawns. Although the survival rate was as high as 95% with feed No. 18, the growth was less (0.253 mm per day). But, feed No. 19 exhibited a slightly better growth rate (0.360 mm per day) with lesser survival rate (33.33%). Thus it was found that feed No. 15 containing 41.67% of fishmeal and 33.33% of tapioca powder, by weight, gave the best results.

TABLE 2. *Chemical composition of artificial prawn feeds* (%)

Feed number	Protein	Starch	Fat	Ash	Moisture
1	21.60	38.00	0.99	3.28	11.80
2	16.60	7.31	1.05	3.33	3.14
3	16.60	37.05	2.00	2.33	4.66
4	20.10	12.40	4.35	3.11	6.68
5	20.50	28.40	4.21	9.29	6.49
6	21.88	26.15	3.89	11.34	7.15
7	30.63	27.95	2.90	7.54	8.00
8	27.13	16.15	4.04	15.05	5.35
9	17.97	40.66	0.58	1.07	9.48
10	25.36	36.56	0.67	1.60	8.78
11	16.72	34.48	0.16	4.47	7.37
12	17.50	31.95	0.08	7.54	5.71
13	15.31	44.32	0.40	7.57	4.86
14	21.88	33.13	0.42	22.01	7.54
15	22.41	18.27	0.91	22.54	6.40
16	26.77	14.14	0.55	27.94	5.42
17	34.30	7.83	1.09	40.14	6.61
18	22.82	15.00	1.29	26.17	6.77
19	22.28	22.77	0.72	26.88	7.69

Increase in weight of the experimental prawns were measured for feed Nos. 9 to 19. It will be seen from Fig. 1 and Table 4 that feed No. 15 was the best in the order of efficiency, giving an average growth of 0.015 g per day for 60 days period. Feed No. 17 with 63.33% of fishmeal was the least in efficiency (0.003 g per day) while the one with 25% of tapioca powder (Feed No. 18) was slightly better (0.007 g per day). Feed No. 10 with 50% wheat flour was second best.

The growth increment in relation to the size of the container in which the prawns were reared was also determined by another set

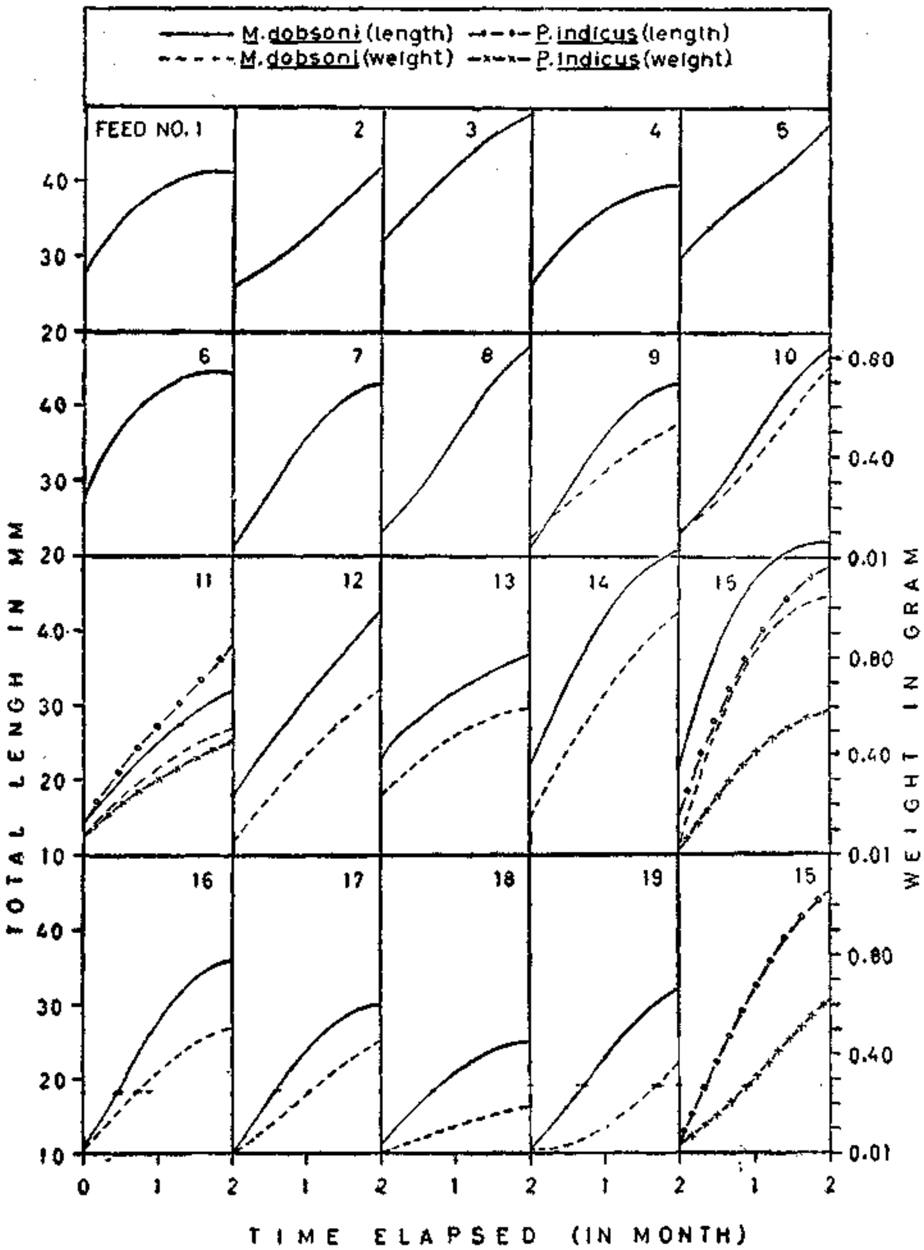

FIG. 1. Growth of postlarvae and juveniles of *M. dobsoni* and *P. indicus* fed on different artificial feeds.

of experiments. For this purpose, the growth rate shown by postlarvae of *P. indicus* (with feed No.15), reared in plastic pool and in glass aquarium tanks was compared and the higher growth rate of 0.574 mm per day was observed in the plastic pool than the slightly lesser growth of 0.468 mm per day in the aquarium.

TABLE 3. *Average growth in length of* M. dobsoni *and* P. indicus *fed on different artificial feeds*

Feed No.	Average initial length of prawns (mm)	Initial number of prawns	Average final length of prawns (mm)	Final number of prawns	Survival percentage	Average growth per day (mm)
M. dobsoni						
1	27.67	9	44.25	6	66.67	0.243
2	26.50	8	42.00	2	25.00	0.225
3	32.50	8	50.00	6	65.00	0.291
4	26.00	8	38.00	4	50.00	0.200
5	30.60	10	49.00	2	20.00	0.273
6	28.20	10	44.20	5	50.00	0.262
7	21.50	10	45.33	6	60.00	0.397
8	23.40	10	48.00	3	30.00	0.410
9	21.20	10	42.67	5	50.00	0.425
10	23.40	10	48.00	3	30.00	0.410
11	13.64	25	31.57	19	76.00	0.265
12	18.40	10	43.00	5	50.00	0.410
13	23.00	15	37.67	10	66.67	0.245
14	22.48	11	51.20	9	81.82	0.462
15	22.10	20	52.40	14	70.00	0.505
16	10.48	25	36.23	13	52.00	0.396
17	9.20	25	29.71	7	28.00	0.342
18	10.08	30	25.26	19	63.33	0.253
19	10.20	25	31.80	15	60.00	0.360
P. indicus						
15 (in aquarium)	14.56	25	48.50	5	20.00	0.468
15 (in pool)	10.48	65	45.00	14	21.63	0.574

The estimated cost of the feeds prepared and utilised in the present investigations ranged between Rs. 1.80 to Rs. 3.80 per kilogram (Table 1). The increase in the cost of feed No. 1 to 10 was due to the use of wheat flour as a source of carbohydrate. Subsequently, tapioca powder which was the cheapest starch available, was substituted and the price was brought down considerably. Prawnmeal was replaced by fishmeal as the former was costlier and less efficient. The cost of compounding the feed can be still reduced when it is manufactured on a large scale.

