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BENTHOS AND SUBSTRATUM CHARACTERISTICS OF PRAWN CULTURE FIELDS IN AND AROUND THE COCHIN BACKWATER

P. N. Aravindakshan, T. Balasubramanian, C. B. Lalithambika Devi, K. K. Chandarasekharan Nair, T. C. Gopalakrishnan, K. V. Jayalakshmy and M. Krishnan Kutty

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

Abstract

Benthic ecology of certain selected seasonal and perennial prawn culture fields in the Cochin Backwater was studied for understanding the environmental factors controlling the abundance of the major groups of macrobenthos which form significant component of food of prawns. Substratum characteristics, bottom temperature, salinity, pH, oxygen, Eh and organic carbon content of the mud are the parameters examined for identifying the governing factors controlling the benthic abundance in the areas investigated. Areas of high benthic abundance are characterised by substratum comprising fine sand, silt and clay with not less than 20% fine sand. Only in area 3 the multiple regression model for predicting total biomass based on sand, silt, clay, organic matter and salinity was found to be significant explaining about 79% of the variability. Sand, clay and silt were found to be relatively important factors controlling the benthic biomass. However, seasonal fluctuations of the substratum characteristics were found to influence the qualitative and quantitative composition of the biota in areas 1, 2 and 4. In all the areas of the seasonal and perennial ponds, almost all the groups, particularly the most dominant ones, *viz*. polychaetes, amphipods and tanaidaceans were correlated with sand and clay, but negatively with silt. Generally the benthos showed little coexistence; rather they preferred indepedent existence. None of the areas showed significant positive correlation between groups, $r < 0.632$. Species diversity and biomass in the distribution showed much seasonal variations. Area 2 appeared to be more productive and rich in distribution compared to the rest of the areas.

Introduction

The long chain of backwater is the characteristic feature of Kerala Coast. The fields around the backwater are suitable for aquaculture. They support a traditional, seasonal and perennial prawn fishery. Alteration in the configuration of the backwater, its steady shrinkage and the sharp decline in postlarvae of penaeid prawns entering the backwater in recent years (Gopalan *et al.*, 1983) have caused concern to the future of the prawn fishery and the highly productive ecosystem. As part of the programme to understand the aquaculture potential of the Cochin Backwater, an ecological study has been undertaken. Nair *et al.* (1988) and Gopalakrishnan *et al.* (1988) have examined the impact of the environmental variations in the prawn fields in three different regions of the backwater in relation to prawn production by linking its effect at the lower trophic levels also. The present paper examines the benthic ecology of these culture fields in the Cochin Backwater.

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areas 1, 2 and 3. The remaining 16 stations were from canals adjacent to the fields, near the discharge site of a fertilizer factory in area 2 and also at the harbour entrance (area 4).

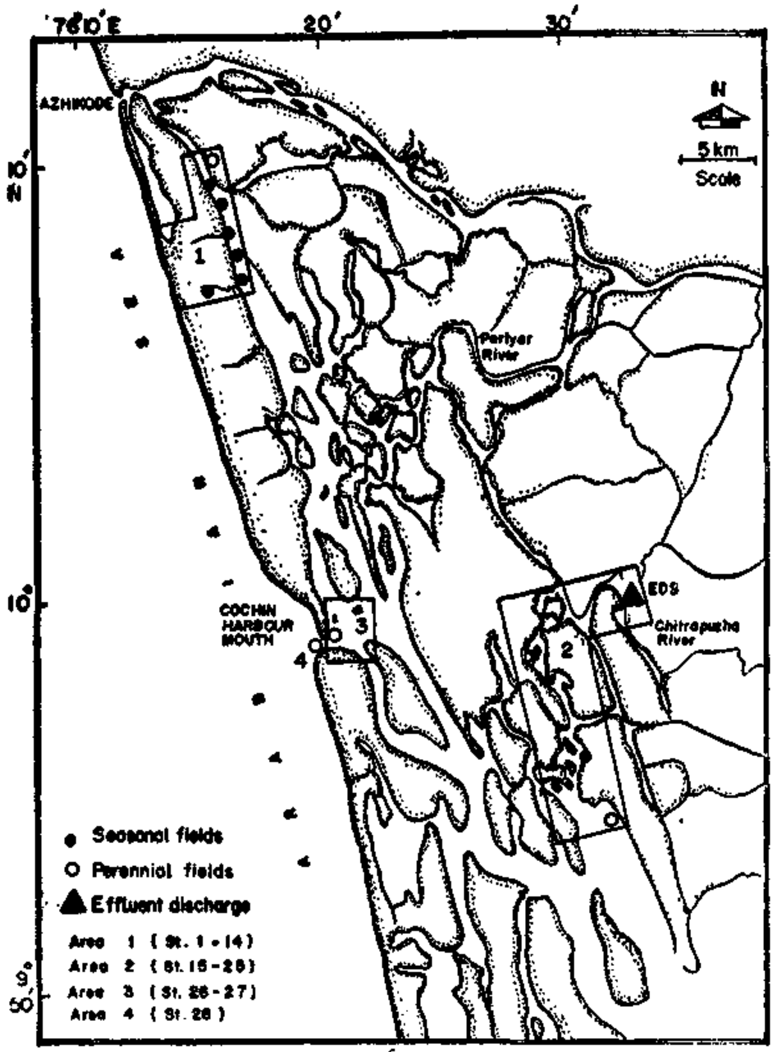

FIG. 1. Station location of the study area.

