Zooplankton Composition and Abundance and its Relationship with Physico-chemical Parameters in Manila Bay

Ellaine C Jose*, Elsa F Furio, Valeriano M Borja, Norvida C Gatdula and Mudjekeewis D Santos

Oceanography Section, Resource and Ecological Assessment Division, National Fisheries Research and Development Institute, Corporate 101 Bldg Mother Ignacia Avenue, South Triangle, Quezon City 1103,Philippines

Abstract

Anthropogenic activities affect water quality and biological resources in bays such as zooplankton community. A survey on the zooplankton in Manila Bay was done from January to December 2013 in relation to physico-chemical parameters.Temperature and salinity in the bay showed uniform spatial patterns. Mean DO concentrations in the bay ranges from 2.79-6.25 mg/L, the lowest value was recorded in station 14 in the month of July with a value of 1.01 mg/L. Mean concentrations of nitrate, phosphate, nitrite, silicate ranges from 0.0265-8.3902 µM, 0.0135-0.2573 µM, 0.1385-0.8396 µM, and 5.4887-53.2027 µM respectively. Arthropods, consist mainly of copepods, dominated the zooplankton community in the bay. High concentrations were observed in the eastern and southern part of the bay. Copepod nauplii, calanids and *Oithona* sp. were among the dominant species. Redundancy Analysis revealed that salinity, temperature, dissolved oxygen, phosphate and nitrate have positive correlation with zooplankton.

Introduction

Manila bay is one of the most important bodies of water in the Philippines because of its socio-economic importance.[1] The natural resources available have been the primary source of livelihood for people in the areas within the bay. Rapid increase in population and industrialization in the watershed cause the bay to suffer from serious water quality deterioration.

Zooplankton plays a major role in the functioning and the productivity of aquatic ecosystems through its impact on the nutrient dynamics and its key position in the food webs. [2] Zooplankton community is highly sensitive to environmental change [3] they respond to disturbances in the environment like nutrient loading [4] and fish densities [5]. A change in the physico-chemical conditions in aquatic systems brings a corresponding change in the relative composition and abundance of organisms thriving in the water, therefore they can be used as a tool in monitoring water systems, [6] hence are considered of ecological importance.

Several studies have examined and reported about zooplankton, internationally in different parts of the world [3], some studies were zooplankton as indicators of water quality done by Webber et al. in 2005 [7] in Discovery Bay in Jamaica and the identification of water quality and zooplankton characteristics in Daya Bay in China done by Wang et. al., 2011 [8] but in Manila Bay, despite the studies done concentrating on the pollution of the bay especially regarding its water quality and harmful algal bloom issues, only very few studies are presently available on the structure of zooplankton community and its interaction with environmental pollution.

The study aimed to describe the species composition of zooplankton community in the bay and the spatio-temporal variations in the abundance of zooplankton in Manila Bay and to describe the environmental condition of the bay and to know the relationship of zooplankton abundance and species composition with environmental factors.

Materials and Method

Study site

Sixteen stations in Manila bay were established for investigation.

(Figure 1) Manila bay has an area of 1,994 km^2 (769.9 sq mi) with an average depth of 17 m (55.8 ft). It is bounded by the province of Cavite and Metro Manila in the east, Bulacan and Pampanga on the north and the province of Bataan on the west [1].

Collection of samples

Zooplankton samples were collected in the months of January, March, May, July, September and November in 2013. Samples were collected using plankton net about two feet in length with 64 µM mesh size. The net is slowly lowered down the water up to 5 meters sieving 706 L of water. This is then reduced to 100 ml and then preserved in 4% formalin an aliquot of 1 ml was subjected to counting and identification.
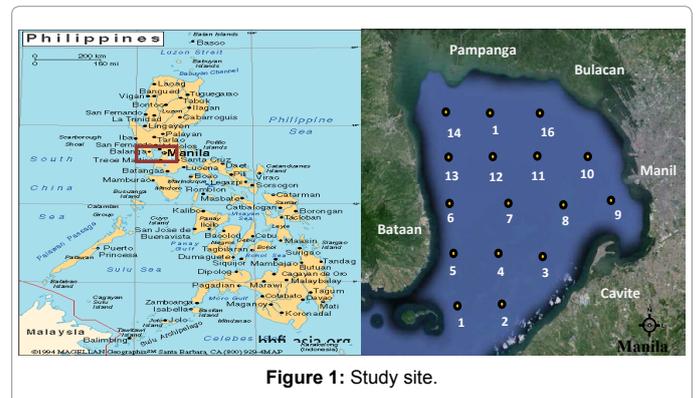

Figure 1: Study site.

