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Use of benthic biodiversity for assessing the impact of shrimp farming on environment

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Abstract: *An attempt was made to find out the impact of shrimp farm discharges on benthic diversity in the discharge point of a shrimp farm. The duration of the study was one culture period right from stocking to harvest. The results revealed that the values of environmental entities were in the safe levels. As regards nutrients, maximum value of TOC and phosphorus were recorded in the sample collected after harvest and minimum in the sample collected during culture. BIO-ENV method revealed that nitrogen, sediment salinity and TOC were manifested as best variable combination explaining faunal distribution. Polychaetes are the dominant group (50%) with 13 species followed by crustaceans (32%) with 10 species, gastropods (10%) with 2 species and bivalves (8%) with 3 species. The faunal density was found to vary in relation to months as observed in the samples which were collected during various seasons in the other areas of estuary. In line with this, diversity values were also paralleled to the faunal density. In a nut shell, the study revealed no negative impact of shrimp farming to the estuarine benthic biota.*

Key words: *Benthos, Biodiversity, Shrimp farm, Estuary, Environment*
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Introduction

The aftermath of industrialization, urbanization and increase in population resulted in the release of discharges to the immediate ecosystem which causes the deleterious effects as one of the exigent and perplexing problems of the environment. Estuaries receive these pollutants through river runoff, which have profound influence on fauna and flora of the ecosystem. In addition to this, the setting up of shrimp farms along the coastal areas has also become a matter of great concern. Extensive survey made by Environmentalists elsewhere pointed out that the discharges from shrimp farms are detrimental to the bottom fauna. Many reviews lead one to conclude that aquaculture had only positive impact on environments (Phillips *et al*., 1993; Csavas, 1993; Newport and Jawahar, 1995). But occasionally the range and severity of these effects have been exaggerated, that is mainly owing to the high visibility of the aquaculture sector, failure to distinguish between actual and hypothetical hazards and inadequate coverage of its beneficial impact (Jerald, 1996). But there are no pertinent data to support this, which called for a detailed study on the influence of farm discharges on estuarine biota. It is recognized that for understanding the highly productive nature of the coastal waters, a ken of the benthic system is imperative. It is a well – etched fact that benthos have important link in marine food webs and feature significantly in the diets of many bottom-feeding fishes (Uschakov, 1965; Parulekar *et al*., 1980). In addition to this, benthos in general and polychaetes in particular have also been used as "stress indicator" species in environmental impact assessment (EIA) studies world over (Pocklington *et al*., 1994). Many species of polychaetes are known for their tolerance to anoxic conditions with high organic enrichment. Monitoring of the biodiversity in general and of selected species in particular may give the relevant authorities early warnings so action can be taken. In light of these, benthic biodiversity was used as a device in the present study. Careful perusal of literature revealed that only a few studies have been carried out in this line which include those of Raman *et al*. (1975), Mitra *et al*. (1992) who studied on the appearance and build up of benthos in fish ponds of Andhra Pradesh. Stephen *et al*. (1995) documented environmental impact of shrimp farming on continental United States. Grant *et al*. (1995) used a multidisciplinary approach for evaluating impacts of shellfish aquaculture on benthic communities. Hein (2000) documented the impact of shrimp farming on mangroves in east coast of India. Ward (2000) studied on the effect of shrimp farming on the hydrography and water quality of El Pedaegaland San Bernardo estuaries. Pohle *et al*. (2001) assessed the impact of salmon mariculture on benthic biota of Lime Kiln Bay. Gupta *et al*. (2002) studied the effect of shrimp farming on agriculture land and ground water in Cuddalore district of Tamil Nadu. Similarly Joseph *et al*. (2002) conducted a study on water quality characterization of intake point, pond and outlet waters of shrimp farms in Nellore district of Andhra Pradesh. Boyd and Green (2002) prepared a status report on coastal water quality monitoring in shrimp farming areas and conducted a consortium programme on shrimp farming and the environment. McKinnon *et al*. (2002) made an inventory on water column production and nutrient characteristics in mangrove creeks receiving shrimp farm discharges. Keeping in view the above facts, an attempt was made to study the impact of shrimp farming on benthic biodiversity of discharge point of a private shrimp farm.

