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A comparative study on plankton dynamics in vannamei culture ponds and adjacent coastal waters along Thoothukudi coast, India

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Abstract

The present study was carried out to assess the biomass and diversity of plankton in *Litopenaeus vannamei* culture pond (station 1) and effluent treatment pond, receiving the shrimp pond effluent (station 2) in comparison to a reference (station 3) of apparently an unpolluted coastal waters relatively free from any pollution, nor influenced by the effluents from the shrimp ponds. The density of phytoplankton was counted using Sedgewick rafter counting chamber and found to be dominant in station 1 (73400 to 164600 cells/l) during November 2013 and April 2014 compared to station 2 (39200 to 84000 cells/l) and station 3 (38400 to 75200 cells/l) whereas the species diversity index (H') of phytoplankton was comparatively lower in station 1 (0.99 to 2.03) followed by station 2 (1.62 to 2.94) and station 3 (2.37 to 2.96). The maximum and minimum density was recorded during summer and monsoon season, respectively. With regard to zooplankton composition, station 1 recorded high density (182500 to 397500 numbers/m³) compared to station 2 (12500 to 352500 numbers/m³) and station 3 (97500 to 272500 numbers/m³). The species diversity index (H') for zooplankton in station 1, 2 and 3 varied from 1.01 to 33, 2.39 to 2.95 and 2.37 to 2.96, respectively. The present investigation showed that the shrimp culture pond (station 1) had high densities of plankton with less species diversity than unpolluted coastal waters of station 3. This indicates that the presence of Vannamei farm near coastal area of Kalaignanapuram seemed to have no influence on plankton dynamics of coastal waters. The effluent treatment ponds receiving shrimp pond effluent (station 2) had only slight variation in the plankton diversity compared to the unpolluted station.

Keywords: Diversity, phytoplankton, zooplankton, shrimp pond effluents

Introduction

Aquaculture is a rapidly growing sector worldwide over the last three decades and becoming an important global economic activity. Demand for a cheap protein source has been the driving force fueling the aquaculture sector in the forward direction (Aruljothi and Sampathkumar, 2020) [2]. Shrimp farming is one of the major aquaculture activity attracting huge investments worldwide as well as in India, owing to its greater economic returns. In shrimp farming, the production depends on the feed cost and its associated water quality management issues. This feed cost involved can be reduced to a greater extent by enhancing the organic productivity of the ponds, particularly by improving the plankton productivity. Any culture pond with good biomass of phytoplanktonic assemblages will favour the multiplication of herbivorous zooplankton, particularly copepods. These would form a excellent protein rich live food organism (50 - 75% protein on dry weight basis) to the larval and juvenile shrimps in the ponds.

Harmful algae blooms are known to reduce the feeding and growth of shrimps and increase the susceptibility of shrimp to diseases. Hence, the development of harmful algal bloom is a serious concern and if this is not properly managed and controlled, this would cause mass mortality of the entire shrimp stock in the ponds, which would lead to the major economic loss to the entrepreneurs (Varghese *et al.* 2022) [30]. Further, the discharge of the effluent from the bloom-affected shrimp ponds into the adjoining coastal waters could be a serious environmental concern as the dissolved protein from the bottom accumulated uneaten shrimp feed and ammonia along with metabolic wastes of the culture organisms enter into

the coastal water bodies. When nutrient rich effluent are released into the coastal waters, eutrophication in the surrounding aquatic environment can result in the formation of harmful algal blooms (Burford and Williams, 2001; Ayyanna *et al.* 2024) ^[7] ^[4]. The diversity of plankton varies from location to location and from pond to pond of the same location with similar ecological conditions (Boyd, 1982) ^[6].

