Indian J. Fish., 61(4) : 60-67, 2014

Diversity and seasonal variations of plankton in coastal waters receiving salt pan effluents off Thoothukudi, south-east coast of India

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ABSTRACT

The present investigation deals with the assessment of diversity and seasonal variations of plankton in coastal waters receiving salt pan effluents (station 1) in comparison to a reference site (station 2) of apparently unpolluted water. The species diversity of phytoplankton was comparatively more in station 1as compared to station 2 whereas the density of phytoplankton was found to be lower in station 1 (48 – 177 cells l^{-1}) compared to station 2 (44 - 565 cells l^{-1}). The maximum and minimum density were recorded during summer and monsoon season respectively. With regard to zooplankton composition, station 2 recorded higher numbers of species (42) followed by station 1. In both stations, maximum density of zooplankton was observed during summer. Zooplankton density ranged from 9,800 (November, 2011) to 70, 800 no. m^{-3} (May, 2012) at station 1 and 15,400 (December, 2011) to 2,07,000 (May, 2012) at station 2. The species richness index 'D' for phytoplankton varied from 0.43 to 0.76 and 0.79 to 2.05 in station 1 and 2 respectively. The species richness index 'D' for zooplankton in station 1 and 2 varied from 0.99 to 1.63 and 1.09 to 3.84 respectively. The species diversity index ('H') for the phytoplankton in station 1 and 2 varied from 0.75 to 1.37 and 1.06 to 1.95 respectively. The species diversity index ('H') for the zooplankton in station 1 and 2 varied between 1.64 to 2.28 and 1.66 to 3.25 respectively. The present investigation showed that the plankton diversity of coastal waters receiving salt pan effluents (station 1) was influenced by seasonal variations as compared to the unpolluted coastal waters of station 2.

Keywords: Diversity, Plankton, Seasonal variations, Salt pan effluents

Introduction

In the marine environment, phytoplankton communities vary according to the ambient environmental factors. The surrounding factors have a determinative role on the phytoplankton communities. Phytoplankton blooms may occur due to seasonal change of the environmental conditions. The appearance of blooms is also one of the responses of phytoplankton to environmental perturbations such as pollution. Solar salt pans are man-made seasonal ponds constructed mainly for the production of raw salt along sides of creeks and other low lying coastal areas. They are characteristically exposed to a wide range of environmental stress and perturbations which manifest mainly through salinity changes. Salt pans represent most simplified ecosystems for the simple reason that the number of species at any trophic level is low. In the hypersaline extreme environments of salt pans plankton community and diversity is very low. Among the halophilic cyanobacteria, diatoms and green algae are abundant in salt pans (Nagasathya and Thajuddin, 2008). There is very little information available on the impact of effluents discharged from the salt pans. The purpose of this study was to investigate the diversity and seasonal variation of plankton in coastal waters receiving salt pan effluents in comparison to a pollution free area.

Materials and methods

The present investigation on plankton diversity was carried out in the salt pan effluent discharging areas along coastal waters in Tharuvaikulam (station 1, lat 8˚55'N; long 18˚10'E) and apparently unpolluted waters in Vembar (station 2, lat 9˚04'N; long 78˚22'E). Plankton samples were collected from the two stations (1 and 2) during the study period from October 2011 to May 2012 at fortnightly intervals for assessment of phytoplankton as well as zooplankton populations. Plankton samples were collected from the surface water by filtering 500 l of seawater using hand plankton net (boiling silk no. 30, 41 µ mesh size). The collected

samples were preserved in 5% formalin at the sample collection site itself. Phytoplankton and zooplankton were identified using the keys of Kasturirangan (1963), Santhanam *et al.* (1987) and Santhanam and Srinivasan (1994). For the quantitative estimation of both phytoplankton and zooplankton, a known volume of plankton sample (50 ml) and a sub sample of 1 ml was taken in a Sedgewick-Rafter counting cell for counting under a microscope. Each plankton sample was counted two times and the average was recorded. The species richness (D) of plankton samples was determined following Gleason (1922) and species diversity was calculated as per Shannon and Wiener (1949).

Result and discussion

The phytoplankton seasonal distributions observed at station 1 and 2 are given in Table 1 and 2 respectivley. The total numbers of phytoplankton species recorded were 14 and 29 at station 1 and 2 respectively (Table 1 and 2). At station 1, diatoms, dinoflagellates and blue-green algae dominated and formed 67.57%, 21.28% and 11.15% respectively. In station 2, diatoms, dinoflagellates and blue-green algae contributed 62.06 %, 27.58 % and 10.34 % respectively.