*Corresponding author: Ellaine C. Jose, Oceanography Section, Resource and Ecological Assessment Division, National Fisheries Research and Development Institute, Corporate 101 Bldg Mother Ignacia Avenue, South Triangle, Quezon City 1103, Philippines; Tel: +639175235102; E-mail: ellainecjose@outlook.com

Physico-chemical analysis of water

Physico-chemical parameters like temperature, salinity, dissolved oxygen and chlorophyll-a concentration were measured using YSI MDS 6600. Particulate and dissolved matter was separated by filtration, the water samples were filtered through a 0.45 µMmembrane filters. Nutrients such as phosphate, nitrate, nitrite and silicate were analyzed using spectrophotometry.

Analysis of zooplankton

The zooplanktons were observed and counted using sedgewick rafter cell under a microscope with 400 × magnification. It was identified to lowest possible taxa. Multivariate analysis of species composition and ecological data was done using CANOCO software. Multivariate analyses are more sensitive than univariate analyses at detecting changes in complicated biological and environmental factors. They are also exceedingly useful for analyzing differences between communities at spatial and temporal scales, and for illustrating how these communities vary along gradients of environmental conditions [9-16]. RDA was used to determine the relationships between the zooplankton and physico-chemical parameters. Redundancy analysis was done because the species exhibited a linear response to the environmental variables.

Results

Mean temperature values in the bay in 2013 ranged from 25.29-30.91°C, temperatures were highest in the months of May and July (Figure 2). The mean salinity values in the bay ranged from 14.83-28.73 ppt. Salinity in the months of January, May, July and November showed almost the same spatio-temporal patterns, the concentrations were observed in the northwestern and eastern part of the bay while in March, concentration was observed in the eastern part of the bay (Figure 3).

The highest DO concentration recorded was in recorded in Station 3 the month of March with a value of 9.54 mg/L and the lowest was recorded in station 10 in November with a value of 1.47 mg/L, mean concentrations in the bay ranged from 2.79-6.25 mg/L (Figure 4). The spatio-temporal patterns were shown to be uniform in in the months of January to May. The mean chl-a concentration ranged from 0.3619-2.8546 µg/L (Figure 5). No data were obtained in the month of July.
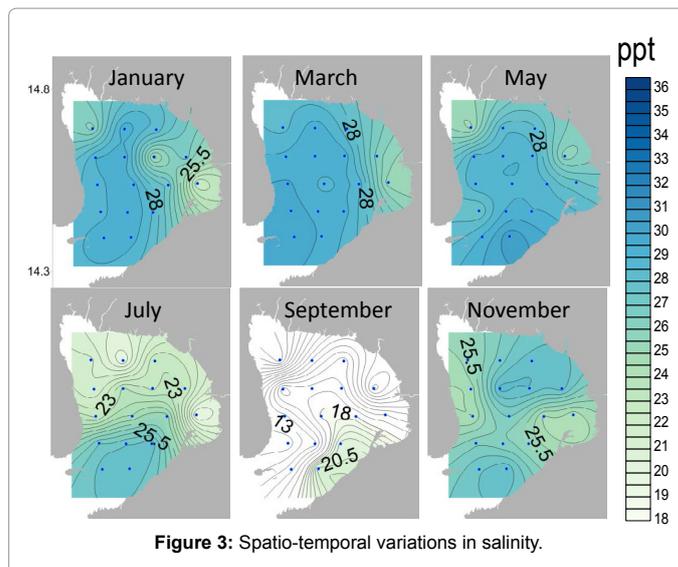

