Journal of Aquatic Biology & Fisheries, Vol. 2(1) 2014: 238-246

IMPACT OF TITANIUM EFFLUENTS ON THE COMMUNITY STRUCTURE OF ZOOPLANKTON IN THE INSHORE WATERS OF LAKSHADWEEP SEA AT VETTUKAD, THIRUVANANTHAPURAM, KERALA.

Sini Wilson, *Benno Pereira, F.G., Sachin, S.R., Sumesh, C. and Jyothilal, C.S.
Dept. of Aquatic Biology & Fisheries, University of Kerala, Thiruvananthapuram
**Dept. of Fisheries and Aquaculture, St. Alberts College, Ernakulam.*
**Corresponding author: bennopereira@gmail.com*

Received on: 10.04.2013, accepted on: 11.11.2013

Abstract: The coastal waters of Thiruvananthapuram is being polluted by the effluents discharged from Travancore Titanium Products (TTP) Ltd., Kochuveli. Studies on the distribution, density and ecology of zooplankton in the Lakshadweep Sea adjacent to the effluent discharge point during February- April, 2004 revealed the adverse effect caused by the discharge from TTP on the zooplankton community in the region. In terms of incidence, density and distribution, zooplankton was low in highly polluted zones represented by stations 3 and 4 and was impressive in the zones represented by stations 5 and 6, lying 0.5 km and 1km away from the point of effluent outfall. An increasing trend in terms of distribution, density and incidence was the pattern observed from station 3 to station 6. The effluent discharge has altered the water quality critically. Elevated temperature and reduced pH was the striking water quality changes noted at stations 3, 4 and 5. The sea at this area has been in a warm and acidic state. The less incidence, distribution and density of zooplankton can be attributed to these extremely hostile environmental conditions. There is the paramount need to treat these industrial effluents prior to discharge into the Sea.

Key Words: Pollution, Plankton, Zooplankton, Effluent, Biomass, Ecology, Community

INTRODUCTION

Marine pollution is a global concern which is due to increase in human population, coupled with rapid urbanization and industrialisation. Inventions in science and technology have enabled man to unscrupulously exploit natural resources without regard for the future generations of mankind. The urban and industrial pockets along the Indian coasts, release their waste water into the nearby coastal waters. The coastal waters of India are unpolluted except for some localised "Hot Spots" adjacent to urban and industrial areas (Zingde, 1989). Man power, proximity to coastal waters, estuaries and rivers with facility for rapid discharge of effluents, plentiful availability of water for industrial processes, availability of ports and excellent transportation facilities have lead to the concentration of industries along the coastal tract of Kerala (Azis, 1990). In Thiruvananthapuram, the coastal waters are being polluted by effluents discharged from the Travancore Titanium Products (TTP) Ltd. The effluents spread along the coast, northward or southward depending on the direction and force of the littoral current. The oxidation of ferrous ion to ferric ion in the sea imparts a reddish brown colour to the sea water.

Plankton is a large assemblage of marine life consisting of both plants and animals. According to Riley (1967) the term zooplankton is used to designate an assemblage of small animals living in the pelagic habitat. Zooplankton occupies an important trophic niche in the aquatic ecosystem as they constitute the most important link in energy transfer between phytoplankton and higher aquatic fauna (Iloba, 2002). Zooplankton is a very heterogenous group having representatives among different phyla, from protozoans to vertebrates (Nair *et al*., 1985). The present study is particularly relevant in the context of the ever increasing threat to the inshore waters of Lakshadweep Sea from the TTP Ltd, situated at Vettukad fishing village, Kochuveli. The present study was undertaken to elucidate the community structure of zooplankton in the sea up to a distance of 1km from the high tide line.

MATERIALS AND METHODS

Study Site

The Travancore Titanium Products Ltd. is situated at Kochuveli bordering the Vettukad fishing village, a very dense hamlet of traditional fishermen. The TTP Ltd. is on the shores of the Lakshadweep sea (8º25' Lat.N, 75º5' Long.E). The effluent from the titanium factory is carried through a closed channel that discharges the effluent directly on the Vettukad beach. Basically this is an open, surfacedischarge on the sea shore. Four stations (Stations 3, 4, 5 & 6) (Fig.1) were selected for a detailed study to understand the impact of TTP effluents on the zooplankton and its ecology in this region.

Station 1: It was located at the beginning of effluent stream on the beach. In this region TTP empties its effluent on the beach.

