Indian Journal of Marine Sciences
Vol. 17, March 1988, pp. 24-30

Environmental Conditions of Some Paddy-cum-Prawn Culture Fields of Cochin Backwaters, Southwest Coast of India

K K C NAIR, V N SANKARANARAYANAN, T C GOPALAKRISHNAN, T BALASUBRAMANIAN, C B LALITHAMBIKA DEVI, P N ARAVINDAKSHAN & M KRISHNAN KUTTY

National Institute of Oceanography, Regional Centre, Cochin 682 018, India

Received 30 *April* 1986; *revised received* 25 *May* 1987

Temperature, salinity, *p*H, dissolved oxygen, inorganic phosphate, ammonia, nitrite and nitrate of seasonal and perennial prawn culture fields from 3 areas of Cochin backwaters are studied. Area 1 is a region least affected ecologically and the salinity values $> 10 \times 10^{-3}$ occur here during December to June. Area 2 which is near to the location of effluent discharge from a fertiliser factory shows high concentration of nutrients with low prawn production. Area 3 is most favourably situated to resist ecological distortions because of its proximity to the sea. The results indicate that the fields in areas 1 and 3 have environmental conditions highly suited for prawn culture whereas in area 2 the salinity conditions are not very conducive for prawn growth.

In Kerala traditional shrimp culture is practised in the low lying fields adjacent to the backwaters. These fields fall into 2 categories, the seasonal fields and perennial fields. In the seasonal fields paddy is grown during monsoon months (June to September) when the backwater system is fresh water dominated. Soon after the monsoon when the water becomes brackish, the postlarvae and juveniles of commercially important prawns migrate into these fields in large numbers and they are trapped through suitably located sluice gates. They are allowed to grow and periodically harvested until the season ends in April. The perennial fields where prawns are raised round the year are deeper than seasonal paddy fields and are comparable to the prawn culture fields of Singapore[1]. The yields from these fields are generally higher than those of seasonal fields[2].

In view of the importance of backwaters for large scale culture of prawns a detailed ecological investigation of 3 regions in the Cochin backwaters, has been undertaken. The study is primarily aimed to assess the environment's impact on the prawn production. Data are also collected from the neighbourhood of the harbour mouth area, which forms the main outlet into the sea, to enable comparison with the chosen area to understand the role of tidal and monsoonal flushing and the resiliency of the backwater ecosystem to pollution.

Materials and Methods

Prawn culture fields 1 - 3 selected for the study are shown in Fig. 1. Area 1 is located about 20 km north of Cochin harbour entrance in the proximity of the Azhikode entrance where the northern branch of the Periyar river discharges. Area 2, 15 km southeast from the Cochin harbour entrance is in the vicinity of a fertilizer factory. Area 3, near the