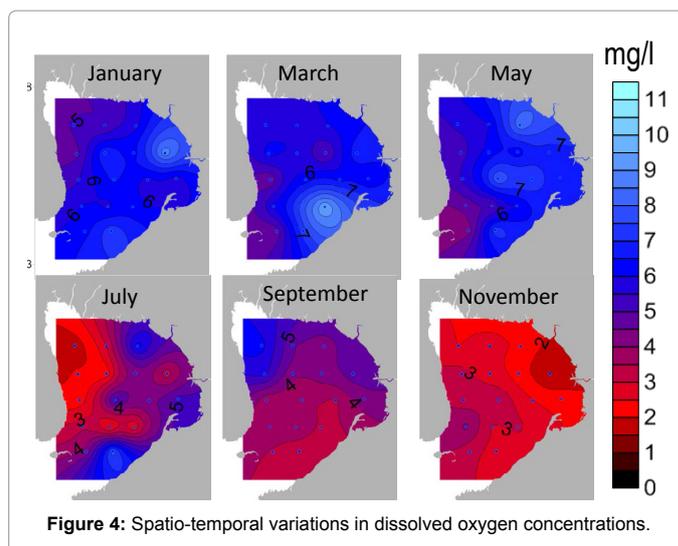**Figure 3:** Spatio-temporal variations in salinity.

Figure 4: Spatio-temporal variations in dissolved oxygen concentrations.
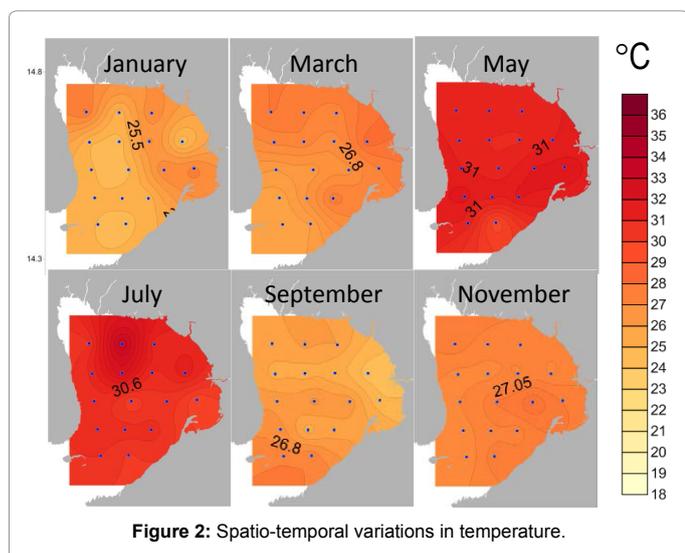

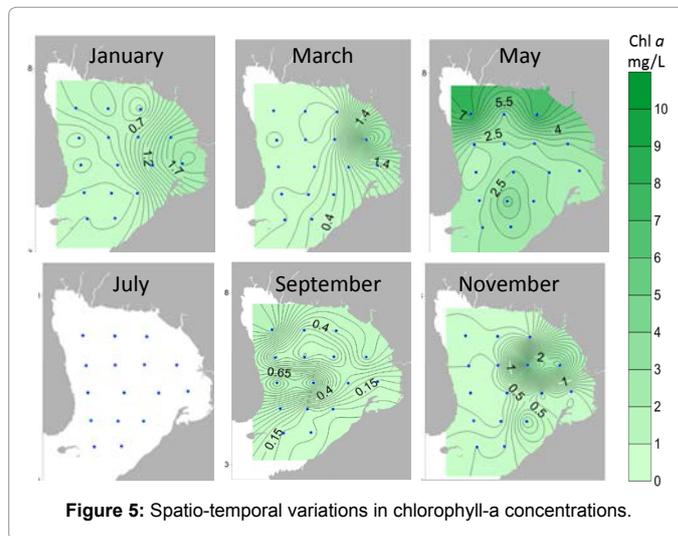**Figure 2:** Spatio-temporal variations in temperature.

Figure 5: Spatio-temporal variations in chlorophyll-a concentrations.

Phosphate concentrations with mean values ranged from 0.0135 to 0.2573 μM, of which the highest value was recorded in station 14 in September (0.7762 μM) (Figure 6), showed positive relationship with zooplankton abundance (Table 1). The average nitrate concentration in the bay ranged from 0.0265-8.3902 μM, the highest concentration was recorded in the month of November where it reached 22.6677 μM (Figure 7). Zooplankton was also abundant in the month of November, showing positive relationship with nitrate (Table 1).

