J. mar. biol. Ass. India, 1999, 41 (1 & 2) : 19 – 27

TRACE METAL DISTRIBUTION IN ZOOPLANKTON OF THE COROMANDEL COAST, BAY OF BENGAL

C. GOVINDASAMY, L. KANNAN* AND JAYAPAUL AZARIAH

Department of Zoology, University of Madras, Guindy Campus, Madras-600 025, India.

ABSTRACT

Absorption, assimilation and uptake of metals by zooplankton provides entry for heavy metals into the cycling process and to be passed on and concentrated at higher trophic levels through the food-chain. The present report focusses attention on the levels of heavy metals (Cu, Zn, Ni, Co, Cd and Hg) in the costal waters of Coromandel coast. Annual mean concentration of heavy metals in zooplankton varied spatially, as the concentrations of Cu and Hg and Zn, Ni, Co and Cd were high at stations 1 and 2 respectively. Concentrations of these metals were high during the postmonsoon season at station 1. At station 2, Zn, Co and Hg concentrations were high during the postmonsoon season whereas, Cu, Ni and Cd concentrations were high during the summer seasons. High concentrations of these metals in zooplankton coincided with their higher concentrations in the phytoplankton, facilitating metals to the direct absorption from water and also by assimilation through food substances by zooplankton. This is substantiated by higher concentration factors (CFs) exhibited by zooplankton and the order of metals abundance in these phytoplankton (food) and seawater.

INTRODUCTION

ZOOPLANKTON are capable of concentrating large quantities of heavy metals from seawater. These metals may be passed on and concentrated at higher trophic levels through the food chain. So, there is a growing concern about the occurrence of heavy metals in the marine environment which has lead to intensified research to establish levels of metals at different trophic tiers in the sea. Most pollution that occurs in the costal areas has local hydrographical conditions which render plankton monitoring impractical. But the non-motile benthos is largely used for monitoring due to their sessile and most tolerant nature to pollution (Gray, *et al.,* 1980). Environmental factors such as distance from land run, water depth, temperatures, salinity, species composition and trace elements concentrations in seawater will affect the accumulation of metals in plankton. Present study is therefore aimed at the investigation of the accumulation of Copper, Zinc, Nickel, Cobalt, Cadmium and Mercury in zooplankton collected from the coastal waters of the middle part of Coromandel coast for a total period of two years from April 1989 to March 1991 at Mahabalipuram (Lat. 12° 37′ N; Long. 80° 12′ E) (Station 1) and Pondicherry (Lat. 11° 53′ N; Long. 79° 49′ E) (Station 2) (Fig. 1).

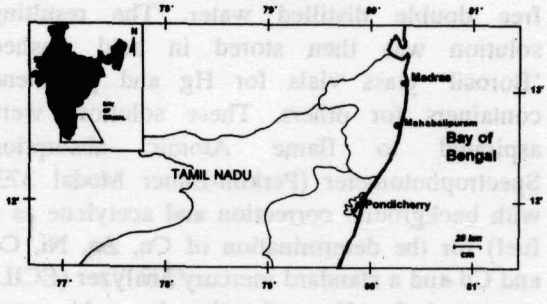

FIG. 1. *Map showing the study area.*

*Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 502, India.

Authors thank the Director, C.A.S. in Marine Biology, Annamalai University and the University authorities for facilities and encouragement. They also thank the Department of Ocean Development and Council of Scientific and Industrial Research, Government of India for the financial support.