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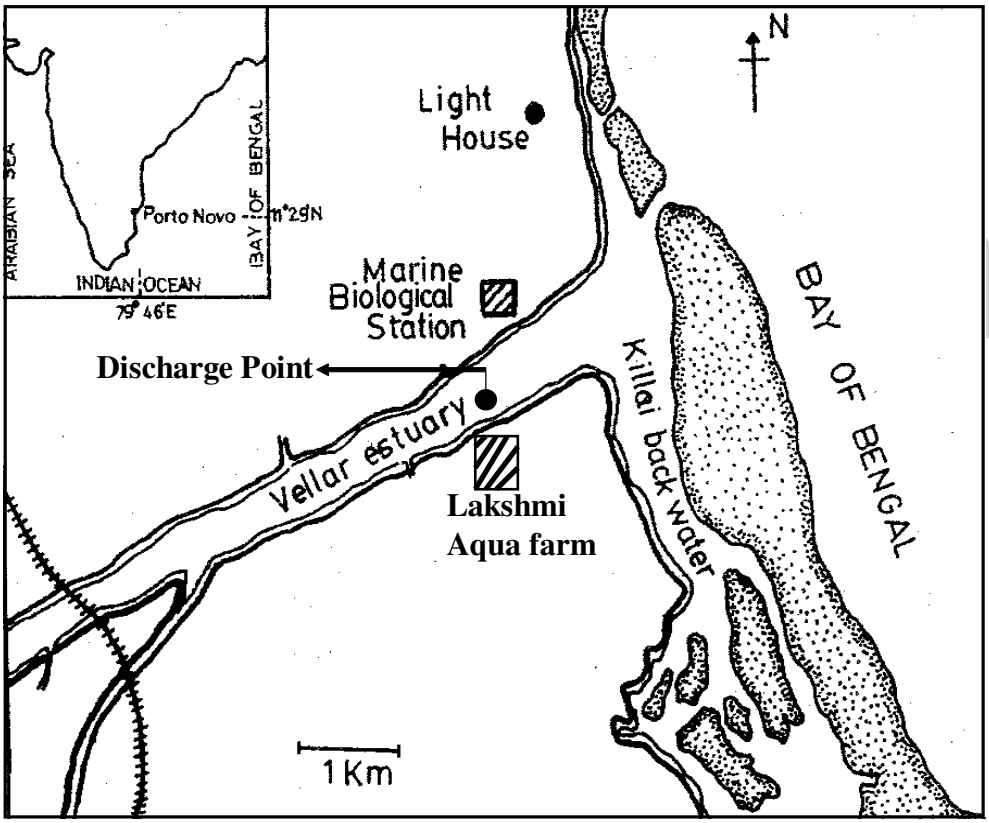