The mean nitrite concentration of the bay ranged from 0.1385-0.8396 μM. Maximum value was recorded in station 11 in November (Figure 8). Mean silicate concentration in the bay ranged from 5.4887-53.2027 μM of which the maximum value was observed in station 10 (Figure 9). Both nitrite and silicate showed no significant relationship with the zooplankton abundance (Table 1).

The summary of the species composition of zooplankton in Manila bay in 2013 is presented in Table 2. 29 genera excluding copepodites and copepod naupli which comprise the bulk of the zooplankton community, distributed to 7 phyla Arthropoda (14), Chordata (3), Ciliophora (3), Annelida (2), Mollusc (2), Echinoderm (2), Chaetognatha (1), Foraminifera (1), Sipunculida (1). Arthropods dominated the community making up 87% of the total population. Those that belong to the Ciliophora comprise the 6% of the population, Chaetognatha 3%and the other 4% was made up by the remaining phyla.

The average abundance of arthropods consists mainly of copepods was 11497 ind/m³with copepod nauplii comprising the bulk of the
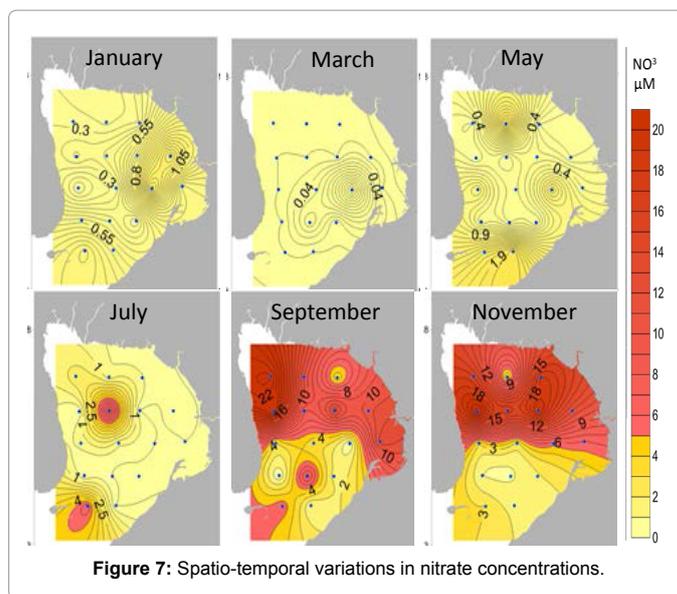

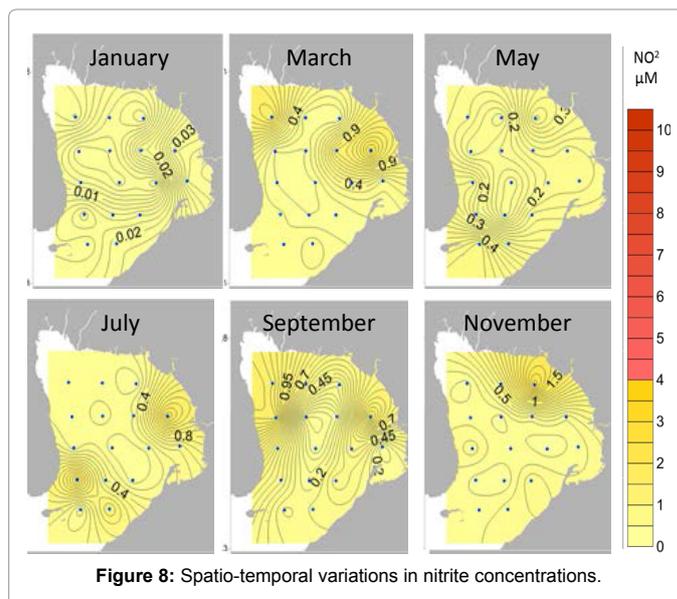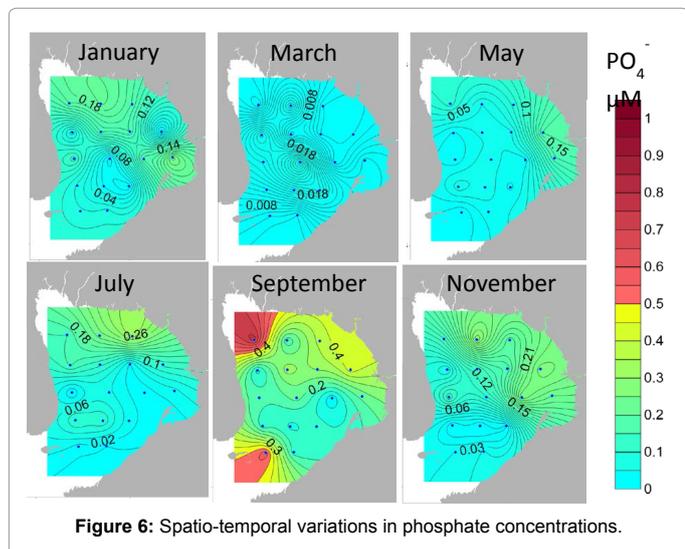**Figure 6:** Spatio-temporal variations in phosphate concentrations.