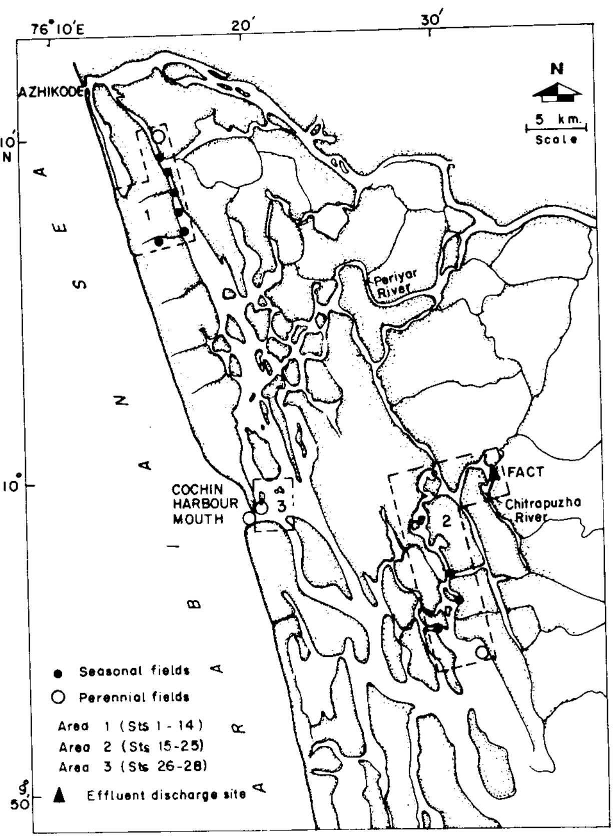


Fig. 1—Study area

Cochin harbour entrance is a reference station for the purpose of comparison.

The Cochin backwater has geographical contiguity with the northern part of the Vembanad Lake. The main river discharges into the region of study are from Periyar in the north and Muvattupuzha and Meenachil rivers in the south. The backwater has a permanent connection with the sea at Cochin and Azhikode through which seawater enters the backwater, and its extensive ramifications and intricate system of canals feed paddy-cum-prawn culture fields as well as the perennial prawn fields.

Monthly samples were taken from 28 stations from different fields in the 3 areas (Fig. 1). In areas 1 and 2, the fields studied included one perennial field each and in area 3 the sampling was possible in the only perennial field available. Sampling was done between December 1980 and March 1981 in the fields with seasonal prawn culture; it was however continued till November 1981 in the perennial fields in areas 1 - 3. Water samples were collected from the surface and bottom during high tide. Surface water samples were collected using a clean plastic bucket and the bottom samples with a cascella type sampling bottle. Water samples were analysed using standard methods[3]. Horizontal tows were made with a square net of 625 cm^2 mouth area and the filtering cone made of 200 μm mesh. Phytoplankton was collected by filtering 30 l of water through a 55 μm mesh bolting silk. Benthos samples were collected from the core samples taken in the upper 10 cm. As the prawn fields and adjacent canals were shallow (1 - 3 m), the environmental data did not show any significant vertical variations, therefore, surface and bottom values were averaged. Since seasonal prawn fields studied in each area were closely located, the above mentioned average values did not show any appreciable difference, from field to field. Hence values from seasonal fields of each area were put together and their average taken for interpreting the result. The values noted from the effluent discharge of the fertilizer factory located in area 2 are treated separately.