Discussion

An attempt is made here to compare the growth rate of *M. dobsoni* attained during the present investigations with those given for the species by earlier workers, as no control had been kept. Menon (1951) observed a growth rate of 0.233 mm per day (7 mm per month) in the laboratory reared juveniles of *M. dobsoni* while Mohamed and Rao (1971) recorded a higher growth rate of 8 to 11 mm per month for the juveniles of the same species based on length frequency studies. The present record of still higher growth rate (0.550 mm per day) can be attributed to the quality of the feed, especially the optimum protein content. For *P. indicus*, Sultan *et al.* (1973) reported a growth of 0.70 mm per day when juveniles were reared in the plastic pool of 3.5 m diameter in 1 m depth of water for 60 days, while Sampath and Menon (1975) recorded a slightly higher growth of 1.2 mm per day when reared in large sized rectangular cages of size 4.5 m × 2 m × 1 m for 2 months.

TABLE 4. *Average growth in weight of* M. dobsoni *and* P. indicus *fed on artificial feeds and percentage of increase in body weight*

	Feed number	Average initial weight (g)	Average final weight (g)	Average growth per day (g)	Percentage increase in body weight
M. dobsoni					
	9	0.078	0.550	0.007	579.5
	10	0.105	0.773	0.011	636.2
	11	0.018	0.269	0.004	1394.4
	12	0.043	0.440	0.006	923.3
	13	0.006	0.368	0.005	457.5
	14	0.052	0.718	0.011	1280.7
	15	0.054	0.962	0.015	1681.5
	16	0.012	0.113	0.002	841.6
	17	0.008	0.054	0.001	575.0
	18	0.018	0.160	0.002	788.8
	19	0.029	0.218	0.003	990.0
P. indicus					
	15 (in aquarium)	0.040	0.662	0.040	1555.0
	15 (in pool)	0.032	0.624	0.010	1850.0

The lesser growth rate (0.574 mm/day) noticed in *P. indicus* during the present studies may perhaps be due to the smaller size of the container in which the juveniles of this species were reared.

The protein content of the feed used by Kanazawa *et al.* (1970) is 50% and those of the feeds prepared by Deshimaru and Shigeno (1972) and Balazs *et al.* (1973) are 69% and 40% respectively. These authors have recorded different growth rates in reared prawns: 20 to 72% in *P. japonicus* (Kanawaza *et al.*, 1970), 106 to 109% in *P. japonicus* (Deshimaru and Shigeno, 1972), 107% in *P. aztecus* (Balazs *et al.*, 1973) and 105 to 329% in *P. japonicus* (Balazs *et al.*, 1973). In the present study 1,681.5% increase in weight was observed for *M. dobsoni* and 1,550.0% for *P. indicus* when fed with feed containing 22.41% of protein. Though Deshimaru and Shigeno (1972) and Balazs *et al.* (1973) opined that feed containing 40 to 60% of protein gave good results, the present feed No. 15 containing 22.41% of protein has recorded the highest increase in weight (1,681.5%) which agrees with the optimum protein level recommended for faster growth by Andrews *et al.* (1972).

The results presented here indicate the possibility of fabricating less expensive as well as efficient artificial feed which can be used as a supplementary feed in large scale prawn culture operations.

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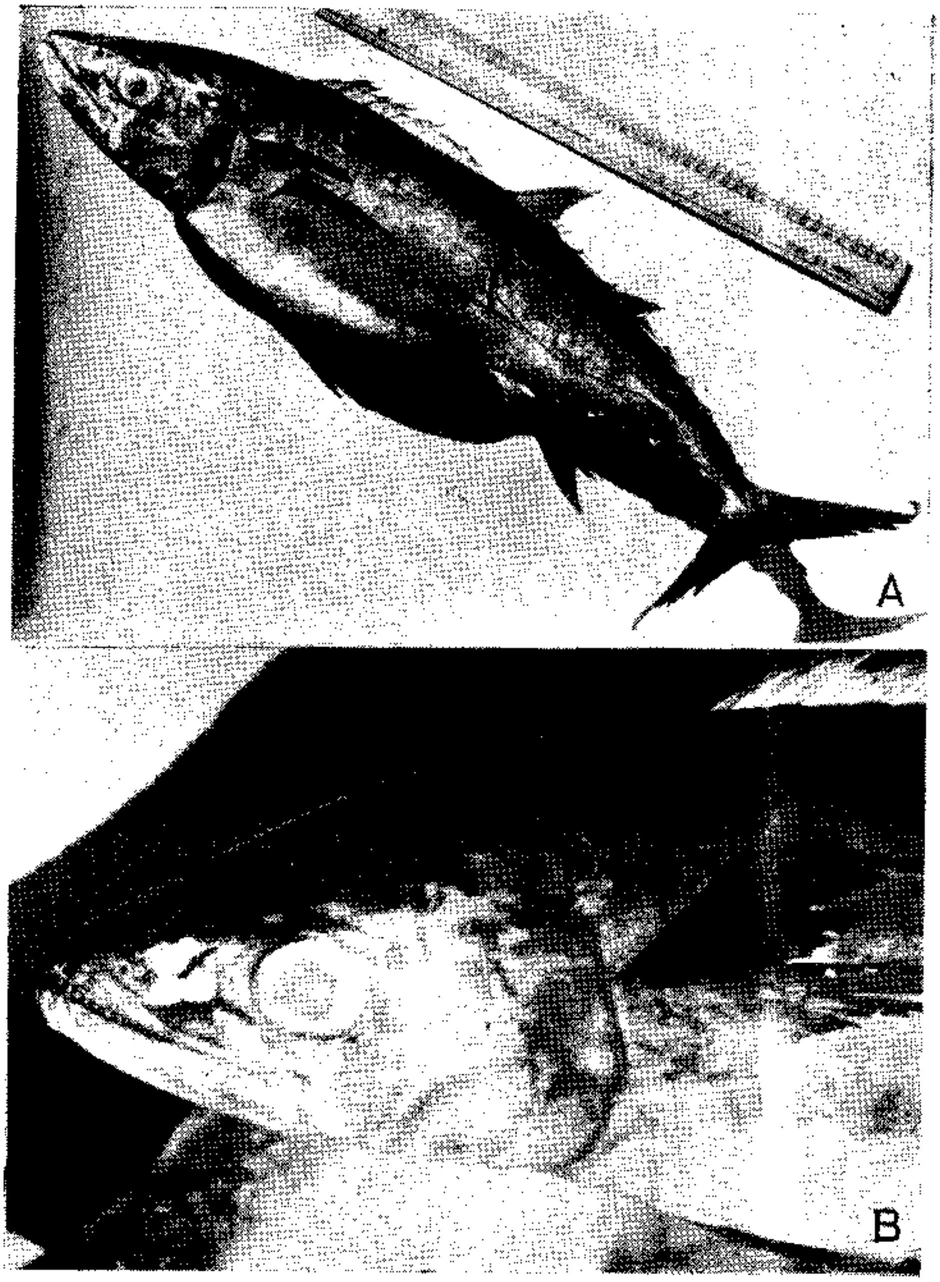

Plate I A. Lateral view of *Gymnosarda unicolor* Rüppell and B. a close-up view of the head showing the teeth.

