ZOOPLANKTON (SMALL PLANKTONIC COPEPODS) COMMUNITIES IN LIANGA BAY MARINE ECOSYSTEM

[1]Gemma A. Asufre*

Abstract

Lianga Bay is an important marine ecosystem that caters diverse organisms with critical roles in marine production. Small copepods are the most abundant zooplankton and are important links in marine food webs. There is no available record of the diversity of small planktonic copepods communities in Lianga Bay. This study was conducted in order to document the biodiversity of zooplankton with special consideration on the small planktonic copepods in Lianga Bay marine ecosystem. Zooplankton samples were collected using conical plankton net. Physico-chemical parameters were also determined. Shannon diversity index was used for diversity analysis. A total of 95 copepod taxa belonging to 41 genera, 17 families and 4 orders were observed in the 2 sampling stations in Lianga Bay from the months of May to July 2009. Among the 95 taxa, there were 15 small planktonic copepods observed dominated by the genus Oithona.. The copepod species were dominated by Paracalanidae with 18 taxa under 9 genera while the family with the highest abundance (20.5%) was Calanidae. Shannon index (4.382) showed high diversity. However, this composition of small copepods in Lianga Bay could not be considered as an indicator of coastal eutrophication due to its less abundance (14.64%) in the overall community structure of copepods in the area.

Keywords: copepods, zooplankton, diversity, planktonic community, Lianga Bay

*Corresponding Author: Gemma A. Asufre, gaasufre@yahoo.com

1.0 Introduction

Zooplankton is a collective name of small microscopic animals floating or drifting in the bodies of water. Because they are too small or weak to swim against the current, their movement depends largely on tides, currents, and winds (Microsoft Encarta, 2008). These small marine organisms have critical functions in the marine environment as they played the important part of the food chain. The most important role of zooplankton is as the major grazers in marine food webs, providing the principal pathway for energy from primary producers to consumers at higher trophic levels, such as fish, marine mammals, and turtles.

Zooplankton also plays an important role in shaping the extent and pace of climate change. The ocean's ability to act as a sink for CO_2 relies partially on the biological pump. Zooplankton plays a role in the biological pump because much of the CO_2 that is fixed by phytoplankton, and then eaten by zooplankton, eventually sinks to the seabed. Much of this carbon can be locked up in sediments and removed from the carbon cycle. Zooplankton also facilitates this process by moving large quantities of carbon from the ocean's surface to deeper layers when they dive each day into the ocean depths. Zooplankton does not only support the large, highly visible, and charismatic components of the ocean food web, but also support the microbial community (Schminke, 2007).

Zooplankton communities are highly diverse and thus perform a variety of ecosystem functions. The most prominent zooplankton are copepods which are considered most abundant multicellular animals on Earth, even outnumbering insects by possibly three orders of magnitude (Schminke, 2007). Small planktonic marine copepods (<1 mm length) are undoubtedly the most abundant metazoans on Earth. This includes adults and copepodites of calanoid genera such as *Paracalanus*, *Pseudocalanus*, *Acartia*, and *Clausocalanus*; cyclopoid genera such as *Oithona*, and *Oncaea* and *Corycaeus*; planktonic harpacticoids of the genus Microsetella; and nauplii of almost all copepod species. Small copepods are abundant and are important links in marine food webs. They serve as major grazers of phytoplankton, as components of the microbial loop (Turner and Roff, 1993) by preying upon bacterioplankton and heterotrophic protists, and as prey for ichthyoplankton and other larger pelagic carnivores. Small copepods exhibit various reproductive and feeding strategies which help to maximize population size, in order to counter heavy losses due to predation. Small copepods are important prey items for larval fish and other zooplanktivorous consumers. Failure to adequately account for small copepods may cause serious underestimations of zooplankton abundance, biomass, and production, copepod grazing impact on phytoplankton primary production, zooplankton-mediated fluxes of chemicals and materials, and trophic interactions in the sea. This study was conducted in order to investigate the biodiversity of zooplankton with special consideration on the small planktonic copepods to recognize their importance and roles in neritic marine environment of Lianga Bay. The result of the study will serve as baseline data of the small planktonic copepods in this particular area for future studies.

2.0 Research Methodology

Description of the Study Area

The study area is situated in between the Lianga Coastal Waters and Barobo Coastal Waters (Fig. 1).The Municipality of Lianga is situated in the central part of