Materials and methods

The present investigation was undertaken to study plankton distribution in the *Litopenaeus vannamei* culture ponds at Kalaighanapuram (station 1, Lat. 09°01 N; Long. 78°16 E), coastal waters receiving shrimp pond effluents (station 2, Lat. 06°30 N; Long. 76°07 E) and unpolluted coastal water (station 3, Lat. 10°23 N; Long. 78°06 E). Plankton samples were collected from the three stations (1, 2 and 3) for a period of 5 months from November 2013 to April 2014 at fortnightly intervals for the assessment of phytoplankton and zooplankton population. Plankton samples were collected from the surface water using a hand plankton net made up of bolting silk (Number 30 mesh size and aperture size 41µ). Plankton samples were collected by filtering 200 litres of surface water through the hand plankton net (Rajdeep Dutta, 2005) ^[18]. The collected samples were preserved in 5% formalin in the collection site for further analysis at the laboratory. Phytoplankton and zooplankton species were identified using the keys of Kasturirangan (1963) ^[11], Santhanam *et al.* (1987) ^[22] and Santhanam & Srinivasan (1994) ^[20]. The quantitative estimation of phytoplankton and zooplankton was done following the method of Srinivasan and Santhanam (1991) ^[28]. By this method, the plankton sample (50 ml) was made upto a known volume, and a sub sample of 1 ml was taken in a Sedgwick-Rafter counting cell which was subsequently transferred to a microscope. The density of phytoplankton and zooplankton was expressed as cells per liter and numbers per m³ respectively. For each plankton sample, two counts were made, and the average was recorded. The species diversity (H') was calculated using Shannon-Weiner (1949) ^[25] function.

Result and discussion

The seasonal distributions of phytoplankton observed at station 1, 2 and 3 are given in Table 1. The total numbers of species recorded in the different study stations were 20, 30 and 34 in station 1, 2, and 3, respectively (Table 1). At Station 1, a total of about 20 species were found to be distributed including 12 species of diatoms, 6 species of dinoflagellates and 2 species of blue-green algae. The percentage composition of diatoms, dinoflagellates and blue-green algae were 60%, 30% and 10%, respectively. In Station 2, a total of about 30 species of phytoplankton including 16 species of diatoms, 12 species of dinoflagellates and 2 species of blue-green algae. The percentage composition of diatoms, dinoflagellates and blue-green algae were 53.33%, 40.00% and 6.67%, respectively. At Station 3, a total of about 34 species of phytoplankton including 22 species of diatoms, 10 species of dinoflagellates and 2 species of blue-green algae. The percentage composition of diatoms, dinoflagellates and blue-green algae were 64.71%, 29.41% and 5.88%, respectively.

The monthly variations of phytoplankton density recorded for all three stations is depicted in Fig. 1. In Station 1, the

total phytoplankton density was found to be ranging between 73400 and 164600 cells/l. The minimum and maximum values were observed during November 2013 and April 2014 respectively. During the period of maximum density, *Coscinodiscus gigas* (52.49%), *C. excentricus* (25.88%) and *Oscillatoria sp* (6.32%) were the dominant species. The contribution of diatoms, dinoflagellates and blue-green algae to the overall density was 84.81%, 10.42% and 4.77%, respectively. In this study, among all the species of phytoplankton recorded, the diatom species such as *Coscinodiscus excentericus* and *C. gigas* formed the dominant species invariably in all the stations during the study period. This observation seems to be the same as Keawtawee *et al.* (2012) ^[13] observed in the shrimp culture ponds. The species composition in the shrimp ponds are minimum, and low species diversity is due to the low water renewal in the ponds as reported earlier by Burford (1997) ^[8].