The monthly variations in total phytoplankton density recorded for station 1 and 2 are depicted in

Table 1. Seasonal distribution of phytoplankton at station 1

Species\Group	Oct 11	Nov 11	Dec 11	Jan 12	Feb 12	Mar 12	Apr 12	May 12
Bacillariophyceae								
Centrales								
Bellerochea malleus	+	+	+	+	+	+	+	+
Coscinodiscus eccentricus	+	-	-	-	-	+	-	-
Coscinodiscus gigas	-	-	-	-	-	-	+	+
Cyclottela striata	-	-	+	+	-	-	-	-
Rhizosolenia sp.	-	-	-	-	+	-	-	-
Pennales								
Climacosphenia moniligera	-	-	-	-	+	-	-	-
Fragillaria oceanica	-	-	+	-	-	-	-	-
Pleurosigma angulatum	-	-	-	+	-	-	-	-
Thalassionema bacillare	-	-	-	-	+	-	-	-
Dinophyceae								
Ceratium fusus	+	-	-	-	-	+	-	+
Ceratium trichoceros	-	+	-	+	-	-	+	+
Peridinium depressum	-	-	-	-	+	+	-	-
Cyanophyceae								
Oscillatoria sp.	-	-	+	+	-	+	+	-
Trichodesmium erythraeum				+		+		
Total	3	2	4	6	5	6	4	4

Table 2. Seasonal distribution of phytoplankton at station 2

Species\Group	Oct 11	Nov 11	Dec 11	Jan12	Feb 12	Mar 12	Apr 12	May 12
Bacillariophyceae								
Centrales								
Bellerochea malleus	-	-	-	-	-	-	+	+
Biddulphia sinensis	+	-	-	-	+	-	-	-
Bellerochea heteroceros	-	-	-	+	-	-	-	-
Bellerochea mobiliensis	-	+	+	-	-	+	-	-
Chaetceros coarctatus	-	-	-	-	-	-	-	-
Chaetceros diversus	-	-	-	-	-	+	-	+
Chaetceros lorenzianus	-	-	-	+	+	-	-	+
Chaetceros peruvianus	-	-	-	-	-	-	+	-
Coscinodiscus eccentricus	+		+	+	+	+	+	+
Coscinodiscus gigas	-	+	-	+	-	+	-	-
Isthmia inervis	-	-	-	+	+	-	-	-
Planktoniella sol	-	-	-	-	-	+	-	-
Rhizosolenia sp.	-	-	-	-	-	-	-	-
Rhizosolenia castracanei	-	+	-	-	+	+	-	-
Triceratium reticulatum	-	-	-	-	-	-	-	+
Cyclottela striata	-	-	-	+	-	-	+	-

Pennales								
Amphiprora gigantean	-	+	+	+	-	-	-	-
Climacosphenia elongate	-	-	-	-	-	-	+	-
Thalassiothrix frauenfeldii	-	-	-	-	-	+	-	-
Dinophyceae								
Ceratium inflatum	-	+	-	-	-	-	-	-
Ceratium trichoceros	+	+	+	+	+	+	+	+
Ceratium tripos	+	-	-	-	-	-	+	-
Ceratium furca	-	-	-	-	-	+	-	-
Ceratium contortum	-	-	-	-	-	+	-	+
Peridinum steinii	-	-	-	-	-	+	-	-
Peridinum oceanicum	-	-	-	+	+	+	+	+
Noctiluca miliaris	+	+	+	-	-	-	-	-
Cyanophyceae								
Oscillatoria sp.	-	+	-	-	+	+	-	-
Trichodesmium erythraeum	+	+						
Total	6	9	5	9	8	13	8	8

(Fig. 1.). In station 1, the total phytoplankton density was found to vary between 48 to 177 cells l^{-1} compared to station 2 (44 - 565 cells l^{-1}). The minimum and maximum values were observed during November 2011 and October 2011 in station 1 and during the month of March 2012 and December 2011 in station 2, respectively. The main species contributing to the phytoplankton density in station 2 were *Coscinodiscus escentricus* (33.64%), *Coscinodiscus gigas* (26.55%), *Chaetoceros peruvianus* (16.99%), *Cheatoceros diversus* (3.89%), *Biddulphia sinensis* (3.7%) and *Ceratium tripos* (2.65%). Among the total population, the contribution of diatoms and dinoflagellates to the overall density were 92.60% and 7.40% respectively and the density of diatoms ranged from 32 to 523 cells l^{-1}.