MATERIAL AND METHODS

Monthly collections of bottom samples were taken from 28 stations (Fig. 1). Nine stations were from seasonal fields of areas 1 and 2; and 3 stations were from perennial fields in

Sampling was done during the active prawn culture season (November to April) of 1980-81, from seasonal fields of areas 1 and 2. In the perennial fields of areas 1, 2 and 3 as well as at the effluent discharge site and the harbour entrance the sampling was continued for

12 months. Bottom samples in triplicate were collected and pooled together from each field and macrofauna using a hollow perspex cylinder of 8.3 cm (inner diameter) and 25 cm length. The depth of the sampling areas ranged from 1 to 3 m. Sediment samples were sieved through a sieve of 0.5 mm mesh to separate benthic organisms. They were preserved in 5% formaldehyde coloured with Rose Bengal. Benthos were counted and weighed at the laboratory to assess the bio. mass. Mud samples were also taken from the same location with a cylinder of 10 cm (inner dia.) for substratum analysis. Grain size analysis was carried out on the above samples by sieving and pipette method for estimating the percentage of sand, silt and clay (Krumbein and Pettijohn, 1966). Organic carbon of samples was estimated by wet oxidation method (Wakeel and Riley, 1957). The percentage of organic matter was calculated as 1.724 times the carbon (not corrected for nitrogen) (Trask, 1955). Bottom water samples were collected using a casella type sampling bottle. Temperature of bottom water and mud samples were measured by using laboratory thermometer, oxygen by Winkler method (Strickland and Parsons, 1968), salinity by Harvey's (1955) method and pH and Eh by pH meter with respective electrodes. In the case of the seasonal fields of areas 1 and 2 the stations being closely located, monthly average values of different parameters were taken for plotting graphs.

Data on benthic biomass of seasonal ponds of areas 1 and 2 and perennial ponds of all the areas were studied with respect to parameters such as sand, silt, clay and organic matter in the mud. The data were subjected to various statistical analysis—Tukey's test of additivity (Snedecor and Cochran, 1967) ANOVA technique, Duncan's Multiple 't' test (Federer, 1963), Species co-existence and species affinity to the parameters (Federer, 1963), Shannon-Weaver diversity function (Sanders, 1978), Heip's (1974) index of evenness and Multiple regression model to study the relative importance of the parameters (Snedecor and Cochran, 1967).

Results and Discussion

Substratum characteristics, percentage organic matter in the mud and numerical abundance of benthic organisms are given in Tables 1-3. Bottom temperature, salinity, pH, dissolved oxygen, organic carbon of the mud and biomass (Fig. 2-4) were the major parameters examined for understanding the benthic ecology.

Substratum characteristics

The areas were characterised by soft sediment with silt fraction forming the major component of the substratum. Table 1 shows significant regional variations in their composition. Sediment characteristics showed reasonable stability in all areas except area 4. This area was least predictable, because the effect of constant movement of the dredged material from the harbour, strong current, etc. Values in the prawn fields suggest that the sand-silt-clay proportion is not significantly altered by the monsoonal influx and may be because they are mostly fed through narrow sluice gates. But the fine sand fraction (29.61%) in the perennial pond of area 1 was intermediate between that of areas 2 and 3. Highest sand fraction was observed in area 3 with a mean of 32.4 % with values ranging from 21.41 - 39.8 %. Perennial pond in area 2 has the lowest percentage of sand with the minimum value of 8.65 in October and a maximum of 20.34 in September. Seasonal ponds in area 2 have a considerably higher sand fraction when compared to that of the perennial pond. They are shallow ponds where paddy is cultivated during the off season. Mud samples in these ponds showed 20-26 % of sand while those from seasonal ponds in area 1 had 13.1 - 25.3 % of sand.

TABLE 1. *Mean percentage composition of sand, silt, clay and their range in different fields*

	Area 1						Area 2		
	Seasonal			Perennial			Seasonal		
	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.
Sand ..	19.42	25.32 Jan.	13.10 Feb.	29.61	40.78 Jun.	15.58 Nov.	24.38	26.32 Mar.	20.00 Apr.
Silt ..	48.22	64.60 Feb.	38.14 Jan.	36.47	60.42 Nov.	20.13 Apr.	50.10	53.84 Feb.	46.2 Dec.
Clay ..	32.36	40.42 Dec.	22.30 Feb.	33.92	51.50 Apr.	11.00 Aug.	25.55	28.38 Dec.	21.90 Feb.
Biomass ..	51.03	116.11 Dec.	6.00 Feb.	41.33	255.67 Oct.	2.00 Apr.	44.03	80.00 Feb.	10.00 Mar.

The data of minimum values of substratum in the seasonal ponds of areas 1 and 2 was transformed as

$$Y = \frac{1}{X+1} [F\ (1,\ 11) = 22.2728$$

by Tukey's test ($P < 0.01$)]. Two way ANOVA application, on the transformed data of minimum values and original data of maximum and mean values showed significant difference among grain size mean values (mean value of silt$\gg$mean values of sand and clay, pair wise difference > *l. s. d.* (17.5756) in both areas).

