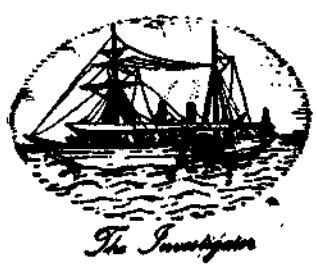
PROCEEDINGS OF THE SYMPOSIUM ON COASTAL AQUACULTURE

Held at Cochin

From January 12 to 18, 1980

PART 1 : PRAWN CULTURE

(Issued on 25th February 1982)



MARINE BIOLOGICAL ASSOCIATION OF INDIA

POST BOX NO. 1244, COCHIN 682 011, INDIA

Price : Rs. 400.00

SYMPOSIUM SERIES 6

Abbreviation

Proc. Symp. Coastal Aquaculture, Pt. 1.

PRINTED IN INDIA BY K. G. JOHN AT THE DIOCESAN PRESS, MADRAS 7 AND PUBLISHED BY E. G. SILAS ON BEHALF OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA, COCHIN-682 011.

Proc. Symp. Coastal Aquaculture, 1982, 1 : 369-382

ENVIRONMENTAL CHARACTERISTICS OF THE SEASONAL AND PERENNIAL PRAWN CULTURE FIELDS IN THE ESTUARINE SYSTEM OF COCHIN

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ABSTRACT

The paper embodies the results of investigations conducted to study the environmental characteristics of the prawn culture fields in the estuarine system of Cochin from Azhikode in the north to Kumarakam in the south including the Vembanad Lake. Primary productivity and related hydrobiological parameters of the water have been studied from 50 stations during December '77 to May '78 when the prawn and other brackishwater fishes are cultivated in the fields lying adjacent to the ecosystem. In addition, the epifauna, benthic fauna and chemical constituents of the mud of these fields have also been analysed and results presented. Significant regional variation in the case of primary production, faunistic composition of epifauna and benthos of these prawn culture fields were observed. The chemical composition of the mud also evinced distinct regional variations. Based on these productivity parameters, an attempt has been made to categorise the various prawn culture fields existing in the estuarine system.

INTRODUCTION

THE DYNAMIC ENVIRONMENT of the estuarine system of Cochin and the connected backwater plays a significant role in the fishery of the area in general and the prawn fishery in particular. Due to the high demand for prawns in the recent years, efforts are being made to augment their production through prawn/shrimp farming. In Kerala, about 5120 ha of fields are utilised for prawn culture, of which about 3500 ha are situated in and around the Cochin estuarine system. Although several publications (Qasim *et al.*, 1968, 1969; Qasim and Gopinathan, 1969; Sankaranarayanan and Qasim, 1969; Qasim and Sankaranarayanan, 1972; Gopinathan *et al.*, 1974; Nair *et al.*, 1975; Pillai *et al.*, 1975; Madhu Pratap and Haridas, 1979) provide informations on the hydrobiology and ecology of the Cochin Backwater and adjacent areas, detailed account dealing with the productivity of the prawn culture fields situated in the estuarine system is lacking. The main objective of this study is to assess the productivity of the seasonal and perennial fields at various trophic levels through a baseline survey with productivity techniques and from other related parameters in assessing the biogenic capacity of water in the fields, a pre-requisite in determining the stocking strategies and in the evaluation of the production in the culture system.

The authors are grateful to Dr. E. G. Silas, Director for suggesting this topic for study and also for the encouragement. They are also thankful to Dr. P. Vedavyasa Rao, for critically going through the manuscript and offering improvements. Thanks are also due to Smt. K. K. Valsala of this Institute and

Shri. Purushothaman Nair, FACT, Udyogamandal, for the help extended in this study.

Material and Methods

The area of investigation includes the extensive estuarine system from Azhikode in the north to Kumarakam in the south including the Vembanad Lake enclosing a large number of prawn culture fields, both seasonal and perennial ones. Fifty stations (32 seasonal and 18 perennial fields) were covered during the prawn/fish culture period of December 1977 to May 1978 (Fig. 1). Although culture practice is extensively carried out in the entire system, at Thanneermukkom, virtually no prawn culture fields are in operation in the zone south of the barrage since its commissioning in 1976. In the seasonal fields, paddy is cultivated from May to August. After the harvest of paddy, juvenile prawns brought in by the tidal currents are allowed to enter and grow in the fields and are periodically harvested. Since the perennial fields are deeper than the seasonal ones, only prawn culture is possible which is carried out throughout the year. The average depth of the seasonal fields is about 1 m whereas the perennial fields are 2-3 m deep.

Light and dark bottle oxygen technique has been used to estimate the primary production with occasional cross checks by ^{14}C technique. The production per unit volume has been computed using PQ 1.25. The sampling has been done at the surface only and the incubation has been carried out under identical conditions of light and temperature. In view of the limited depth of the water bodies, it was not felt necessary to conduct sampling at various depths. As the light penetration takes place upto the bottom, there is not much limitation regarding the available energy for photosynthetic activity. Hydrological properties such as salinity, oxygen and nutrients (Nitrite, Nitrate, and Phosphate) were determined by standard methods (Strickland and Parsons, 1968). The epifauna was collected by filtering a known volume (100 l) of water through sieves of 0.097 mm and 0.069 mm. Samples of epifauna and suspended detritus were collected by filteration method from the fields investigated. Mud samples were collected to analyse the faunal index of benthic organisms as well as to estimate the chemical composition such as organic carbon, pH, phosphate and total soluble salts. Estimation of the amount of organic carbon in the mud sample was done by the chromic acid oxidation method. For the convenience of presenting the results, the stations located in the northern and southern areas of Cochin are discussed separately.