Results and Discussion

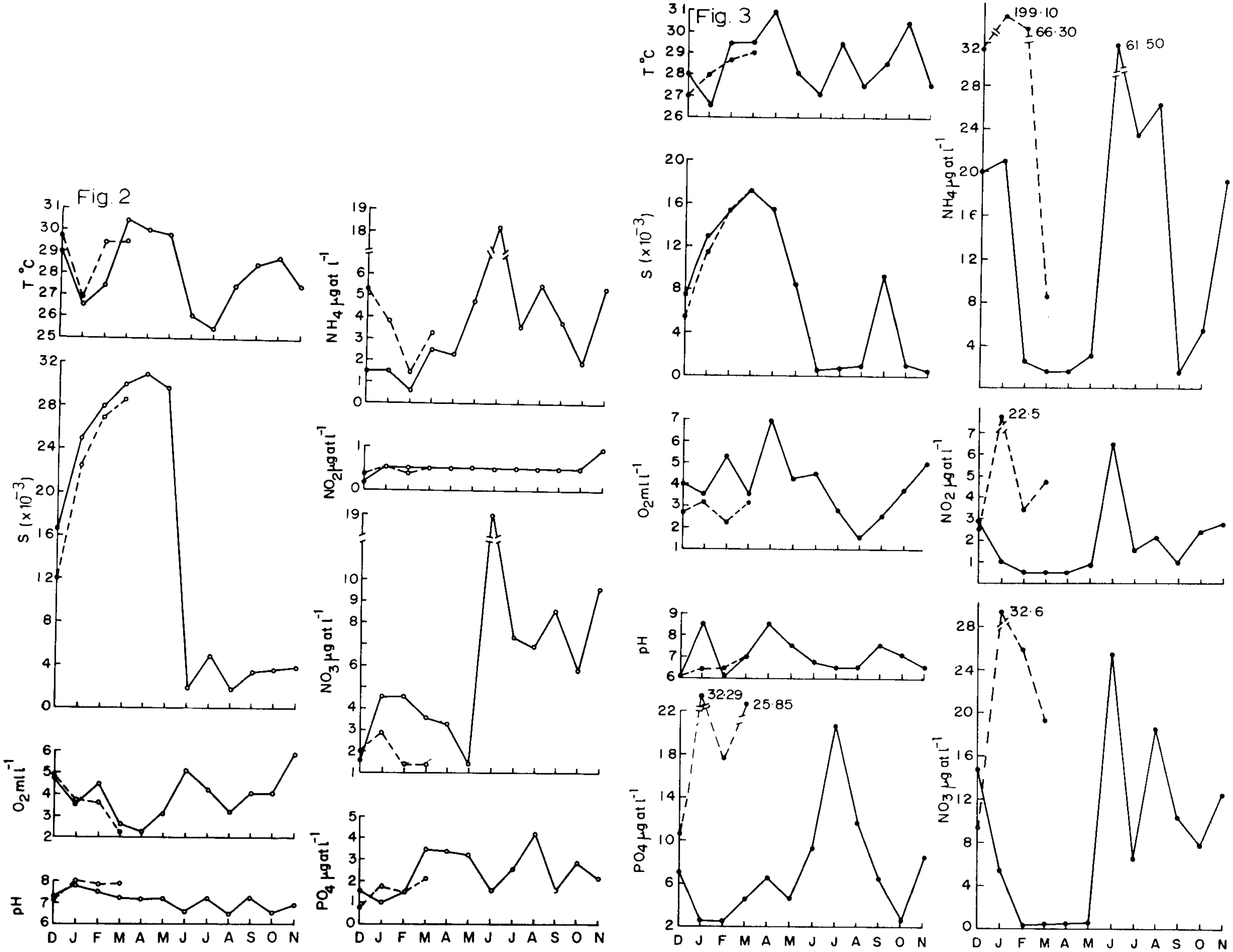
Monthly variations in major physico-chemical parameters estimated in areas 1 to 3 and from effluent discharge site and from the barmouth are given in Figs 2 to 5. Seasonal prawn production is shown in Fig. 6.

The environmental data presented here and their bearing in relation to the prawn production in the prawn fields are discussed from 3 perspectives—(a) spatial variations in the salinity conditions, (b) in relation to primary production and (c) the environmental impact arising from the industrial development.