Analysis 'RDA' Conditional Term Effects:

Name	Explains %	pseudo-F	P
SAL	9.2	7.9	0.002
DO	7.5	6.9	0.002
TEMP	7.4	7.4	0.002
PO4	2.6	2.7	0.002
NO3	1.8	1.9	0.022
CHLA	1.5	1.6	0.07
SiO4	1.3	1.4	0.16
NO2	1	1.1	0.344

Table 1: (Summary of Monte Carlo test of significance).

Figure 7: Spatio-temporal variations in nitrate concentrations.

Figure 8: Spatio-temporal variations in nitrite concentrations.

population followed by calanids, *Oithona* sp. and *Euterpina* sp. The maximum abundance of arthropods mostly copepods was observed in the month of May, July and November (Figure 10) where the highest temperatures were also recorded.

The mean abundance of the three genera, *Codonellopsis* sp., *Favella* sp., *Tintinnopsis* sp. recorded belonging to Phylum Ciliophora, was 397 ind/m³. Ciliates are most abundant in the month of July reaching 763 ind/m³. There are also three genera of chordates recorded during the survey with the mean abundance of 812 ind/m³ having *Oikopleura* sp. as the most abundant. A species of chaetognath also constitute to the zooplankton community making up the 3% of the total population (Table 1) with a mean abundance of 417 ind/m³. Polychaete and oligochaetelarvaes were also recorded and was found to be abundant in the months of July and September. Under the phylum Mollusca, gastropod and bivalve veliger were recorded and two genera were recorded under Echinodermata namely, *Euchinopluteus* sp.and
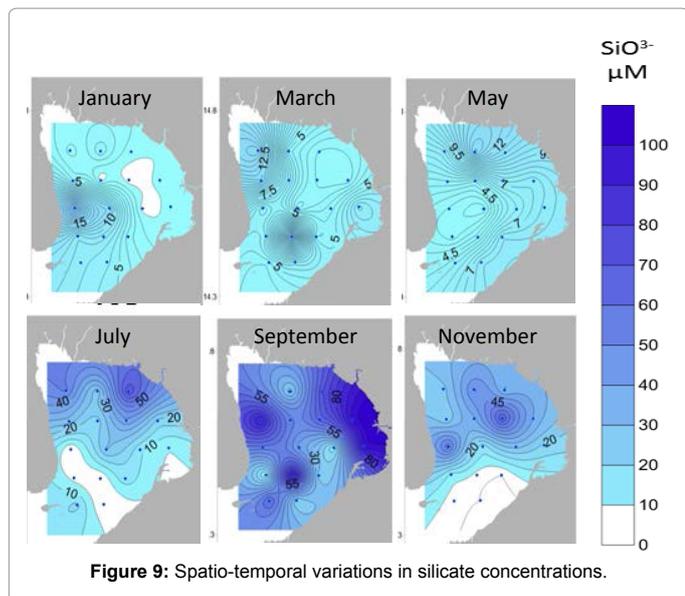
Figure 9: Spatio-temporal variations in silicate concentrations.