Results

The data on the various physico-chemical properties of the water along with that on the primary production is presented in Fig. 2.

Hydrological properties

Temperature : The temperature of the ambient water of the fields recorded a difference of 6°C, ranging from 26.8 to 33°C (Fig. 2 g) during the period of survey (December-May). It has already been established that in the Cochin Backwater and adjacent areas, temperature has little significance in the production of organic matter (Qasim *et al.*, 1969).

Salinity : In contrast to temperature, wide range of salinity variations were observed which ranged from 1-27‰ in the different fields investigated (Fig. 2 f). Since the northern region of the estuary has two connections with the sea, relatively high salinity values were recorded in the fields of this zone.

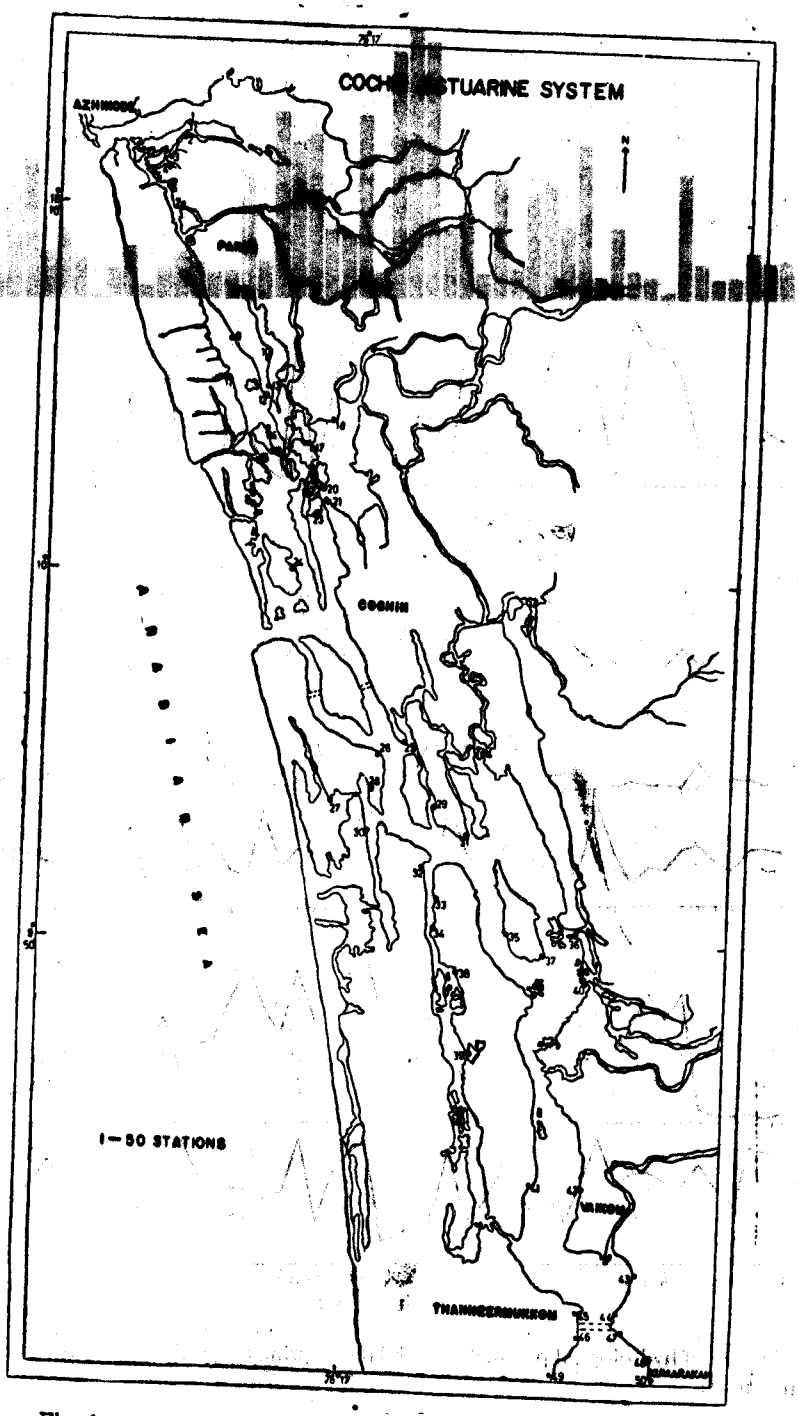

Fig. 1 Location of stations in the Cochin estuarine system.