ON A NEW DISTRIBUTIONAL RECORD OF THE DOGTOOTH TUNA *GYMNOSARDA UNICOLOR* RÜPPELL FROM THE CALICUT COAST, INDIA

ABSTRACT

The Dogtooth tuna *Gymnosarda unicolar* Rüppell is reported for the first time from the main land coast of India having earlier been reported only from Lakshadweep and Andaman waters.

THE TAXONOMY and distribution of tunas and tuna-like fishes in the Indian Ocean are given by Silas and Pillai (1982). From this, it is seen that the Dogtooth tuna *Gymnosarda unicolor* Rüppell is not so far recorded from the coasts of India's mainland and the earlier records are from Lakshadweep and Andaman waters only.

On a routine collection of data from Vellayil, Calicut, a specimen of *G. unicolor* (Pl. I) was obtained in drift gill-net. It had a standard length of 59 cm and weighed 3.25 kg.

Gymnosarda unicolor Rüppell

Gymnosarda unicolor Rüppell, 1838. Nvue Wirbetthiere. *Fische des Rothen Meers.*, 148 pp. Gill, 1862. *Proc. Acad. Nat. Sci. Philad.*, **1814**: 124-127.

Thynnus (*Pelamis*) *unicolar* Rüppell, 1836. *Fische des Rothen Meers* 40-41, P. 112 (fig. 1).

Pelamis nuda Gunther, 1860. *Cat. Fish. Bri. Mus.*, **11** : 548.

Gymnosarda nuda Kishinouye, 1923. *J. Coll. Agric. Imp. Univ. Tokyo*, **8** (3) : 293-475.

Description : D_1 XIV, D_2 13 + 7, P 26, A 10 + 6.

In per cent of standard length, total length 122.0; fork length 107.6; head length 26.6; snout length 9.7; eye diameter 5.1; snout to first dorsal 32.2; snout to second dorsal 59.3; snout to ventral 28.8; snout to lateral 27.1; snout to anal 66.1; length of pectoral 18.0.

Gill-rakers 12, teeth large and conical in both jaws, 17 and 23 on one side of lower and upper jaw respectively. Two patches of teeth on tongue. Maxilla reaches middle of eye. Interpelvic process single. Caudal peduncle slender with well developed median keel. Lateral line prominent and arched over pectoral fin. Body naked.

Colour : The original colour had faded as it was landed ashore very late. Back and upper side of body, light blue black. Lower side and belly dirty white. No lines or any markings on body.

Distribution : In the Indian Ocean, it has been reported from Madagascar, Reunion, Seychelles and from nearby oceanic Islands, Southeast Coast of Sri Lanka, Lakshadweep Sea, Andamans, around Maldives and now from Calicut.

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THE EFFECTS OF NUTRIENTS ON *THALASSIOSIRA FLUVIATILIS* (HUST.) IN DARK AND LIGHT CONDITIONS

Abstract

The effects of nutrients on growth of *Thalassiosira fluviatilis* were found out by incubating the culture for a period of one week in complete darkness and exposing it to light of 3000 lux intensity continuously. Complete darkness did not favour much growth though the nutrients are supplied as in F/2 medium level. When the culture exposed to light after dark period, maximum growth was observed at full enrichment level. Nitrogen and phosphorous had been found to be very effective than other nutrients in enhancing or declining the growth of *T. fluviatilis*.

Long periods of darkness are a feature of natural environment, yet comparatively little is known of their influence on the light activities of algal metabolism (Yentsch and Reicherf, 1963). The algae incubated in continuous light for a longer duration when subjected to darkness for a short period capable of increasing in its growth. The present study is an attempt to explore how long can an autotrophic microalgae retain its viability in the dark when the nutrients are supplied in a different compositions and its growth response to periods of light exposure.

The author expresses ner sincere thanks to Prof. A. Subramanian and Prof. K. Krishnamurthy, Director, CAS in Marine Biology for providing the facilities and to Dr. Kathiresan for his critical comments on the manuscript.

Materials and methods

Unialgal culture of *Thalassiosira fluviatilis* grown exponentially at 30‰ salinity (Temperature 29 ± 2°C ; pH 7 ± 0.5) under 3000 lux of continuous light was inoculated in sterilized seawater and kept for four days in dim light. A series of media omitting nitrate (NO_3), phosphate (PO_4), silicate (SiO_3), trace metals (TM) and vitamins (V) from Guillard medium of F/2 (Guillard, 1967) and the medium containing only NO_3, PO_4, SiO_3, TM and V as in F/2 level were prepared and sterilized separately. F/2 medium and sterilized seawater were used as two controls. The nutrient deficient cultures were then inoculated with series of media in 150 ml flask containing 50 ml media and incubated for 7 days in continuous dark. The experiment was set up in duplicate. Every day aliquots were taken from these culture for growth estimation and the same culture was exposed to continuous light of 3,000 lux intensity for a week. Cell counts were taken from these flasks every day with Sedgewick Rafter Counter and growth rate was estimated using the formula

$$K = \frac{\log_2 (N_1 - N_0)}{t_1 - t_0}$$

where N_1 and N_0 are the cell concentrations at the end and beginning of a period of time T days (Guillard, 1973).

Results

The final yield of cell number and divisions/day after a week in the dark and after 7 days in the light are shown in Table 1 a, b. The culture showed very low growth when incubated in the dark, particularly when seawater alone used as medium (Control I). The addition of NO_3 and PO_4 individually did not promote much growth in the dark whereas the full enriched medium (F/2,control II) favour maximum growth among all the culture conditions (K = 0.016). With the omission of nutrients from the F/2, nitrogen deficiency supported growth of 0.01 divisions/day and the generation time was decreased with omission of PO_4, SiO_3 and V. TM deficiency did not decrease the growth rate like other nutrients.

TABLE 1 a. *Effects of nutrients under continuous darkness on growth rate (Final yield Cell number* X 10^3/ml ; *division rate (K) of* Thalassiosira fluviatilis

Nutrients as in F/2		Final yield X 10^3 cells/ml	K
Sea water (SW) Control I		8.75	0.004
SW + NO_3	..	11.95	0.010
SW + PO_4	..	11.85	0.009
SW + SiO_3	..	10.20	0.006
SW + TM	..	9.50	0.005
SW + V	..	11.25	0.008
Full Enrichment			
F/2 (Control II)	..	17.00	0.16
F/2 — NO_3	..	12.3	0.010
F/2 — PO_4		12.6	0.011
F/2 — SiO_3	..	12.70	0.011
F/2 — TM	..	15.25	0.014
F/2 — V	..	13.00	0.012

Cell counts taken from the cultures exposed to continuous light for a week after seven days in the darkness showed that non-enriched medium supports growth rate of only 0.042 divisions/day. Nitrate enrichment promoted higher growth than any other nutrients when supplied individually. Vitamins enrichment alone supported higher cell division next to nitrate and phosphate. Silicate had little effect in increasing the growth followed by TM. The omission of nutrients had the effect in the order of NO_3 — PO_4 — V — TM and SiO_3 in bringing down the growth rate to a lower level. NO_3 deficiency had higher effect in reducing the growth to 0.065 divisions/day. Omission of vitamins also caused increase in generation time, though the other nutrients are present as in F/2. Lack of SiO_3 and TM in the medium did not reduced the growth to a large extent (K = 0.79 and 0.78).