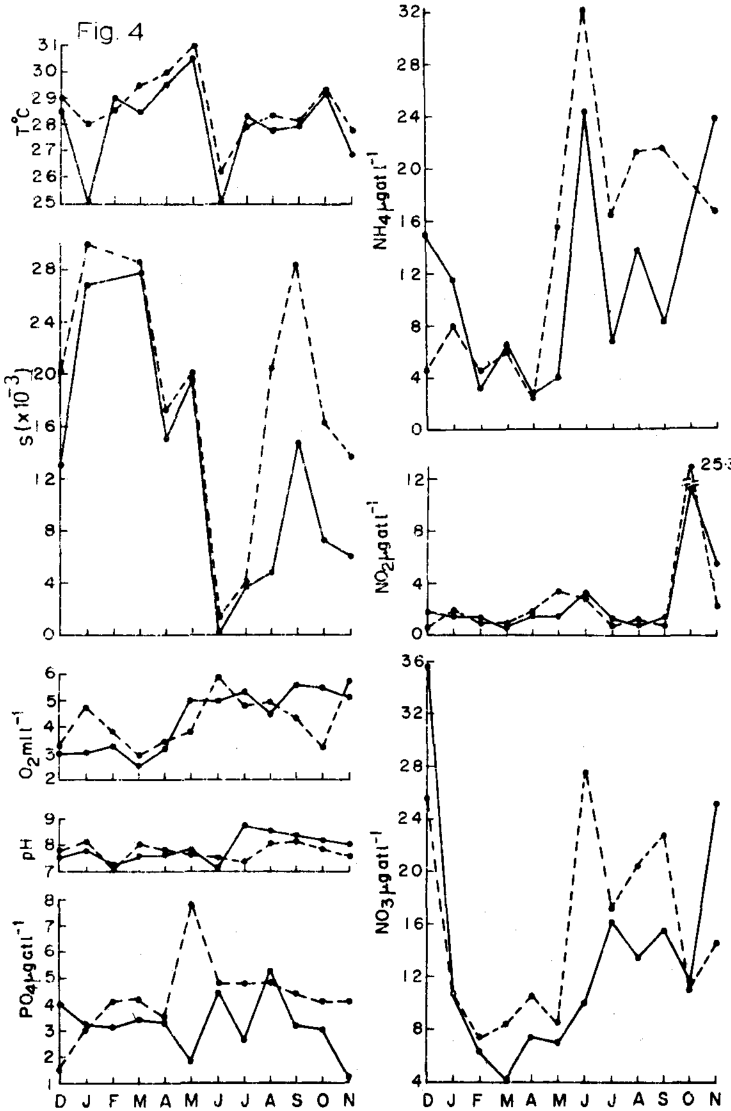
In the prawn fields of areas 1 to 3 the monsoon brings out changes from nearly marine conditions during the premonsoon period to fresh water conditions during the monsoon season. Physico-chemical conditions in the backwaters, connected canals and the adjacent paddy fields of the regions of study are controlled by tides[4].

The importance of temperature and salinity in the survival and growth of prawns was discussed[5-7]. The annual variation in temperature in the area of study was small (~ 5°C) to affect the environment. In all the 3 areas, the temperature was low during December to February and showed increasing trend afterwards. This was followed by a decrease during monsoon months and again an increase during later months at some stations. The fields in all the areas showed similar seasonal variation in temperature.

Salinity of the water increased from December through May from 11 to 31×10^{-3} in area 1, from 5 to 17.3×10^{-3} in area 2 and from 13 to 27.9×10^{-3} in area 3. Higher salinity conditions ($> 10 \times 10^{-3}$) developed in areas 1 and 3 during December and salinity values remained high ($> 30 \times 10^{-3}$) till June. Whereas in area 2 salinity values $> 10 \times 10^{-3}$ were only observed from January with a maximum of 17.3×10^{-3} during March. The erratic pattern in the salinity distribution may be due to the effect of the freshwater discharge through the river. After December the rate of freshwater discharge from the rivers decreases thereby increasing the salinity in the system. Depending on the distance from the backwater the salinity varied from station to station. The variation with distance was maximum during December/January ($\sim 9 \times 10^{-3}$) and minimum ($< 5 \times 10^{-3}$) in March. Nair and Kutty[7] have found that the growth of *Penaeus indicus* is significantly high in salinity of 10×10^{-3} for postlarval stages and 30×10^{-3} for juvenile prawn. Postlarvae and juveniles are mainly recruited in these fields in large numbers from November[8]. Therefore, the conditions for the growth of postlarvae and juveniles of various species of penaeid prawns in areas 1 and 3 are more conducive from December than in area 2. Higher salinity values observed in area 1 are largely due to the influence of the estuarine system maintained by the Azhikode inlet and the less amount of fresh water discharged from the northern branch of Periyar river. Lower salinity values observed in area 2 are partly due to the Chitrapuzha river water influence and also partly due to the lesser tidal volume from the river mouth to this area due to the shallowness of the backwater in this region. The environmental conditions in area 3 have not been discussed



Figs 2 and 3—Distribution of various physico-chemical parameters in seasonal (broken lines) and perennial culture fields (solid lines) in areas 1 (2) and 2 (3)