Ophiopluteus sp. *Globigerina* sp. was observed under the phylum Foraminifera and was most abundant in the month of September and November.

Zooplankton mean abundance in 2013 was 381 ind/m³ of which the highest density was recorded in the month of November (Figure 2) with a mean abundance of 483 ind/m³ followed by July (460 ind/m³) and May (447 ind/m³).

RDA ordination plot (Figure 11) revealed that most of the dominant zooplankton species tend to favor nutrient rich waters. *Microsetella* sp., *Podon* sp., and *Oikopleura* sp. favored warmer temperatures, as warmer waters were also recorded in July. *Acartia* sp., polychaete larvae, and copepod nauplii favored phosphate-rich waters as they dominated in the month of September. As much as the species prefer highly saline waters, they have managed to survive in an environment with low levels of salinity. The species *Euterpina* sp., calanids, and *Oithona* sp favored a nitrate rich environment as they clustered during November wherein the northern half of the bay exhibited high nitrate concentrations (Figure 7).

Discussion

Coastal ecosystem is widely exposed to anthropogenic pollution since it receives inputs from terrestrial, littoral, marine and atmospheric sources. Urban development around coastal areas and consequent increase in the levels of anthropogenic contaminants from the catchment area cause serious water quality deterioration problems worldwide, particularly in Asian regions having larger populations and higher precipitation compared with other regions of the world [17].

In aquatic ecosystem, zooplankton play an important role as they themselves serve as a source of food for higher organisms. The composition and abundance of zooplankton are affected by the properties of water masses [18] like temperature and salinity. Twenty

	January	March	May	July	September	November	Total	Relative Abundance
copepod nauplii (cnau)	2745.098	702.8266	6905.186	6782.107	4222.052	5403.616	26760.886	32.15%
Acantharia (acan)	56.02241	0	0	0	0	0	56.02241	0.07%
Acartia sp (acar)	5.092946	0	547.4917	236.2561	213.9037	203.71785	1206.4623	2.00%
bivalve veliger (bvel)	40.74357	61.11536	8.488244	33.95298	66.2083	407.4357	617.94416	0.74%
Calanid	2561.752	4064.171	2582.47	2666.723	1797.81	5749.9363	19422.862	23.34%
Chaetognath	117.1378	1731.602	171.1796	189.5708	203.7179	112.04482	2525.2529	3.03%
Clytemnestra sp	0	137.5095	0	11.31766	20.37179	0	169.19895	0.20%
Codonellopsis sp	0	0	0	257.4767	203.7179	0	461.1946	0.55%
Oncaea sp	0	0	0	0	0	86.580087	86.580087	0.10%
Echinopluteus sp	0	15.27884	80.63832	0	0	0	95.91716	0.12%
Euterpina sp	1354.724	0	141.4707	421.5828	835.2432	2368.22	5121.2407	6.15%
Evadne sp	0	89.12656	35.36768	59.41771	56.02241	402.34276	642.27712	0.77%
Favella sp	0	0	217.8649	456.9505	448.1793	0	1122.9947	1.35%
Globigerina sp	71.30125	7.639419	36.78239	89.12656	106.9519	25.464731	337.26625	0.41%
Macrosetella sp	0	0	19.8059	140.056	168.0672	0	327.9291	0.39%
Microsetella sp	0	710.466	304.1621	407.4357	580.5959	325.94856	2328.6083	3.00%
Gastropod veliger	10.18589	0	0	0	0	71.301248	81.487138	0.10%
Oikopleura sp	0	667.176	1003.027	1154.401	998.2175	264.83321	4087.6547	5.00%
Oithona sp	1273.237	2523.555	3607.504	2366.805	763.9419	1869.1113	12404.154	15.00%
Ophiopluteus sp	0	53.47594	16.97649	0	0	0	70.45243	0.09%
Podon sp	0	313.2162	158.4472	323.968	371.7851	0	1167.4165	2.00%
Polychaete larvae	112.0448	20.37179	0	383.3857	432.9004	305.57678	1254.2795	0.02%
Fritillaria sp	0	0	0	339.5298	305.5768	142.6025	787.7091	1.00%
Tigriopus sp	0	443.0863	59.41771	4.244122	5.092946	0	511.84108	0.62%
Tintinnopsis sp	20.37179	0	186.7414	48.10005	35.65062	0	290.86386	0.35%
Xystonella	30.55768	0	14.14707	0	0	0	44.70475	0.05%
decapod shrimp zoea	157.8813	76.39419	12.73237	162.6913	183.3461	0	593.04526	0.71%
Corycaeus	0	0	0	21.22061	20.37179	112.04482	153.63722	0.20%
Decapod larvae	0	0	0	0	0	478.73695	478.73695	0.60%
Oligochaete	0	0	0	0	0	25.464731	25.464731	0.03%