TABLE 1 b. *Effects of nutrients on growth rate of* T. fluviatilis *under continuous light for one week after incubation in continuous dark for seven days.*

Nutrients as in F/2		Final yield X 10^3 cells/ml	K (divisions)
SW	..	67.2	0.042
SW + NO_3	..	190.8	0.061
SW + PO_4	..	140.0	0.056
SW + SiO_3	..	109.7	0.051
SW + TM	..	95.8	0.049
SW + V	..	113.6	0.052
F/2	..	750.0	0.087
F/2 — NO_3	..	230.4	0.065
F/2 — PO_4	..	290.1	0.070
F/2 — SiO_3	..	500.0	0.079
F/2 — TM	..	440.0	0.077
F/2 — V	..	400.0	0.075

Initial Inoculum 7.15 × 10 cells/ml.

DISCUSSION

When the culture was exposed to light for a period of week after seven days in the darkness, seawater without enrichment enhance minimum growth rate of *T. fluviatilis*. *Rhizosolenia fragilissima* also showed no growth when seawater alone was supplied. (Ignatiades and Smayda, 1970). In the present study nitrate and phosphate enrichment individually yields maximum growth rate of 0.061 and 0.56 respectively. Smayda (1973) found that nitrate enrichment alone favours luxurious growth in *Skeletonema costatum*. Similarly in *Biddulphia sinensis* and *S. costatum* higher growth rate was recorded when nitrate and phosphate supplied individually (Subramanian, 1979). Full enriched medium (F/2) supported eleven times increase in the growth of *T. fluviatilis* over the non-enriched medium. This was much higher than the value obtained in *B. sinensis* and *S. costatum*, where only 3-4 fold increase over control (seawater) was observed (Subramanian, 1979). Smayda (1973) recorded 10 to 24 fold increase in growth of *S. costatum* and 10 to 24 fold increase in growth of *S. costatum* and *Cyclotella nana* due to enrichment (Smayda, 1973). In the present study nitrogen deficiency caused reduced growth rate representing 0.065 divisions/day. Phosphorous deficiency also lowered the growth rate of *T. fluviatilis*. Similar observations were made by Subramanian (1979) when exclusion of phosphate and nitrate resulted in reducing growth rate of *S. costatum* and *B. sinensis*. Low cell number of *S. costatum* was recorded when nitrate and phosphate were omitted from the medium (Curl, 1962). In the present observation, growth was not much limited in the medium devoid of vitamin or silicate or trace elements, but the division rate was comparatively lower than that of full enrichment. No remarkable reduction in the growth of *B. sinensis* and *S. costatum* were observed when SiO_3, TM and V were omitted from the medium (Subramanian, 1979).

The present study suggests that nutrients particularly nitrate and phosphate seem to be responsible for either increasing or decreasing the growth of *T. fluviatilis* under both dark and light conditions. In the natural aqautic environment under certain circumstances phytoplankton are forced to undergo unfavourable situation for their growth especially during monsoon period when turbidity of water is high and the light penetration to deeper layers is almost nil. Under those conditions, *T. fluviatilis* may sustain its survival potential if nitrate and phosphate are available in adequate concentrations.

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YEASTS FROM THE SEDIMENT SAMPLES OF THE EEZ ALONG THE SOUTHWEST COAST OF INDIA

ABSTRACT

Fiftyeight yeast isolates were obtained from the benthic sediment samples of 19 stations during R. V. *Gaveshani* Cruise No. 187 of the Exclusive Economic Zone along the southwest coast of India. The depths ranged from 20 to 1,055 m. Asporogenous yeast isolates were more in number belonging to the genera *Candida*, *Rhodotorula* and *Geotrichum*. Isolates of sporogenous yeasts belonged to *Debaryomyces* and *Saccharomyces*. Genus *Candida* was the most common represented by its species at all depths and distances from the coast and *Rhodotorula* was next in abundance. Colony forming units (cfu) per gram of wet weight of samples ranged from 4 to 54.

OCCURRENCE of yeast along with other microorganisms had been reported since the last century (Fischer, 1894; Issatchenko, 1914; ZoBell and Feltham, 1934; ZoBell, 1945). Bhat and Kachwalla (1955) were the first to analyse 17 samples of sea water off Bombay Coast reporting a number of yeasts and were the first to establish that sea had autochthonous yeast flora. Since then several papers appeared dealing specifically with marine yeast biota from different seas and oceans of the world (Fell *et al.*, 1960; Roth *et al.*, 1962; Kriss, 1963; Fell and Van Uden, 1963; Meyers *et al.*, 1967, 1971; Ahearn *et al.*, 1968; Volz *et al.*, 1974). Fell (1967) studied the distribution of yeasts in the Indian Ocean for 16 stations along 60°E meridian. Since last decade there was hardly any report on the yeast flora of open sea and oceans, although their occurrence in coastal areas in relation to coastal pollution studies have been reported by Bruni *et al.* (1983), Mujdaba-Apas (1980), Ahearn *et al.* (1980) and Pagnocca (1989). No systematic study has been carried out on the yeast flora of EEZ along the Indian Coast, their distribution, taxonomy and ecology, except the recent one by Ranu Gupta and Prabhakaran (1989). This is the second report of the incidence of yeast along the EEZ of the Indian Coast.

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Materials and methods

The position of 20 sampling stations of R. V. *Gaveshani* Cruise No. 187 (10-10-1987 to 26-10-1987) is shown in Fig. 1. The depth of the station ranged from 20 to 1,055 m and distance from the coast 3.59 to 154.33 km.

LaFond Dietz Snapper was used to collect the sediment samples. The snapper was wiped with cotton wool soaked in alcohol (95%) before each collection. After each collection the whole lump of the sediment sample was immediately taken in a pre-sterilized polythene bag. The samples were taken out aseptically inside a sterile chamber from the centre of the lump to avoid any chance of contamination. One gram of this sediment sample was shaken well with 100 ml of sterilized sea water till the suspension was homogenous, then it was allowed to stand for 10 minutes to let the sediment particles to settle down. The supernatant was then concentrated on 0.45 μm porosity millipore cellulose acetate membrane filter which was placed in petri plates on nutrient medium with antibiotic mixture (modified GYPA medium to avoid bacterial growth — Van Uden and Fell, 1968). Triplicate samples were taken from each collection, then from each sample triplicate plates were prepared. The plates were incubated at 20 ± 2°C for the samples above 500 m depth and at 10 ± 2°C for the samples below 500 m depth. The yeast isolates were identified according to Kreger Van Rij (1984).