MATERIAL AND METHODS

Plankton samples were collected from seawater surface by towing a plankton net, made of bolting silk (mesh aperture size 250 μm) for half an hour. To avoid metal contamination, the net is equipped with a stainless steel ring, nylon bridles and rope. Immediately after collection, the plankton samples were kept in precleaned and acid washed polythene bottles which were sealed and kept in an ice box until further analysis. In the laboratory, the plankton samples were washed with metal free double distilled water and dried in an oven at 60°C (40°C for Hg, EPA-1979) for 5-6 hours till a constant weight was obtained. Later, ground and redried sample weighing 250 mg of zooplankton was taken in a precleaned and acid washed 50 ml glass beaker to which 5 ml of Con. HNO_3 was added and then evaporated to dryness. The residue was redissolved in 10 ml of 0.1 N HCl (Romeo and Nicolas, 1986). This solution was filtered using Whatman No. 42 filter paper in a metal free double distilled water. The resulting solution was then stored in acid washed 'Borosil' glass vials for Hg and polythene containers for others. These solutions were aspirated to flame Atomic absorption Spectrophotometer (Perklin-Elmer Modal 373, with background correction and acetylene as a fuel) for the determination of Cu, Zn, Ni, Co and Cd and a standard mercury analyzer (ECIL) was used for Hg estimation by cold vapor Atomic Absorption Spectrophotometry.

A series of standard metal solution (Cu, Zn, Ni, Co, Cd and Hg) were prepared in the optimum concentration range with metal free double distilled water. Calibration curves were prepared by plotting the absorption against concentration of the working solution for each element. Metal concentrations in the samples were calculated with the help of these calibration curves and expressed as $\mu g\ g^{-1}$ dry weight for all metals; and as $ng\ g^{-1}$ dry weight for Hg of zooplankton. Further, concentration factors (CFs) for heavy metals in Zooplankton was worked out as concentrations metal per gram, phytoplankton and per ml of water concentration metal per gram zooplankton. Analysis of the NIES Sargasso samples obtained from Japan was carried out to check on the technique.

Analysis of heavy metals (Zn, Ni, Co and Cd) in phytoplankton was carried out adopting the method given by Knauer and Martin (1972).

For the sake of convenience and interpretation, a calendar year was divided into four seasons based on the northeast monsoon which alone brings bulk rainfall to the southeast coast of India where the present study area is situated. The seasons are : monsoon (October -December), postmonsoon (January-March), summer (April-June) and premonsoon (July-September).

RESULTS

Monthly variations of trace metals (Cu, Zn, Ni, Co, Cd and Hg) recorded during the study period shown in Fig. 2.

Copper

Copper concentration in zooplankton ranged from 25.80 to 306.50 $\mu g\ g^{-1}$ at both the stations. Minimum (25.80 $\mu g\ g^{-1}$) and the maximum (306.50 $\mu g\ g^{-1}$) concentrations were recorded during the premonsoon (July 1990) and summer (April 1990) seasons respectively

at station 1. At station 2, the minimum concentration (46.00 μg g^{-1}) was recorded during the premonsoon (July 1990) season and

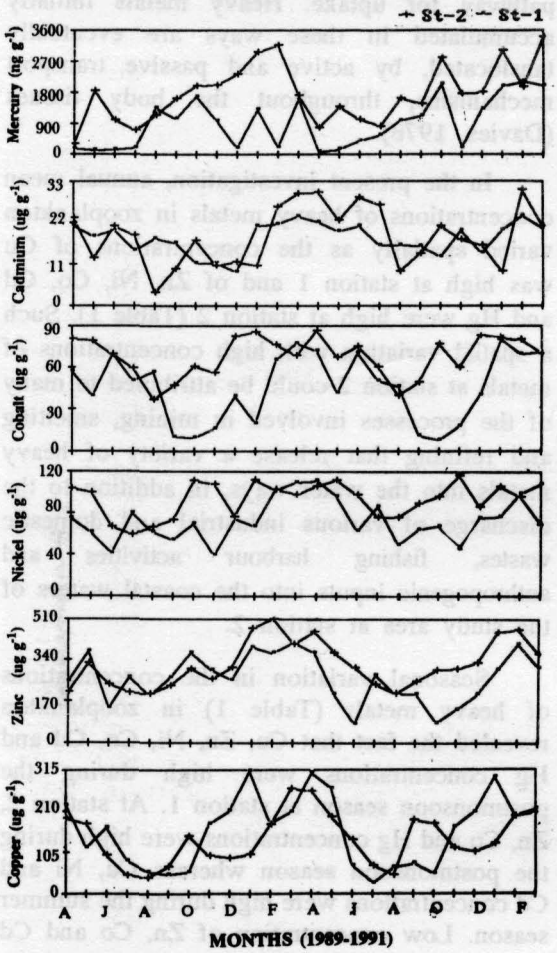

FIG. 2. *Monthly variation of copper, zinc, nickel, cobalt, cadmium and mercury in zooplankton at stations 1 and 2 from April 1989 to March 1991.*

the maximum concentration (266.20 μg g^{-1}), during the postmonsoon (March 1990) season. In general, the low and high concentrations of Cu were recorded at station 1.