Station 2: This is the point where effluent stream joins the sea. The effluent outflows the pool and enters the sea cutting the beach front as a gully.

Station 3: This is the part of the open sea 50 m away from the shore margin.

Station 4: This is the part of open sea about 250 m away from the shore margin.

Station 5: This is part of open sea about 500 m away from the shore margin.

Methods

Monthly plankton samples were collected from four stations (3, 4, 5 and 6) (Fig. 1) during February-April, 2004, using a plankton tow net of 50 cm diameter made of number 21 bolting silk cloth hauled from a catamaran. The collections were made in the early morning between 7am and 10am. Two local fishermen were engaged for collecting plankton samples. The method described by Santhanam (1987) and Aziz *et al*. (2003) was followed for collecting plankton samples. Plankton was collected by using the standard procedure of horizontal surface haul for 200 metres. The volume of water filtered through the net was 39.25 m^3. The plankton samples were fixed in 5% formalin. The biomass of the plankton was determined by settling volume method. 1ml sample was subjected to detailed numerical analysis under an Inverted compound microscope. The identification of different groups of plankton and species were done with the help of standard references (Zheng Zhong, 1989; Kasthurirangan, 1963; Pillai, 1986; Todd *et al*., 1996). Temperature of surface sea water and effluent were recorded using a Celsius thermometer. The pH of water samples were measured using a pH meter (Model No.L1-10 pH meter, ELICO, India) and salinity was measured by a hand refractometer (ERMA, Inc, Tokyo).

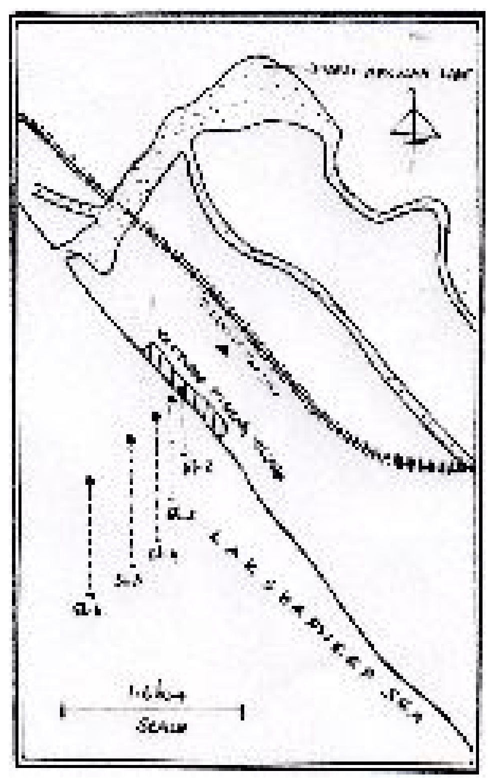

Fig. 1. Map of Thiruvananthapuram coast showing the study sites

RESULTS & DISCUSSION

The observations were made along the Vettukad beach from February to April, 2004.

Waves

The waves in the Vettukad region are comparatively calm. The waves observed are mainly plunging and surging types. The breaking waves that incessantly pound the coast were found to play an effective role in mixing and dilution of titanium effluents that reached the sea. The wave data agrees with the observation of Baba and Kurien (1988).

Tidal Conditions

The tides of the Thiruvananthapuram coast are generally of mixed type with a semidiurnal influence. The diurnal influence is large (Nair and Rajan, 1974). As the tide rises and falls, successive areas of the beach get regularly subjected to the tidal action helping in the mixing, dilution and diffusion of the effluents that reached the sea. Low tides were observed during the period of study.

Colour

Normally the colour of Sea varies from a deep blue to an intense green colour (Sverdrup *et al*.,1962). During the period of present observation the colour of the sea remained reddish brown and this is presumed to be caused by the suspended particles present in titanium effluents that flow into the region. Effluents discharged from TTP represents a mixture of sulphuric acid (20%), ferrous sulphate (7%), titaniumoxysulphate (1%) and some trace elements such as aluminium, magnesium, manganese, vanadium, zinc, zircornium and chromium all in form of sulphates. The oxidation of ferrous ion to ferric ion in the sea imparts a reddish brown colour to the sea water which is spreading up to 8 Kms. (Madhupratap *et al*.,1979).

Fishing Activities

The Vettukad fishing village lying between the Titanium factory and the Lakshadweep Sea is a famous fishing village and it is facing the biggest threat from the discharge of effluents from TTP. The fishing activities were low during February and very brisk during March and April.