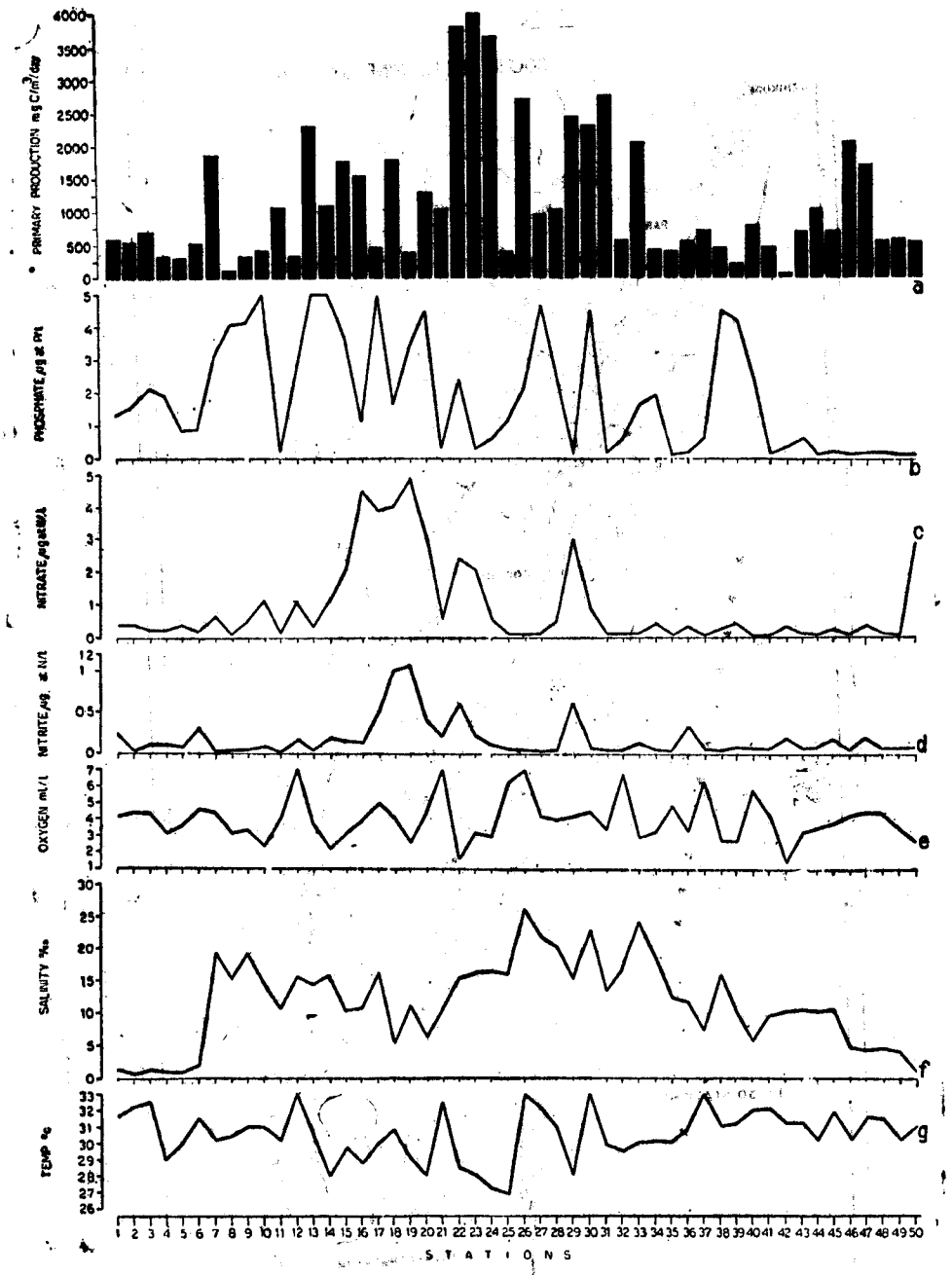

Fig. 2. Distribution of hydrological parameters and data on primary production in the different prawn culture fields.

Similarly low values were recorded in the fields adjacent to the Vembanad Lake. However, the effect of interstitial salinity on the survival and growth of the organisms will be of much significance in some of the fields located away from the bar mouth. The variation in salinity has already been reported from the entire estuarine system (Josanto, 1971; Qasim *et al.*, 1972; Gopinathan *et al.*, 1974; Pillai *et al.*, 1975).

Dissolved oxygen: The dissolved oxygen content of the water in the prawn culture fields showed distinct regional variations. The fields of the northern region have high or optimum values (4-6 ml/l) as compared to the southern regions (2-3 ml/l) (Fig. 2 e). Although the dissolved oxygen content has no direct role in the production of organic matter in the estuary, it is an index of the metabolic activities of the entire community comprising producers as well as consumers.

Nutrients: During the present investigation, nutrients such as nitrite, nitrate and phosphate were estimated from the water samples. The nitrite content of the water was very low (< 1 μg at N/l) in almost all the stations and ranged from 0.2 to 1.10 μg at N/l (Fig. 2 d). However, wide variations were noted in the nitrate values, ranging from 0.24 to 4.94 μg at N/l in the fields investigated (Fig. 2 c). Both nitrite and nitrate showed moderate to high values in the fields located in the middle regions of the estuary. The fields situated in the northern and southern regions had very low values of nitrogenous compounds. The phosphate values ranged from 0.06 to 5.80 μg at P/l (Fig. 2 b). As in the case of nitrate, the phosphate also showed high values in the fields of the middle zone as well as in a few stations of the northern zone. The observed values of nutrients showed an increasing trend in the fields located in the middle and northern regions as compared to the fields located in and around the Vembanad Lake.