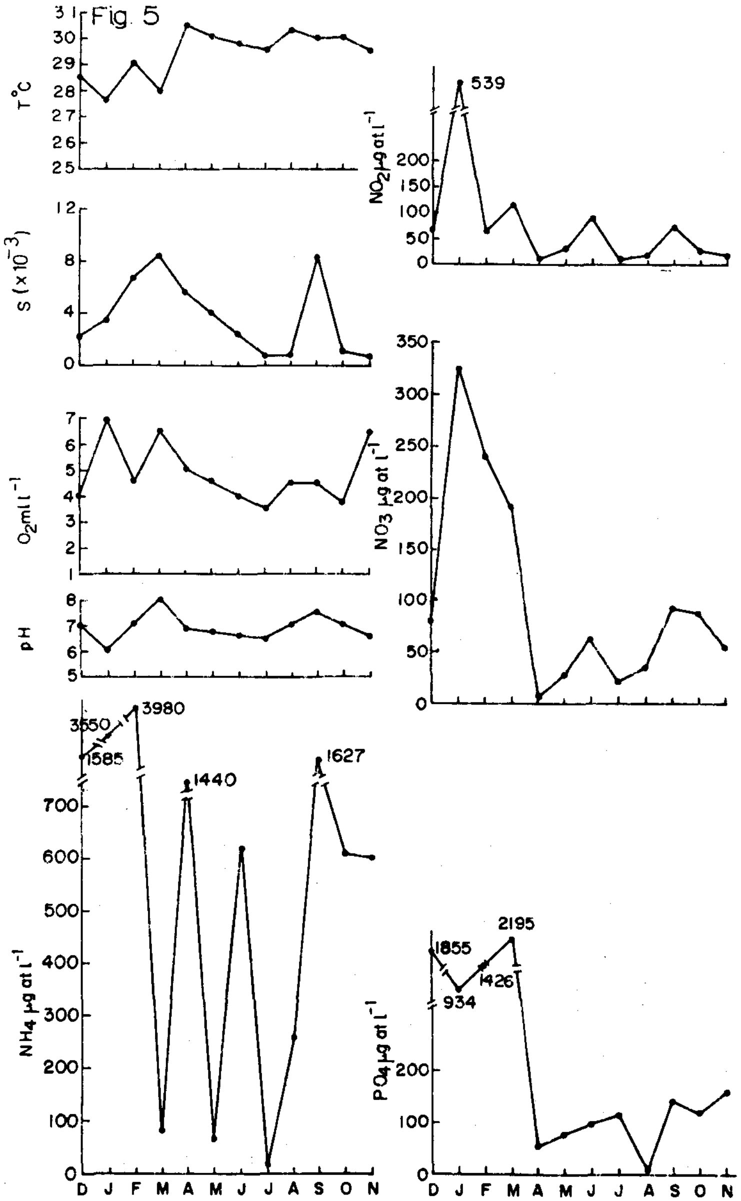


Fig. 4—Distribution of various physico-chemical parameters in area 3 (solid lines) and at barmouth (broken lines)

Fig. 5—Distribution of various physico-chemical parameters at the effluent discharge site

in detail as the area has already been studied by Sankaranarayanan *et al.*[9].

Low *p*H values were observed during monsoon months. In area 2, the *p*H generally remained lower than the other two regions. These low values may be due to the effect of the effluent discharged from the fertilizer factory.

Dissolved oxygen content of the water body showed wide fluctuations with tide and with varying rate of tidal flow. Seasonal fields being shallow, showed low oxygen when compared to the perennial fields. This may be due to the decomposition of organic matter present at the bottom. In areas 1 and 2 lower oxygen concentration observed during the period December to April may be due to high microbiological activity.