[1]Department of Agriculture- Tagbina, Surigao del Sur

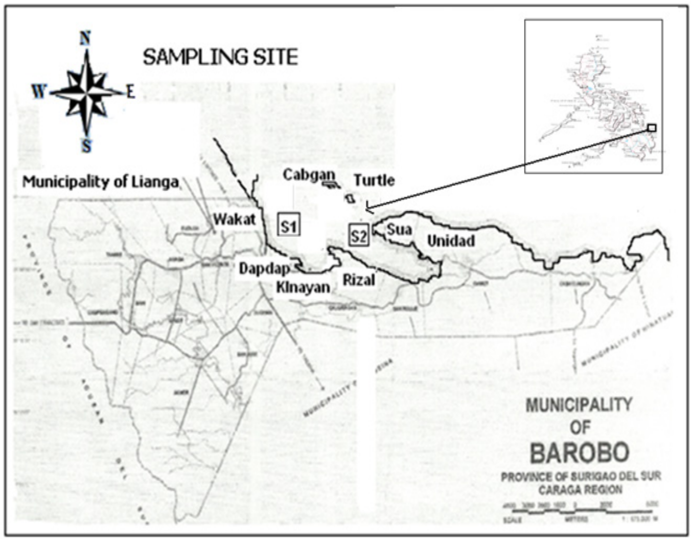


Figure 1. Map of Barobo Coastal Waters, Lianga Bay

Surigao del Sur with grid coordinates between $8^0$30’ N latitude and $126^0$35’E longitude. The municipality of San Agustin is in the northern part, on the south the municipality of Barobo, on the west the municipality of Prosperidad in Agusan del Sur and the east by the Pacific Ocean bounded by the municipality of Lianga (MPDO, Lianga).

The coastal waters of Barobo have an area of approximately 12,000 ha. along the coast of Lianga Bay with geographical grid coordinates of $8^0$33’ N Latitude and $126^0$08’E Longitude. It is bounded on the North by the Municipality of Lianga on the South by the municipalities of Hinatuan and Tagbina on the West by the Province of Agusan del Sur and on the East by the Pacific Ocean (MPDO, Barobo, Surigao del Sur).

Sampling Stations

Using a Global Positioning System (GPS), a total of two (2) stations were established in Lianga Bay. The two (2) sampling stations were located in the following grid coordinates; Station 1- $8^0$34’07.7”N Latitude and $126^0$07’14.3” E Longitude; and Station 2 was located in $8^0$33’08.3” N Latitude and $126^0$08’53.3” E Longitude. Station 1 was situated in Barobo Municipal Coastal Waters while Station 2 was within the Municipal Coastal Waters of Lianga.

Sampling Period

Sampling was conducted once a month for a period of three (3) months from May to July, 2009.

Determination of Physico-chemical Parameters

Temperature. Water temperature was determined in situ using a field thermometer. The thermometer was dipped for 15 seconds into the water sample that was collected from a depth of two (2) meters using the water sampler.

Water Transparency. Water transparency was determined using a Secchi disc painted alternately with black and white. The disc was lowered slowly into the water until the white portion could no longer be seen, and then the disc was raised slowly toward the surface until the disc reappeared. The depth of the water during the reappearance of the disc is the vertical visibility or water transparency.

Salinity. Water salinity was determined in situ using a refractometer (ATAGO).

Total Suspended Solids (TSS). The total suspended solids were measured using the gravitational filtration set-up. One-liter of water samples were filtered using the pre-weighed Whatman filter paper (#41). The filter paper was then oven dried at 100^0C for twenty-four (24) hours and again re-weighed. The weight difference of the filter paper before and after oven drying represents the total suspended solids expressed in mg/l.

pH. Determination of the pH of the water was done using a portable pH (Multiline F/SET-3) meter.

Dissolved Oxygen (DO). The dissolved oxygen was determined using the Winkler Titration Method as outlined by Grasshoff et al., (1993).

Nitrate. Nitrate was measured using the colorimetric method with sulfanilamide; nitrate (reduction method with cadmium).

Phosphorous. Dissolved reactive phosphorous was determined through colorimetric method based on the formation of molibdate.

Water Movement. Surface water movement (based on current speed and direction) was measured at three (3) hour interval from 0400 to 1600 hour during low and high tides using an improvised weighted current drogue made from heavy duty vinyl coated material (size: 48 inches; weight: 3 lbs.; stowed dimensions: 12”x6”x4”), which has enough buoyancy to float, but stays below the water surface out of the wind drag. The drifting detritus (seaweed, wood chips, etc.) in the water was examined to determine the direction of the flowing of the surface current. This direction was measured with the marine compass. A fixed length (5 meters) along the side of the boat was measured using meter stick, then the drogue was released and, the drogue’s rate of movement in centimeters/second was measured using stop watch. The measurement was the surface current velocity. The drogue was recovered with a dip net and the measurement was repeated four times.

Collection and Preservation of Zooplankton Samples

Zooplankton samples was collected using conical plankton net (length:0.45m; mouth diameter: 0.21 m; mesh size opening: 50 µm) with a flow meter (Rigosha and Co., Ltd No. 1687) attached to the center of the mouth of the net. The flowmeter, with a propeller that rotates with the flow of the water and records the number of revolutions was used to measure the quantity of water filtered by the net. Prior to zooplankton sampling, the flowmeter was first calibrated following the standard procedure described by Omori and Ikeda (1984). During the field collection, the plankton net, with the attached calibrated flowmeter, was lowered to a depth of 2m and then the net was hauled back to the surface. Zooplankton samples collected at the cod-end of the net was drained into a properly labeled polyethylene bottle. Four replicate samples were collected in each sampling station. Immediately after each zooplankton collection, the sample was fixed with buffered formalin. Preparation of the buffered formalin was done by adding 2g of borax (serves as a neutralizer) to 100 ml concentrated formalin at pH 7-8. Based on the volume of the gathered zooplankton sample, 5% buffered formalin was added.