Primary Production: The productivity values obtained during the survey period of December—May of all the stations were plotted in Fig. 2 a. The measurements indicate that the entire area covered during the investigation can be classified into 3 categories; *viz.* highly productive (> 1500 mgC/m³/day), low productive (<500 mgC/m³/day), and moderately productive zones (500-1500 mgC/m³/day). The prawn fields in the middle region of the estuary which showed high rate of production as compared to the extreme northern and southern regions, (Fig. 1, stations: 7, 13-16, 18, 22 - 24 in the northern half and stations 26, 29 - 31, 34 in the southern half). Moderate values were observed in the northern and southern extremities of the estuary especially at stations: 1, 3, 6, 11, 20, 21, 27 - 28, 33, 37 - 38, 44 - 45 (Fig. 1). Low values were observed in the prawn fields where there is direct connection with the main land, such as the stations: 4-5, 8-10, 12, 17, 19 of the northern region and stations 25, 32, 35-36, 39 - 40, 42 - 43 in the southern region. However, the fields near Thanneermukkom Bund showed rather high values when compared to the other fields located in the interior regions of the northern half of the estuary.

Among the prawn fields, the seasonal fields are found to be more productive than the perennial ones. This is reflected in the occurrence of more seasonal fields in the northern regions of the estuary where the productivity parameters showed an increasing trend. Based on the data on primary production, it has been possible to classify the different regions of the prawn culture fields as follows:

1. A highly productive area north and south of Cochin bar mouth where there

is a constant incursion of seawater and influx of river water. In such a dynamic environment, due to high replenishment rate, the water is never 'old'. Similarly, a belt of high productive area is found in the prawn fields lying adjacent to Azhikode bar mouth where there is freshwater discharge from the Chalakudy river. During the period of freshwater discharge, high concentrations of nutrients occur with great variations within the system. Large quantity of organic matter are brought into the estuary through the land run off. These are probably decomposed at the bottom and as a consequence seem to have a marked influence on the nutrient distribution.

The waters in between the highly productive zones, *i.e.* between Cherai (Stn. 7) and Vallarpadam (Stn. 24) on the northern half of the estuary and the waters in the region of Vembanad Lake are found to be moderately productive. The effect of Thanneermukkom Bund, on the basic productivity of the water on either side seem to be insignificant, though in the overall population structure, there has been significant variation.

The water bodies on the hinter-land around Vaikom in the south form a low productive area as observed earlier by Nair *et al.* (1975). This is probably because the incursion of nutrient-laden water is highly restricted in this zone which may be limiting the primary production. In such areas, it would be necessary to provide artificial feeds or other additional inputs to supplement the basic productivity.

Epifauna and suspended detritus

Assessment of the epifauna, the organisms occupying the secondary level of the food chain and detritus, the biogenic and non-biogenic material undergoing various stages of microbial decomposition, form a major pre-requisite in the studies of organic productivity of a given area. With this in view, a survey of the distribution of epifauna and suspended detritus, occurring regularly in the plankton has been carried out in certain selected prawn fields (Fig. 3) in the estuarine system as part of the present study and the results are presented here.

Faunistic composition of the epifauna indicate that the following groups/species formed the major components in the order of their abundance: Rotifers, copepods and copepodites; copepods such as *Oithona* spp., *Acartia* spp., *Pseudodiaptomus* spp., *Acartiella* spp., *Diaptomus* spp., nauplii of other crustaceans, bivalve larvae, radiolarians, fish larvae, nematodes, polychaetes, fish eggs, cladocerans, tintinnids and harpacticoid copepods. The percentage composition of different groups shows that rotifers constitute more than 50% of the epifauna in almost all the fields, followed by copepod nauplii and copepodites (2-8%). Other groups listed above formed only a minor portion in different fields (<2%).

The total biomass of epifauna was relatively high in the northern area (Stns. 1-5) as compared with that in the middle region of the estuary between stations 15 and 41. In the vicinity of Thanneermukkom (Stn. 46), relatively high values of biomass have been recorded. Further, analysis of the pattern of quantitative distribution of the faunal elements indicates that they are numerically abundant in the vicinity of the stations 5 and 7 in the northern sector and around stations 36, 46 and 49 in the southern region. The constituent fauna in the area

between stations 15 and 30 were found to be of a minority in the collections.

Direct correlation between primary production and the quantitative distribution of epifauna was difficult to derive at since, the faunal elements were poorly represented in the fields located in the vicinity of Cochin, both to the south and north, where high rates of primary production were recorded. Similarly the quantitative distribution of epifauna showed a negative correlation with salinity (Fig. 3 b) especially in to fields situated around Cochin. However, rotifers showed distinct abundance in most of the fields where gross production rates and quantity of suspended detritus were relatively high.