The highest values of phosphate in area 2 observed during December to March may be due to the discharge of larger amount of effluents containing phosphate[4]. High concentration of the phosphate was followed by an abundance of phytoplankton and presumably the subsequent decrease in the concentration of phosphate may be due to its utilisation by phytoplankton. The high phosphate concentration observed in area 2 is contributed by the effluent discharged from the fertilizer factory, whereas its influence is high in the seasonal fields which are more close to the factory site (~ 8 km). As is to be expected there is a steady decrease in the nutrient levels with distance from this source.

Unlike inorganic phosphate, the ammonia concentration in different fields showed an annual pattern of distribution (Figs 2 to 5). In the area 1, the ammonia concentration was low (0.5 to 2.5 μg-at.l^{-1}) during the premonsoon months and with the onset of the monsoon it reached its peak (18.1 μg-at.l^{-1}) in June. In the seasonal fields, during the premonsoon months the ammonia concentration was higher compared to perennial fields. This may be due to the effect of rich organic manure applied in the culture fields. As it was in area 1, during the premonsoon months the ammonia concentration in area 2 also remained comparatively low and with the onset of monsoon (June) the values increased. At the effluent discharge site (area 2) the ammonia concentration was very high during most of the year. As was the case with phosphate, the concentration of ammonia also gradually decreased downstream from the discharge point. The high values of ammonia observed in areas 1 and 3 and barmouth during the monsoon months might be due to the heavy fresh water discharge. But in area 2, other than the monsoon the effect of the effluent from the fertilizer factory is responsible for the high concentration of ammonia.

The general trend in the nitrite-nitrogen distribution showed lower values during December and higher values during October-November in the different areas except in area 2. The higher value observed in October/November may be due to the local regeneration and the lower value encountered in December may be due to utilization. In area 2 the nitrite distribution was mainly influenced by the effluent discharged from the fertilizer factory.

The nitrate-nitrogen values in the culture fields showed an increasing trend during the monsoon months due to fresh water discharge. The low nitrate concentration during the remaining period was due to less land drainage and high production.

Data on various nutrients (Figs 2-5) indicate that they are not limiting the primary production in the various environments studied. There was an increase in the inorganic phosphate concentration in area 1 from December to April (0.1 to 3.5 μg.at.l^{-1}). The increase in nutrients is due to the turnover rate within the system exceeding the advective supply from the external sources[4]. Upper reaches of the southern arm of river Periyar contain high amounts of phosphate due to the discharge of the effluents from the fertilizer factory[4]. However, little of this enters in these prawn fields as can be seen from the data. As the system is shallow the vertical mixing induced by tidal flow and wind will hasten the recycling process. Since the system is shallow, it is believed that one of the major factors governing the distribution of nutrients may be the variations in the regenerative property of the bottom mud rich in organic matter due to biological and chemical oxidation. In shallow systems the major recycling of nutrients is affected through sediments[10]. In area 2 as well as in the factory site the nutrients' concentrations were high throughout the year as a result of the effluents discharged from the fertilizer factory. Therefore it becomes difficult to draw the seasonal picture in this region.

Among the biological features, phytoplankton concentration (cells.l^{-1}) in the perennial fields of area 1 showed 2 peaks, one in May (7436) and the other in September (5661); peaks were observed in July (10072) and in April (5398) in the perennial fields of area 2 also. In the seasonal field highest concentration (15380) was observed in April. At the effluent discharge area, the phytoplankton concentration was very high throughout (15000 - 25000). Likewise, area 3 also had high phytoplankton concentrations with peaks in May (22516), July (14223) and November (13939).