Laboratory Analysis of Zooplankton Samples

Copepods encountered in the samples were identified to the nearest taxa using the guide illustrations of Yamaji (1982), Todd and Laverack (1991) and Boltovsky (1999). Prior to counting, the total volume of the zooplankton sample was measured and recorded. Then, the entire sample was placed in a large culture dish and larger zooplankton (visible to the naked eye), megaloplankton and micronekton were removed and transferred into another vial. For the abundance of the smaller zooplankton individuals, a 1-ml subsample was taken from the entire zooplankton sample using an improvised wide mouth pipette (1.0 ml). The subsample was placed into a sedgewick-rafter counting chamber cell (deep: 1 mm; length: 50 mm; width: 20 mm; area: 1000mm^2; volume: 1 ml) and was covered with a coverslip (no. 1 ½) in a manner where no bubbles could occur. Each zooplankton individuals (copepods) encountered in the entire counting chamber was identified and counted using a dissecting microscope (Carton TB-20). The counting was repeated several times until each major zooplankton representative reached 300 individuals. The abundance of each copepod individuals or groups was expressed as individuals per m^3 following ICES Zooplankton Methodology Manual (2000).

Statistical Analysis of Plankton Samples

ANOVA, Scheffe Comparison of the means, Shannon-Weaner Index, Margalef Index and Menhinick Index were utilized.

3.0 Results and Discussion

Environmental Variables of the Two Sampling Stations in Lianga Bay

The following physico-chemical factors were determined to evaluate the quality of the sampling areas: temperature, water transparency, salinity, total suspended solids, pH, water movement, dissolved oxygen, ammonia Nitrogen, Nitrate and Phosphorous concentrations.

Temperature. Environmental temperature was done by sampling from 7:00 am to 5:00 pm. Water temperature ranged from 26.75^{0}C to 30.0^{0}C from May to July in two stations (Fig. 2). Highest temperature was observed in Station 1 in the month of June and Station 2 in the month of July. The lowest was observed in station 2 during the month of May. There was a slight variability in monthly temperature in all sampling stations with significant differences occurring between May and June and between May and July while there was no observed difference occurred between stations.

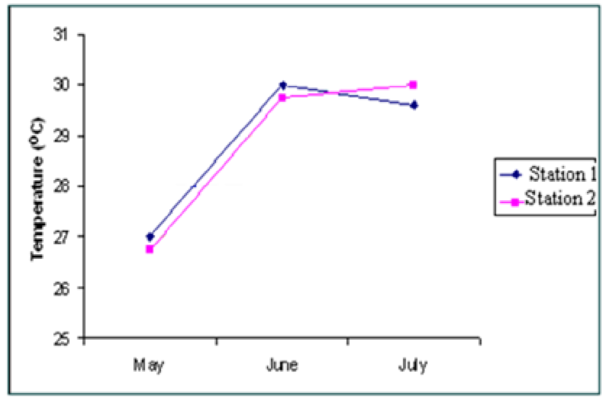


Figure 2. Fluctuation of temperatures in two sampling stations from May to July, 2009

Water Transparency. Transparency is basically affected by the amount of sediments found in the water. In this study, at what depth is the water transparent or clear was investigated among sampling stations within Lianga Bay. Generally, water transparency could be related to the amount of sunlight that penetrates through the water. This is affected by the degree of turbidity thus could be a limiting factor of photosynthesis (Umali and Cuvin, 1988). As shown in Fig. 3, during the month of May was observed to have the highest water transparency at 5 meters in Station 2. The lowest measure of water transparency was observed at 2 meters in stations 1 in the month of June. Generally, Station 2 has higher transparency throughout the sampling months.

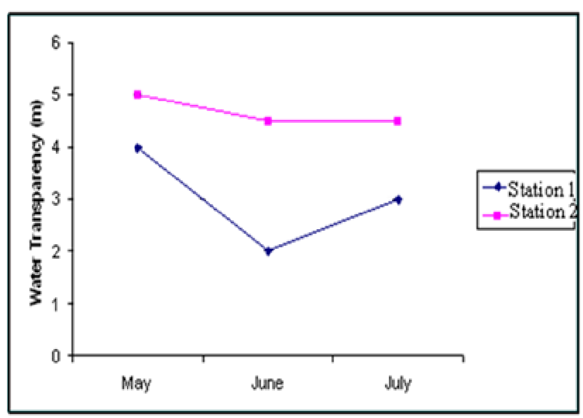


Figure 3. Fluctuation of temperatures in two sampling stations from May to July, 2009

Salinity. Salinity is the salt content of water and is greatly affected by temperature, the degree of evaporation and the amount of freshwater influx (Nybakken, 1997). Fig. 4 shows a fluctuating range of salinity ranging from 31.5 to 32.75 ppt for all the sampling months in two sampling stations. Significant monthly differences in salinity were observed between May and July in sampling stations 1 and between May and June in Station 2. Lowest salinity was observed in Stations 2 in the month of June. Highest salinity was in Station 1 during the month of May.