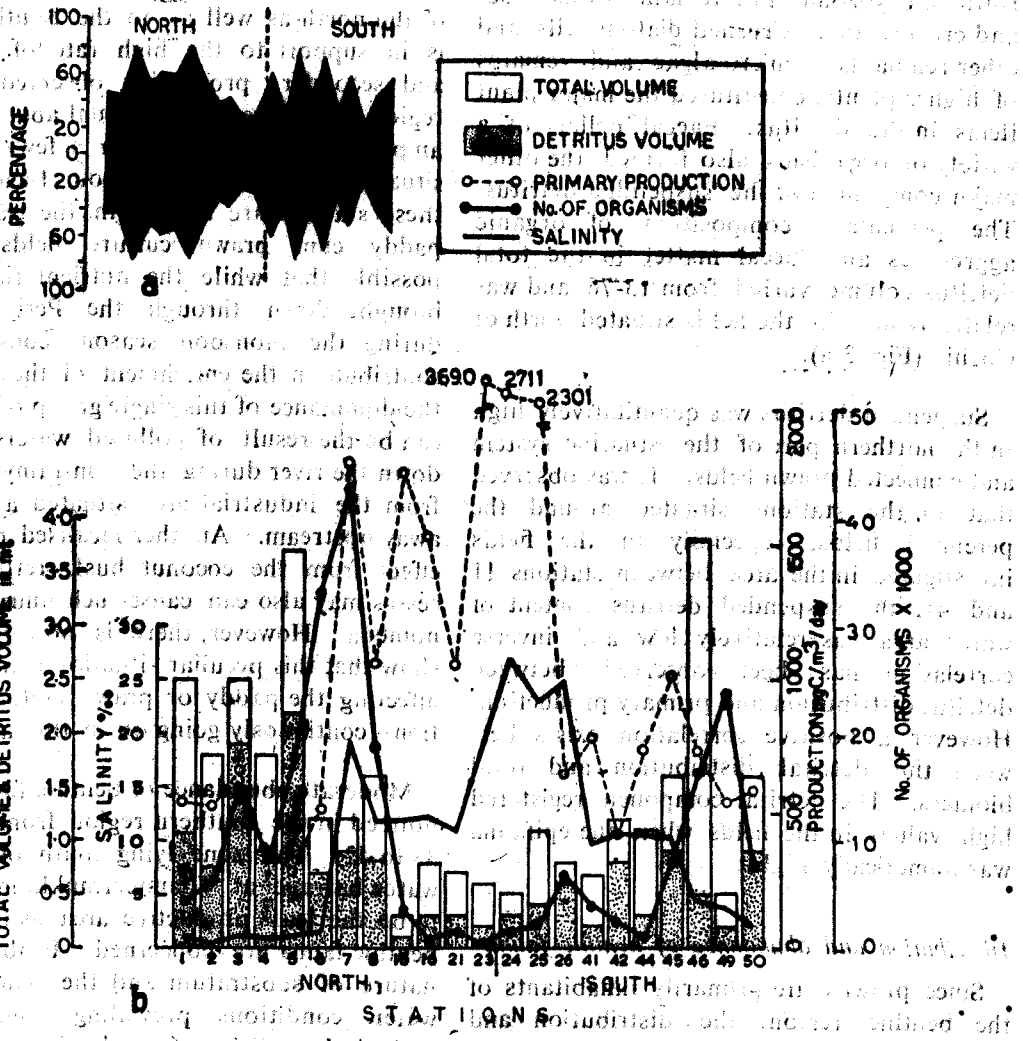

Fig. 3. a. Detrital volume (%) observed in the stations in the northern and southern zones of the estuarine system and b. Distribution and abundance of epifauna and suspended detritus in relation to salinity and primary production.

Examination of the suspended detritus (which occurs regularly in the plankton and can be differentiated from the settled detritus) revealed that it was of different size and shapes and basically composed of silt or sand. Organic matter, such as the remains of animals and plants was found to be deposited around such particles. Major groups of identifiable organisms include foraminifera, nematodes, polychaetes, rotifers, bryozoans and remains of molluscs and crustaceans. Crushed diatom cells, and other remnants of micro-algae and remains of higher plants, constituted the major plant items in the detritus. Faecal pellets of a variety of organisms also formed the other major component of the suspended detritus. The percentage composition of organic aggregates and faecal matter in the total detritus volume varied from 13-76, and was relatively high in the fields situated north of Cochin (Fig. 3 a).

Suspended detritus was quantitatively high in the northern part of the estuarine system and connected prawn fields. It was observed that in the stations situated around the perennial fields, especially in the fields investigated in the area between stations 11 and 41, the suspended detritus content of water area was relatively low and inverse correlation has been observed between detritus distribution and primary production. However, a positive correlation exists between the detrital distribution and total biomass. The detrital component registered high values in the fields when the epifauna was numerically high.

Distribution and abundance of benthic fauna

Since prawns are primarily inhabitants of the benthic region, the distribution and abundance of the benthic population is of great significance when the ecological conditions for prawn culture are assessed and evaluated. It is well known that benthic population represents an important link in the trophic cycle in this type of ecosystem.