The total phytoplankton density recorded in Station 2 ranged between 39200 and 84000 cells/l. The minimum and maximum values were observed during December 2013 and April 2014, respectively. The maximum density was due to the abundance of *Coscinodiscus gigas* (13.10%), *Oscillatoria sp* (10.48%), *C. eccentricus* (8.81%), *Ceratium extensum* (8.57%), *Trichodesmium erythraeum* (8.33%) and *Rhizosolenia sp* (6.67%). The contribution of diatoms, dinoflagellates and blue-green algae to the overall density was 70.79%, 21.30% and 7.91%, respectively. The total phytoplankton density of Station 3 was found to be ranging between 38400 to 75200 cells/l. The minimum and maximum values were observed during December 2013 and April 2014, respectively. Arumugam *et al.* (2016) ^[3] reported the density of phytoplankton between 22,450 and 64,520 cells/l in Muthupet estuary. The only species responsible for the maximum density was *Coscinodiscus eccentricus* (11.97%), *Ceratium extensum* (8.78%), *C. gigas* (6.91%), *Leptocylindrus sp* (6.38%), *Peridinium depressum* (6.38%) and *Pleurosigma angulatum* (5.59%). The contribution of diatoms, dinoflagellates and blue-green algae to the overall density was 59.85%, 36.02% and 4.13%, respectively. The maximum occurrence of phytoplankton species during summer might be because of the maximum light availability and nutrient regeneration by microbes in the water column. Saravanakumar *et al.* (2008) ^[24] and Cross *et al.* (2018) ^[9] also made a similar observation in the mangrove bordered coastal waters of Kutch and Perumal *et al.* (2009) ^[16] in the coastal waters of Nagapattinam. Interestingly, diatom species contributed the maximum species composition, followed by dinoflagellates and blue-green algae in stations 2 and 3. Similarly, Sithik and Thirumaran (2009) ^[27] had also reported the same trend in the species composition in Rameshwaram coast of Bay of Bengal.

Table 2 summaries the seasonal distributions of zooplankton recorded in three stations. At Station 1, a total twenty two numbers of species/components of zooplankton were recorded. The percentage and species contribution of protozoans, copepods, decapoda, rotifera and meroplanktonic forms to the zooplankton composition were 18.18% and 4 numbers, 31.82% and 7 numbers, 4.55% and 1 number, 4.55% and 1 number and 40.90% and 9 numbers respectively. In this station, the number of zooplankton species/components distributed during the different study period ranged from 5 to 15. While the maximum number of

species/components recorded during December 2013 and the minimum during November 2013. In Station 2, the total number of species/components of zooplankton recorded was 34. The percentage and number of species contribution of protozoans, copepods, decapods, rotifera and meroplanktonic forms to the zooplankton composition were 20.59% and 7 numbers, 47.06% and 16 numbers, 2.94% and 1 number, 2.94% and 1 number and 26.47% and 9 numbers respectively. In this station, the number of zooplankton species/components at any one time of the study period was found ranging between 17 and 27. While the maximum number was observed during April 2014, the minimum was observed during January 2014. In Station 3, the total number of species/components of zooplankton recorded was 46. The percentage and species contribution of protozoans, copepods, chaetognaths, cladocera, decapods, rotifera and meroplanktonic forms to the zooplankton composition were 17.39% and 8 numbers, 41.31% and 19 numbers, 2.17% and 1 number, 4.35% and 2 number, 2.17% and 1 number, 2.17% and 1 number and 30.44% and 14 respectively. In this station, the number of species/components of zooplankton at any one time was found varying from 18 to 34. While the maximum number of species/components appeared during February and March 2014, the minimum was during November 2013.

The monthly variations in total zooplankton density recorded for all three stations are depicted in Fig. 2. At

Station 1, the zooplankton density was found to vary between 182500 and 397500 numbers/m³. The minimum and maximum density were during November 2013 and December 2013, respectively. The maximum value was mainly due to the species such as copepod nauplii (22.64%), *Acartia erythraea* (13.21%), *Oithona brevicornis* (11.95%), Bivalve veligers (10.69%) and crustacean nauplii (7.55%). The dominant groups observed were protozoans (6.79%), copepods (19.29%), and meroplanktonic forms (70.57%). Among the total species, copepods and meroplankton groups have contributed the maximum numbers in the distribution to the zooplankton species composition in the *Litopenaeus vannamei* shrimp ponds. Simultaneously, a similar observation of zooplankton species with maximum number of copepods in shrimp ponds was reported by Shil *et al.* (2013) [26] in Bagerhat with 11 genera of zooplankton. Ghosh *et al.* (2011) [10] have reported only a total of 8 zooplankton genera in the *Penaeus monodon* farm at Bangladesh. While in shrimp ponds of the present study the number of zooplankton species recorded is found to be higher (28 species) than the values reported by Saraswathy *et al.* (2013) [23] with 15 species in *Litopenaeus vannamei* culture ponds with 5 species of rotifers, 7 species of copepods and 3 species of meroplankton of benthic larval forms. Kavitha *et al.* (2018) [12] recorded 56 copepods species in offshore region of Tuticorin.