For the perennial data of the 5 areas Tukey's test of additivity applied suggested the transformations $Y = (x+1)^{-3.26}$ [$F(1,11) = 14.4476$, ($P < 0.05$)] for mean values and $Y = (x+1)^{-2.06}$ [$F\ (1, 11) = 13.1166$, ($P < 0.05$)] for maximum values. There was no significant difference between areas and between substratum based on mean values as well as maximum values (both transformed). But minimum values of sand and silt are highly different. (Pairwise difference >11.1074 (*l.s.d.*) in all the four areas, minimum value of silt being much higher.

Also the difference in the mean values of substrata between seasonal and perennial ponds of areas 1 and 2 was only due to random fluctuations except for sand and silt in both areas ($P > 0.05$).

Organic carbon and organic matter

The total organic carbon in the sediments (Fig. 2-4) of the perennial fields of areas 1 and 2 ranged from 2.5 mg/g (June and November) to 27.0 mg/g (August) and 12.2 mg/g (May) to 22.5 mg/g (April) whereas in area 3 the corresponding values respectively were 5 mg/g (Feb.) and 19.9 mg/g (Nov.) The effluent discharge site marked the highest organic content with 35.9 mg/g in March.

The percentage of total organic matter remained fairly high and steady in the seasonal fields with values from 2.23 to 3.52 whereas in the perennial fields the variation was more *along with corresponding benthic biomass* gm^{-2}

Perennial			Effluent discharge site			Area 3			Area 4		
Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.
13.37	20.34	8.65	12.81	25.62	4.09	32.42	39.80	21.41	20.47	45.69	4.7
	Sept.	Oct.		Aug.	Feb.		Nov.	Aug.		Dec.	Mar.
53.61	73.43	31.91	56.44	83.91	40.23	40.40	56.91	32.10	48.35	70.26	4.31
	Apr.	Dec.		Feb.	Jan.		Sept.	Dec.		Mar.	Dec.
33.02	52.75	14.50	30.75	50.00	12.00	27.18	40.75	19.74	31.18	50.00	18.00
	Dec.	Apr.		Jan.	Feb.		Aug.	Nov.		Dec.	Jun.
14.16	50.25	0.25	1.37	4.29	1.10	4.62	17.00	0.00	14.48	116.40	0.00
	Mar.	Sept.		Dec.	July		Nov.	Dec. Feb.		Dec.	Dec. Jun. Aug. Oct.

pronounced and was in the range of 1.17 - 4.84. Organic matter content in mud showed significant difference between areas only at 25% level ($P < 0.25$) and between months at 10% level ($P < 0.10$) average organic matter content is more or less similar in the areas 1, 2 and 4 and in the area 3 and effluent discharge site. But area 2 is significantly different from that of area 3 (pairwise difference by Duncan's multiple 't' test >0.6271 (*l.s.d.*).

The months when almost similar organic matter content obtained were (1) December, January, February, March and April, (2) May, October and November, (3) June, July, August and September (pairwise difference <1.2545 (*l.s.d.*). It is being higher during the end of postmonsoon season and during premonsoon seasons, but least during monsoon seasons and thereby increases gradually during postmonsoon season.

Eventhough the percentage total organic matter remained fairly high and steady in the seasonal fields with values ranging from 2.23 to 3.52 it differed significantly between area 1 and area 2 in all the four months [$F(1, 3) = 3.667$, ($P > 0.05$)] it being higher in area 2 than in area 1.

Other major environmental parameters

Temperature : Although the bottom water temperature varied between 24.6 and 30.5°C (Fig. 2-4), both the range and variations exhibited similar trend in all regions.

Salinity : Salinity values ranged from 1 - 35 $\times 10^{-3}$ (Fig. 2-4). Although temperature and salinity are the two parameters showing a distinct cyclic pattern, unlike the former the seasonal fluctuations and the regional difference in salinity exert a pronounced influence on the biota. Ponds in the areas 1, 3 and 4 have waters in the high salinity range unlike in area 2 having maximum and minimum values of 17 and 10 $\times 10^{-3}$ in seasonal ponds, 20 - and 0.5 $\times 10^{-3}$ in perennial ponds and 11.1 and 0.35 $\times 10^{-3}$ near the effluent discharge site.

pH : Maximum variation in pH was noticed near the discharge site with an average value of 5.83 and a maximum and minimum value of 8.0 in April and 6.4 in April. Seasonal pond in area 2 which is about 8 km downstream from the discharge site showed the influence of pollution with an average pH February (-440) respectively. Values reported are well within the range of earlier reports made by Sankaranarayanan *et ol.* (1982) from Cochin Backwater. The same authors recorded even below -120 mv in Ramanthuruthu Island of the Cochin Backwater which is also having similar sediment characteristics (1982).