The dominant benthic fauna were found to be molluscs (bivalve and gastropods) followed by polychaetes, amphipods, kinorhinchids, isopods and cumaceans. The general pattern of their distribution indicates an abundance in stations located in the immediate vicinity of Cochin bar mouth, both to the north as well as to the South. This is in support to the high rate of primary and secondary production observed in this region. However, an unusual abundance of amphipods was noticed in a few stations situated north of Cochin harbour. Incidentally, these stations are located in the traditional paddy cum prawn culture fields. It is possible that while the nutrient rich water brought down through the Periyar river during the monsoon season, considerably contribute in the enrichment of these fields, the dominance of this single group of animals can be the result of polluted waters coming down the river during the non-rainy seasons from the industrial area situated a few km away upstream. Another localised pollution effect from the coconut husk retting processes may also can cause such unusual phenomena. However, there is no evidence to show that this peculiar situation is in anyway affecting the paddy or prawn culture operations continuosly going on in this area.

Moderate abundance of benthic fauna were noticed in the southern region from stations 33 to 42. The zone lying south of the salt water barrage at Thanneermukkom appears to be the least productive area as far as the benthic fauna are concerned. Probably, the nature of substratum and the almost fresh water conditions prevailing and other ecological conditions (*e.g.* the large quantity of floating weed *Salvinia* sinking to the bottom on decay) are the contributing factors

for such a situation. However, from the available data, it can be said beyond doubt that the northern half of the estuarine system and connected prawn culture fields are more productive as far as the benthic fauna are concerned (Fig. 4). The trend revealed from preliminary survey was carried out to estimate the organic carbon, phosphate, pH and total soluble salts. The effect of large scale river discharge and the organic matter reaching the paddy fields and estuarine areas were reflected on the data gathered (Fig. 5).

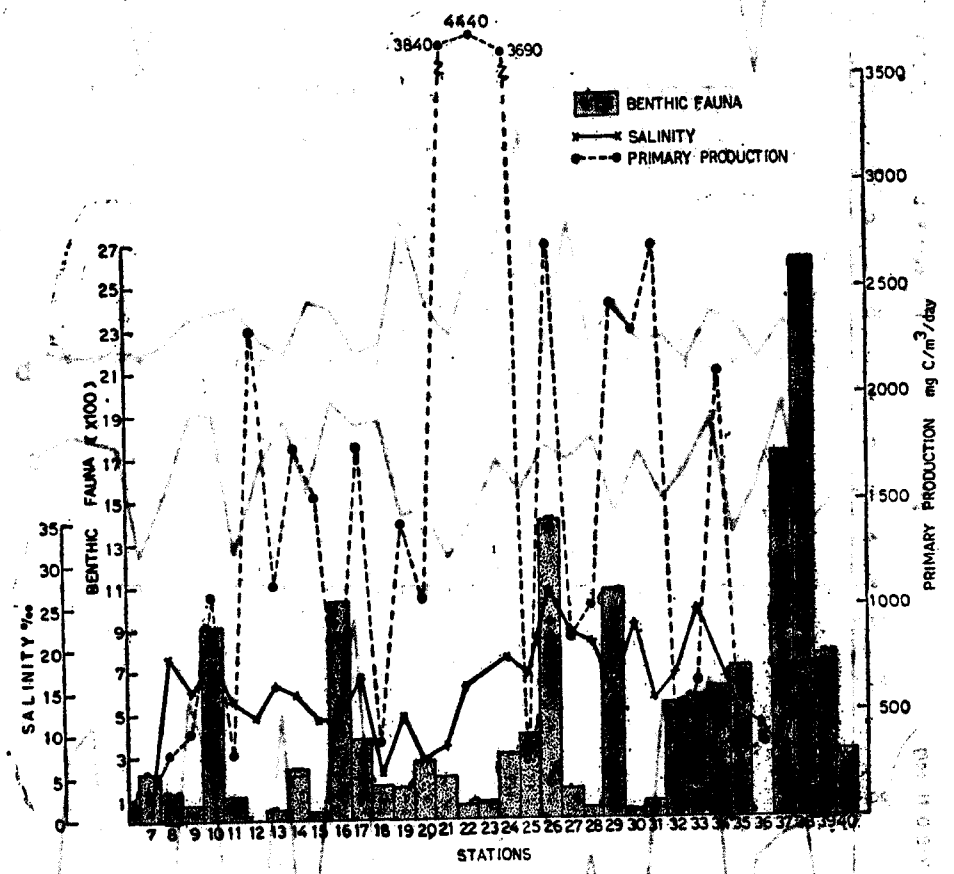

Fig. 4. Benthic fauna of the selected stations in relation to salinity and primary production.

other aspects of investigations in this study also supports this point.

Chemical composition of the sediment

Since the chemical composition of the sediment, especially the carbon content is an index of the input to the ecosystem as well as the overall productivity of the environment, a

Organic carbon: Comparatively high values of organic carbon (22-35 mg/g) were observed at a few stations which are located in the proximity of river water entering the backwaters. The advantageous position of these fields in receiving a constant supply of organic matter may be the reason for this phenomenon. In the fields where the soil