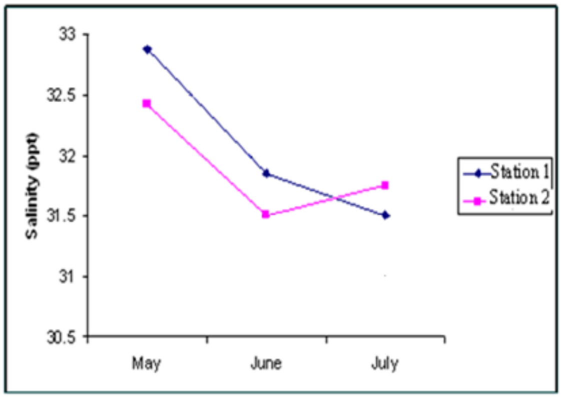


Figure 4. Fluctuation of Salinity in two sampling stations from the months of May to July, 2009

Total Suspended Solids. Turbidity (total suspended solids) varies periodically with the amount of sediment and the number of planktonic organisms in the water. Dawes (1981) suggested that the amount of suspended matter could significantly influence the quality and quantity of light that penetrates the water. As expected the greatest turbidity was observed during the rainy season as the sediment load of streams increased as a result of erosion from land. As a consequence, increased turbidity reduced light penetration and since the depth of the coastal water varied in water depth, photosynthesis could be restricted to the surface layers and this could reduce phytoplankton growth that could also affect the abundance and diversity of zooplankton (Zottoli, 1978). Graph on total suspended Solids (TSS) in two sampling stations from the months of May to July, 2009 is presented in fig. 5.

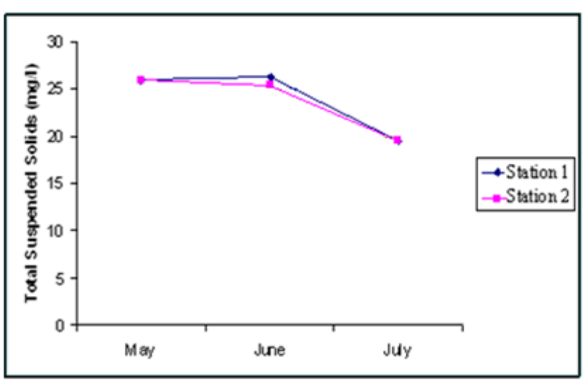


Figure 5. Fluctuation of total suspended solids (TSS) in two sampling stations from the months of May to July, 2009.

Total suspended solids observed ranged from 19.5mg/L to 26.25mg/L, with the highest value seen at 26.25mg/L in two sampling stations specifically during the months of May and June. The lowest value of 19.5 mg/L was observed in Stations 2 during the month of July. A low value that was observed was due to less siltation from the mountain as less rain occurred during the sampling period (Fig. 5). A high value was observed during the rainy months as a result of run-off from the mountains.

pH. pH is the amount of Hydrogen ions in the seawater. Seawater pH ranged from 7 to 8.01 and is slightly basic (Lalli and Parsons, 1993). Generally, pH of water only fluctuates at a narrow range, as it is largely regulated by the concentrations of bicarbonate and carbonate ions. Observed pH ranged from 8.15 to 8.3 (Fig. 6), a favorable condition for phytoplankton growth thus favors the abundance of zooplankton as grazers. There are no significant differences in monthly pH observed between stations and between months.

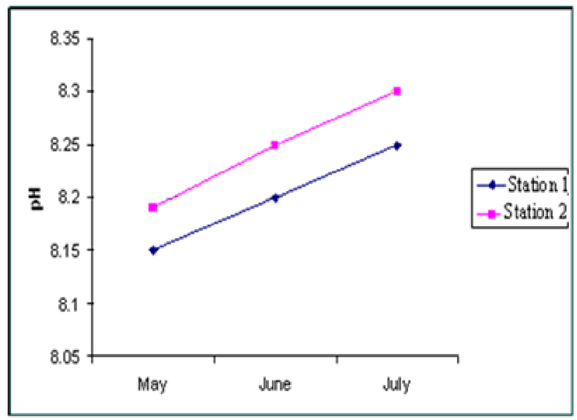


Figure 6. Fluctuation of pH in two sampling stations from the months of May to July, 2009.

Dissolved Oxygen. Dissolved oxygen (DO) is the amount of oxygen dissolved in water. Seawater holds less oxygen than freshwater and mean dissolved oxygen levels of seawater is 7.3 mg/liter at 20°C with dissolved oxygen levels increasing with depth (Nybakken, 1997). Fig. 7 shows the monthly fluctuating levels of dissolved oxygen from May to July in two stations.

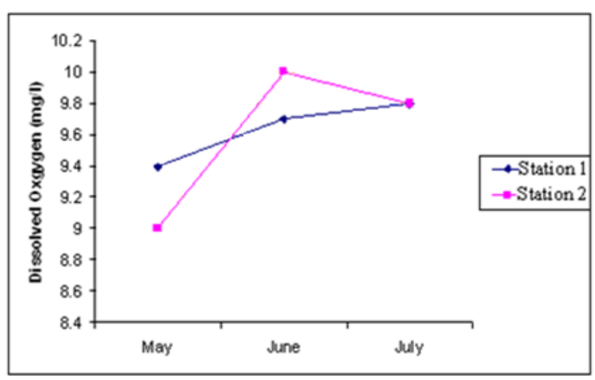


Figure 7. Fluctuation of dissolved oxygen (DO) in two sampling stations from the months of May to July, 2009.

It can be deduced from the graph that the highest level (10 mg/l) of DO was observed in the month of June in Station 2 and lowest DO level (9.00 mg/l) was observed in May in station 2. There is no significant monthly differences observed between stations, the values are favorable for the survival of the organisms in the marine ecosystem including copepods.