Table 2: Zooplankton composition and variation in the zooplankton abundance in Manila Bay from January-November 2013 (ind/m3).
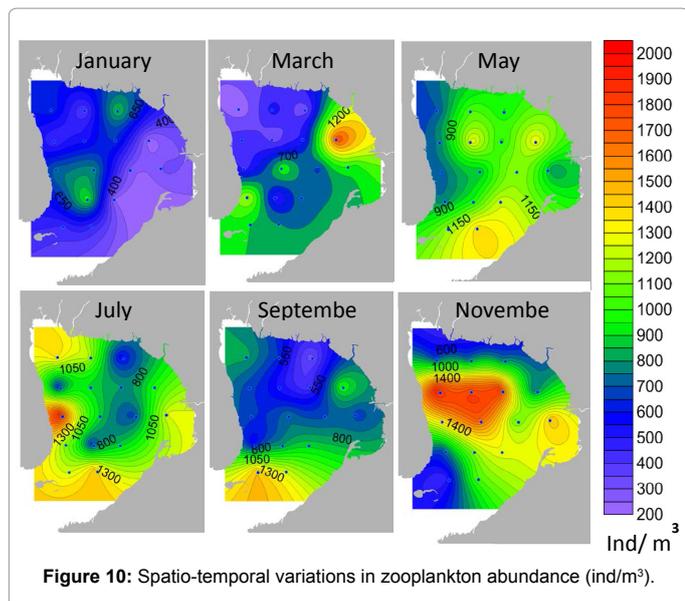
Figure 10: Spatio-temporal variations in zooplankton abundance (ind/m³).

nine (29) genera of zooplankton were observed and recorded in Manila bay and was dominated by copepods during the survey from January to December 2013. Caethognath species was also recorded during the sampling period, despite the limited diversity of species, the number of individuals is large, larger than most of the zooplankton, their diet is consist mainly of copepods as it is shown in the study done by Canino and Grant (1984) in the lower Chesapeake Bay. The highest densities of zooplankton were recorded in the months of March, May, July and November (Figure 4) the highest concentrations of nitrate were also recorded in the months of July and November. The results was showed to be similar with Etilé et al. (2009) [2] who studied the spatio-temporal variations of zooplankton abundance in a tropical coastal lagoon that the copepods constituted the bulk of zooplankton during the dry season.This could be accounted to temperature and nutrients, because according to a study done by Wang et al in 2011[8] these

two parameters play an important role in determining the biomass of zooplankton. Increase in nutrient in the bay would bring about an increase in the abundance of zooplankton in the bay. Temperature is one of the most important environmental factors which greatly affect biota of an ecosystem.[19] Water temperature ranging between 13.5 to 32°C is reported to be conducive for the growth of the planktonic organisms.[20] Results showed that the temperature in the bay is favourable for the survival of zooplankton.

Dissolved oxygen plays an important role in life processes in aquatic environment. [21] Dissolved oxygen concentrations in the bay ranged from 2.79-6.25 mg/Lmg/L (Figure 4) during the survey from January to December 2013. The lowest concentration of dissolved oxygen was recorded in November that reached 1.47 mg/L. Result showed that dissolved oxygen concentration in the bay is one of the deciding factors of the variation in the abundance of zooplankton (Table 1). Low dissolved oxygen concentration would bring about a decrease in the number of species thriving in the environment. Low dissolved oxygen can be attributed to eutrophication [22].