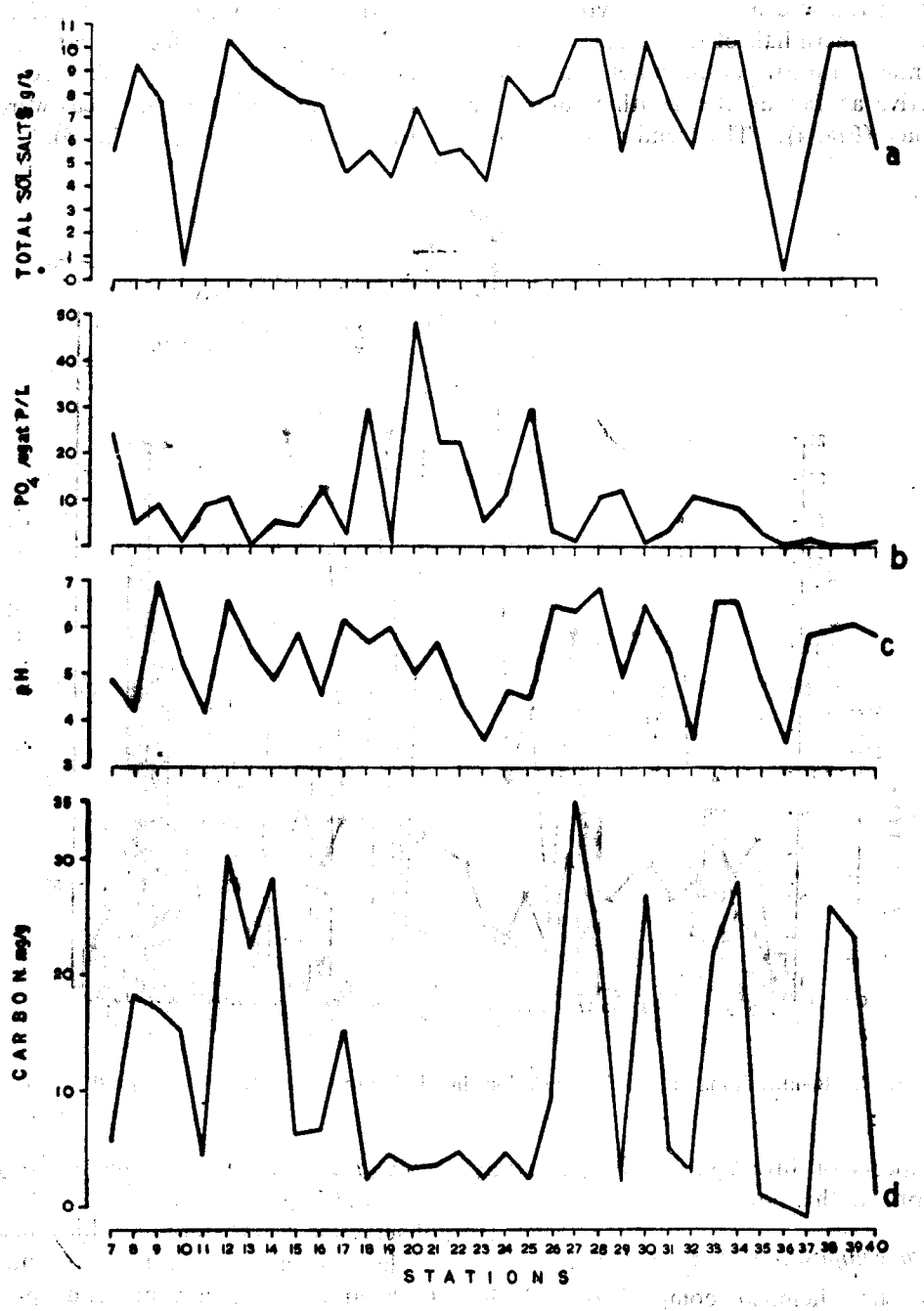

Fig. 5. Chemical composition of the mud from prawn culture fields.

composition was sandy, the organic carbon content was invariably low (<10 mg/g) while in areas where the substratum was of an alluvial nature, the carbon content was moderately high (20 mg/g). This is an apparent reason for high rate of production recorded in the fields around Cochin where the soil is alluvial in nature. Incidentally, the seasonal prawn/paddy culture fields were observed to have high organic content in the sediment, apparently due to the decay of roots and stems of rice plants after the harvest, adding thereby a good amount of organic matter to the soil. The spatial variation of the organic carbon content of the mud sample studied are presented in Fig. 5 d. The periodic enrichment of these fields by river water during the rainy season may also be contributing to this phenomena.

pH: The pH of the sediments indicated a range between 3.5 to 7.0. However, in the majority of stations, the range was between, 5 and 7.0 (Fig. 5 c). Certain low values were recorded in the southern-most stations, obviously because of the effect of large scale decomposition of weed deposits in the area.

Phosphate: Compared to the phosphate content recorded in the ambient water (0-5 μg at P/l), in the sediments fairly high concentrations (0-50 μg at P/l) were recorded, especially in the middle region of the study area (Fig. 5 b). The high rate of manuring in the adjacent agricultural fields may be the causative factor for this phenomena.

Total soluble salts: The total soluble salts in the mud samples do not show much variations, except at one station (Stn. 10). The values ranged from 0.60 g/l to 10.40 g/l. However, most of the stations have moderate values (5-10 g/l) and the data did not reveal any regional variation of this parameter (Fig. 5 a).

Discussion

It is well known that the yield of living resources to man from any water body is closely related to the primary productivity of the waters. In the marine environment, a fraction (about 10-20%) of the productivity of one level is transferred to the next. But in the case of lakes and confined waters where prawns constitute the predominant yield such a prediction is rather untenable. However, some meaningful conclusions could be drawn by examining critically various productivity parameters such as rate of photosynthesis, availability of nutrients and energy and also the quantum of epifauna and detritus of the concerned ecosystem.