WATER QUALITY PARAMETERS

The results of analysis of water quality parameters is shown in Table.1.

Temperature

The temperature at station 1 ranged from 45-47ºC. Water at station 1 is the actual effluent. The wind prevailing in the region played a major role in stripping the temperature of effluent during its flow along the beach channel. The sea surface temperature ranged from 28-31ºC. The available data does not allow us to state whether the sea water temperature return to ambient values even at a distance of 1km from the point of discharge. Excess heat when added to the marine environment, changes ambient conditions and these changes may be detrimental to the organisms present (Sinha, 1999). Pitchaikani (2010) reported the suppression of phytoplankton, zooplankton, finfishes and shellfishes in the sea water, having elevated temperature of 42°C adjacent to Tuticorin Thermal Power Station (TTPS).

pH

The pH of sea water ranged from 5.4-6.9. The sea water remains acidic with varying pH values from stations 3-4 during the entire period of study. The data indicate that despite the immense buffering capacity of the sea, the sea water did not become alkaline even at a distance of 1km from station 2. It indicates that titanium plant discharge goes beyond 1km from the shore. The normal pH of oceanic water is somewhere around 8, slightly alkaline. The discharge of acids into marine environment has become quite disturbing to the natural ecological balance of the systems. Ketchum *et al*. (1958) observed loss of motility of zooplankton in waters receiving acid wastes from barge of titanium plant of National Lead Company. During the present study reduced pH was felt in incidence, composition and distribution of zooplankton.

Salinity

Salinity ranged from 33-35 ppt.

Table 1. Distribution of temperature (°C), pH and salinity (ppt) at different stations in the Lakshadweep Sea coast adjacent to the effluent discharge point of TTP Ltd during February – April, 2004

Months	Stations	Temperature(°C)	pH	Salinity (ppt)
February	1	47	0.2	33
	2	36	0.3	35
	3	31	6	33
	4	31	5.4	34
	5	31	5.7	34
	6	30.5	5.8	33
March	1	47	0.1	33
	2	44	0.2	35
	3	29	6	34
	4	29	6	35
	5	29	6.3	35
	6	28.5	6.6	35
April	1	45	0.1	34
	2	35.5	0.2	35
	3	29	5.6	35
	4	28.5	5.9	35
	5	28	6.1	35
	6	28	6.9	35

Table 2. Biomass in number of plankton (no/haul) at stations 3-6.

Months	Biomass in volume (ml/haul)			
	Station 3	Station 4	Station 5	Station 6
February	14000	20550	32075	46375
March	19275	25950	33575	45075
April	27600	38500	51950	65825

Chracteristics of Zooplankton

Total Biomass (number/haul)

The peak value of zooplankton biomass per haul recorded in the study was 65825 no/haul at station 6 in April. The lowest value was recorded at station 3 (14000 no/haul) in February. An increasing trend can be seen in the value of biomass from the effluent discharge point (station 3) to the point of recovery (station 6). (Table.2). There was perceptible impact of effluents on the general zooplankton biomass.

Table 3. Zooplankton density at stations 3-6 in the Lakshadweep Sea adjacent to TTP Ltd. during February-April, 2004

	Zooplankton groups/ Phylum	Feb-2004				Mar-2004				Apr-2004			
		St 3	St 4	St 5	St 6	St 3	St 4	St 5	St 6	St 3	St 4	St 5	St 6
	PHYLUM PROTOZOA												
1	Globigerina sp.	-	-	6 -	8	-	-	- -	-	-	-	-	-
2	*Triloculina irregularis*	-	-	-	-	-	-	3	8	-	-	-	-
3	*Acanthometra pellucida*	-	-	-	-	-	-	-	-	-	6	8	10
4	*Tintinnopsis orientalis*	1	3	3	4	-	-	-	-	4	7	9	10
	PHYLUM COELENTERATA												
5	*Lensia subtiloides*	-	-	1	3	-	-	- +	-	-	-	-	-
6	Gastrozoid	1	1	4	6	-	-	-	-	-	-	-	-
7	*Porpita porpita*	-	-	-	-	-	-	-	-	-	-	1	1
	PHYLUM CTENOPHORA												
8	*Pleurobranchia globosa*	-	4	-	6	-	-	-	-	-	4	-	6
9	*Euchlora rubra*	-	-	-	-	1	3	8	12	-	-	-	-
10	*Beroe cucumis .*	-	-	-	3	-	-	-	-	-	-	-	-