The significant positive correlation between zooplankton abundance and salinity in Manila Bay suggests that higher salinity in the bay would result to greater abundance of zooplankton in the bay. High values of salinity were recorded in the month of May where in station 2 it reached 30.37 ppt. At the same stations zooplankton abundance was also recorded higher as compared to the other stations of the same month. Salinity appeared as the major deciding factor for the composition and abundance of zooplankton in the bay. Ciliates was found in the stations with high salinity. Ciliates are heterotrophic and feed primarily on photosynthetic algae and bacteria [23] which are most commonly found in salt water [24-28].

Conclusion

There were 34 genera belonging to 7 phyla identified during the sampling from January-November 2013 in Manila Bay. The average zooplankton density ranged from368-664 ind/m³. The zooplankton abundance was much higher in the months of July and November compared to the other sampling months this is due to the high
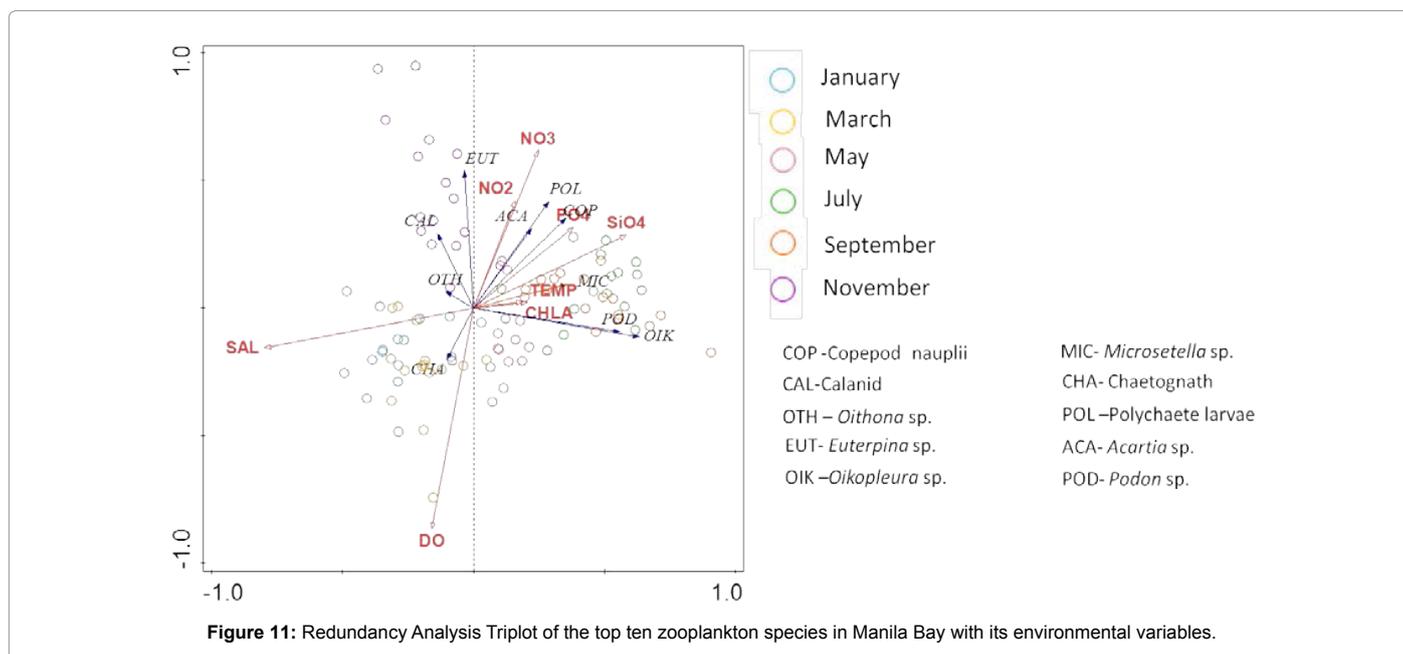

Figure 11: Redundancy Analysis Triplot of the top ten zooplankton species in Manila Bay with its environmental variables.

temperature, salinity and nutrient concentrations which were also recorded the highest in the said months. The results indicated that zooplankton abundance has positive correlation with salinity, temperature, dissolved oxygen, phosphate, and nitrate. This would mean that changes in the environment would bring about a change in the zooplankton community.

Acknowledgement

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