Nitrate. Nitrate is one of the important nutrients that encourage the growth of plankton, which serves as the base for the food chain throughout the marine waters. Fig. 8 shows the concentration of nitrate in four sampling stations where the highest reading (0.18mg/l) was observed in station 2 in the months May and July and in Station 1 in the months of June and July. The lowest concentration (0.16mg/l) was observed in station 2 during the month of June. However, there is no significant difference of the concentration between stations while there is a significant difference between sampling months.

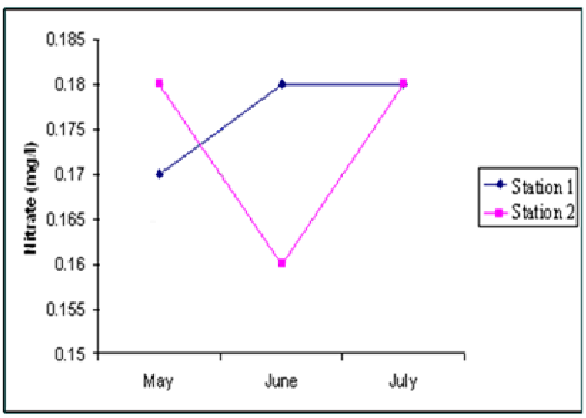


Figure 8. Fluctuation of pH in two sampling stations from the months of May to July, 2009

Phosphorous. Dissolved reactive phosphorous concentrations in four sampling station from the month of May to July were observed in terms of mg/l. The results showed the highest concentration of Phosphorous (0.41mg/l) was observed in Station 1 in the month of May. The lowest reading (0.35 mg/l) was observed in Station 2 in the months of June and July (Fig. 9).

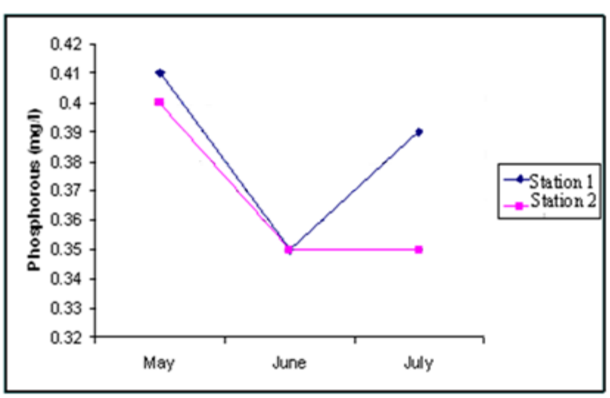


Figure 9. Fluctuation of dissolved oxygen (DO) in two sampling stations from the months of May to July, 2009.

Water Movement. Surface water movement (based on current speed and direction) plays a very significant role in copepod communities. The vertical circulation of open ocean water masses may be more important for marine life. In upwelling, deep ocean water rich in dissolved nutrients moves up the continental slope into coastal surface waters, aided by offshore wind patterns (Microsoft Encarta, 2008). The highest current speed of water (48.17 cm/s) was noticed during the month of July in Station 2, while the lowest current speed (1.87 cm/s) was observed in two stations in the month of May (Fig. 10). The directions of the water movement were varied due to the prevailing wind during the time of sampling.

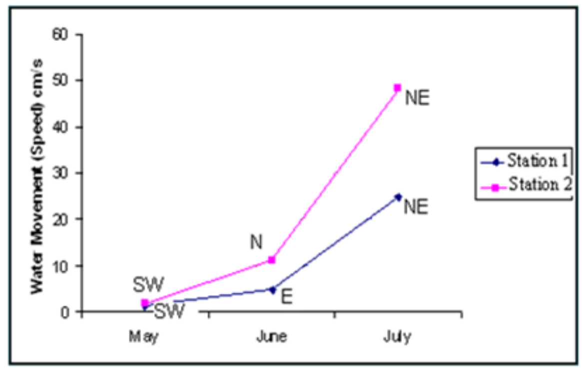


Figure 10. Fluctuation of water movement in two sampling stations from the months of May to July, 2009

Species Composition, Dominant Groups and Community Structure

A total of ninety five (95) copepod taxa belonging to forty one (41) genera, seventeen (17) families and four (4) orders were observed in the two (2) sampling stations in Lianga Bay from the months of May to July 2009. Among the ninety five taxa, there were fifteen (15) small planktonic copepods observed dominated by the genus *Oithona*. The copepod species were dominated by Paracalanidae with eighteen taxa under nine genera while the family with the highest abundance (20.5%) was *Calanidae*. Small copepods are important prey items for larval fish and other zooplanktivorous consumers but according to Uye (1994) anthropogenic activities such as coastal eutrophication may cause replacement of large copepods with small ones. Hence, this composition of small copepods in Lianga Bay could not be considered as indicator of coastal eutrophication due to its less abundance (14.64%) in the overall community structure of copepods in the area. List of copepod species composition and individual counts in three months sampling period is presented in table 1.