Zinc

Zinc concentration in zooplankton ranged from 76.50 to 509.00 μg g^{-1} at both the stations. Minimum (76.50 μg g^{-1}) and maximum (410.00 μg g^{-1}) concentrations were recorded during the summer (June 1990) and postmonsoon (March 1990) seasons respectively at station 1. At station 2, the minimum concentration (196.00 μg g^{-1}) was recorded during the premonsoon (August 1989) season and the maximum concentration (509.00 μg g^{-1}) during the postmonson (February 1990) season. In general, high Zn concentration was recorded during the postmonsoon season at both the stations.

Nickel

Nickel concentration in zooplankton ranged from 41.00 to 116.00 μg g^{-1} at both the stations. Minimum (41.00 μg g^{-1}) and maximum (111.00 μg g^{-1}) concentrations were recorded during the summer season in June 1989 and April 1990 respectively at station 1. At station 2, the minimum concentration (59.00 μg g^{-1}) was recorded during the premonsoon (July 1989) season and the maximum concentration (116.00 μg g^{-1}) during the monsoon (November 1990) season. High Ni concentration was recorded at station 2 than at station 1.

Cadmium

Cadmium concentration in zooplankton ranged from 3.50 to 30.60 μg g^{-1} during the study period at both the stations. Minimum (8.90 μg g^{-1}) and maximum (23.70 μg g^{-1}) concentrations were recorded during the premonsoon (September 1989) and postmonsoon (January 1991) seasons respectively at station 1. At station 2, the minimum concentration (3.50 μg g^{-1}) was recorded during the premonsoon (August 1989) season and the maximum concentration (30.60 μg g^{-1}), during the postmonsoon (February 1991) season. In general, high concentration of Cd was recorded during the postmonsoon season at both the stations.

Cobalt

Cobalt concentration in zooplankton ranged from 10.10 to 86.00 μg g^{-1} at both the stations. Minimum (10.10 μg g^{-1}) and maximum (80.00 μg g^{-1}) concentrations were recorded during the premonsoon (September 1989) and postmonsoon (January 1991) seasons respectively at station 1. At station 2, the minimum concentration (36.50 μg g^{-1}) was recorded during the premonsoon (August 1989) season and the maximum concentration (86.00 μg g^{-1}) during the summer (April 1990) season. In general, high concentration of Co was recorded during the postmonsoon and summer seasons at both the stations.

Mercury

Mercury concentration in zooplankton ranged from 259.00 to 21,001.00 ng g^{-1}. Minimum (790.00 ng g^{-1}) and maximum (21,001.00 ng g^{-1}) concentrations were recorded during the summer (April 1990) and postmonsoon (February 1991) seasons respectively at station 1. At station 2, the minimum concentration (259.00 ng g^{-1}) was recorded during the summer (April 1989) season and the maximum concentration (3396.00 ng g^{-1}), during the postmonsoon (March 1991) season. In general, high concentration of Hg was recorded at station 1 than at station 2.

DISCUSSION

Zooplankton are very important in the cycling process of elements in the sea and oceans. Though the concentrations of heavy metals in zooplankton vary due to many reasons, they do indicate possible environmental characterisitcs of particular region. Moreover, being the major sources of food of larger animals, their role in the transfer of metals to higher trophic levels is of much importance (Kureishy, *et. al.,* 1983). Zooplankton accumulate metals in two ways. The primary process of uptake is from the solution, and assimilation of metals from food and detrital particles ingested by the animals provide the other pathway for uptake. Heavy metals initially accumulated in these ways are eventually tanslocated, by active and passive transport mechanisms, throughout the body tissues (Davies, 1978).