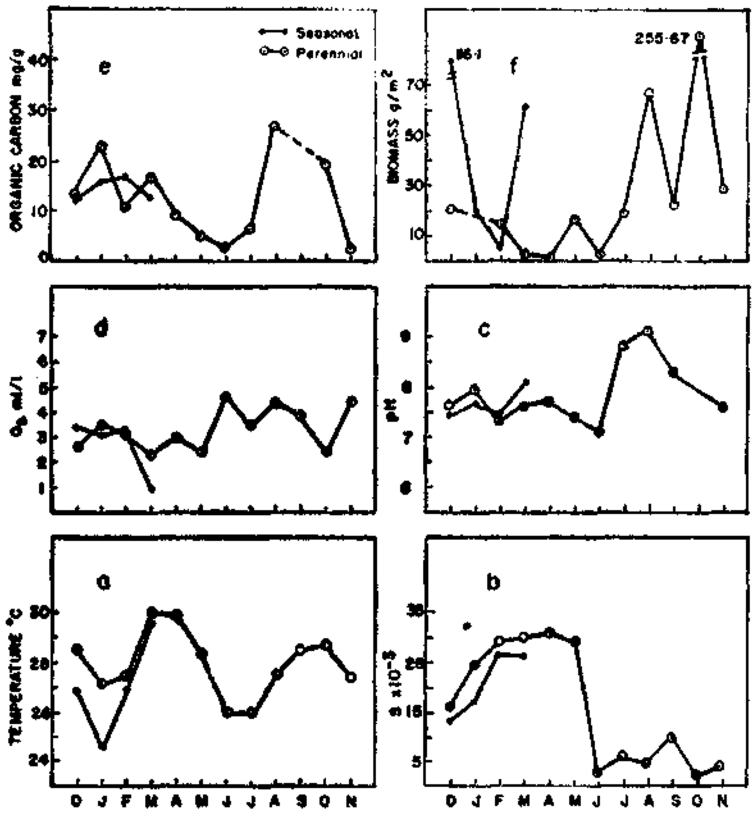

FIG. 2. Temperature, salinity, oxygen, pH, biomass and organic carbon in area 1.

value of 6.38, with a range of 5.5 in December and 7.0 in March. In all other areas except for occasional values below 7 in the perennial pond in area 2 lying 11 km away from the discharge site, pH values always remained 7 or above.

Eh : Redox potential of the mud samples in all areas were negative exceptionally high values in areas 3 and 4 in August (-445) and

Ammonia : Ammonia concentration in various fields showed an annual pattern of distribution (Nair *et al.*, 1988). In all the areas except the effluent discharge site, low values (0.5 to 2.5 μg atom/l^{-1}) were observed during the premonsoon months and at the onset of the monsoon values always reached its peak (18.1 to 199 μg atom/l^{-1}). At the discharge site the ammonia concentration remained high (600 - 3,980 μg atom/l^{-1})

round the year. The relatively high values of ammonia observed except at the discharge site is due to the heavy fresh water discharge during the monsoon months. The extremely high concentration of ammonia observed at the effluent discharge site is from the adjacent fertilizer factory.

TABLE 2. *Organic matter in the mud (%) at different areas in different months*

Months		AREA 1		AREA 2		Effluent Dis. Site	AREA 3	AREA 4
		Seasonal	Perennial	Seasonal	Perennial		Perennial	Perennial
December	..	2.3	3.1	2.8	1.9	5.3	3.3	3.8
January	..	2.8	4.0	3.3	4.1	1.0	1.2	4.2
February	..	3.0	3.7	2.9	4.8	3.2	0.9	2.5
March	..	2.2	3.7	3.5	3.5	6.2	1.6	4.4
April	..	..	3.1	..	4.1	4.3	3.1	2.6
May	..	..	1.8	..	4.0	1.8	1.8	2.3
June	..	..	2.6	..	2.0	..	1.9	2.4
July	..	..	1.2	..	3.8	..	1.9	1.9
August	..	..	2.8	..	..	2.5	1.8	2.3
September	..	..	2.5	..	2.8	1.2	1.7	0.8
October	..	..	3.1	..	3.6	1.1	1.9	1.9
November	..	..	2.1	..	2.3	1.0	3.3	3.3

Oxygen : Dissolved oxygen of the bottom water in all regions throughout the period of study were above 2 ml/l. Seasonal ponds in areas 1 and 2 and the perennial pond in area 1 registered minimum average value in the range of 3 ml/l with moderate fluctuations. In areas 3 and 4 and in the discharge site in area 2 the average values were similar (4.26 - 4.54 ml/l), but the range of fluctuation was more in the discharge site with the lowest value of 0.44 ml/l (Figs. 2-4). The oxygen values in the perennial pond in area 2 were in the range of 2.2 - 5.9 ml/l. Low values of oxygen were generally noted during pre-monsoon months from February to April.

Benthic biomass : Unlike the various parameters examined above, the qualitative and quantitative aspects of benthos in the different regions present a more complex picture for interpretation and it is because of the involvement of many biological and environmental factors affecting the composition and abundance. Benthic biomass is relatively high in seasonal ponds in areas 1 and 2 with average values of 51.03 and 45.03 g/m² respectively and this difference between the two areas was only due to sampling fluctuations ($P > 0.05$).