Table 1: Phytoplankton species composition observed during the present study

Sl. No.	Species	Station 1	Station 2	Station 3
Bacillariophyceae				
Centrales				
1	<i>Bacillaria sp</i>	+	+	+
2	<i>Bellorocha malleus</i>	-	+	+
3	<i>Biddulphia mobiliensis</i>	-	-	+
4	<i>B. sinensis</i>	-	+	+
5	<i>Biddulphia sp</i>	-	+	+
6	<i>Chaetoceros peruvianus</i>	-	-	+
7	<i>Chaetoceros sp</i>	+	+	+
8	<i>Coscinodiscus eccentricus</i>	+	+	+
9	<i>C. gigas</i>	+	+	+
10	<i>Leptocylindrus sp</i>	+	+	+
11	<i>Planktonella sol</i>	-	+	-
12	<i>Rhizosolenia alata</i>	-	+	+
13	<i>Skeletonema costatum</i>	-	+	+
14	<i>Triceratium favus</i>	-	-	-
Pennales				
15	<i>Asterionella japonica</i>	+	-	-
16	<i>Climacosphenia elongata</i>	-	-	+
17	<i>Diploneis sp</i>	+	-	+
18	<i>Gyrosigma balticum</i>	+	+	+
19	<i>Navicula sp</i>	+	-	-
20	<i>Nitzschia longissima</i>	-	+	+
21	<i>Nitzschia sigma</i>	-	-	+
22	<i>Nitzschia closterium</i>	+	+	+
23	<i>Pleurosigma angulatum</i>	+	+	+
24	<i>P. elongatum</i>	-	+	+
25	<i>Rhaphoneis sp</i>	-	-	+
26	<i>Thalassiothrix sp</i>	+	-	+
Peridinales				
27	<i>Noctiluca miliaris</i>	-	-	-
Dinophyceae				
28	<i>Ceratium contortum</i>	-	+	+
29	<i>C. extensum</i>	+	+	+
30	<i>C. furca</i>	+	+	+
31	<i>C. fusus</i>	+	-	-

32	<i>C. lineatum</i>	+	+	+
33	<i>C. macroceros</i>	+	+	+
34	<i>C. trichoceros</i>	-	+	+
35	<i>C. tripos</i>	-	+	-
36	<i>Dinophysis caudata</i>	-	+	+
37	<i>Peridinium depressum</i>	-	+	+
38	<i>P. oceanicum</i>	-	+	+
39	<i>Prorocentrum</i> sp	-	+	+
40	<i>Pyrophacus horologicum</i>	+	+	-
Cynophyceae				
41	<i>Oscillatoria</i> sp	+	+	+
42	<i>Trichodesmium erythraeum</i>	+	+	+
	Total	20	30	34

Table 2: Zooplankton species/groups composition observed during the present study