In the present investigation, annual mean concentrations of heavy metals in zooplankton varied spatially as the concentrations of Cu was high at station 1 and of Zn, Ni, Co, Cd and Hg were high at station 2 (Table 1). Such a spatial variation with high concentrations of metals at station 2 could be attributed to many of the processes involved in mining, smelting and refining that release a variety of heavy metals into the water ways, in addition to the discharge of various industrial and domestic wastes, fishing harbour activities and anthropogenic inputs into the coastal waters of the study area at station 2.

Seasonal variation in the concentrations of heavy metals (Table 1) in zooplankton revealed the fact that Cu, Zn, Ni, Co, Cd and Hg concentrations were high during the postmonsoon season at station 1. At station 2, Zn, Co and Hg concentrations were high during the postmonsoon season whereas Cu, Ni and Cd concentrations were high during the summer season. Low concentration of Zn, Co and Cd in zooplankton were recorded during the monsoon (station 1) and premonsoon (station 2) seasons. But low Cu and Hg concentrations were recorded during the premonsoon and summer seasons at stations 1 and 2 respectively. Low Ni concentration was noticed during the summer (station 1) and premonsoon (station 2) seasons.

Cu concentration was high during the postmonsoon (station 1) and summer (station 2) seasons. This was perhaps due to the utilization and uptake of Cu by zooplankton through their

TABLE 1. *Seasonal, annual and total mean concentrations of heavy metals in zooplankton (μg g^{-1} dry wt. for all metals; ng g^{-1} dry wt. for Hg) at stations 1 and 2 during April-March 1989-90 and 1990-91*

	Metal	Year	Summer	Premonsoon	Monsoon	Postmonsoon	Annual mean	Total mean
STATION 1	Cu	1989-1990	168.90	61.90	146.90	231.80	152.40	157.10
		1990-1991	214.10	56.41	140.60	235.80	161.60	
	Zn	1989-1990	254.40	233.80	306.70	390.70	296.40	262.10
		1990-1991	213.85	222.80	137.20	336.90	227.70	
	Ni	1989-1990	58.80	65.30	61.40	93.10	69.60	74.10
		1990-1991	90.00	66.50	63.40	94.70	78.60	
	Co	1989-1990	55.10	38.80	21.60	53.90	42.30	45.10
		1990-1991	60.900	35.70	21.90	73.20	47.90	
	Cd	1989-1990	19.80	16.40	10.0	22.10	17.20	17.80
		1990-1991	20.90	15.90	15.60	21.10	18.0	
	Hg	1989-1990	128.70	854.70	942.70	1033.70	739.40	902.20
		1990-1991	200.30	878.00	116.10	2015.30	1065.10	
STATION 2	Cu	1989-1990	155.34	51.60	110.90	180.20	124.50	138.00
		1990-1991	196.70	100.90	132.70	176.00	151.60	
	Zn	1989-1990	255.20	211.20	289.20	461.30	304.20	319.80
		1990-1991	377.00	228.70	307.80	427.70	350.30	
	Ni	1989-1990	89.80	66.40	98.40	104.20	89.90	91.80
		1990-1991	105.30	80.40	99.30	90.30	93.80	
	Co	1989-1990	76.10	47.40	66.20	76.60	66.60	67.70
		1990-1991	75.90	49.50	72.90	76.80	68.80	
	Cd	1989-1990	18.90	10.60	13.20	22.10	16.20	18.10
		1990-1991	27.00	16.40	18.20	20.20	20.50	
	Hg	1989-1990	1029.30	1148.00	2094.00	2604.20	1718.90	1763.80
		1990-1991	1045.70	1267.50	2110.10	2781.00	1808.60	

TABLE 2. *Seasonal, annual and total mean concentrations of heavy metals in phytoplankton (μg g^{-1} dry wt.) at stations 1 and 2 during April-March 1989-90 and 1990-91*