Modassir and Ansari (2011) recorded 13 phytoplankton species in hypersaline environment. However, Chandra (1993) observed lesser number of phytoplankton species in stations receiving polluted waters. In the present study, the density of phytoplankton was found to be lower in station 1 compared to station 2. In station 1, the maximum net phytoplankton density (177 cells l^{-1}) recorded was less than that reported by Chandra (1993) in polluted

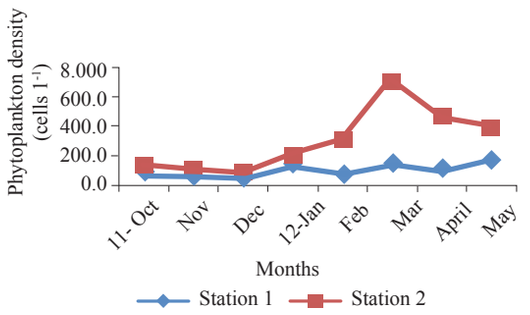

Fig 1. Monthly variations in phytoplankton density at station 1 and 2

waters where she observed 356 cells l^{-1}. This could be attributed to the hypersaline conditions observed at station 1 due to discharge of salt pan effluents. The maximum phytoplankton density of 565 cells l^{-1} observed in station 2 is found to be higher than the maximum phytoplankton density as reported by Santhanam and Srinivasan (2000).

Table 3 and 4 summerise the zooplankton seasonal distributions recorded in the two stations. The total number of zooplankton species observed at station 1 was 23. The percentage contribution and number of species of different groups of zooplankton recorded were: chaetognaths (3.04% and 1 species), decapods (3.04% and 1 species, protozoans (7.05% and 2 species, meroplanktonic forms (23.24% and 8 species) and copepods (63.63% and 21 species). At station 2, the total number of species/components of zooplankton recorded were 42 and the percentage contribution and number of species of different groups of zooplankton recorded were: chaetognaths (2.35% and 1species), chordates (2.35% and 1 species), protozoans (7.10% and 3 species), meroplanktonic forms (26.30% and 12 species) and copepods (61.90% and 26 species). At station 2, the number of species/components of zooplankton observed at any one time varied from 16 to 23. Minimum numbers of species were observed during the month of January, 2012 and maximum number of species were observed in December, 2011.

At station 1, the zooplankton density was found varying between 9,800 to 70, 800 nos. m^{-3} (Fig. 2). The maximum density was observed during May, 2012 and the minimum values were observed during October 11. During the study period, maximum density was contributed by species *viz*., *Acartia danae* (26.84 %), *Oithona brevecornis* (15.54%), *Favella philippinensis* (12.71%), copepod

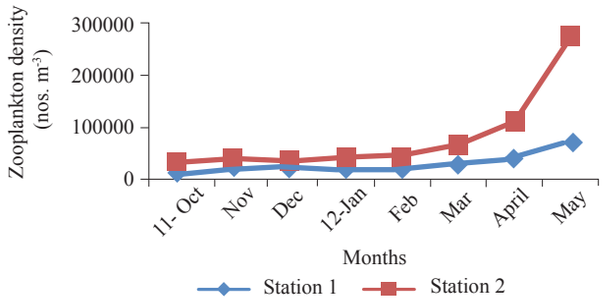

Fig. 2. Monthly variations in zooplankton density at station 1 and 2

nauplii (11.30%), *Longipedia weberi* (7.06%), *Oithona rigida* (7.91%), *Acrocalanus gracilis* (4.24%) followed by bivalve veliger (5.65%) and gastropod veliger (2.82%). The dominant groups observed were copepods (65.54%), protozoans (12.71%) and meroplankton (21.75%). The density of copepods ranged from 6,800 to 46,400 nos. m^{-3} during October, 2011 and May, 2012 respectively.