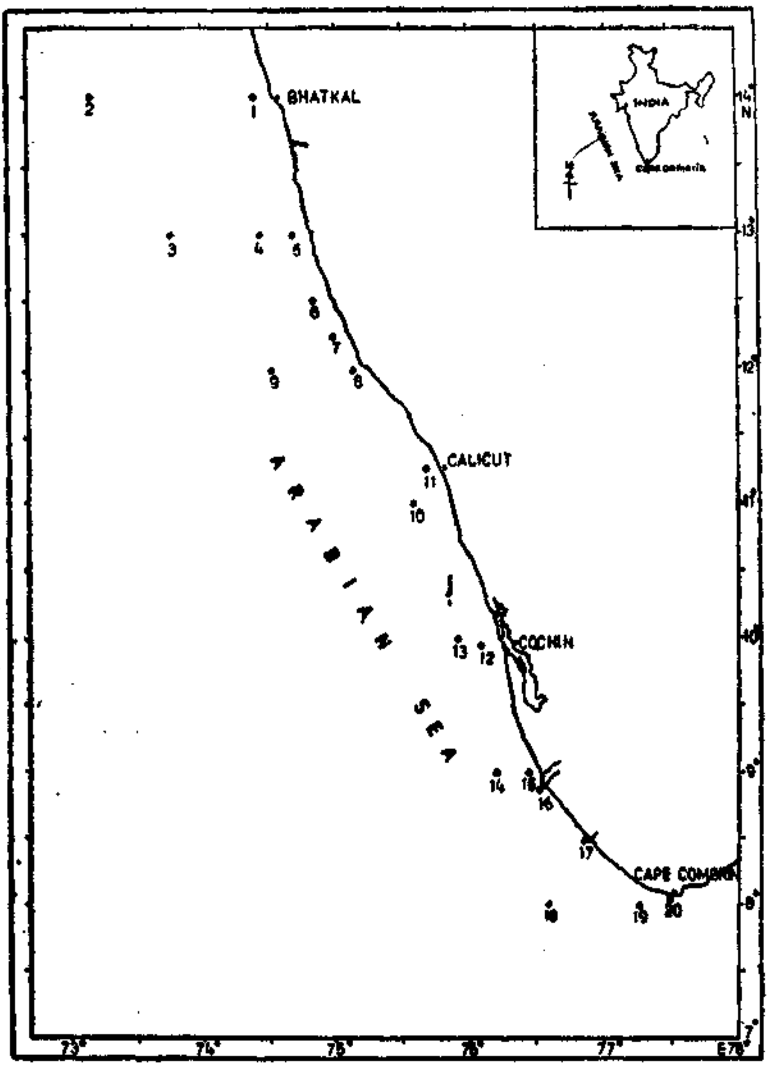

FIG. 1. Sampling stations along the southwest coast of India.

Results and discussion

The sporogenous yeasts isolated during the cruise were *Debaryomyces hansenii* and *Saccha-*

romyces sp. Asporogenous yeasts were *Candida albicans*, *C. quilliermondii*, *C. parapsilosis*, *C. tropicalis*, *Candida* spp., *Geotrichum candidum*, *Rhodotorula glutinis*, *R. graminis*, *R. minuta*, *R. rubra* and *Rhodotorula* sp.

The station numbers, their depths and the yeast species obtained are given in Table 1. The results of the isolation and colony counts show more number of asporogenous yeast isolates than the sporogenous ones. The control plates did not show any yeast growth.

Candida was the dominant genus of all with a number of species ; next in abundance was *Rhodotorula*. Obligate marine yeasts isolated were *R. glutinis* and *Candida* sp. The facultative marine yeasts were *C. guilliermondii*, *C. albicans*, *C. tropicalis*, *C. parapsilosis*, *D. hansenii* and *Saccharomyces* spp.

Macrozonation : When observed broadly, it is clear that the stations having shallower depth range of 20 to 50 m and with lesser distances from the coast of 3.59 to 36.48 km had higher densities of yeast populations (Table 1). This indicates the formation of macrozonation in the inshore areas and in the intracontinental waters than the open sea (Van Uden and Fell, 1968).

Microzonation : Station 13 with 47 m depth and 35.80 km off the coast was quite similar to station 14 with 15 m depth and 36.48 km off the coast, yet they showed marked difference in yeast flora. The former yielded only *Candida* spp. with 5 cfu while the latter 28 cfu of *C. albicans*, *C. tropicalis*, *Candida* spp. and *R. graminis*. Similarly Station 5 and 6 were of the same depth of 20 m and the same distance of 14.36 km off the coast, yet the former station yielded 50 cfu. of *D. hansenii*, *C. albicans*, *Candida* spp. and *R. minuta*, while the latter station failed to yield any yeast colony. According to Van Uden and Fell (1968) the distribution of yeasts in sea water is characterised by microzonation, an irregularity possibly

TABLE 1. *Number and species of yeasts isolated from sediment samples of the EEZ along the southwest coast of India during R. V.* Gaveshani *Cruise No.* 187

Station No.	Depth (m)	Distance from the shore (km)	Species isolated	Number per gram sediment (cfu)
1	20	16.15	*Debaryomyces hansenii*	5
			Candida guilliermondii	10
			Rhodotorula graminis	5
			Rhodotorula minuta	3
			Rhodotorula rubra	10
2	1017	154.33	*Candida* spp.	5
3	1055	116.64	*Candida* spp.	5
4	53	43.07	*Candida parapsilosis*	10
			Candida spp.	2
			Rhodotorula glutinis	5
			Rhodotorula rubra	10
5	20	14.36	*Debaryomyces hansenii*	15
			Candida albicans	20
			Candida spp.	10
			Rhodotorula minuta	5
6	20	14.36	—	

Station No.	Depth (m)	Distance from the shore (km)	Sbecies isolated	Number per gram sediment (cfu)
7	28	14.26	*Debaryomyces hansenii*	5
			Saccharomyces spp.	4
			Candida albicans	8
			Candida spp.	11
			Rhodotorula rubra	18
8	20	12.7	*Candida albicans*	7
			Candida guilliermondii	15
			Candida spp.	10
			Rhodotorula rubra	20
			Rhodotorula spp.	2
9	120	82.33	*Candida* spp.	8
10	33	32.30	*Debaryomyces hansenii*	7
			Candida tropicalis	8
			Candida spp.	3
			Rhodotorula rubra	18
11	20	11.49	*Candida albicans*	9
			Rhodotorula minuta	10
12	28	17.89	*Candida albicans*	15
			Candida guilliermondii	2
			Candida tropicalis	5
			Candida parapsilosis	9
			Candida spp.	3
13	47	35.80	*Candida* spp.	5
14	50	36.48	*Candida albicans*	6
			Candida tropicalis	9
			Candida spp.	8
			Rhodotorula graminis	5
15	22	8.95	*Debaryomyces hansenii*	12
			Candida albicans	3
			Candida parapsilosis	8
			Candida spp.	9
16	20	7.18	*Candida albicans*	2
			Geotrichum candidum	6
			Rhodotorula minuta	10
17	28	3.59	*Saccharomyces* spp.	5
			Rhodotorula graminis	6
			Rhodotorula minuta	3
18	970	66.21	*Candida* spp.	4
19	51	16.09	*Candida* spp.	12
20	29	5.37	*Saccharomyces* spp.	8
			Candida tropicalis	19
			Candida spp.	3
			Rhodotorula rubra	8

correlated with analogues discontinuities in the distribution of assimilable organic matter. This could be a factor for such small scale spatial differences in the occurrence of yeasts in two of the cases cited above of nearly identical stations.

The results of this initial study of the yeast populations along the EEZ of the southwest coast of India indicated that more detailed study along this line will reveal the interesting distributional patterns of yeast flora and the factors governing these patterns.

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RANU GUPTA

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ANNUAL REPORTS

ANNUAL REPORT OF THE SECRETARY FOR THE YEAR 1990

President Dr. P. S. B. R. James, Vice-President Dr. C. T. Samuel and members of the Association,

On behalf of the Executive Council of the Marine Biological Association of India, I have great pleasure to welcome you all and present the 32nd Annual Report of the Association for the year ending 31st December 1990.

As all of you are aware, the Association decided to award the Fellowship (FMBA) from the year 1989 onwards. The first batch of Fellowships was awarded to 109 members for 1988. In the year 1989, 14 members became eligible for the fellowship and for the year 1990, 12 members are eligible. The fellowships will be awarded accordingly.

The membership position as on today is satisfactory and the details regarding the membership position is as follows :

		Life member	*Individual member*	*Institution member*	*Total*
Indian	..	173	260	82	
Foreign	..	34	10	105	664

The publication of the Journal is up-to-date with the latest Volume 32 for the year 1990 is just released. As decided by the Executive Council on 22-2-1991, with effect from the next volume, the cost of the Journal has been increased to Rs. 250/- per copy. The financial position is also satisfactory. Details will be presented in Editor's and Treasurer's Reports shortly. For the year 1990, the Indian Council of Agricultural Research has sanctioned a grant of Rs. 20,000. On behalf of the members, I wish to record our gratitude and thanks to the I.C.A.R. for the generous grant and patronage given to the Association.