Fig. 1: Map showing the study area

Materials and Methods

Sediment samples were collected in triplicate from the discharge point of a private shrimp farm called Lakshmi aqua farm (Fig. 1). The farm is situated on the southern bank of Vellar estuary, south east coast of India (11°29'N; 79° 46'E) from where the water was drawn into the farm and released back. The farm had 3 ponds with waterspread area of 0.7, 0.8 and 0.85 ha. All the ponds were stocked with hatchery bred *Penaeus monodon* PL 20 (postlarva 20) at a stocking density of 1 lakh larvae per ha. The animals were fed with commercial pellet feed. The crop duration was 135 days from February to June 1999. At the end of the culture, the production was 1.29, 1.95 and 1.90 tons ha^{-1} in the three ponds. The Feed conversion ratio (FCR) recorded was 1:2.2. Samples were collected at an interval of 20 days after every water exchange, using a long armed Peterson grab (Mackie, 1994). After collecting samples, the larger organisms were handpicked immediately and then sieved through a 0.5 mm mesh screen. The organisms retained by the sieve were placed in a labelled container and fixed in 5% formalin. Subsequently, the organisms were stained with Rose Bengal solution (0.1 g in 100 ml of distilled water) for enhanced visibility during sorting and identification. Once the fixatives were added, each sealed sample container was gently upturned and rotated to distribute the formalin evenly throughout the sieved sample. Once back at the laboratory, the sieved samples were gently but thoroughly washed in freshwater. This removed the formalin and salt, preventing the former from dissolving the shells of delicate molluscs. After a day or two, all the organisms were sorted, enumerated and identified to the advanced level possible with the consultation of available literature (Fauvel, 1953; Day, 1967; Barnes, 1980; Shanmugam *et al.,* 1997; Srikrishnadhas *et al.,* 1998; Rajagopal *et al.,* 1998; Lyla *et al.,* 1999). The organisms identified were expressed as number per m^2. The total biomass (wet weight) of benthic macro fauna was estimated. In the case of molluscs, the shells were removed and the weight of animal alone was taken into account. Physico–chemical parameters such as temperature, salinity, pH and dissolved oxygen were analyzed following the standard methodology both in water and sediment samples (Strickland and Parsons, 1972). For sediment analyses, a little quantity of soil was taken in each grab haul and was transferred into cleaned polythene bags, then air dried and used for the analysis of total organic carbon and soil nutrients (El Wakeel and Riley, 1956). The data collected were approached to univariate and graphical techniques using PRIMER statistical package (Clarke and Gorley, 2006).

Results and Discussion

With advancing crop period, the temperature was found to increase from 30.9 to 32.8°C; water salinity from 29 to 30.5 psu (practical salinity units); sediment salinity from 35 to 37.3 psu; water pH from 7.6 to 7.8; sediment pH from 7.8 to 8.1 and dissolved oxygen (DO) level from 3.98 to 4.52 mg l^{-1} in the discharge point

Table - 1: Physico- chemical variables estimated at discharge point

Period	Water temp.(°C)	Water salinity (psu)	Sediment salinity (psu)	Water pH	Sediment pH	DO (ml l^{-1})
20th day	30.9	29	35	7.6	7.9	4.12
40th day	31.5	29.4	36	7.6	7.8	3.98
60th day	32.8	30	36	7.8	8.1	4.34
Before harvest	32.0	30.5	37.3	7.8	8.1	4.52

Table - 2: Soil nutrients estimated at discharge point

Period	Nitrogen (mg 1^{-1})		Phosphorous (mg l^{-1})		Total organic carbon (mgC g^{-1})	
	Mean	SD	Mean	SD	Mean	SD
20th day	5.15	0.017	1.70	0.017	7.80	0.017
40th day	4.75	0.015	1.30	0.017	8.10	0.012
60th day	4.86	0.012	2.25	0.017	7.95	0.006
Before harvest	5.18	0.012	1.95	0.012	8.05	0.012
After harvest	5.24	0.012	2.15	0.006	8.12	0.012

Table - 3: Harmonic rank correlation (rw) between faunal and environmental similarity matrices at discharge point

No. of variables	Best variable combinations	Correlation (pw)
3	Nitrogen-sediment salinity-total organic carbon	0.615
3	Dissolved oxygen-nitrogen- total organic carbon	0.605
2	Nitrogen- water salinity	0.598
1	Total organic carbon	0.589