	PHYLUM ANNELIDA												
11	*Owenia fusiformis*	7	8	11	13	-	-	-	-	-	-	-	-
	PHYLUM ARTHROPODA												
12	*Semibalanus balanoides*	-	-	-	-	-	-	-	-	-	-	3	4 +
13	*Podon polyphemoides*	-	-	-	-	14	17	19	39	-	-	-	-
14	*Penilia avirostris*	-	-	-	-	15	20	26	34	-	-	-	-
15	*Euchaeta marina*	-	-	-	-	27	34	39	47	18	27	33	41
16	*Acrocalanus gibber*	10	15	20	24	17	19	27	34	18	31	34	41
17	*Acartia spinicaudata*	9	17	24	26	-	-	-	-	-	-	-	-
18	*Calanoipa minor*	7	14	22	27	22	24	27	34	9	17	24	27
19	*Nannocalanus minor*	-	-	-	-	17	18	22	30	23	24	31	62
20	*Miracia effarata*	7	11	15	27	-	-	-	-	-	-	-	-
21	*Undinula vulgaris*	5	7	13	18	-	-	-	-	22	28	46	62
22	*Oithona rigida*	30	34	53	62	47	52	58	67	50	59	72	80
23	*Oithona similis*	14	27	44	54	22	39	36	45	38	40	48	53
24	*Oithona spinirostris*	11	17	22	29	-	-	-	-	-	-	-	-
25	*Oncaea venusta*	8	11	12	15	-	-	-	-	30	34	53	60
26	*Euterpe acutifrons*	-	-	-	-	12	15	20	28	22	36	46	60
27	Zanis sp.	-	-	-	-	11	13	25	23	14	27	44	54
28	Tigriopus sp.	-	-	-	-	12	15	24	25	7	9	12	5
29	*Themisto gracilipes*	8	10	14	17	-	-	-	-	11	12	14	15
30	*Vibilia gibbosa*	6	7	9	13	-	-	-	-	-	-	-	-
31	*Ampelisca cyclops*	3	7	9	13	-	-	-	-	3	8	8	14
32	*Euphausia diomedae*	-	-	-	-	-	-	-	-	3	7	12	15
33	Zoea larva	-	-	-	10	-	-	-	-	9	15	17	23
34	Megalopa larva	-	-	-	-	-	-	-	-	7	8	9	12
35	Mysis larva	-	-	-	-	-	-	-	3	-	-	-	-
36	Phyllosoma larva	-	-	-	-	-	-	-	6	-	-	-	-
37	Nauplius larva	9	14	20	28	11	20	21	29	36	40	46	53
38	Clione sp	-	-	-	5	-	-	-	-	-	-	3	7
39	*Paraclione longicaudata*	-	-	-	-	8	18	21	29	-	-	-	-
40	Trochophore larva	-	-	3	-	-	-	3	4	-	-	-	-
41	Veliger larva	-	2	-	-	-	-	-	-	-	-	-	-
	PHYLUM CHAETOGNATHA												
42	*Sagitta enflata*	1	3	4	7	-	-	-	-	-	-	-	-

	PHYLUM CHORDATA												
43	*Oikopleura dioica*	12	15	24	39	7	9	11	17	10	14	15	31
44	*Fritillaria pellucida*	8	13	25	32	4	7	9	13	8	-	9	12
45	*Doliolum denticulatum*	-	-	-	-	-	4	6	7	-	3	4	7
46	Salpa fusiformis	3	4	7	12	-	-	3	4	-	6	4	7
47	Fish eggs	10	11	14	21	7	8	11	18	10	14	15	20

General density distribution

The zooplankton density at stations 3-6 in the Lakshadweep Sea is depicted in Table.3. Station 3 showed the minimum zooplankton density throughout the present study. The zooplankton density was generally higher at station 6 throughout the study showing that the site is offering a vastly more congenial environment for the occurrence of higher zooplankton abundance and diversity (Table 3).