Sl. No.	Species/Group	Station 1	Station 2	Station 3
Tintinnida				
1	<i>Codonellopsis ostenfeldi</i>	-	+	+
2	<i>Favella philippinensis</i>	-	+	+
3	<i>Metacilis jorgensenii</i>	+	+	+
4	<i>Tintinnopsis butschlii</i>	+	+	+
5	<i>T. cylindica</i>	+	+	+
6	<i>T. mortensenii</i>	-	-	+
7	<i>T. tubulosa</i>	-	-	-
8	<i>T. tocaninensis</i>	-	-	-
Foraminifera				
9	<i>Globigerina inflata</i>	+	+	+
10	<i>Globigerina</i> sp	-	+	+
Copepoda				
11	<i>Acartia danae</i>	+	+	+
12	<i>A. erythraea</i>	+	+	+
13	<i>A. spinicauda</i>	+	+	+
14	<i>Acrocalanus gracilis</i>	-	+	+
15	<i>Centropages furcatus</i>	-	-	-
16	<i>Eucalanus subcrassus</i>	-	-	+
17	<i>Isias tropica</i>	-	-	+
18	<i>Labidocera acuta</i>	-	-	-
19	<i>L. pavo</i>	-	-	-
20	<i>Paracalanus parvus</i>	+	+	+
21	<i>Temora turbinata</i>	-	-	-
22	<i>Undinula</i> sp	+	+	+
23	<i>Corycaeus catus</i>	-	-	-
24	<i>C. danae</i>	-	+	+
25	<i>C. speciosus</i>	-	+	+
26	<i>Oithona brevicornis</i>	+	+	+
27	<i>O. linearis</i>	-	+	+
28	<i>O. rigita</i>	+	+	+
29	<i>Oncaea venusta</i>	-	-	+
30	<i>Euterpina acutifrons</i>	-	+	+
31	<i>Longipedia coronata</i>	-	-	+
32	<i>L. weberi</i>	-	+	+
33	<i>Macrosetella gracilis</i>	-	-	-
34	<i>Metis jousseaumei</i>	-	+	+
35	<i>Microsetella norvegica</i>	-	+	+
36	<i>Microsetella rosea</i>	-	+	+
Chaetognatha				
37	<i>Sagitta</i> sp	-	-	+
Cladocera				
38	<i>Penelia</i> sp	-	-	+
39	<i>Podon</i> sp	-	-	+
Decapoda				
40	<i>Lucifer hansenii</i>	+	+	+
Rotifera				
41	<i>Brachionus rubens</i>	+	+	+
Meroplankton				
42	Bivalve veligers	+	+	+
43	<i>Balanus nauplii</i>	+	-	+
44	Cyprids larva	+	+	+

45	Copepod nauplii	+	+	+
46	Crustacean nauplii	+	+	+
47	Lepas nauplii	-	-	+
48	Crab zoea	+	+	+
49	Fish eggs	-	+	+
50	Fish larvae	-	-	+
51	Gastropod veligers	+	+	+
52	Lucifer zoea	+	+	+
53	Polychaete larvae	+	+	+
54	Prawn mysids	-	-	-
55	Prawn zoea	-	-	+
	Total	22	34	46