Chlorophyll *a* content forms an index for the amount of phytoplankton in the pelagic zone which varied from 4.8 to 8.3 μg.l^{-1} in the seasonal fields of area 1, whereas it varied from 6.4 to 19.2 $\mu g.l^{-1}$ in the perennial fields. Maximum chl *a* concentrations were observed during August to October and in March. The high concentration during August to October is due to the effect of the land drainage bringing in nutrients during the monsoon. Nutrient concentrations also indicate high values during these months. The second peak observed in March is due to the blue green algal bloom as a result of rapid regeneration of nutrients during this period. In area 2 the chl *a* content varied from 4.3 to 15 $\mu g.l^{-1}$ in the seasonal fields and from 9.6 to 25.6 $\mu g.l^{-1}$ in the perennial fields. In this area also the peaks were more or less in the same period. Very high chl *a* values were observed in the effluent discharge area (6.4 to 224.3 $\mu g.l^{-1}$). Among the culture fields, area 3 showed maximum chl *a* concentration (128 $\mu g.l^{-1}$). In all the culture fields the phaeophytin values were high. As the system being shallow the degradation products of chlorophyll such as phaeophytin, phaeophorbidae are found from the biogenous detritus and stirred up sediment.

The zooplankton population was highest (52662 specimens. 100 m^{-3} in January), in area 1; mostly constituted by gammarid amphipods (75%) during January to March. The population was very poor both in the perennial and seasonal fields in December and as the season progressed the population increased. In area 2, the zooplankton population was totally absent in December in the seasonal fields and during December and January in the perennial fields. In this area, eventhough amphipods were present throughout the season, copepods were found to be the most dominant group contributing more than 50% of the total zooplankton population. At the effluent discharge area the zooplankton was sparse, except for the sporadic occurrence of copepods and cladocerans. In area 3 also the zooplankton community was very poor (10-484 specimens. 100 m^{-3}), mostly represented by decapod larvae. In general, in all the areas the zooplankton community was represented by one or two groups during the low salinity regime and the zooplankton increased as the salinity increased. The dominant groups in the zooplankton of the areas were copepods, amphipods, fish larvae and decapod larvae.

Benthic biomass in area 1 showed an average of 51.2 $g.m^{-2}$ and 51.9 $g.m^{-2}$ in the seasonal and perennial fields respectively. Maximum biomass was observed during December (207.6 $g.m^{-2}$) and minimum in February (2.7 $g.m^{-2}$). In area 2 the average biomass was 83.2 $g.m^{-2}$ in the seasonal field and less in the perennial field. Maximum biomass was observed (189.1 $g.m^{-2}$) in April and minimum (3.3 $g.m^{-2}$) in January. In area 3 the average biomass was low (6.4 $g.m^{-2}$). In area 1, benthic biomass decreased from February perhaps due to predation. In area 2 the highest biomass was observed during April when the system becomes more saline and the benthic community consisted of brackish water forms. As the prawn population was low in the area the predation was also kept at a lower level showing a higher biomass.

The prawn production in various fields indicate that the highest production was in the seasonal fields of area 1 (Fig. 6). The maximum production (362 $kg.ha^{-1}$) was in February. The lowest catch (< 40 $kg.ha^{-1}$) was in December. In the perennial fields of the same area the higher prawn production (> 60 $kg.ha^{-1}$) was found to occur during January to April with a peak (125 $kg.ha^{-1}$) in January. In the seasonal fields of area 2 the prawn production varied from 2 to 41 $kg.ha^{-1}$ (Fig. 6). In this area also the higher prawn production was observed during February and March. In the perennial fields of this area, prawn production was higher and it varied from < 5 $kg.ha^{-1}$ to 70 $kg.ha^{-1}$ with a maximum production during January to April.

Phytoplankton counts and the chl *a* concentration in all the areas showed that these areas are rich in phytoplankton population. A comparative study reveals that the maximum phytoplankton production is seen in the site near the effluent discharge area and in the fields of area 2. Though the primary production and the benthic biomass are high in area 2 the prawn production does not seem to be very encouraging, as in the other 2 areas.