Community structure of Zooplankton

Zooplankton showed widely varying pattern of distribution in a station wise and month wise consideration. The zooplankton community was represented by 39 species forming part of 10 classes and 14 orders belonging to 8 phyla. The largest assemblage of zooplankton was formed by phylum Arthropoda constituting 83.01% of the total zooplankton collected. The next important phylum was Chordata representing 10.95% of the total zooplankton. Coelenterates and Annelids were less than 1%. The percentage of abundance of Protozoa, Ctenophora and Mollusca lies between 1 and 2% (Fig. 2). Chaetognatha was the lowest occurring zooplankton representative. All the 6 phyla except Chordata and Arthropoda showed low species diversity. An ascending pattern was noticed in zooplankton density from station 3 to 6.

The general composition of the zooplankton identified in the study is represented in Table.4. Station wise concept showed that station 3 was represented by 29 species, station 4 by 31 species, station 5 by 38 species and station 6 by 39 species out of the total 39 species encountered during the present study. Increase in species diversity can be seen from stations 3 to 6. All species reported were present at station 6, the least impacted zone at a distance of 1 km from the shore. Certain species like globigerina, *Triloculina irregularis, Lensia subtiloides*, *Porpita porpita, Beroe cucumis and Semibalanus balanoides* were found only at stations 5 and 6. The species were very sensitive groups and hence could not thrive in adverse environmental conditions. The sensitive groups occur within a temperature range

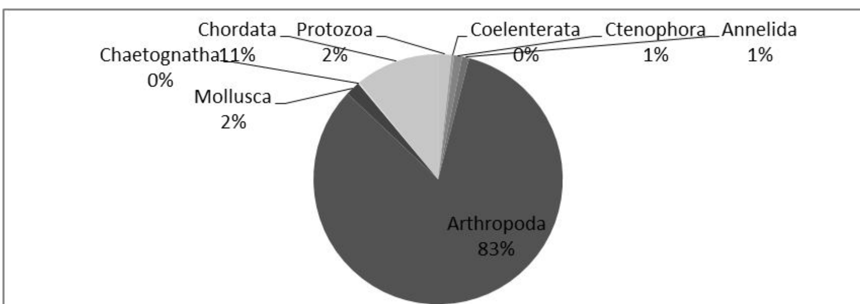

Fig.2. Percentage composition of major phyla of zooplankton at stations 3-6

of 28-31ºC and pH of 5.7 to 6.9. Larval stages were totally absent at station 3, the highly polluted zone. This corroborates the observation of Vijayalekshmi *et al*. (1981) that larval forms are found to be more sensitive to changes in environmental conditions and consequently a reduction in the abundance of larvae are quite natural in polluted waters. *Tintinnopsis orientalis*, *Euchaeta marina, Acrocalanus gibber, Calanoipa minor, Nannocalanus minor* and *Oithona rigida* were found at all stations showing their resilience to adverse environmental conditions. A reduced faunal assemblage was observed at the discharge site by previous workers. Rao and Rao (1978) observed low species diversity of foraminiferans at the TTP discharge point. Low species diversity of zooplankton was observed in the present study. This agrees with the observation that species diversity was high at unpolluted regions compared to polluted regions (Gabhijye *et al*., 1984).

CONCLUSION AND RECOMMENDATIONS

Studies on distribution, incidence and density of zooplankton in the Lakshadweep Sea revealed the adverse effect of titanium discharge on the zooplankton community in the Sea. The less incidence, distribution and density of zooplankton can be attributed to the extremely hostile environmental conditions prevailing in the Sea. The TTP management should view with real concern the threat it has been posing to the

Table 4. Total composition of Zooplankton showing their absence or presence at stations 3-6 in the Lakshadweep Sea adjacent to TTP Ltd. during February-April, 2004

	Zooplankton groups/ Phylum	Feb-2004				Mar-2004				Apr-2004			
		St 3	St 4	St 5	St 6	St 3	St 4	St 5	St 6	St 3	St 4	St 5	St 6
	PHYLUM PROTOZOA												
1	Globigerina sp.	-	-	+ -	+	-	-	- -	-	-	-	-	-
2	*Triloculina irregularis*	-	-	-	-	-	-	+	+	-	-	-	-
3	*Acanthometra pellucida*	-	-	-	-	-	-	-	-	-	+	+	+
4	*Tintinnopsis orientalis*	+	+	+	+	-	-	-	-	+	+	+	+
	PHYLUM COELENTERATA												
5	*Lensia subtiloides*	-	-	+	+	-	-	- +	-	-	-	-	-
6	Gastrozoid	+	+	+	+	-	-	-	-	-	-	-	-
7	*Porpita porpita*	-	-	-	-	-	-	-	-	-	-	+	+
	PHYLUM CTENOPHORA												
8	*Pleurobranchia globosa*	-	+	-	+	-	-	-	-	-	+	-	+
9	*Euchlora rubra*	-	-	-	-	+	+	+	+	-	-	-	-
10	*Beroe cucumis* .	-	-	-	+	-	-	-	-	-	-	-	-
	PHYLUM ANNELIDA												
11	*Owenia fusiformis*	+	+	+	+	-	-	-	-	-	-	-	-