Species Diversity and Abundance

Diversity is a measure of the total number of species in a particular community in relation to its relative abundance. Species diversity has several components which may respond differently to differences in

Table 1. Copepod species composition and individual counts in three months sampling period

Copepod Species	Months May	June	July	Total
Order: CALANOIDA				
Family: AUGAPTILIDAE				
Haloptilus longicornis (Claus, 1863)	4	8	5	17
Labidocera japonica (Mori, 1935)	2	6	10	18
Family: ACARTIIDAE				
Acartia clausi (Giesbrecht, 1889)	11	18	11	40
Acartia longiremis (Lilljeborg, 1853)	8	5	1	14
Family: CALANIDAE				
Calanus cristatus (Kroyer, 1845)	29	30	30	89
Calanus finmarchicus (Gunner, 1765)	21	21	16	58
Calanus glacialis (Jaschnov, 1955)	20	23	25	68
Calanus minor (Claus, 1863)	19	19	22	60
Calanus plurnchrus (Marukawa, 1921)	27	23	23	73
Calanus sinicus (Brodsky, 1962)	37	38	38	113
Calanus tenuicornis (Dana, 1849)	8	6	11	25
Canthocalanus pauper (Giesbrecht, 1888)	8	14	10	32
Neocalanus gracilis (Dana, 1852)	5	16	11	32
Neocalanus robustior (Giesbrecht, 1888)	19	15	12	46
Undinula darwini (Lubbock, 1860)	24	23	25	72
Undinula gracilis	9	11	14	34
Undinula vulgaris (Dana, 1849)	2	7	6	15
Family: CANDACIIDAE				
Candacia bradyi (Scott, 1902)	13	14	8	35
Family: CLAUSOCALANIDAE				
Clausocalanus arcuicornis (Dana, 1849)	0	3	8	11
Clausocalanus furcatus (Brady, 1883)	5	9	13	27
Clausocalanus pergens (Farran, 1926)	3	6	14	23
Family: CENTROPAGIDAE				
Centropages abdominalis (Sato, 1913)	11	11	12	34
Centropages furcatus (Dana, 1849)	7	6	3	16
Centropages gracilis (Dana, 1849)	6	11	14	31
Sinocalanus tenellus (Kikuchi, 1928)	2	3	0	5
Family: EUCALANIDAE				
Eucalanus attenuatus (Dana, 1849)	11	12	11	34
Eucalanus bungii (Giesbrecht, 1893)	12	15	10	37
Eucalanus crassus (Giesbrecht, 1888)	12	22	14	48
Eucalanus elongatus (Dana, 1848)	15	17	18	50
Eucalanus mucronatus (Giesbrecht, 1883)	12	9	9	30
Eucalanus subcrassus (Giesbrecht, 1888)	13	7	2	22
Eucalanus subtenuis (Giesbrecht, 1888)	11	12	7	30
Rhincalanus cornutus (Dana, 1849)	6	8	9	23
Rhincalanus nasutus (Giesbrecht, 1888)	5	8	12	25
Eucalanidae copepodid	9	8	7	24
Family: EUCHAETIDAE				
Euchaeta concinna (Dana, 1849)	5	4	6	15
Euchaeta icalfendeni	4	6	6	16
Euchaeta longicornis (Giesbrecht, 1888)	3	7	12	22
Euchaeta marina (Prestandrea, 1833)	18	17	18	53
Euchaeta media (Giesbrecht, 1888)	21	18	22	61
Euchaeta plana (Mori, 1937)	5	5	0	10
Euchaeta wolfendeni (Scott A., 1909)	10	9	1	20

Copepod Species	Months May	June	July	Total
Euchaetidae copepodid	13	8	3	24
Undeuchaeta plumosa (Lubbock, 1856)	1	6	2	9
Family: METRIDINIDAE				
Metridia curticauda (Giesbrecht, 1889)	3	4	6	13
Metridia longa (Lubbock, 1854)	4	0	9	13
Pleuromamma gracilis (Claus, 1863)	7	11	9	13
Pleuromamma indica (Wolfenden, 1905)	12	8	9	29
Family: PARACALANIDAE				
Acrocalanus gibber (Giesbrecht, 1888)	7	9	7	23
Acrocalanus gracilis (Giesbrecht, 1888)	9	11	11	31
Acrocalanus longicornis (Giesbrecht, 1888)	6	7	9	22
Acrocalanus monachus (Giesbrecht, 1888)	13	11	16	40
Aetideus armatus (Boeck, 1872)	7	7	1	15
Aetideus giesbrechti (Cleve, 1904)	10	10	6	26
Ctenocalanus vanus (Giesbrecht, 1888)	3	5	6	14
Gaetanus armiger (Giesbrecht, 1888)	2	4	10	16
Paracalanus aculeatus (Giesbrecht, 1888)	14	12	15	41
Paracalanus parvus (Claus, 1863)	18	17	20	55
Pareuchaeta elongata (Esterly, 1913)	10	11	9	30
Pareuchaeta russilli	20	15	13	48
Pareuchaeta simplex (Tanaka, 1958)	15	12	11	38
Pseudocalanus gracilis (Sars G.O., 1903)	22	16	12	50
Pseudocalanus minutus (Krøyer, 1845)	15	15	12	42
Scaphocalanus echinatus (Farran, 1905)	2	12	9	23
Scaphocalanus helenae	2	1	7	10
Undinopsis bradyi (Sars G.O., 1903)	18	20	13	51
Family: PONTELLIDAE				
Pontella surrecta (Wilson, 1950)	20	14	14	48
Pontellina plumata (Dana, 1849)	18	11	12	41
Pontellopsis armata (Giesbrecht, 1889)	13	13	10	36
Pontellopsis tenuicauda (Giesbrecht, 1889)	2	10	8	20
Pontellidae copepodid	14	15	6	35
Family: SCOLECITRICHIDAE				
Scolecithricella abyssalis (Giesbrecht, 1888)	14	12	14	40
Scolecithricella bradyi (Giesbrecht, 1888)	2	10	9	21
Scolecithricella ctenopus (Giesbrecht, 1888)	2	5	8	15
Scolecithricella minor (Brady, 1883)	17	13	8	38
Scolecithrix danae (Lubbock, 1856)	2	4	7	13
Family: TEMORIDAE				
Eurytemora nauplius	32	30	38	100
Eurytemora pacifica (Sato, 1913)	26	24	18	68
Temora discaudata (Giesbrecht, 1889)	24	28	17	69
Temora turbinata (Dana, 1849)	22	16	23	61
Family: TORTANIDAE				
Tortanus discaudatus (Thompson I.C. & Scott A. In Herdman, Thompson & Scott, 1897	2	7	5	14
Order: CYCLOPOIDA				
Family: OITHONIDAE				
Oithona brevicornis (Giesbrecht, 1891)	9	7	14	30
Oithona fallax (Farran, 1913)	15	11	17	43
Oithona oculata (Farran, 1913)	21	22	15	58
Oithona plumifera (Baird, 1843)	5	12	11	28