	Metal	Year	Summer	Premonsoon	Monsoon	Postmonsoon	Annual mean	Total mean
STATION 1	Zn	1989-1990	24.20	40.00	141.00	69.60	68.70	109.20
		1990-1991	50.80	84.50	232.10	231.80	149.80	
	Ni	1989-1990	0.20	5.70	7.90	18.10	8.00	15.20
		1990-1991	6.70	14.30	14.30	54.20	22.40	
	Co	1989-1990	33.20	23.00	14.20	2.50	18.20	21.90
		1990-1991	41.60	47.40	13.90	0.20	25.80	
	Cd	1989-1990	1.40	3.30	3.90	0.50	0.30	6.90
		1990-1991	2.10	11.30	10.20	15.90	9.90	
STATION 2	Zn	1989-1990	118.50	58.30	68.90	34.00	69.90	122.90
		1990-1991	178.40	150.30	148.00	226.70	175.90	
	Ni	1989-1990	0.40	8.70	90.90	27.70	31.90	38.30
		1990-1991	2.90	21.80	95.40	58.30	44.60	
	Co	1989-1990	41.20	29.40	37.60	68.40	44.10	47.00
		1990-1991	40.20	42.90	45.50	68.50	50.10	
	Cd	1989-1990	0.50	2.80	5.40	3.20	2.90	5.40
		1990-1991	2.90	5.20	11.40	11.40	7.80	

TABLE 3. *Concentration of heavy metals (μg g^{-1} dry wt.) in zooplankton reported from various marine environs of the world*

Location	Cu	Zn	Ni	Co	Cd	Hg	Reference
Coromandel coast, India	25.80-331.0	76.50-509.00	39.90-116.00	7.90-86.00	3.50-30.60	0.08-3.40	Present study
Arabian Sea	10.00-232.00	942.00-2249.40	ND-17.00	ND-73.00	—	—	Kureishy and George, 1977
Bombay	16.30-305.00	—	27.30-90.90	5.00-20.60	6.85-14.57	—	Gajbhiye *et al.*, 1985
Mediterranean Sea (Eastern Central)	11.80-161.00	79.00-1276.00	—	—	0.70-3.80	—	Flower *et al.*, 1976
Bay of Villefranche	5.90-129.10	52.00-742.00	—	—	0.30-10.90	—	Romeo and Laumond, 1980
East Coast of Corsica	12.60-28.90	37.00-61.00	—	—	0.12-0.52	2.00-16.00	Romeo and Nicolas, 1986

food and from their ambient environment. Evidently, high productivity of phytoplankton (227.80 mgC m^{-3} hr^{-1} and 220.90 mgC m^{-3} hr^{-1}) was recorded during the postmonsoon season at station 1 and during the summer season at station 2 respectively (Fig. 3). Low concentration of Cu recorded during the premonsoon season at both the stations could have resulted due to the rapid sinking of planktonic skeletal structures along with the organic detritus and excretion through faecal pellets (Romeo and Laumond, 1980).

Zn, Co and Hg concentrations in zooplankton were high during the postmonsoon season at both the stations. This would have resulted due to the direct absorption from water and also by assimilation through food substances (Gajbhiye *et. al.*, 1985). During the present investigation, high concentrations of these metals were also recorded in phytoplankton during the postmonsoon season *viz.*, Zn (226.70 μg g^{-1}) and Co (68.50 μg g^{-1}) at station 2 (Table 2). This would indicate that the increased levels of heavy metals in zooplankton necessarily reflect their food concentrations. Further, there also exists a strong and significant positive correlation between the metal concentrations in phytoplankton and zooplankton *viz.*, Co ($r=0.972$; $p < 0.001$) at station 2.

Low concentrations of Zn and Co in zooplankton were recorded during the monsoon (station 1) and premonsoon (station 2) seasons and low Hg content was recorded during the summer (stations 1 and 2) season. This could be attributed to the rapid sinking of planktonic skeletal structures (Romeo and Laumond, 1980) along with excretion through faecal pellets and egg laying. Evidently, the biomass (10,667 Orgs. m^{-3}) and productivity (18.70 mgC m^{-2} d^{-1}) of zooplankton were low during the monsoon season, influencing the metals concentration (Fig. 3).