As Secretary, I wish to express my sincere thanks to the President and all Fellow Office-bearers for their whole-hearted support and co-operation in the successful working of the Association. I specially thank Dr. N. Gopalakrishna Pillai, Associate Secretary for his help and to Mrs. Lakshmy for the efficient secretarial assistance.

Thank you all,

Sd.

Cochin-31,
9-4-1991.

V. K. Pillai
Secretary

ANNUAL REPORT OF THE EDITOR FOR THE YEAR 1990

Respected President Dr. James, Respected Vice-President Dr. Samuel, distinguished members and friends,

I am extremely happy to be with you this evening and it is my privilege to present the Annual Report relating to the publication of the Association. The year 1990 is another successful year for the Association, as we have published Volume 32 of the Journal for 1990. The distribution of the copies of the Journal is in progress. In this volume, 23 papers and notes received from the Secretariat of the Symposium on Tropical Marine Living Resources held by our Association and 11 papers and notes received for the regular Journal were published.

I personally feel heartened that the support extended by all members of the Association during 1990 has enabled me to bring out the Journal on time.

The processing and editing of manuscripts for Volume 33 meant for 1991 is fast progressing and the first batch of manuscripts will be sent to the C. L. S. Press, Madras by next week. It is proposed to publish about 43 papers in Volume 33 of the Journal. Still we are left with 55 papers from the Symposium lot and 95 papers received for the regular Journal, totalling to 150 papers which are to be published starting from 1992.

We are continuing our endeavour to improve our financial position and to expedite the publication of the Journal. I look forward to have your wholehearted co-operation to reduce the long delay in publishing the papers in the Journal.

As our members are well aware that we have a sad news. With profound sorrow and grief, I record here the sudden and untimely demise of our Associate Editor Shri I. David Raj who was associating very much in all activities of the Association from 1970 till his very last day. It is a great loss to the Editor to loose a long standing and active Associate Editor.

Before I conclude I wish to express my gratitude to the Indian Council of Agricultural Research, New Delhi for sanctioning a grant-in-aid of Rs. 20,000/- towards the publication of the Journal for the year 1990-1991. I sincerely thank Dr. P. S. B. R. James, President for his wholehearted support and encouragement. I record here my sincere thanks to Shri P. T. Meenakshisundaram, Joint Secretary and late Shri I. David Raj, Associate Editor for their wholehearted, timely and continued co-operation and help for the publication of the Journal. Mrs. Lakshmy Janakiraman, the Association staff deserves my appreciation for the assistance rendered by her. I warmly appreciate and thank the support extended by Shri A. D. Thomas Stephen and his staff at the C. L. S. Press, Madras in bringing out the Journal on time. I extend my sincere thanks to all members of the Executive Council and members of the Association who are always extending their co-operation.

Thank you all,

Sd.

K. RENGARAJAN
Editor

Cochin-31,
9-4-1991.

ANNUAL REPORT OF THE TREASURER FOR THE YEAR 1990

Dear President, Vice-President and members of the Association and guests,

I have the honour to present the audited statement of accounts for the year ended 31st December 1990. During the year under report an amount of Rs. 40,811.00 has been received under the membership subscription and entrance fee against Rs. 33,985.50 during the previous year indicating an increase of Rs. 6,825.50 in 1990 over that of 1989. Under the sales of Journals, reprints and memoirs during 1990 and 1989 respective amounts realised were Rs. 54,327.85 and Rs. 56,137.75 thus showing a marginal decrease of Rs. 1,809.90 in 1990 when compared to that of 1989. A decrease of Rs. 6,409.75 was noticed in the sales of special publications and Symposium Proceedings of Crustacea, Mollusca, Indian Ocean, Corals and Coral Reefs, Coastal Aquaculture and Endangered Marine Animals and Marine Parks, the sales proceedings during 1990 and 1989 being Rs. 22,219.25 and Rs. 28,629.10 respectively. Against a Bank interest of Rs. 14,533.90 realised in 1990 the same was Rs. 15,151.10 in 1989, thus showing a marginal decrease of Rs. 617.20. This year the overall receipts stood at 1,59,583.91 against payments of 1,12,170.52 thus showing an excess income of Rs. 47,423.39. It would be interesting to note that this year an additional payment of Rs. 14,238.10 was made against interest to the Bank for the loan that was taken in connection with Symposium expenses. Otherwise this excess in income would be more by this amount. However, during 1989 the receipts were to the tune of Rs. 1,77,253.35 against Rs. 1,59,593.91 in 1990 as mentioned earlier. Hence it is requested that all out efforts may be made to increase the receipts. As suggested by the Founder President in the last Annual General Body Meeting we have opened short term deposits for a period of 46 days with an interest of 8% and this has started improving the financial position of the Association. In this connection it may be thought of depositing a part of the total fixed deposits of Rs. 1,60,866.90 in high interest yielding deposits.

We are extremely grateful to the I.C.A.R. for the grant of Rs. 20,000/- for the publication of the Journal during this year.

It is earnestly hoped that by increasing the receipts and reducing the expenditure the assets of the Association may be improved for which suggestions and kind co-operation of the members are solicited.

I am thankful to the President and all other Office-Bearers of the Association for their valuable advice and support. I am thankful to Shri K. E. Rangaswami, Chartered Accountant for having audited the accounts and sending his report in time to enable me to present the annexed audited statement of accounts for the year 1990. I am also thankful to Shri G. Subbaraman of C.M.F.R.I. for his valuable help in this regard.

Thanking you,

Sd.

Cochin-31,
9-4-1991.

K. Alagaraja
Treasurer

REPORT OF THE AUDITOR TO THE MEMBERS OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA ERNAKULAM, COCHIN-31

I have audited the attached Statement of affairs (Balance Sheet) of THE MARINE BIOLOGICAL ASSOCIATION OF INDIA as at 31st December 1990 and also the annexed Income and Expenditure Account for the year ended on that date and report that :

1. I have obtained all the information and explanation which to the best of my knowledge and belief were necessary for the purpose of the audit.

2. The Statement of affairs and the Income and Expenditure account referred to in this report are in agreement with the books of account.

In my opinion and to the best of my information and according to the explanation given to me, the said accounts give a true and fair view,

(*a*) In the case of the Statement of affairs the state of affairs The Marine Biological Association of India, Ernakulam as at 31st December 1990 and

(*b*) In the case of Income and Expenditure account, the excess of Income over Expenditure for the year ended on that date.

(*c*) The book of maintained on cash basis receipts and payment account on 31-12-1990 is also given.

Sd.

Madurai,
2-3-1991.

K. E. RANGASWAMI
Chartered Accountant

THE MARINE BIOLOGICAL ASSOCIATION OF INDIA, ERNAKULAM, COCHIN, INDIA

Statement of affairs as at 31*st December*, 1990

As at 31-12-1989	LIABILITIES		As at 31-12-1990	As at 31-12-1989	ASSETS		As at 31-12-1990
Rs. P.		Rs. P.	Rs. P.	Rs. P.		Rs. P.	Rs. P.
	Balance as per last year ..	1,59,542.66			Cash with Treasurer ..	Nil	
	Add : Excess of Income over Expenditure ..	21,340.73			Cash with Office-Bearers on postage	284.14	
	Symposia receipts ..	22,091.75		1,846.80			284.14
1,59,542.66			2,02,975.14		*Cash at Banks :*		
Nil	Due to Treasurer ..		3,990.91		Indian Bank, Ernakulam ..	21,314.97	
					United Commercial Bank, Ernakulam ..	477.24	
				93,673.06			21,792.21
				40,000.00	Fixed Deposit with Indian Bank ..		40,000.00
				Nil	Short Term Deposit with Indian Bank ..		1,20,866.90
				8,254.30	Typewriter ..		8,254.30
				864.00	Bicycle ..		864.00
				14,904.50	Furniture ..		14,904.50
1,59,542.66			2,06,966.05	1,59,542.66			2,06,966.05

PER MY REPORT ANNEXED

Sd.