Table 1(cont.) Copepod species composition and individual counts in three months sampling period

Copepod Species	Months			
	May	June	July	Total
Oithona rigida (Giesbrecht, 1896)	12	13	12	37
Oithona similis (Claus, 1866)	19	14	14	47
Oithona sp. (Nishida, 1985)	32	41	32	105
Oithona vivida (Farran, 1913)	24	19	14	57
Paracyclopina nana (Smirnov, 1935)	20	24	18	62
Paroithona pulla (Farran, 1913)	17	16	12	45
Order: HARPACTICOIDA				
Family: Euterpinidae				
Euterpina acutifrons (Dana, 1847)	5	9	12	26
Order: POECILOSTOMATOIDA				
Family: SAPPHIRINIDAE				
Sapphirina gastrica (Giesbrecht, 1891)	16	21	13	50
Sapphirina intestinata (Giesbrecht, 1891)	14	20	14	48
Sapphirina opalina (Dana, 1849)	15	16	14	45
Total	130	1219	1140	3489

geographical area and physical factors. One component is the species richness that is simply the number of species. A second major component is the evenness or the equitability value which is the apportionment of individuals among the species (Odum, 1980). Index of dominance is the inverse of evenness value, where a high value of evenness indicates a low value of dominance. The third component is the Shannon Weiner Index, a widely used index combining the variety and the evenness components as one overall index of diversity. These different indices of diversity were determined in the two stations from May to July.

Table 2. Species richness, Shannon's index, Margalef Index, Menhinick Index, Hill's numbers and evenness values of copepods in selected sampling stations

Indices	Station 1	Station 2
Taxa (S)	95	95
Individuals	1988	1510
Dominance (D)	0.01467	0.01405
Shannon (H)	4.368	4.398
Simpson (1-D)	0.9853	0.9859
Evenness (e^H/S)	0.8304	0.8555
Menhinick	2.131	2.445
Margalef	12.38	12.84
Equitability	0.9592	0.9657
Fisher alpha	20.78	22.51
Berger-Parker	0.0337	0.03311

Table 2 shows the different levels of the diversity of copepods in two sampling stations in Lianga Bay. It can be seen from the results that the two sampling stations has the same number of taxa observed. Based on the different indices of diversity, station 2 has higher diversity than station 1. These results revealed abundance of taxa is not directly correlated with high diversity.

Across all sampling months, the number of individuals is in the following order: May = June > July. Diversity based on Shannon index is in the following order: June> July> May. It can be observed from this rank order that diversity is also not correlated with both abundance of taxa and number of individuals (Table 3).

Table 3. Species richness, Shannon's index, Margalef Index, Menhinik Index, Hill's numbers and evenness values of copepods during the three sampling months

Indices	Sampling Months		
	May	June	July
Taxa (S)	94	94	93
Individuals	1139	1219	1140
Dominance (D)	0.01532	0.0141	0.01429
Shannon (H)	4.318	4.392	4.379
Simpson (1-D)	0.9847	0.9859	0.9857
Evenness (e^H/S)	0.7982	0.8594	0.8573
Menhinick	2.785	2.692	2.754
Margalef	13.21	13.09	13.07
Equitability	0.9504	0.9667	0.966
Fisher alpha	24.3	23.75	23.95
Berger-Parker	0.03248	0.03363	0.03333

The diversity indices of the copepods per month in two sampling stations. It reveals that during the month of May station 2 has higher number of taxa than station 1 but has with lower number of individuals compared to station 2. In the month of June, Station 2 has higher number of taxa than station 1 but lower also in number of individuals than the later. During the month of July, Station 2 has higher number of taxa compared to Station 1, while when it comes to the number of individuals, station 1 is higher than in Station 2. The result also of the comparison of abundance of copepods, fig. 11 shows that Station 1 has higher abundance compared to station 2. While during the monthly sampling, June has the highest abundance.