Like Cu, Ni and Cd concentrations were also high during the postmonsoon season at

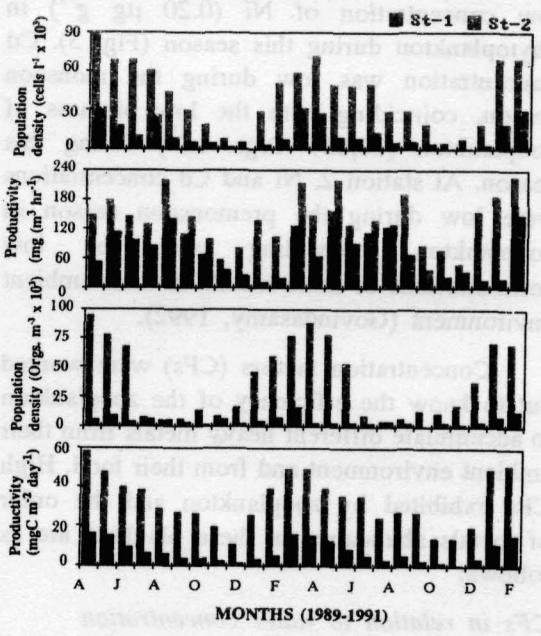

FIG. 3. *Monthly variation in biomass and productivity of phyto and zooplankton recorded at stations 1 and 2 from April 1989 to March 1991.*

station 1. This could have resulted due to the uptake and absorption by the zooplankton from their food (phytoplankton). Evidently, high concentrations of heavy metals (Ni and Cd) in zooplankton coincided well with the high concentrations of Ni (54.20 μg g^{-1}) and Cd (15.90 μg g^{-1}) in phytoplankton during this season (Table 2). At station 2, high concentrations of these metals in zooplankton were recorded during the summer season when high biomass (17,700 Orgs. l^{-1}) and productivity (13.16 mgC m^{-2} d^{-1}) of zooplankton were also recorded (Fig. 3). This could be one of the reasons for higher accumulation of heavy metals in zooplankton during the summer season. Evidently, Ni ($r=0.851$; $P < 0.001$) at station 2 showed significant positive correlation with zooplankton biomass and productivity.

Ni concentration was low during the summer season (station 1) coinciding with the low concentration of Ni (0.20 μg g^{-1}) in phytoplankton during this season (Fig. 3). Cd concentration was low during the monsoon season, coinciding with the low biomass of zooplankton (10,667 Orgs. m^{-3}) during this season. At station 2, Ni and Cd concentrations were low during the premonsoon season in zooplankton, coinciding with the low concentrations of these metals in their ambient environment (Govindasamy, 1992).

Concentration factors (CFs) were worked out to know the efficiency of the zooplankton to accumulate different heavy metals from their ambient environment and from their food. High CPs exhibited by zooplankton and the order of metals abundance in these plankton are as follows:

CFs in relation to water concentration

Station 1

Co(24394) > Ni(16076) > Cu(11169) > Zn(5732) > Cd(789) > Hg(15037)

Station 2

Ni(29504) > Co(23503) > Cu(18019) > Zn(5172) > Cd(887) > Hg(29396)

CFs in relation to phytoplankton concentration

Station 1

Ni(4.88) > Cu(4.41) > Cd(2.93) > Zn(2.39) > Co(2.05) > Hg(1.26)

Station 2

Cd(3.42) > Zn(2.60) > Ni(2.39) > Cu(2.17) > Co(1.44) > Hg(1.81)

A high concentration factor (CFs) is indicative of high accumulation of elements by plankton whereas low concentration factors indicate active uptake (Alberts *et al.*, 1990). High CFs were exhibited by plankton indicating their differential bioconcentration capability for different heavy metals.