At station 2, the zooplankton density was found varying between 15,400 to 2, 07,000 nos. m^3. The maximum density was observed during May, 2012 and the minimum values were observed during the month of December, 2011. During the period of study, the main zooplankton species recorded were: *Acartia danae* (18.36%), *Oithona brevecornis* (14.50%), *Acrocalanus gracilis* (6.28%), *Longipedia cornata* (4.35%), *Oithona rigida* (4.35%), *Nannocalanus minor* (3.80%), *Euterpina acutifrons* (2.90%), *Oithona similis* (2.90%), *Paracalanus parvus* (2.80%) and *Labidocera acuta* (1.93%). The dominant groups were copepods (82.41%), meroplankton (14.60%), protozoans (0.67%), chaetognatha (0.58%), chordata (0.77%) and decapoda (0.97%). The density of copepods ranged from 10,700 (January, 2012) to 1, 70,600 nos. m^{-3} (May, 2012).

With regard to zooplankton composition, station 2 recorded higher numbers of species (42) followed by station 1. The occurrence of higher number of species at station 2 would certainly reflect the absence of pollution in this station when compared to station 1. At station 2, copepod population belonged to 26 species. Among the copepod population, species belonging to the genera *Acartia, Acrocalanus, Bomolochus, Corycaeus, Oithona,* and *Paracalanus* were common. Similar genera of copepod population were observed by Acchuthankutty *et al.* (1980). In the present investigation, minimum and maximum percentage composition was recorded during monsoon and summer season at two stations. Similar observations were also made by Prabhahar *et al.* (2011) from Cuddalore coastal zone, Tamil Nadu. The copepods contributed 65.54 and 82.41% to total

Table 3. Seasonal distribution of zooplankton at station 1

Species\Group	Oct 11	Nov 11	Dec 12	Jan 12	Feb 12	Mar 12	Apr 12	May 12
Tintinnida								
Favella philippinensis	-	-	+	-	+	+	+	+
Favella brevis	+	-	-	-	-	-	-	-
Copepoda								
Acartia danae	-	-	+	-	-	-	+	+
Acartia erythraea	+	-	-	-	-	+	-	+
Acartia spinicauda	-	-	-	-	-	+	+	-
Acrocalanus gracilis	+	+	+	+	+	+	+	+
Bomolochus sp.	-	-	-	-	-	-	-	+
Centropages furcatus	+	-	-	+	-	-	-	-
Clytemnestra scutellata	-	-	-	-	-	-	-	-
Corycaeus danae	-	+	-	+	+	+	-	-
Euterpina acutifrons	-	+	+	+	+	+	-	+
Longipedia coronata	-	-	-	-	+	-	-	-
Longipedia webri	+	+	+	+	+	+	+	+
Metis jousseamei	+	-	-	-	+	-	-	-
Microsettla norvegica	+	+	+	+	+	+	-	+
Nanocalanus minor	-	+	-	-	+	+	-	-
Oithona brevicornis	+	+	+	+	+	+	+	+
Oithona rigida	+	-	-	+	+	+	+	+
Oithona similis		-	-	-	+	-	+	-
Paracalanus parvus	+	+	+	+	+	+	+	+
Pseudodiaptomus sp.	-	-	-	-	-	+	-	-
Sapphirina sp.	-	-	-	-	+	-	+	-
Undinulla spp.	-	-	-	-	-	+	-	-