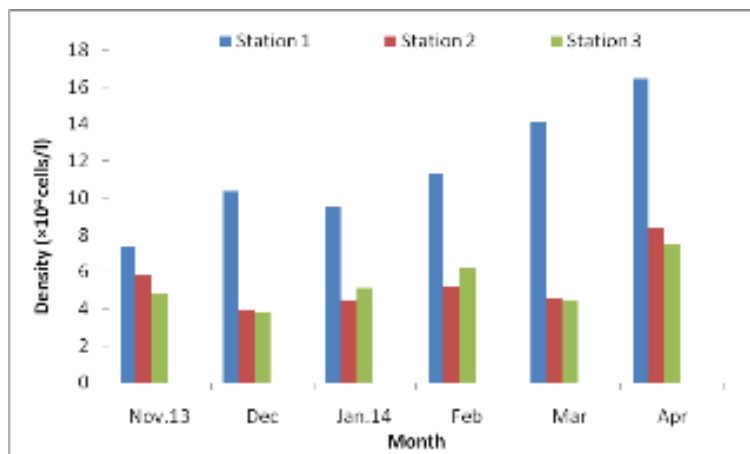


Fig 1: Monthly variations of Phytoplankton Density in Station 1, 2 and 3

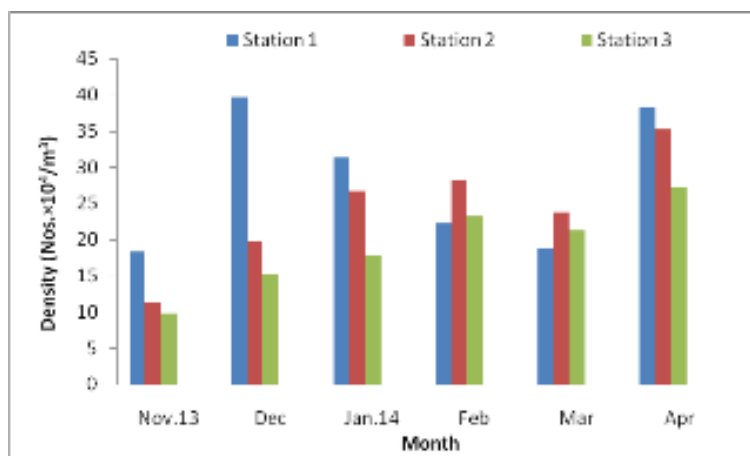


Fig 2: Monthly variations of Zooplankton Density in Station 1, 2 and 3

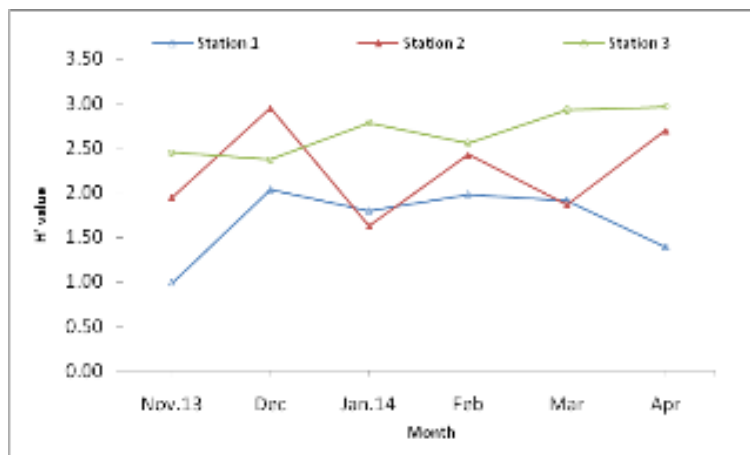


Fig 3: Monthly variations of Phytoplankton species Shannon-Weiner Index in Station 1, 2 and 3

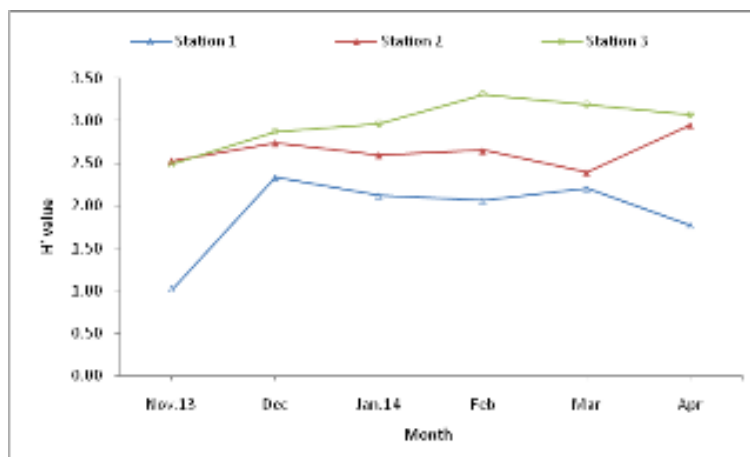


Fig 4: Monthly variations of Zooplankton species Shannon-Weiner Index in Station 1, 2 and 3