K. E. RANGASWAMI
Chartered Accountant

Sd.

K. ALAGARAJA
Treasurer

Madurai,
2nd March, 1991.

THE MARINE BIOLOGICAL ASSOCIATION OF INDIA, ERNAKULAM, COCHIN, INDIA

Income and Expenditure Account for the year ended 31st December, 1990

Year ended 31-12-1989	EXPENDITURE	Year ended 31-12-1990	Year ended 31-12-1989	INCOME	Year ended 31-12-1990
Rs. P.		Rs. P.	Rs. P.		Rs. P.
14,450.00	To Salaries to staff	9,600.00	644.00	By Entrance fee	707.50
2,366.10	,, Printing and Stationery expenses	1,245.97	33,341.50	,, Subscription	40,103.50
11,545.24	,, Postage expenses	9,186.15	15,151.10	,, Interest from Bank	14,533.90
1,12,547.25	,, Printing charges for Journals	74,246.75	56,137.75	,, Sale of Journal, Reprints and Memoirs	54,327.85
Nil	,, Interest to Bank	14,238.10	397.50	,, Sale of special publications	127.50
3,916.25	,, Miscellaneous expenses	3,653.55	3,500.00	,, Grant-in-aid from ICAR for Journal	20,000.00
Nil	,, Excess of Income over Expenditure	21,340.73	3,850.00	,, Miscellaneous receipts	3,711.00
			302.99	,, Excess of Expenditure over Income	Nil
1,44,824.84		1,33,511.25	1,44,824.84		1,33,511.25

PER MY REPORT ANNEXED

Madurai,
2nd March, 1991.

Sd.
K. E. RANGASWAMI
Chartered Accountant

Sd.
K. ALAGARAJA
Treasurer

THE MARINE BIOLOGICAL ASSOCIATION OF INDIA, ERNAKULAM, COCHIN, INDIA

Receipts and Payments Accounts for the year ended 31st December, 1990

RECEIPTS	Rs. P.	Rs. P.	PAYMENTS	Rs. P.	Rs. P.
To Opening Balance :			By Printing and Stationery ..		1,245.97
Fixed Deposit with Indian Bank, Ernakulam ..	40,000.00		,, Postage excluding advance ..		9,186.15
Cash at Indian Bank, Ernakulam ..	92,781.57		,, Printing charges for Journal ..		74,246.75
Cash at United Commercial Bank, Ernakulam ..	891.49		,, Salary to staff ..		9,600.00
Advance with Office-Bearers on postage ..	570.29		,, Miscellaneous expenses including audit fee ..		3,653.55
Cash with the Treasurer ..	1,276.51	1,35,519.86	,, Interest to Bank ..		14,238.10
,, Entrance fee ..		707.50	,, *Closing Balance :*		
,, Membership subscription ..		40,103.50	Fixed Deposit with Indian Bank, Ernakulam ..	40,000.00	
,, Interest from Bank ..		14,533.90	Short Term Deposit with Indian Bank, Ernakulam ..	1,20,866.90	
,, Sale of Journals, Reprints and Memoirs ..		54,327.85	Cash at Indian Bank, Ernakulam ..	21,314.97	
,, Sale of Special Publications ..		127.50	Cash at United Commercial Bank, Ernakulam ..	477.24	
,, Symposium on Crustacea ..		510.00	Advance with Office-Bearers on postage ..	284.14	1,82,943.25
,, Symposium on Mollusca ..		382.50			
,, Symposium on Indian Ocean ..		220.00			
,, Symposium on Corals and Coral Reefs ..		191.25			
,, Symposium on Coastal Aquaculture ..		10,496.00			
,, Symposium on Endangered Marine Animals and Marine Parks ..		10,292.00			
,, Grant-in-aid from I.C.A.R. for Journal ..		20,000.00			
,, Miscellaneous receipts ..		3,711.00			
,, Cash from Treasurer ..		3,990.91			
		2,95,113.77			2,95,113.77

PER MY REPORT ATTACHED

Sd.
K. E. RANGASWAMI
Chartered Accountant

Sd.
K. ALAGARAJA
Treasurer

Madurai,
2nd March, 1991.

REGISTRATION OF NEWSPAPERS (CENTRAL) RULES 1958

Statement about ownership and other particulars about newspaper

JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA

FORM IV

(SEE RULE 8)

1. *Place of Publication* — Cochin.

2. *Periodicity of its publication* — Half-yearly.

3. *Printer's Name* — Mr. A. D. Thomas Stephen.
Nationality — Indian.
Address — The C. L. S. Press, 10 Vepery Church Road, Vepery,
Madras-600 007.

4. *Publisher's Name* — Dr. K. Rengarajan, for the Marine Biological Association of India.
Nationality — Indian.
Address — C.M.F.R.I. Campus, Dr. Salim Ali Road, Cochin-682 031.

5. *Editor's Name* — Dr. K. Rengarajan.
Nationality — Indian.
Address — C.M.F.R.I. Campus, Dr. Salim Ali Road, Cochin-682 031.

6. *Names and addresses of individuals who own the newspaper and partners or shareholders holding more than one per cent of the total capital* — Marine Biological Association of India, C.M.F.R.I. Campus, Dr. Salim Ali Road, Cochin-682 031.

I, K. Rengarajan, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Cochin-31,
Dated: 31-12-1991.

Sd.
K. RENGARAJAN
Signature of Publisher

INSTRUCTIONS TO AUTHORS

Manuscript Requirements : Only manuscripts solely intended for publication in the *Journal of the Marine Biological Association of India* may be sent in final form for consideration to the Editor. Manuscripts should be type-written on one side in double space throughout on foolscap paper leaving 4 cm margin and submitted in duplicate consisting of the original and one neat carbon copy. About one and a half manuscript foolscap pages in elite type will normally reduce to one printed page and manuscripts should not exceed twentyfive type-written pages including Tables and Figures which should be less than 15 per cent of the entire paper. Major papers are those longer than six pages of double spaced (elite type) manuscript. If the manuscript is from a thesis, it should be revised and made suitable for publication in the Journal. Before submitting the manuscript, the authors should check whether there are inconsistencies between the Tables and Figures and the text or within the text. Both Tables and graphs illustrating the same point will not be accepted. As a rule, footnotes should be avoided except when they are used to credit institution contribution series number and unpublished material. In Tables superscript numerals should denote footnotes which should be explained below the concerned Table, with the first line indented.

Manuscript Details : Acknowledgement should be made preferably in the 'Introduction' in a separate paragraph. Indent the first line of each paragraph except the first line under 'Introduction.' Underscore only where italics are intended as in the address under the author(s) name(s), scientific names and source of publication in literature citation at the end of the paper. Both in zoological and botanical names only the initial letter of the genus is capitalised. The specific and subspecific names always begin with a small letter even if they refer to a person or place. Author's names after species, sub-species, varieties, forms and notations such as sp. nov. and so on associated with scientific names should not be underscored.