Table 4. Seasonal distribution of zooplankton at station 2

Species/Group	Oct 11	Nov 11	Dec 12	Jan 12	Feb 12	Mar 12	Apr 12	May 12
Tintinnida								
Favella philippinensis	+	-	+	+	+	+	+	+
Tintinnopsis beroidea	-	-	+	-	-	-	-	-
Tintinnopsis cylindica	-	+	+	-	+	-	+	-
Copepoda								
Acartia centrura	+	-	-	-	-	-	-	-
Acartia danae	-	-	+	-	-	-	+	+
Acartia erythraea	-	+	-	-	-	+	-	-
Acartia spinicaduda	+	-	-	+	-	-	-	+
Acrocalanus gracilis	+	+	+	+	+	+	-	+
Bomolochus sp.	-	-	-	-	-	-	-	+
Corycaeus danae	+	+	+	-	+		+	-
Euterpina acutifrons	+	+	+	+	-	+	-	+
Isias tropica	-	-	+	-	-	-	-	-
Labidocera acuta	-	-	-	-	-	+	-	-
Labidoperca pavo	-	-	-	-	+	-	-	-
Longipedia webri	+	+	+	_	+	+	+	
Longipedia coronata	+	+	+	-	+	+	+	+
Metis jousseamei	-	+	-	-	+	-	-	-
Microsetella norvegica	+	+	+	+	-	-	-	+
Microsettla rosea	-	+	+	-	-	-	-	-
Nannocalanus minor	-	+	+	-	-	-	-	-
Oithona brevicornis	+	+	+	+	+	+	+	-
Oithona rigida	+	+	+	+	+	+	+	-
Oithona similis	+	+	-	+	+	+	+	+
Onacea sp.	-	-	-	-	+	-	+	-
Paracalanus parvus	-	-	+	-	-	-	-	-
Sapphirina sp.	+	+	+	+	+	-	-	+
Scoleicithrix danae	-	+	-	-	+	-	-	+
Temora turbinata	-	-	+	-	-	-	-	-
Chaetognatha								
Sagitta sp.	-	-	+	-	-	+	-	+
Chordata								
Oikopleura dioica	+	+	+	-	-	-	-	-
Decapoda								
Lucifer hanseni	-	+	-	-	+	-	+	-
Meroplankton								
Balanus naupli	-	+	-	+	+	+	+	+
Bivalve veligers	-	+	+	-	-	+	+	+
Cirripede nauplii	+	-	+	+	-	+	-	-
Chyphanautes larvaie	-	-	-	+	+	+	-	-
Copepod nauplii	+	+	-	+	+	+	-	-
Crab zoeae	-	+	-	-	-	+	+	-
Fish eggs	-	-	-	-	-	-	+	+
Fish larvae	-	-	+	-	+	-	-	+
Gastropod veligers	+	-	-	+	-	-	+	+
Nauplii of *Acetes indicus*	+	-	-	+	+	-		-
Polychaete larvae	+	+	+	+	+	+	+	+
Prawn mysis	-	+	-	-	+	-	+	-
Total	18	23	23	16	20	17	17	18

zooplankton population in station 1 and 2 respectively. Similar to the present observation, copepod contribution of 79.6%, and 87.2% to the total zooplankton population was observed by Gagbhiye *et al.* (1991) from Bombay coastal waters, Varghese and Krishnan (2009) from Cochin backwaters, Kerala and Padmavati *et al.* (2008) from Bay of Bengal. In the present study, tintinnids population was 12.7 and 0.67% of total zooplankton in station 1 and 2 respectively. Similar observation of tintinnid population of 0.12 to 29.52% to the total zooplankton population was observed by Varghese and Krishnan (2009) in Cochin backwaters of Kerala. In the present study, out of the 3 species of tintinnids observed, 2 species were found in all the stations. Prabhu *et al.* (2005) observed maximum of 39 species of tintinnids, out of which, 21 species were found in all the stations of coastal waters

of Parangipettai. Copepods were the only single and most dominant group occurring throughout the study period. The dominance of copepods among the zooplankton groups were reported by several researchers (Nair and Azis, 1987; Madhu *et al.,* 2007, Reddy *et al.,* 2011). Copepods are dominant as they can tolerate wide fluctuations in environmental conditions and breed throughout the year. Similar observation was also made by Srinivasan and Santhanam (1998 and recorded a total of 12 species of copepods in sewage polluted waters along Tuticorin coast. Meroplanktonic organisms such as *Balanus* nauplii, bivalve veliger, cirripede nauplii, crab zoea, fish egg, fish larvae, gastropod veliger, nauplius of *Acetes indicus*, polychaete larvae and prawn mysis were commonly found in the study area. The pattern and occurrence of chaetognaths were fairly uniform during the study period. Similar observation was made by Mustafa *et al.* (1999). Padmavati *et al.* (2008) recorded chaetognath percentage of 2.7% from Anadman Sea, which is higher than that recorded in the present study. This may be due to the variation in depth of plankton samples collected. Among decopoda, *Lucifer* were observed in station 1 and 2. Prasad (1954) reported the occurrence of these species in Gulf of Mannar region throughout the year.

The monthly variations in phytoplankton species richness index 'D' for station 1 and 2 are depicted in Fig 3. At station 1, species richness index 'D' for phytoplankton ranged between 0.43 to 0.76. The minimum and maximum values were observed during April, 2012 and November, 2011 respectively. At station 2, the values of D were found to vary between 0.79 and 2.05 and the minimum and maximum values were observed during December 2011 and May, 2011 respectively. In general, summer season recorded maximum values of phytoplankton richness at both the stations as reported by Prabhahar *et al.* (2011). These values were comparatively lesser than the values reported earlier by Ayyakkannu and Edwards (1991) from Kollidam Estuary and Saraswathi (1993) from the Arasalar and Kaveri estuaries.