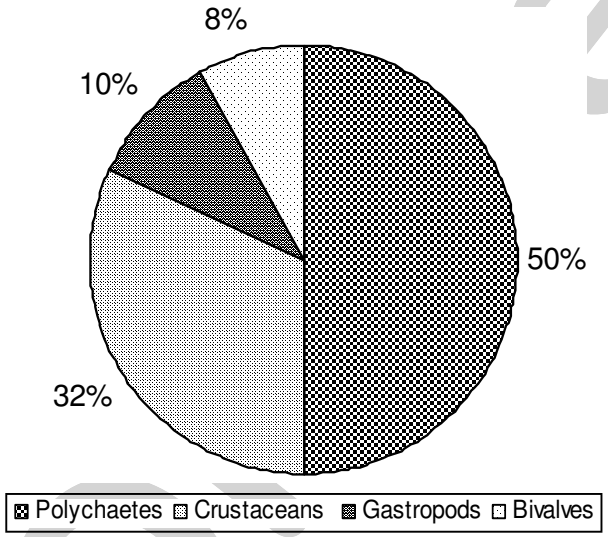

Fig. 2: Percentage composition of macro fauna

(Table 1). The organic carbon content varied between 7.80 and 8.12 mgC g^{-1} with minimum value during the month of February (20th DOC – Day of culture) and the maximum during May (after harvest) (Table 2). The nitrogen values ranged from 4.75 to 5.24 mg l^{-1}. with minimum value was observed during the month of March (40th day) and the maximum during May (after harvest). The phosphorous values were found to be low when compared to nitrogen. It varied from 1.30 to 2.25 mg l^{-1}. The minimum value was noticed during March (40th day) and the maximum in May (60th day; Table 2).

As regards biological entities, polychaetes were found to be the dominant group with 13 species followed by crustaceans with 10 species. Bivalves and gastropods were represented by 3 and 2 species respectively. The polychaetes *viz*., *Ancistrosyllis constricta, Nephthys polybranchia, Prionospio cirrifera* and *Cossura delta* were found to occur throughout the study period. Among crustaceans, *Tanais* spp and *Apseudes killaiyensis* showed consistency in their occurrence. Similar is the case with respect to gastropod *Cerithidea cingulata*. The density varied between 465 and 1465 animals per square meter with minimum in the sample collected on 40th DOC (March) and maximum in the sample collected after harvest (May). The polychaetes contributed 50% to the total number of organisms followed by crustaceans with a percentage occurrence of 32% (Fig. 2). Molluscs showed the maximum biomass of 381.76 g m^{-2} followed by crustaceans and polychaetes with biomass of 54.248 and 18.48 g m^{-2} respectively.

Coming to the diversity indices, the values of species diversity were found to vary from 3.149 to 3.704. The minimum was noticed on the 20th day of sampling and maximum before harvest. Similar is the case with respect to species richness and evenness indices. The values were between 1.270 and 1.778 and evenness 0.948 and 0.973 respectively. As samples were collected in triplicates, the data of three samples were amalgamated and then mean and 95% confidence limits were calculated. The results of diversity indices are shown in Fig. 3-5. The abundance biomass comparison (ABC) curve drawn for the samples collected in the discharge point is illustrated in Fig. 6. The biomass curve was found to lie above the abundance curve throughout its entire length. To ascertain the facts further, the data were presented as points on the 95% confidence funnel and Ellipse plot, which revealed that the delta+ and lambda+ values of all the samples were found to lie well

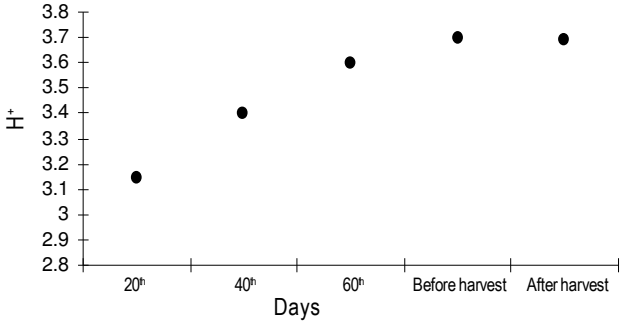

Fig. 3: Means and 95% confidence limits of Shannon – Wiener diversity (H^+) recorded at discharge point

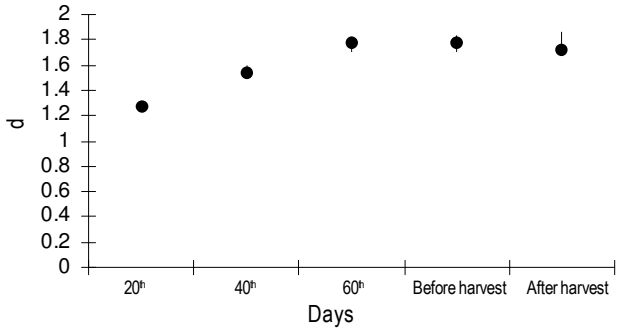

Fig. 4: Means and 95% confidence limits of Margalef richness (d) recorded at discharge point