Certain qualitative differences in the distribution of benthos were also noticed between different regions during the period of study. Polychaetes, amphipods and tanaidaceans were the most dominant benthic organisms in all areas often contributing 100% of the benthic biomass and among these, the polychaetes were the most abundant and the best represented group. Salinity does not seem to be a major factor in the distribution of tanaidaceans as observed from their abundance in relation to other groups in each region (Table 3) as also evidenced from the work of Gopalan *et al.* (1986). However, the perennial

TABLE 3. *Numerical abundance (No/m²) of benthic organisms*

	Seasonal Ponds				Perennial Ponds									
AREA 1	Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar.	Apr.	Jun.	Jul.	Aug.	Oct.	Nov.
Polychaetes ..	8748	1540	493	4436	1294	370	1109	554	2033	555	185	2590	185	—
Amphipods ..	2033	4559	370	370	3327	739	185	185	739	—	925	2035	925	185
Isopods ..	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tanaidaceans ..	2649	493	—	123	8132	1848	—	370	—	—	15355	12395	94905	20535
Oligochaetes ..	—	—	—	246	—	370	—	—	—	—	—	—	—	—
Bivalves ..	123	—	—	—	—	—	—	—	—	—	—	—	—	—
Prawn larvae ..	—	—	—	—	—	—	—	1294	—	—	—	—	—	—
Gastropods ..	—	—	—	—	—	—	—	—	185	—	—	—	—	—

AREA 2	Dec.	Jan.	Feb.	Mar.	Apr.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug
Polychaetes ..	1787	2711	1047	6345	2464	1848	924	1663	7208	5545	1479	5914	1884	1109
Amphipods ..	616	493	—	2403	493	—	—	—	1479	555	739	1294	370	185
Isopods ..	—	—	185	2464	—	—	—	—	—	—	—	—	—	—
Tanaidaceans ..	493	—	—	1232	370	—	—	—	—	1109	555	554	—	—
Oligochaetes ..	308	—	185	5914	—	—	—	—	—	—	—	—	—	—
Bivalves ..	—	—	739	—	—	—	—	—	—	—	—	—	—	—
Prawn larvae ..	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gastropods ..	—	—	—	—	—	—	—	—	—	—	739	—	—	—

AREA 3	Jan.	Feb.	Mar.	Apr.	May	Jun.	Oct.	Nov.
Polychaetes ..	3327	554	924	1109	924	5360	—	370
Amphipods ..	—	—	185	924	185	—	185	185
Isopods ..	—	—	—	—	—	—	—	—
Tanaidaceans ..	—	554	554	—	—	—	1109	1109
Oligochaetes ..	—	—	—	—	815	—	—	—
Bivalves ..	—	—	—	—	—	—	—	—
Prawn larvae ..	—	—	—	—	—	—	—	185
Gastropods ..	—	—	—	—	—	—	—	—

TABLE 3 (*Contd.*)

AREA 4	Seasonal Ponds		Perennial Ponds						
	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Nov.
Polychaetes ..	—	1663	554	739	185	1109	2957	—	—
Amphipods ..	—	—	—	—	185	185	—	—	—
Isopods ..	—	—	—	—	—	—	—	—	—
Tanaidaceans ..	—	—	—	—	—	185	—	—	—
Oligochaetes ..	—	—	—	—	—	—	—	—	—
Bivalves ..	739	—	—	—	—	—	—	1109	5
Prawn larvae ..	—	—	—	185	—	—	—	—	—
Gastropods ..	—	—	—	—	—	—	—	185	—

The months during which animals were absent are not shown in the Table.

pond in area 1 seems to provide most conducive conditions for their growth during certain months where numbers between 15,000-95,000/m^2 were recorded contributing 93 - 99% of the total benthos. Amphipods appear to be the most stable population in areas 1 and 2 and maintaining moderate abundance. The more regular presence of oligochaetes in the seasonal ponds of area 2 may be due to low salinity (Chandrasekharan Nair and Tranter, 1971) and their absence in the perennial ponds in the same region indicate adverse condition for their growth despite favourable salinity conditions.

In the seasonal ponds, regarding the affinity of the benthic groups with the substratum, organic matter and salinity, in area 1, only polychaetes with biomass ($r = 0.9587$), Tanaidaceans with clay ($r = 0.9899$) are highly positive ($P < 0.05$). All the groups except oligochaetes are negatively correlated with silt, but positively with clay all being high ($|r| > 0.6$), but not significant. All the groups are moderately correlated, but negatively with organic matter ($|r| > 0.4679$) except amphipods ($r = 0.0867$) and with salinity ($|r| > 0.5845$) except oligochaetes ($r = 0.5619$). Total biomass is positively correlated with clay ($r = 0.5981$) and negatively with organic matter ($r = -0.9431$).

In area 2 only isopods with clay ($r = -0.9174$), polychaetes with organic matter ($r = 0.8784$) were significant ($P < 0.05$). All the groups were positively correlated with organic matter except bivalves ($r = -0.4277$) and feebly correlated with salinity ($|r| < 0.5876$) and total biomass with salinity ($r = -0.5234$) is negative.

In the perennial ponds of area 1 all the groups except Tanaidaceans ($r = 0.5983$) with silt are negative and except tanaidaceans with clay ($r = -0.2444$) are positive. Only polychaetes with silt ($r = -0.7031$) is significantly negative. 'r' of all the groups except tanaidaceans with organic matter ($r = 0.3204$) and with salinity ($r = -0.3946$) are positive. Total biomass is negatively correlated with salinity ($r = -0.5162$).