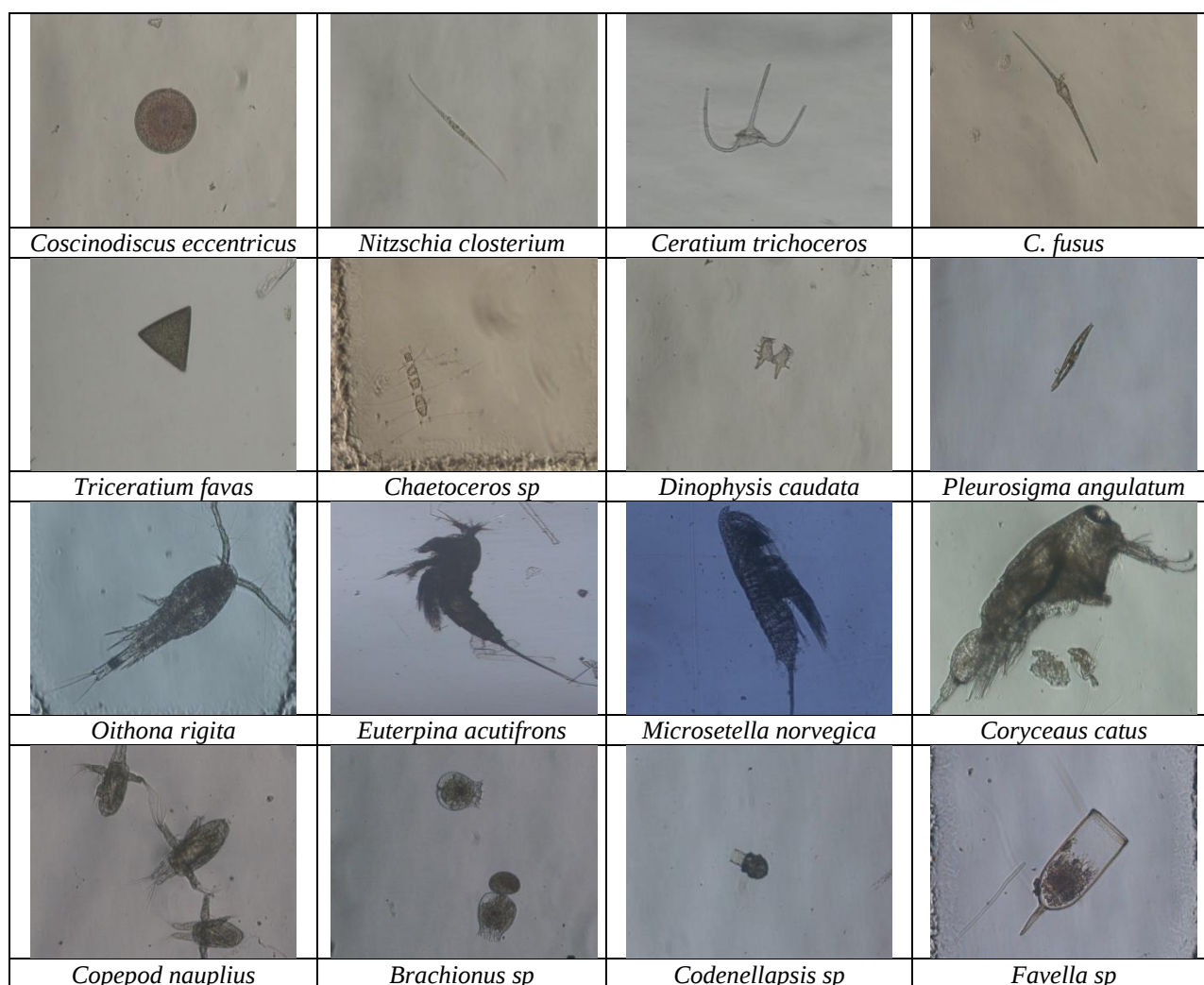


Fig 5: Microphotograph pictures (10x) of common phytoplankton and zooplankton species in all the three stations

In Station 2, the zooplankton density was found varied from 1,12,500 to 3,52,500 numbers/m³. The minimum and maximum densities were observed during November 2013 and April 2014, respectively. During the period, maximum density was observed mainly due to species such as *Brachionus rubens* (17.73%), *Acartia erythraea* (13.48%), *Acrocalanus gracilis* (6.38%) and *Oithona brevicornis* (6.38%). The dominant groups observed were mainly protozoans (6.38%), copepods (52.45%) and meroplankton (25.76%). However, this station, which is influenced by the discharge of shrimp farm effluent, had relatively lower

species composition (34 species) compared to the other two unpolluted coastal stations (51 and 46 numbers). Similar observation of higher species numbers (64 species) was also reported by Rajdeep Dutta (2005) [18] and Kothandapani *et al.* (2016) [14] in the unpolluted coastal waters of Thoothukudi, Southeast coast of India.