Among the two stations in relation to water and phytoplankton concentration, high CFs for Cu, Ni, Cd and Hg were recorded at station 2 than at station 1 whereas CFs for Zn and Co were high at station 1 than at station 2. In relation to phytoplankton concentration, high CFs for Cu, Ni and Co were recorded at station 1 than at station 2. But the CFs for Zn, Cd and Hg were high at station 2 than at station 1. When the concentrations of heavy metals (Cu, Zn, Ni, Co, Cd and Hg) in marine zooplankton recorded in the present investigation are compared with the levels reported from the other regions, it was found that lower concentrations exist in some other regions of the world (Table 3), most of the regions showed lower concentrations than this coast indicating the increased load of heavy metal pollution along this coast due to various factors such as river run-off, discharge of industrial wastes and municipal sewage, anthropogenic inputs and harbour activity. Moreover, concentrations of heavy metals are increasing from year to year. So it is concluded from the present study that the Coromandel coast of India is rapidly getting polluted with these metals, thus substantiating the view of Ramachandran (1990) who reported that the coastal waters are definitely polluted with heavy metals. It may be concluded that the zooplankton may be potential sentinel organisms for the assessment of metal pollution in coastal waters. Higher concentration of heavy metals in zooplankton also points towards the general high trend of these metals in these stations. Higher concentrations of these metals in plankton, would also depend upon their direct absorption from water and also assimilation through food substances by

zooplankton. Further, in an environmental perspective, the accumulation of heavy metals in zooplankton may be a significant step in the transfer of metals to higher organisms. Surprisingly little research has been conducted despite the fact that they form a particularly important substrate for many ecological communities and often contain a large portion of the nutrient component of many coastal water ecosystems.

REFERENCES

ALBERTS J. J., M. T. PRICE AND M. KANIA 1990. Metal concentration in tissues of *Spartina altermiflora* (Loisel.) and sediment of Georgia salt marshes. *Estu. Cost. Shelf. Sci.,* **30** : 47-58.

DAVIES, A. G. 1978. Pollution studies with marine plankton. Part II. Heavy metals. *Adv. Mar. Biol.,* **1** : 381-508.

EPA, 1979. Methods for chemical analysis of water and wastes U.S. Environmental Protection Agency, Cincinnati, Ohio, 430.

FOWLER, S.W., B. OREGIONI AND J. LAROSA 1976. Trace metals in pelagic organisms from the Mediterranean Sea, In : Activities of the International Laboratory of Marine Radioactivity, Report *I.A.F.A.,* **187** : 110-112.

GAJBHIYE, S. N., V. R. NAIR, P. V. NAVEKAR AND B. N. DESAI 1985. Concentration and toxicity of some metals in zooplankton from nearshore waters of Bombay. *Indian J. mar. Sci.,* **14** : 181-183.

GOVINDASAMY, C. 1992. *Coramandel Coast of India-A Study on Hydrobiology and Heavy Metals. Ph.D.,* Thesis, Annamalai University, 119 pp.

GRAY J. S., D. BOESCH, C. HEIP, A. M. JONES, J. LASSING, R. VANDERHORT AND D. WOLF 1980. The role of ecology in marine pollution monitoring. rapp. P. V. Reun. Cons. *Int. Explor. Mer,* **179** : 237-252.

KNAUER, G. A. AND J. H. MARTIN 1972. Mercury in a marine pelagic food chain. *Limnol. Oceanogr,* **17** : 868-876.

KUREISHY, T. W. AND M. D. K. GEORGE 1977. Trace metals in zooplankton from the west coast of India. *NIO Tech. Rep.,* 02/77 : 60-62.

———— S. SANZGIRY, M. D. GEORGE AND A. BRAGANCA 1983. Mercury, cadmium and lead in different tissues of fishes and in zooplankton from the Andaman Sea. *Indian J. mar. Sci,* **12** : 60-63.

RAMACHANDRAN, S. 1990. Marine pollution in Tamil Nadu-a status report, *Proc. Intl. Symp. Mar. Pollution,* 143-160.

ROMEO, M. H. AND F. LAUMOND 1980. Zinc, Copper and Cadmium in zooplankton from the N. W. Mediterranean. *Mar. Pollut. Bull,* **11** : 133-137.

———— E. NICOLAS 1986. Cadmium, copper, lead and zinc in three species of planktonic crustaceans from the coast of Corsica. *Mar. Chem,* **18** : 359-367.