	PHYLUM ARTHROPODA												
12	*Semibalanus balanoides*	-	-	-	-	-	-	-	-	-	-	+	+
13	*Podon polyphemoides*	-	-	-	-	+	+	+	+	-	-	-	-
14	*Penilia avirostris*	-	-	-	-	+	+	+	+	-	-	-	-
15	*Euchaeta marina*	-	-	-	-	+	+	+	+	+	+	+	+
16	*Acrocalanus gibber*	+	+	+	+	+	+	+	+	+	+	+	+
17	*Acartia spinicaudata*	+	+	+	+	-	-	-	-	-	-	-	-
18	*Calanoipa minor*	+	+	+	+	+	+	+	+	+	+	+	+
19	*Nannocalanus minor*	-	-	-	-	+	+	+	+	+	+	+	+
20	*Miracia effarata*	+	+	+	+	-	-	-	-	-	-	-	-
21	*Undinula vulgaris*	+	+	+	+	-	-	-	-	+	+	+	+
22	*Oithona rigida*	+	+	+	+	+	+	+	+	+	+	+	+
23	*Oithona similis*	+	+	+	+	+	+	+	+	+	+	+	+
24	*Oithona spinirostris*	+	+	+	+	-	-	-	-	-	-	-	-
25	*Oncaea venusta*	+	+	+	+	-	-	-	-	+	+	+	+
26	*Euterpe acutifrons*	-	-	-	-	+	+	+	+	+	+	+	+
27	Zanis sp.	-	-	-	-	+	+	+	+	+	+	+	+
28	Tigriopus sp.	-	-	-	-	+	+	+	+	+	+	+	+
29	*Themisto gracilipes*	+	+	+	+	-	-	-	-	+	+	+	+
30	*Vibilia gibbosa*	+	+	+	+	-	-	-	-	-	-	-	-
31	*Ampelisca cyclops*	+	+	+	+	-	-	-	-	+	+	+	+
32	*Euphausia diomedae*	-	-	-	-	-	-	-	-	+	+	+	+
33	Zoea larva	-	-	-	+	-	-	-	-	+	+	+	+
34	Megalopa larva	-	-	-	-	-	-	-	-	+	+	+	+
35	Mysis larva	-	-	-	-	-	-	-	+	-	-	-	-
36	Phyllosoma larva	-	-	-	-	-	-	-	+	-	-	-	-
37	Nauplius larva	+	+	+	+	+	+	+	+	+	+	+	+
	PHYLUM MOLLUSCA												
38	Clione sp.	-	-	-	+	-	-	-	-	-	-	+	+
39	*Paraclione longicaudata*	-	-	-	-	+	+	+	+	-	-	-	-
40	Trochophore larva	-	-	+	-	-	-	+	+	-	-	-	-
41	Veliger larva	-	+	-	-	-	-	-	-	-	-	-	-
	PHYLUM CHAETOGNATHA												
42	*Sagitta enflata*	+	+	+	+	-	-	-	-	-	-	-	-
	PHYLUM CHORDATA												
43	*Oikopleura dioica*	+	+	+	+	+	+	+	+	+	+	+	+
44	*Fritillaria pellucida*	+	+	+	+	+	+	+	+	+	-	+	+
45	*Doliolum denticulatum*	-	-	-	-	-	+	+	+	-	+	+	+
46	*Salpa fusiformis*	+	+	+	+	-	-	+	+	-	+	+	+
47	Fish eggs	+	+	+	+	+	+	+	+	+	+	+	+

+ Present, - Absent

marine ecosystem. On a priority basis, the company should establish a modern effluent discharge system by which effluents can be taken to offshore region through a subsurface pipeline. The pollution of the sea shore also should be stopped. The fishermen of the Vettukad region who bear the most direct impact of this wanton effluent discharge on account of health, hygiene and occupation deserve a better deal and adequate compensation.

ACKNOWLEDGEMENT

The first author is grateful to the Department of Aquatic Biology and Fisheries, University of Kerala for providing necessary laboratory facilities. This work was carried as part of M.Sc programme.