The low prawn production in area 2 (Fig. 6) may be due to (i) the possible lethal effects of the effluent discharged on the biota and (ii) to the less saline conditions of the region. The primary and secon-

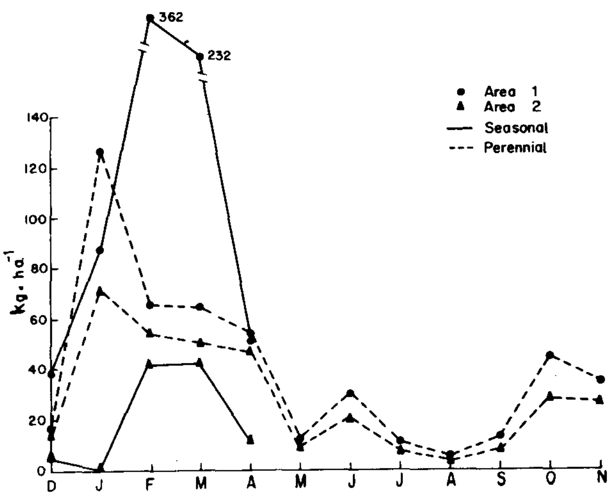


Fig. 6—Monthly prawn production in the culture fields of areas 1 and 2

dary trophic levels and the benthic production in this region do not indicate any possible bad effect of the effluent in the seasonal and perennial culture fields as can be seen from the high production at different trophic levels. The effluents discharged into the river, about 8 km upstream, get diluted by the time they reach the culture fields. High phytoplankton production in the effluent discharge area rule out any possible lethal effect of the effluent on phytoplankton. Ammonia in unionised form, which is considered injurious to organisms[11], perhaps does not exist in marked levels although it exists as ammonium ion. The mortality of fishes reported[12] earlier from the vicinity of the factory may be due to the increase in the unionised form in the effluent. In the study area *p*H of the waters is not high (< 8) and the percentage of the unionised form is kept relatively at a lower level, thereby the lethal effect is minimised in all these culture fields. Moreover, during the period of observation there is no instance of mortality of animals in the river where the effluent is discharged or in any of the culture fields. There is also no report of any permanent ecological distortion.

Salinity conditions clearly indicate less tidal volume influx into the system. As the tidal volume is less[13] the prawn larvae and juveniles entering the system with the tide, may be less as compared to other areas. Low benthic biomass observed in areas 1 and 3 may be due to the predation by the prawn population. The low prawn production in area 2 inspite of high benthic biomass indicates that salinity conditions in this area are not very congenial for prawn growth.

Acknowledgement

The authors express their gratitude to Director for encouragement.

References

1 Hall D N F, *Observations on the taxonomy and biology of some Indo-west Pacific Crustacea (Decapoda)*, Special Publication, **17**, (Colonial Office, London) 229.
2 George K V, *Indian J Fish*, **21** (1974) 1.
3 Strickland J D H & Parsons T R, *A practical handbook of seawater analysis* [*Bull Fish Res Bd Can*, **167** (1968) pp 311].
4 Sankaranarayanan V N, Udaya Varma P, Balachandran K K, Pylee A & Joseph T, *Indian J Mar Sci*, **15** (1986) 166.
5 Williams A B, *Biol Bull Woods Hole*, **119** (1960) 560.
6 Zein-Eldin Z P & Griffith G W, *FAO Fish Rep*, **57** (1969) 1015.
7 Nair S R S & Krishnan Kutty M, *Bull Dept Mar Sci Univ Cochin*, **7** (1975) 181.
8 George M J, *Indian J Fish*, **9** (1962) 110.
9 Sankaranarayanan V N, Kumaran S, Balasubramanian T, Rosamma Stephen & Panampunnayil S U, *Indian J Mar Sci*, **11** (1982) 253.
10 Reddy C V G & Sankaranarayanan V N, *Indian J Mar Sci*, **1** (1972) 57.
11 Boyd C E, *Water quality management for pond fish culture* (Elsevier Sci Publ Co, Amsterdam) 1982, pp 318.
12 Venugopal P, Remani K N, Saraladevi K & Unnithan R V, *Seafood Export J*, **12** (1980) 1.
13 Varma U, (Personal communication).