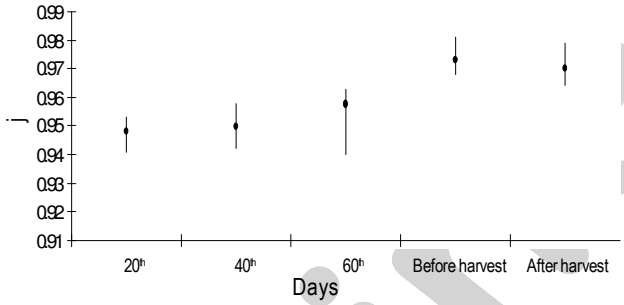

Fig. 5: Means and 95% confidence limits of Pielou's evenness (j) recorded at discharge point

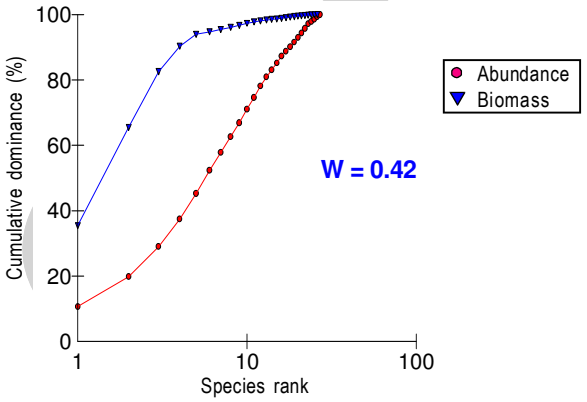

Fig. 6: ABC-plot (k-dominance curve) for macro fauna recorded at discharge point

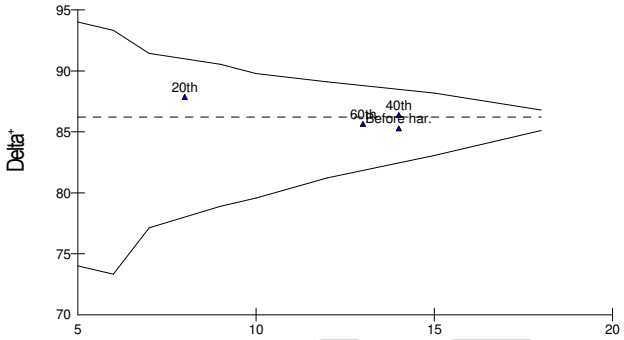

Fig. 7: 95% confidence funnel for delta+ values recorded at discharge point

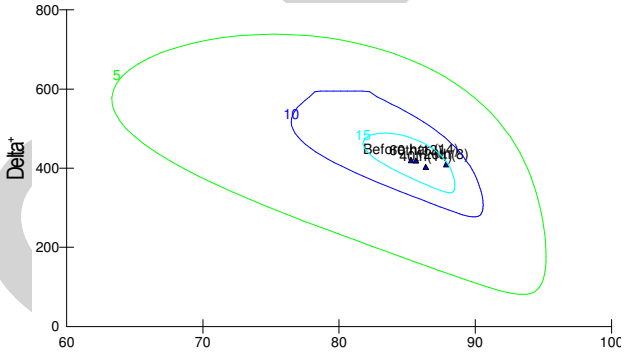

Fig. 8: Fitted 95% probability contours of joint delta+ and lambda+ distribution from 1000 simulations at discharge point

within the 95% confidence envelope of the simulated distribution (Fig. 7,8). To find out the relationship between biological entities and environmental entities, BIO-ENV method was used. The results revealed that nitrogen, sediment salinity and organic carbon were featured as the best variable combinations influencing the faunal diversity. Likewise, dissolved oxygen, nitrogen and total organic carbon formed the next best variable combination explaining the faunal distribution and results are given in Table 3.