The productivity in lakes as well as in freshwater bodies is a function of the nutrient supply. In these environments, nutrient availability is largely the result of sediment composition as well as variations in the surrounding land use and resultant run off. The river input also contributes to this significantly. However, beyond the critical concentration required for phytoplankton production excess nutrients may be just assimilated without further plant growth (Gerloff, 1969) which has been termed as 'luxury consumption' (Hendersen *et al.*, 1973) by the phytoplankton.

Figure 2 gives the primary production in terms of carbon per day as well as the basic nutrients that govern the rate of turn over. It may be seen that the phosphate in the ambient water and in the mud as well as organic carbon which is an index of the available nitrogen supply do not show direct proportionality with primary production values. The critical concentration factor of the nutrient supply may probably be the reason for this.

Based on productivity and related parameters a certain amount of zonation can be

derived. The present survey substantiates the earlier observations (George *et al.*, 1968; George, 1974; Pillai and George, 1974) that the fields located in between Cochin and Azhikode bar mouth is relatively a more productive area. The ecological advantage of having two openings to the sea within a short distance through which there is a regular incursion of saline water and also the periodical enrichment from the run off from Periyar river to this area can be the causative factor for this phenomenon.

Based on organic production, the estuarine system of Cochin extending from Azhikode to Alleppey, covering an area of about 300 sq. km has been classified into low, moderate and high productive areas—where production exceeds 1500 mgC/m³/day is being highly productive and less than 500 mgC/m³/day being low productive and areas between these two rates of production being considered as moderate. High rate of production has been recorded at the regions south and north of Cochin bar mouth where the influx of the inshore water is relatively greater. So also where there is the influx of freshwater from river discharge, the rates are comparatively high. The estuarine region, where there is least influence either from replenishment by the 'new water' or influx of freshwater, the rate of production is low.

It is also observed that the seasonal fields are more productive than the perennial fields. Due to paddy cultivation and also by the regeneration process of the nutrients in the sediment, the organic compounds in the benthic region increase. The nutrient content of the water of the seasonal fields, located in the northern region of the estuary show higher values as compared to the southern region.

The total biomass of the epifauna was relatively high in the northern part of the estuarine area and in some fields in the southern sector. Numerical abundance of organisms in the fields also followed the same pattern of distribution. No positive correlation between productivity and salinity and abundance of epifauna as well as benthic fauna has been observed during the present survey. However, the preponderance of rotifers in the epifauna over other groups in the areas located near seasonal paddy-cum-prawn fields indicates that the fields are rich in organic matter. Result of the investigation on the chemical composition of the sediments presented (Fig. 5) in this account also support this assumption.

In the fields located far away from the bar mouth as well as those fields which do not have proper inlet canals, circulation of water is a major factor. In fact the higher productivity of shallow water bodies can be related to continuous stirring of the bottom by waves and water circulation. In addition, large inputs of particulate organic material or detritus is also important. Detritus may be formed either by internal supply from remains of phytoplankton, other rooted vegetation and dead zooplankton. It is also formed partly by mineralization of organic inputs from man-made sources. The tidal movement keep this detritus matter in suspension for a prolonged period.

The importance of detritus as food of estuarine and nearshore organisms has been documented by earlier authors (Fox, 1950; Darnell, 1961; Newell, 1965). Nutritional value of suspended detritus has been reported by Parsons (1963) and Kenchington (1970). Qasim and Sankaranarayanan (1972) studied the organic detritus at a station in the Cochin Backwater and concluded that the detrital sedimentation in the estuary attains its maximum during April-June period. They also stated that detritus form a major portion of the seston but phytoplankton productivity constitutes only 0.1 to 1.0% of the settled detritus. Results of the present

study on the quantitative relation between phytoplankton production and suspended detritus indicate that the detritus is not wholly of phytoplankton origin. As stated earlier, it mainly contained the organic aggregates and faecal pellets of a variety of organisms. However, detrital components showed a positive co-relation with the total biomass and the numerical abundance of organisms. It has been observed that normal abundance of detritus occurs in environments which have a high organic load (Qasim and Sankaranarayanan, 1972). Their accumulation in the vicinity of prawn fields situated in the southern and northern zones of the estuarine system, might have been contributed by the organic material brought down by the rivers in these regions and land run-off from the adjacent areas.

Thus, the amount of detritus, nutrient level as well as the magnitude of primary production together could be taken as the criteria for estimating the stocking potential and also to determine the other inputs required for taking an optimum sustainable yield from the seasonal and perennial fields. It may be pointed out here that the yield of fish or other resources have been estimated from productivity and certain other easily measurable parameters by developing what is termed as 'morpho-edaphic index' (Ryder, 1965) which has been successfully applied in certain African lakes (Hendersen *et al.*, 1973). It may therefore be suggested that fields with a productivity rate of 2000 mgC/m³/day and having a relatively high detrital concentration could be stocked intensively without any additional inputs as fertilizers. Other fields with varying levels of productivity would require addition of organic material or inorganic manure, the requirement of which should be carefully calculated on the basis of the productivity of an ecosystem already available.

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