AES BIOFLUX
Advances in Environmental Sciences -
International Journal of the Bioflux Society

Community structure of mesozooplankton in Casiguran waters, Aurora, Northern Philippines

[1]Maria L. D. G. Lacuna, [2]Eusebio V. Angara, [2]Gerardo S. Rillon, [3]Marvelisa L. Carmona, [3]Joer E. M. Ferreras, [3]Myra I. Vallejo, [1]Christar R. Merano

[1] Mindanao State University - Iligan Institute of Technology, Andres Bonifacio Avenue, Iligan City 9200, Philippines; [2] Aurora State College of Technology, Zabali Campus, Aurora Province, Philippines; [3] Aurora State College of Technology - Aurora Marine Research and Development Institute, Zabali Campus, Aurora Province, Philippines. Corresponding author: M. L. D. G. Lacuna, mileskung@yahoo.com

Abstract. Diversity, composition and abundance of mesozooplankton and their relation with the physico-chemical parameters of the waters during low and high tides in Casiguran waters, Aurora, Northern Philippines were compared. A total of 105 species belonging to 10 major groups were identified. Copepoda constituted the major bulk of the mesozooplankton community with *Corycaeus andrewsii*, *C. affinis*, *Oithona similis*, *Clausocalanus arcuicornis*, *Acrocalanus gracilis*, *Centropages furcatus* and *Canthocalanus pauper* being the most abundant and widely distributed copepods in the said area during the two tidal phases. Using several diversity indices, high diversity in the mesozooplankton taxa was observed, but no differences were seen between the sampling stations and between the two tidal phases. Likewise, the results of NPMANOVA revealed no significant differences ($p > 0.05$) in mesozooplankton relative abundance between and within sampling stations between and during low and high tides. The results may imply that the level of mesozooplankton diversity and abundance did not fluctuate with changes in the tide levels and that mesozooplankton taxa were thus uniformly distributed in the waters of Casiguran Sound and Bay. Results of Canonical Correspondence Analysis revealed pH, dissolved oxygen and water temperature in influencing the mesozooplankton composition and abundance; however other factors (i.e. diverse feeding habits, vertical migration, predators) may also be important in shaping the community structure of mesozooplankton. Considering the importance of copepods as major component of the marine zooplankton and its function in marine food webs, the present records are therefore crucial in understanding the dynamics of marine ecosystems and are necessary for purposes of management and conservation of marine resources.
Key Words: tropical copepods, community structure, tidal phases, Northern Philippines.

Introduction. Zooplankton encompass an array of macro and microscopic animals and comprise representatives of almost every taxon of the animal kingdom. They occur as holoplankton, which are organisms that exist as plankton in their whole lifetime, and the meroplankton, comprising of eggs and larvae that exists as plankton for some time until they grow and reach their adult stage (Goswami 2004). Among these varied groups of zooplankton, copepods are the most common and numerically important group in the coastal, open neritic and oceanic environments (Huys & Boxshall 1991; Hwang et al 2000, 2003) since they occupy an integral part of the marine food web both as predator and prey. Their abundance and distribution have been reported to be influenced by hydrographic conditions (Hsieh et al 2004; Lan et al 2009; Shih & Chiu 1998; Boucher et al 1987) because of their sensitivity to water mass properties thus making them good indicators of various water masses (Hwang et al 2006, 2007). Moreover, copepods are also considered best biomarkers for trace metals in monitoring marine ecosystems (Hsiao et al 2006). Several studies focusing on copepod composition, abundance, distribution in relation to physical and chemical factors of the water have been investigated comprehensively in some Asian countries like Taiwan (Tseng et al 2013; Hsiao et al 2011; Ka & Hwang 2011; Hwang et al 2010; Tseng et al 2008; Dur et al 2007; Hwang et al 2007; Lee et al 2006; Lo et al 2004; Hsieh et al 2004; Hsieh & Chiu 2002), Japan (Takahashi & Hirakawa 2001; Noda et al 1998), Korea (Kang & Hong 1995), Malaysia (Johan et al 2013; Yoshida et al 2006), Thailand (Maiphae & Sa-ardrit 2011; Jitchum & Wongrat 2009) and some parts in the Philippines (Angara et al 2013a; Uy et al 2006; Relox et al 1998), but such study was quite limited or poorly represented in Casiguran waters, Aurora, Northern Philippines. To address this issue, this study was carried out during the two tidal phases in order to investigate (1) the composition, diversity and abundance of mesozooplankton, (2) to measure the physico-chemical condition of the water and then (3) correlate the physico-chemical parameters of the water to the mesozooplankton diversity and abundance. By doing this, any future effects in diversity, whether due to natural, climate or human-induced changes, can be recognized so that proper policy and management decisions be formulated.