In area 2, all the groups are negatively correlated with sand, ($r = -0.6729$ for amphipods with sand, $P < 0.05$) and positive with silt ($r < 0.4895$) except gastropods ($r = -0.0030$) and negatively with clay ($|r| < 0.5973$) except gastropods ($r = 0.1128$). All the groups and the total biomass have affinity only for organic matter ($|r| < 0.2010$) and salinity ($|r| < 0.3746$).

Similarity in area 4, no group is significantly correlated with the grain size distribution. 'r' with sand except bivalves ($r = 0.1992$) are negative, with silt except bivalves ($r = -0.5227$) and with clay except polychaetes ($r = -0.2307$) and prawn larvae ($r = -0.2484$) are positive. Similarly 'r' with organic matter except prawns ($r = -0.5269$) are positive and

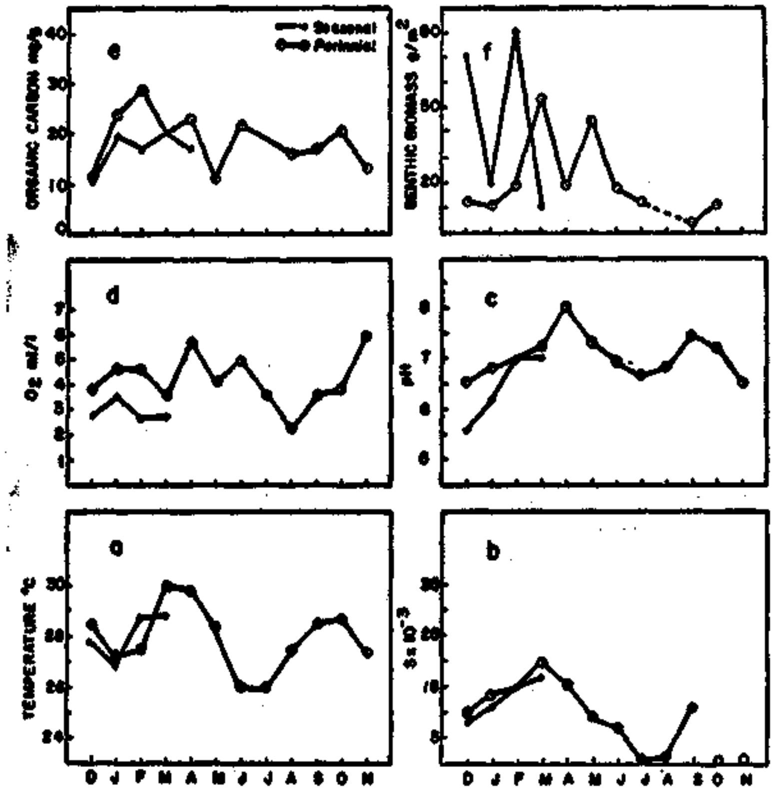

FIG. 3. Temperature, salinity, oxygen, pH, biomass and organic carbon in area 2.

In the area 3 only 'r' of oligochaetes with sand ($r = -0.7773$) and polychaetes with silt ($r = 0.7332$) are significant ($P < 0.05$) 'r' of tanaidaceans with sand ($r = 0.6981$), with silt ($r = -0.4918$), with clay ($r = -0.5855$) and prawn larvae with clay ($r = -0.6644$) are opposite to that of other species. Only 'r' of total biomass with salinity ($r = -0.6498$) is negative. This implies that benthic abundance is not supported by high salinity conditions.

with salinity except bivalves ($r = 0.2752$) are negative.

Therefore it follows that oligochaetes prefer high salinity, but tanaidaceans prefer low salinity in area 1. In area 4 benthic groups are not controlled by grain size distributions and almost all groups except bivalves are negatively correlated with salinity. In area 2 also none of the benthic groups was seemed to be controlled by salinity. But in area 3 most of the groups are dependent on salinity eventhough feebly (Table 6).

Multiple regression model fitted for predicting total biomass from the grain size distribution and organic matter and salinity concluded that variations in grain size distributions, organic matter and salinity distributions do not have significant effect on the variations in the biomass distribution except for area 3 where the significance was only 75% [$F(5, 2) = 5.3355$ ($P < 0.25$)] and explained variability was only 77.02%, prediction equation was

$$Y = -1670.745 + 16.5979\, x_1 + 17.6080\, x_2 + 16.3333\, x_3 - 1.3956\, x_4 - 0.7115\, x_5,$$

where Y = total biomass, x_1 = sand, x_2 = silt, x_3 = clay, x_4 = organic matter, x_5 = salinity. Among the 5 parameters considered, the grain size distribution and salinity are observed to be the most important factors determining the distribution of total biomass of benthos in the prawn culture fields of Cochin Backwater as justified by the following relative importance of the parameters, clay>silt>salinity>sand>organic matter for area 1, salinity>clay>sand>organic matter>silt for area 3, silt>sand>clay>salinity> organic matter for area 4 (Table 7).