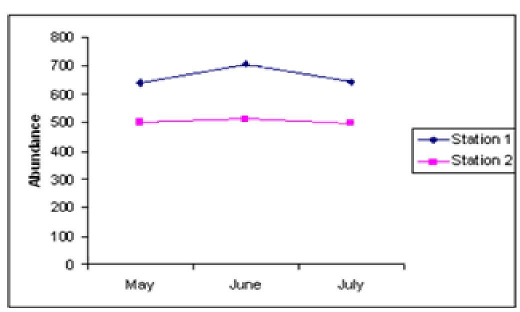
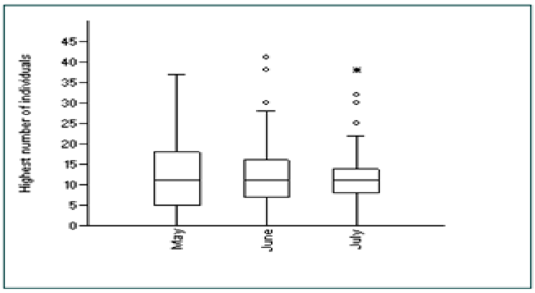
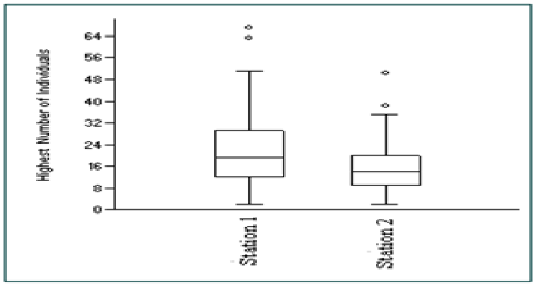


Figure 11. Abundance of copepods in two sampling stations from the months of May to July, 2009

The highest number of individuals counted for 95 taxa was during the month of June and the lowest in the month of May. Station 1 has higher count of individuals compared to station 2 (Figs. 11a and b).



(a)



(b)

Figure 11. Highest number of individuals counted (a) during sampling months and (b) in two sampling stations. Abundance of copepods in two sampling stations from the months of May to July, 2009

4.0 Conclusion

The dynamics of rapid (or massive) increase or decrease of plankton populations is an important subject in marine plankton ecology and have generally fascinated many plankton ecologists. Knowledge of what small copepods eat, though limited but it is clear that many higher-trophic level consumers eat them. Copepod nauplii, *Oithona* spp., and other small copepods are important prey of fish larvae, and other planktivores as shown in many studies. The results of this study that showed variations in abundance, number and diversity within sampling sites and between monthly sampling periods clearly indicates temporal and spatial changes in species composition of planktonic copepods. The physico-chemical properties like water temperature and salinity of the sampling sites were within the range and the similarities and variations in taxonomic compositions of the copepods. Potential causes may include variations in light, advection and turbulence, nutrients, production of resting stages, ectocrines, and predation, as well as water mass movement. Given these variables and their potential interactions as well as our paucity of information about critical parameters relating most of them to division rates of species, it is concluded that prediction of temporal changes in species assemblages of small planktonic copepods in the sampling areas is currently not possible.

References

Bell, R.T. (1990). An explanation for the variability in the conversion factor deriving bacterial cell production from incorporation of (^{3}H) thymidine. *Limnol. Oceanogr., 35 (4), 910-915.*

Grasshoff, T.C. Jr. (1993). *Methods of seawater analysis.* Germany: Springer Verlag. 48p.

Marshall, S.M. & Orr, A.P. (1966). Respiration and feeding in some small copepods. *Journal of the Marine Biological Association of the United Kingdom, 46 (3),513-530.* doi:10.1017/S0025315400033312.

Turner, J.T. (2004). The importance of small planktonic copepods and their roles in pelagic marine food webs. *Zoological Studies, 43(2), 255-266.*

Turner, J.T. & Roff, J.C. (1993). Trophic levels and trophospecies in marine plankton: lessons from the microbial food web. *Mar. Microb. Food Webs 7: 225-248.*

Umali, R.C. & Cuvin, M.A. (1988). *Limnology. Laboratory and Field Guide, Physico-Chemical Factors and Biological Factors.* National Book Store Philippines. 322pp.

Uye, S.I. (1991). Temperature-dependent development and growth of the planktonic copepod Paracalanus sp. in the laboratory. *Proc. 4th International Conference on Copepoda. Bull. Plankton Soc. Jpn. Spec., 627-636.*

Uye, S.I. (1994). Replacement of large copepods by small ones with eutrophication of embayments: cause and consequence. *Hydrobiologia 292/293: 513-519.*

Uye, S.I., Aoto, I. & Onbé, T. (2002). Seasonal population dynamics and production of Microsetella norvegica, a widely distributed but little-studied marine planktonic harpacticoid copepod. *J. Plankton Res. 24: 143-153.*

Uye, S.I. & Kasahara, S. (1983). Grazing of various developmental stages of *Pseudodiaptomus marinus* (Copepoda: Calanoida) on naturally occurring particles. *Bull. Plankton Soc. Jpn. 30: 147-158.*

Yamaji, I. 1982. *Illustration of the Marine Plankton of Japan*. Hoikusha Pulication Co., Ltd. 538p.

Microsoft Encarta, 2008.