At station 1, zooplankton species richness index '(D') values ranged from 0.99 (December, 2011) to 1.63 (October, 2011) (Fig. 4). At station 2, D values varied from 1.09 to 3.84. The maximum values were observed during April 2012 and the minimum values in the month of January 2012. Similar to this observation, Prabhahar *et al.* (2011) observed high species richness (3.36) during summer season and low (0.57) during monsoon season. Maximum value of zooplankton diversity was recorded during the summer season revealing even distribution of species and minimum value recorded during the monsoon season with unequal distribution of species.

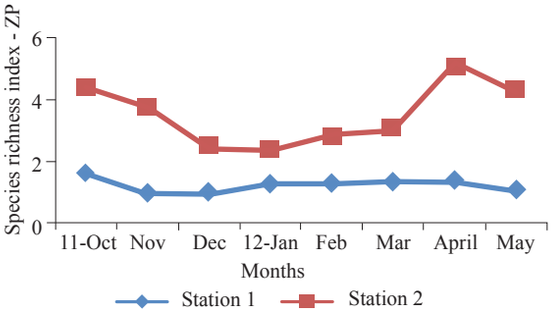

Fig. 4. Monthly variations in species richness index (D) for zooplankton in station 1 and 2

Monthly variations in phytoplankton species diversity index 'H' for station 1 and 2 are depicted in Fig. 5. In station 1, 'H' values ranged from 0.75 to 1.37 with minimum values during April, 2012 and the maximum during November, 2011. At station 2, H values ranged between 1.06 (April, 2012) to 1.95 (May, 2012).

At station 1, zooplankton species diversity index (H) values ranged from 1.64 to 2.28 (Fig. 6). The maximum index was in October 2011 and minimum was observed in

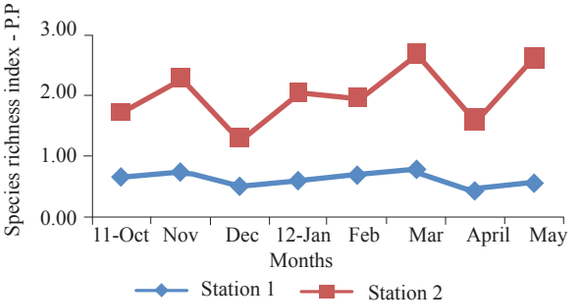

Fig. 3. Monthly variations in species richness index (D) for phytoplankton in station 1 and 2

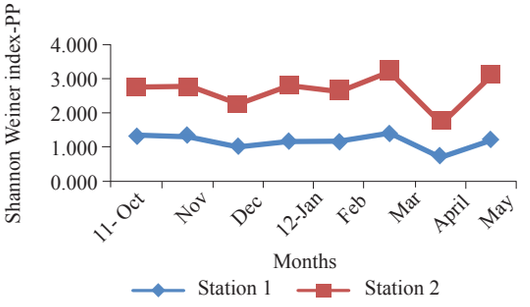

Fig. 5. Monthly variations in Shannon Weiner index for phytoplankton in station 1 and 2

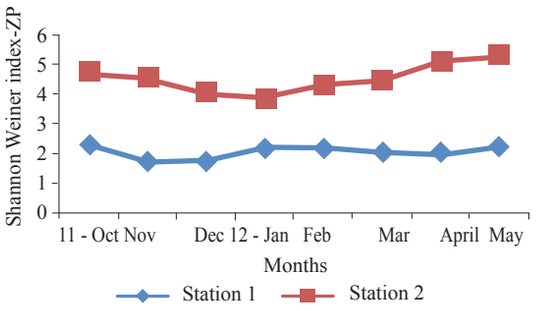

Fig. 6. Monthly variations in Shannon Weiner index- ZP in station 1 and 2

November, 2011. At station 2, the H values varied between 1.66 (January, 2012) to 3.25 (April, 2012).

The results of the present investigation clearly indicated that the plankton diversity of coastal waters receiving salt pan effluents (station 1) was highly influenced by seasonal variations in the study area, compared to the unpolluted coastal waters of station 2.

Acknowledgements

The authors are grateful to the Dean, Fisheries College and Research Institute, Thoothukudi for providing facilities and encouragement.

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Date of Receipt : 23.06.2013
Date of Acceptance : 16.04.2014