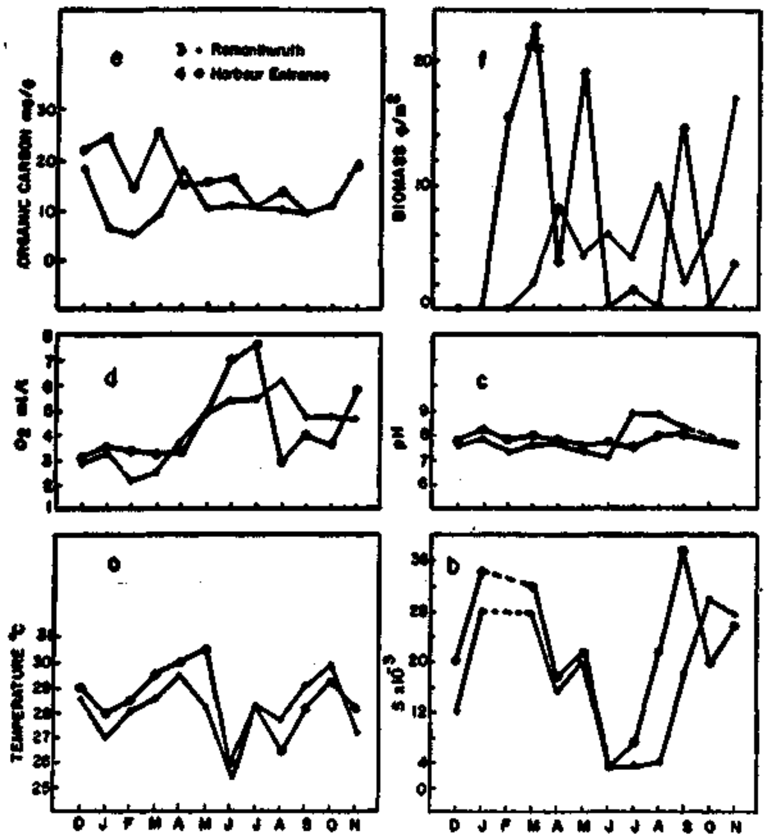

Fig. 4. Temperature, salinity, oxygen, pH, biomass and organic carbon in areas 3 and 4.

Considering the coexistence of the benthos, in seasonal ponds of areas 1, amphipods and oligochaetes ($r = -0.5572$) and oligochaetes with bivalves ($r = -0.3333$) were negatively

TABLE 4. *Species diversity index by Shannon Weaver diversity function*

	Area 1		Area 2		Area 3	Area 4
	Seasonal	Perennial	Seasonal	Perennial	Perennial	Perennial
December ..	1.34010	1.25460	1.66746	—	—	1 spec.*
January ..	1.14332	1.65808	0.61944	—	1 spec.*	—
February ..	0.98530	0.59196	1.64352	—	1.00000	—
March ..	0.79981	1.66932	2.09062	0.65829	1.35181	0.72236
April ..		1.12174	1.08141	0.99145	0.99402	1.00000
May ..		—		1.89239	1.35797	1.061715
June ..		—		1.00160	1 spec.*	1 spec.*
July ..		0.400027		0.64415	—	0.59196
August ..		1.11286		0.59196	—	—
September ..		—		—	—	—
October ..		0.33654		—	0.59196	—
November ..		0.02216		—	1.57140	1 spec.*

* Species diversity index not calculated.

TABLE 5. *Heips evenness index*

	Area 1		Area 2		Area 3	Area 4
	Seasonal	Perennial	Seasonal	Perennial	Perennial	Perennial
December ..	0.93981	1.25321	1.43289	—	—	1 spec.*
January ..	1.06859	1.41640	0.85789	—	1 spec*	—
February ..	1.67861	0.80752	1.39112	—	1.71828	—
March ..	0.40837	1.43618	1.77247	0.93148	1.43210	1.05929
April ..		1.03509	0.97441	0.84757	1.70207	1.71828
May ..		—		1.87840	1.44414	0.94566
June ..		—		0.86131	1 spec.*	1 spec.*
July ..		0.24593		0.90437	—	0.80752
August ..		1.02152		0.80752	—	—
September ..		—			—	—
October ..		0.01711			0.80752	—
November ..		0.02240			1.27113	1 spec.*

* Heips evenness index not calculated.

TABLE 6. *Correlation of groups of species and total biomass with parameters, sand, silt, clay, organic matter and salinity in each area*