In Station 3, the zooplankton density was found ranging between 97,500 and 2,72,500 numbers /m³. The minimum and maximum density were observed during November 2013 and April 2014, respectively. During the period, the maximum density was observed due to copepod nauplii

(15.60%), *Oithona brevicornis* (11.93%), bivalve veligers (10.09%), crustacean nauplii (8.26%) and *Metacilis jorgensenii* (8.26%). The dominant groups observed were protozoans (15.35%), copepods (29.49%), and meroplankton (51.79%). During the study period, copepods constituted an overall average of 36.19% of the total zooplanktonic population. More or less similar findings were also reported by Prasad (1954) ^[17], Marichamy *et al.* (1985) ^[15] and Rajdeep Dutta (2005) ^[18]. The occurrence of calanoid species in these coastal water stations further corroborates the influence of oceanic waters as reported by Srinivasan (1996) ^[29] in the open coastal waters near Hare Island of Thoothukudi coast. A similar observation was also made by Santhanam *et al.* (1975) ^[21] in the coastal waters of Porto Novo.

Monthly variations in phytoplankton species diversity index H' for station 1, 2 and 3 are depicted in Fig. 3. At Station 1, the Shannon-weinner species diversity index (H') for the phytoplankton varied between 0.99 and 2.03 bits/individual. The observed minimum values were during November 2013 and the maximum value was in December 2013. In Station 2, the H' values were varied from 1.62 to 2.94. The minimum value was in January 2014 and the maximum values in December 2013. In Station 3, the species diversity index (H') values ranged between 2.37 and 2.96 bits/individual. The maximum and minimum values were in April 2014 and December 2013. At the time of maximum diversity, there were 11 phytoplankton species with a total density of 1,03,400 cells/l. This value is lower than the value observed by Babu *et al.* (2013) ^[5] at 3.09. In the case of coastal water stations, station 3 showed maximum diversity during March 2014. During that period, 25 species of phytoplankton were recorded. However, this value is lower than the range of value (3.2 to 5.23) observed by Rajkumar *et al.* (2009) ^[19] in the coastal waters of the Bay of Bengal near Pichavaram mangrove waters.

In Station 1, species diversity index H' for the zooplankton varied from 1.01 to 2.33 bits/individual (Fig. 4). While the maximum value was in December 2013, the minimum value was in November 2013. In Station 2, the observed H' value varied between 2.39 and 2.95 bits/individual. While the maximum value was observed in April 2014, the minimum value was in March 2014. At Station 3, the values of H' ranged from 2.49 to 3.31 bits/individual. The maximum and minimum index values were recorded February 2014 and in November 2013. The diversity value of the present study in shrimp pond is somewhat higher than the value observed by Abu Hena and Hishamuddin (2014) ^[1] in shrimp ponds with 1.09 in Malaysia. In the case of coastal water stations, station 3 showed maximum diversity value during February 2014, during that period 34 species of zooplankton were recorded. The diversity value of the present study in coastal waters was somewhat lower than the value observed by Perumal *et al.* (2009) ^[16] with 5.27 in Nagapattinam coast.

Conclusion

The present investigation showed that the shrimp culture ponds (station 1) had higher densities of plankton with less species diversity, whereas coastal waters had comparatively lower density with higher species diversity. This indicates that the presence of Vannamei farm near coastal area of Kalaiganapuram seemed to have no influence on plankton dynamics of coastal waters. The effluent treatment ponds receiving shrimp pond effluent (station 2) had only slight

variation in the plankton diversity compared to the shrimp farm source water and unpolluted station.

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Author's contributions

Sample collection, species identification and preparing the first version of manuscript: Ramesh P; Critical reviewing of the research work, literature collection and reviewing drafts of the manuscript: R.R. Anupama; Visualization, formal analysis and investigation: K. Madhavi. Laboratory observation and data curation: N. Mohana Swapna; Technical contribution on data analysis: R.S. Sravani and K Dhanapal.

- **Ethical approval:** No live specimens here were used in the present study.
- **Conflict of Interest:** The authors have declared no conflict of interest
- **Research content:** The research content of the manuscript is original and has not been published elsewhere.
- **Consent to Publish:** All the authors agree to publish the paper in the *International Journal of Biology Sciences*.

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