Material and Methods when given should be limited to what scientists need in understanding the design of the study and in judging whether the data obtained is adequate. The relative importance of the headings in the MS should be shown by their position on the page and by proper use of the capitals and lower case as given below :

First order — CENTRE HEADING, ALL CAPITALS.

Second order — Centre Heading, Capitals and Small Capitals.

Side heading — Capitals and lower case underscored, not indented.

Run-in-heading — Capitals and lower case, underscored and indented.

Names of all simple chemical compounds other than their formulae should be used in the text. When Greek symbols or unusual signs which normally cannot be typed are used, they should be written out quite legibly and made easy to differentiate as between : 'K' upper case and 'k' lower case. Similarly, complex mathematical equations should also be clearly written out if they cannot be typed fully. Double space should be left above and below the lines that have equations and formulae with superscript and subscript. All measurements should be given in the metric system only.

Title Page : The title of the manuscript should be brief, but should encompass the content of the paper and should be typed wholly in capitals. This is followed by the author(s) name(s) with the initials preceeding the surname. No periods follow the title or the author(s) name(s). The address of the author(s) given below the name(s) should be underscored with no period at the end.

On a separate slip, a condensed title for running head of less than 45 letters inclusive of spaces should be provided. Titles with scientific names must contain a common identifying term, e.g. '. . . the Fish *Hoplolatilus froticinctus* (Gunther) . . . .'

Abstract : All articles and notes should have an abstract in the form acceptable to all abstracting journals. For articles, this should not exceed 5 per cent of the length of the manuscript and should be typed in double space starting on the title page leaving 5 cm margin. The abstract should not be a summary of the work done, but should highlight the salient points and recapitulate the findings and conclusions.

Notes : Notes are those papers with fewer than six pages of double spaced (elite type) manuscript and will have no centred headings. The title will be followed by an abstract and the name(s) of the author(s) will be given at the end of the article on the right hand side of the page with the address on the left hand side before 'References.' The 'References' cited at the end of the note will be in the same way as full papers, but will not have the titles of papers.

References : Citation of literature should have author, year, title, name of journal, volume number and inclusive pages.

INSTRUCTIONS TO AUTHORS

Abbreviations of the names of the Journals should be according to the '*World List of Scientific Periodicals*' (4th edition, 1964-65) or to recognised forms only. Examples:

FOGG, G. E. 1952. The production of extracellular nitrogenous substances by a blue green alga. *Proc. Roy. Soc.*, **B 139** : 372-397.

HARVEY, H. W. 1931. *Biological Chemistry and Physics of Sea Water*. Cambridge Univ. Press, London, 194 pp.

MOTT, J. C. 1957. The Cardiovascular system. *In:* M.E. Brown (Ed.) *The Physiology of Fishes*. Academic Press, Inc., New York, N. Y., Vol. 1, pp. 103-109.

SCHAEFER, M. B. AND J. C. MARR 1948. Spawning of yellowfin tuna (*Neothunnus macropterus*) and skipjack (*Katsuwonus pelamis*) in the Pacific Ocean off Central America, with description of juveniles. *Fishery Bull. Fish. Wildl. Serv., U. S.*, **51** (44) : 187-196.

In the text, the references should be cited thus : Fogg (1952), Schaefer and Marr (1948) with the author(s) name(s) followed by the year of publication in parenthesis.

Tables : Tables should be avoided if the matter could be covered by the text. Tables when given should not contain bulky data and should be given on separate sheets and their position in the text indicated suitably. They should be neatly typed without any overlapping of the columns and without vertical rules. Each Table should be numbered with Arabic numerals (e. g. Table 3) and should have a brief heading which is underscored. Both Tables and graphs illustrating the same point will not be accepted.

Illustrations : Drawings or illustrations should be made in Indian ink on white Bristol board or good quality tracing paper or on co-ordinate paper with blue grids and normally to twice that of the final printed size. The size of the printed area of the Journal is 18 × 12.5 cm and this will be the maximum size for full page Figure with legend. Figures should be numbered in Arabic numerals and indicated in the text thus : Fig. 1 and should have the Fig. number, legend, author and abbreviated title of the paper or note on the back. All lines, symbols, letters and numerals must be neat and legible and letterings at least 1 mm high when reduced to appropriate size

Photographs or photomicrographs for re-production must be clear and show good contrast and must be free of clip markings and cracks. Prints must be in glossy glazed paper and of a size not smaller than 8.0 × 5.5 cm. When photographs are grouped as one Plate, then should be trimmed and mounted with no space between those in the group as intended for final reproduction. Each photo of such a group should be lettered with a block letter (A, B, C, etc.) at the right bottom corner and in the text indicated thus: Plate I A. Such notations on Text-figures should be given as (a, b, c, etc.). Type-written lettering on Figures is not acceptable.

Legends for figures should be written on a separate sheet headed 'Captions for illustrations' at the end of the manuscript.

Scale of magnification of *camera lucida* drawings should be indicated besides the drawing itself.

Proofs and Reprints : A galley proof will be furnished to the author along with an order blank for reprints. The corrected proof along with the order for the reprints should be promptly returned to the Editor within 10 days of the date of despatch (15 days from abroad) failing which it will be the responsibility of the author if mistakes appear in the paper. Authors may be charged for any changes other than the printer's errors. Authors are also requested to keep the Editor informed of any change of their address.

For every contribution, the author will be supplied *gratis* 25 reprints of the article without cover. In the case of joint authorship, 30 reprints without cover will be supplied *gratis*. Extra reprints should be ordered in multiples of 25 and will be supplied without covers.

Institutional orders for extra reprints must also accompany the galley proof with full instructions about invoicing.

All manuscripts, books for review and correspondence concerning the editorial matters should be addressed to :

THE EDITOR,
Marine Biological Association of India,
Post Box No. 2673, Dr. Salim Ali Road,
Shanmugam Road—P.O., Ernakulam,
Cochin - 682 031, Kerala, India.

JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA

(*J. mar. biol. Ass. India*)

The Journal is the official organ of the Marine Biological Association of India and is issued twice in a year. The available volumes are:

Vol. 1.	Nos. 1 & 2 (1959)	To	Vol. 13. Nos. 1& 2 (1971)	Rs. 75* Each
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Vol. 15.	„ (1973)			Rs. 200
Vol. 16.	Nos. 1 to 3 (1974)	„	Vol. 18. Nos. 1 to 3 (1976)	Rs. 300 Each
Vol. 19.	Nos. 1 & 2 (1977)	„	Vol. 24. Nos. 1 & 2 (1982)	Rs. 150 Each
Vol. 25.	Nos. 1 & 2 (1983)	„	Vol. 32. Nos. 1 & 2 (1990)	Rs. 200 Each
Vol. 33.	„ (1991)			Rs. 250

* Limited numbers are available.

J. mar. biol. Ass. India, 1991, **33** (1 & 2)

ANNOUNCEMENT

Stazione Zoologica di Napoli

President : G. Salvatore

Director : L. Cariello

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THE MARINE BIOLOGICAL ASSOCIATION OF INDIA

Official organ : **Journal of the Marine Biological Association of India**
(Free to the Members)

PROPOSAL FORM FOR MEMBERSHIP (INDIAN/FOREIGN)

To be completed and sent to the Secretary, Marine Biological Association of India,
C. M. F. R. I. Campus, P. B. No. 2673, Shanmugam Road—P.O., Ernakulam, Cochin-682 031

For Individual Membership

Full Name with academic qualifications, etc. (in BLOCK letters)	:	
Nationality	:	
Date of birth/age	:	
Occupation/Designation	:	
Type of Membership required	:	Life Membership/Annual Membership
Mailing address	:	
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