Species Parameters	Polychaetes	Amphipods	Isopods	Tanaidaceans	Oligochaetes	Bivalves	Prawn Larvae	Gastropods
Area 1 Seasonal								
Sand ..	0.4268	0.6341	—	0.7172	0.2656	−0.0994	—	—
Silt ..	−0.6298	−0.8631	—	−0.9341	0.0868	−0.3750	—	—
Clay ..	0.7870	0.7961	—	0.9899*	−0.1168	0.6307	—	—
Org. matter ..	−0.9254	0.0867	—	−0.6411	−0.6574	−0.4674	—	—
Salinity ..	−0.5845	−0.6701	—	−0.7155	0.5619	−0.9216	—	—
Area 1—Perennial								
Sand ..	0.6015	−0.2686	—	−0.5325	0.0820	—	0.0562	0.0028
Silt ..	−0.7031*	−0.1711	—	0.5983	−0.0529	—	−0.0109	−0.4864
Clay ..	0.4115	0.3115	—	−0.2444	0.1263	—	0.1101	0.3845
Org. matter ..	0.4201	0.0315	—	−0.3204	0.3815	—	0.2914	0.0925
Salinity ..	0.3633	0.3037	—	−0.3946	0.3114	—	0.3734	0.381
Area 2—Seasonal								
Sand ..	0.2342	0.1025	0.3853	−0.1764	0.5641	−0.0008	—	—
Silt ..	−0.1648	−0.5381	0.5023	−0.0526	0.0753	0.6013	—	—
Clay ..	−0.0002	0.5454	−0.9174	0.2168	−0.5816	−0.7067	—	—
Org. matter ..	0.8784*	0.5375	0.4188	0.1373	0.0507	−0.4277	—	—
Salinity ..	0.3338	−0.1596	0.5876	−0.0736	−0.0094	0.2565	—	—
Area 2—Perennial								
Sand ..	−0.2356	−0.6729*	—	−0.0846	—	—	—	−0.0415
Silt ..	0.4895	0.6286	—	0.5166	—	—	—	−0.0038
Clay ..	−0.5973	−0.5510	—	−0.5834	—	—	—	0.1120
Org. matter ..	−0.2010	−0.0722	—	−0.0438	—	—	—	0.2182
Salinity ..	−0.1437	−0.3746	—	−0.1678	—	—	—	0.069
Area 3—Perennial								
Sand ..	−0.4634	−0.0578	—	0.6981	−0.7773*	—	0.4097	—
Silt ..	0.7332*	0.0497	—	−0.4918	0.5260	—	0.0896	—
Clay ..	0.1647	0.0195	—	−0.5855	0.5682	—	0.6644	—
Org. matter ..	0.0664	−0.0149	—	−0.3348	0.3995	—	0.4609	—
Salinity ..	0.0705	0.0569	—	0.0572	0.2032	—	−0.3639	—
Area 4—Perennial								
Sand ..	−0.1064	0.0152	—	0.1764	—	0.1992	−0.5794	—
Silt ..	0.3814	0.1456	—	0.0900	—	−0.5227	0.2459	—
Clay ..	−0.2307	0.1315	—	0.2867	—	0.2132	−0.2384	—
Org. matter ..	0.0539	−0.3533	—	−0.3074	—	−0.1440	0.5269	—
Salinity ..	0.1307	0.1478	—	0.1197	—	−0.2752	0.2881	—

* is Significant at 5% level ($P < 0.05$).

correlated. All the other groups coexisted but not significant ($|r| < 0.950$ at 5% level). In seasonal ponds of area 2, all the groups except amphipods with isopods, ($r = -0.1912$), with oligochaetes ($r = -0.0025$) and with bivalves ($r = -0.9763$, $P < 0.05$) and polychaetes with bivalves ($r = -0.7032$) and tanaidaceans with bivalves ($r = -0.6075$) were positive, but not significant ($r < 0.8778$).

TABLE 7. *Relative importance of parameters*

Parameters	Area 1	Area 2	Area 3	Area 4
Sand ..	0.2308	0.1203	16.7782	1.2458
Silt ..	0.8540	0.0306	8.4881	1.7240
Clay ..	1.0261	0.1381	12.7881	1.1007
Organic matter ..	0.0563	0.0933	0.2384	0.1445
Salinity ..	0.5973	0.1809	1.3354	0.6621

In the perennial ponds of area 1, only the groups, polychaetes with amphipods ($r = 0.1424$), with oligochaetes ($r = 0.0078$), with prawn larvae ($r = 0.0706$) and with gastropods ($r = 0.2731$) and amphipods with tanaidaceans ($r = 0.5847$), with oligochaetes ($r = 0.1201$) and gastropods ($r = 0.1201$) and tanaidaceans with oligochaetes ($r = 0.0946$) coexisted, but not high ($r < 0.632$).

In area 2, only polychaetes with gastropods ($r = -0.2232$) was negative, but no two groups showed significant coexistence ($r < 0.6667$).

In area 3 'r' of polychaetes with amphipods ($r = -0.4010$), tanaidaceans ($r = -0.6138$) and prawns ($r = -0.0433$) and 'r' of tanaidaceans with oligochaetes ($r = -0.3769$) and oligochaetes with prawn larvae ($r = -0.1429$) are negative, but in this area also no two groups showed significant affinity ($r < 0.707$).

In area 4 'r' of bivalves with polychaetes ($r = -0.8496$), ($P < 0.05$), with amphipods ($r = -0.3290$) and tanaidaceans with prawn larvae ($r = -0.2476$) are negative indicating that in this area also benthic groups present showed no tendency to exist together.

Diversity and evenness: Shannon Weaver diversity function and Heips evenness function calculated, revealed that area 2 is more productive with more even distribution seasonally than area 1 and perennially than all the 4 areas (Table 4 and 5). Over the period of study, variation could be observed in H (S) and evenness function values.

The standing stock of benthos in a prawn culture field is the net production after the grazing of the tertiary producers. The gross production of benthos in such an area is a function of physico-chemical factors coupled with substratum characteristics. For high benthic biomass, the relative importance of the bottom composition appears to be silt, clay and sand, out of which silt and clay composition were found to play a decisive role in supporting the rich benthic biomass.

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