REFERENCES

Abdul Aziz, P.K., Al-Tisan, I.A., Daili, M.A., Green, T.N., Dalvi, A.G.I and Javeed, M.A. 2003. Chlorophyll and plankton of the Gulf coastal waters of Saudi Arabia bordering a desalination plant. *Desalination*, 154: 291-302.

Abdul Azis, P.K.1990. Status of Coastal Pollution in Kerala *In Proc. envtl. symp. Mar. Pollution.* 161-183.

Baba, M and Kurian, N.P. 1988. Ocean waves and beach processes of the South West Coast of India and their prediction. Monograph, CESS, Trivandrum, 249pp.

Gajbhiye, S.N., Vijayalekshmi, R.N. and Desai, B.N.1981. Diurnal variation of zooplankton in Malad creek, Bombay. *Indian J. Mar. Sci*., 13:75-79.

Kasthurirangan, L. R. K.1963. A key for the identification of more planktonic copepod of Indian coastal waters. INCOR Publ., 2: 1-87.

Ketchum, B.H., Yentch C.S., Corwin, N and Owen D.M.1958. Some studies of the disposal of iron wastes at Sea. Woods Hole Oceanogr.Inst.Ref.No.58-55, 66 pp.

Iloba, K. I. 2002. Vertical distribution of Rotifera in the Ikpoba Reservoir in Southern *Nigeria. Trop. Freshwater Biol*., 11: 69-89.

Madhupatap, M., Haridas, P., Gopalakrishnan, T.C., Sankaranarayanan,V.N. and Gopala Menon P.1979**.** Toxicity of Effluent from a Titaniumdioxide Factory on Some Marine Animals. *Indian J.Mar.Sci*., 8(1): 41-42.

Nair, N.B. and Rajan, K.C. 1974. Observations on the effect of effluents from a titanium plant on the interstitial fauna of the South West Coast of India. Ph.D Thesis, University of Kerala.

Nair, N.B., Arunachalam, M., Abdul Azis, P.K., Krishna Kumar, K. and Dharmaraj K. 1985. Ecology of Indian estuaries. Distribution and seasonal variation of zooplankton in the Ashtamudi estuary. *Proc. Nat. Acad. Sci*., India, 55: 271-289.

Pillai, N.K. 1986. Introduction to Planktonology, Himalaya Publishing House, Bombay, 103 pp.

Pitchaikani, J.S., Ananthan, G and Sudhakar, M. 2010. Studies on the Effect of Coolant Water Effluent of Tuticorin Thermal Power Station on Hydrobiological Characteristics of Tuticorin Coastal Waters, South East Coast of India. *Current Research Journal of Biological Sciences,* 2(2): 118-123.

Rao, K.K. and Rao T.S.S. 1978. Studies on the pollution ecology of foraminifera of the Trivandrum Coast. *Indian. J. Mar.Sci*., 8(1): 31-35.

Riley, G.A.1967. Mathematical model of nutrient condition in coastal waters *Bull. Bingham*. *Oceanogr. Coll*., 19: 72-80.

Santhanam, R., Ramanathan, N., Venkataramanujan,K and Jegadeeshan. G. 1987. Phytoplankton of the Indian Seas, Daya Publishing House, New Delhi, 127pp.

Sinha, R.K.1999. *Marine and Water Environment.* Indian Publishers Distributors, 350pp.

Sverdrup, H.U., Johnson, M.W. and Flemming, R.H. 1962. *The Oceans, their Physics, Chemistry and General Biology.* Asia Publishing House, New York, 873pp.

Todd, C.D., Laverack, M.S. and Boxshall, G.A. 1996. *Coastal Marine Zooplankton- A Practical Manual,* (second edition), Press Syndicate of University of Cambridge, 106 pp.

Vijayalekshmi, R.N., Gajbhiye, S.N., Jayalal Ram, M. and Desai, B.N. 1981. Biomass and Composition of zooplankton in Auranga, Ambika, Purna and Mindola estuaries of Gujarat, *Indian J.Mar.Sci.,*10: 346-349.

Zheng Zhong 1989. *Marine Planktonology.* China Ocean Press, Beijing and Springer-Verlag Heidelberg, 454 pp.

Zingde, M.D. 1989. Environmental status of the coastal marine environment *In* Management of Aquatic ecosystems, pp 37-57.