With respect to environmental parameters, there was not much variation in values obtained in the present study with values obtained in the other areas of the estuary. Gupta *et al*. (2002) studied on the effect of shrimp farming on adjacent agricultural lands and underground waters in Cuddalore district of Tamilnadu. Their study revealed that there was absolutely no salinisation of soil in ground water and also the values of water quality parameters were well within the normal range. Like wise, Joseph *et al*. (2002) studied on the changes in the water quality in shrimp farms of Andhra Pradesh. They came out with a suggestion that proper pond management is the key to sustainability in aquaculture which in turn can improve soil and water quality and reduce the volume and pollution potential of pond effluents. The findings of abovesaid studies corroborate results of the present study. Similarly the values of total organic carbon and nitrogen were found to be more in the discharge point compared to other areas of the estuary. This might be attributed mainly to the nutrient rich used water from the pond, the other

estuarine processes notwithstanding. The results observed in the present study is comparable with the study made by Seralathan *et al.* (1993) who noticed increase in organic carbon content with the progress of culture due to increasing quantity of feed used, animal exuviae and other wastes. As regards bottom fauna, polychaetes were found to be the dominant group followed by crustaceans, molluscs and others. Dominance of polychaetes in terms of density and species composition in diverse ecological niches is due to their high degree of adaptability to a wide range of environmental factors. Such a preponderance of polychaetes in the benthic communities was reported by earlier workers both in west and east coasts (Ajmal Khan *et al.,* 1975; Antony and Kuttyamma, 1983; Ansari *et al.,* 1986). The dominance of polychaetes in the present study could be attributed to the increased quantum of nutrient rich used water which is let into the estuary and also due to seasonal changes. Besides, the mode of feeding and life style of polychaetes and the relatively high proportion of silt-clay fractions in the sediments and organic carbon content of the sediments also favour the occurrence of more polychaetes. In the light of the above statement, in a study conducted elsewhere attributed the dominance of polychaetes in macro benthos to the higher percentage of organic matter in the sediments, which is very much evident in the present study as well (Kurian, 1971). With respect to crustaceans, as they have no specific preference to the substratum formed the second dominant group in the present study. Similarly the molluscs have the preference to sandy substratum, they were not found abundantly in the present study.

The above trend was quite evident in community indices calculated for the present data. In the present study, the diversity value was more than 3 in the samples collected throughout the study period and the values were found to increase with increasing days of culture. Similar to diversity, the richness (d) and evenness (J) measures largely followed the trend of species diversity. It is generally recognised that when the benthic biota is undisturbed, the representation of species in the benthic community is more or less equal and the diversity and evenness would be more (Magurran, 1988). When the disturbance is severe to the biota, the benthic communities become increasingly dominated by one or few species resulting in low evenness. As the study area is found to be pristine in nature, the high diversity and evenness values were recorded. Added to this fact, the ABC- curve drawn showed the biomass curve to lie above the abundance curve indicating the area covered was unstressed. Besides, the 95% confidence funnel and Ellipse plot drawn also showed the similar trend of ABC – plot that the values of delta+ and lambda+ were found to lie well within the simulated distribution signalling the undisturbed nature of the bottom fauna in the discharge point. As these tools have been developed only recently, works done using these techniques are very meagre in the Indian and International scene could not be discussed here. The BIO-ENV method done to match the biota with environmental parameters yielded the combinations of three environmental entities such as nitrogen, sediment salinity and total organic carbon as best variables explaining the faunal distributions. This is in agreement with the values recorded by Clarke and Ainsworth (1993) who noticed combinations as total organic carbon-sediment salinity - nitrate as 'best match'.

Considering the results obtained in the present study it is concluded that the data collected in the present study revealed maximum density of organisms and faunal composition which are comparable in the other areas of the system and more importantly the data treated with various state of the art methods also revealed normal state of the system indicating no negative impact of shrimp farming to the estuarine benthic biodiversity.

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