Material and Method. The Casiguran waters, namely Casiguran Sound and Bay, in Aurora Province is nearly enclosed by the Sierra Madre mountain range and the 12,000-hectare San Ildefonso Peninsula where it provides protection from the typhoons that seasonally ravage most of the province. The Sound and Bay stretches to around a kilometer-wide where it connects itself to the sea. Due to its natural protective spot, the bay area of Casiguran was selected as the country's future first economic zone (or Ecozone and later on as APECO) in the Pacific Coast. The Ecozone or APECO is a custom designed seaport and airport driven economic center which seeks to promote tourism and rake in investments in aquamarine, agro-industrial, commercial trading, banking, outsourcing and financial industries. It aims to boost social, economic and industrial developments in Aurora and nearby provinces by generating jobs for the people, improving the quality of their living conditions, advocating an eco-friendly approach to industrialization and enhancing the potential of the community in productivity (http://www.edangara.com/apeco/). A total of thirteen sampling stations were positioned in the waters of Casiguran (Figure 1) using a GPS (GPS map 76S, Garmin). Description of these stations as well as the method of in situ measurements and collection of hydrological data and laboratory analyses employed in the present study were patterned from those of Angara et al (2013a, b). Stations 1-7 were strategically established in Casiguran Sound while, stations 8-13 at Casiguran Bay. The areas have typical semidiurnal tides with high and low waters in a lunar day of 24 hours. All hydrographic data and zooplankton samples were collected in each of these stations at high and low tides during spring tide in July 23-25, 2012. Hydrographic data, namely surface water temperature, pH, salinity, and dissolved oxygen, were measured "in situ" using the Oxical DO meter while salinity was estimated with the aid of a handheld refractometer (Atago, Japan). For total suspended solids, the gravitational filtration method was adopted. Zooplankton samples were collected in each of the 5 stations by vertical tows using a conical plankton net (length: 1.8 m; mouth diameter: 0.45 m; mesh size opening: 300 µm) from 50 m depth to the surface. A flowmeter (Rigosha and Co., Ltd No 1687) was attached to the center of the net opening to measure the quantity of the water filtered. The zooplankton samples were immediately transferred into a properly labeled polyethylene bottles and preserved in 5% buffered formalin-seawater solution. Triplicate samples were collected in each sampling station. Since the plankton samples collected were not dense/rich with zooplankton, no splitting was done, instead the whole samples were used for counting. Using a Sedgewick-Rafter counting chamber cell, the zooplankton and copepods were counted until it reaches at least 300 individuals. Abundance of each zooplankton and copepod taxa was expressed as density (individuals m^{-3}) and relative abundance. The zooplankton and copepod individuals were sorted and identified to the nearest taxa possible using the standard works of Kasturirangan (1963), Owre & Foyo (1967), Yamaji (1962), Todd & Laverack (1991), Bradford-Grieve (1999), Mulyadi (2004) and Al-Yamani et al (2011).

Diversity indices were computed using Shannon-Weaner Index, Margalef Index and Menhinick index. Cluster analysis was used to deternine the major groupings of zooplantkon present between the five sampling stations between high and low tides. Canonical Correspondence Analysis (CCA) was employed to determine the physico-chemical parameters that influenced the relative abundance of zooplankton during high and low tides. Non-Parametric Multivariate Analyses of Variance (NPMANOVA) was used to determine the differences in zooplankton relative abundance between sites, within sites and between two tidal cycles. All statistical analyses were done using the software PAST version 2.17 (http://folk.uio.no/ohammer/past/) (Hammer et al 2001).

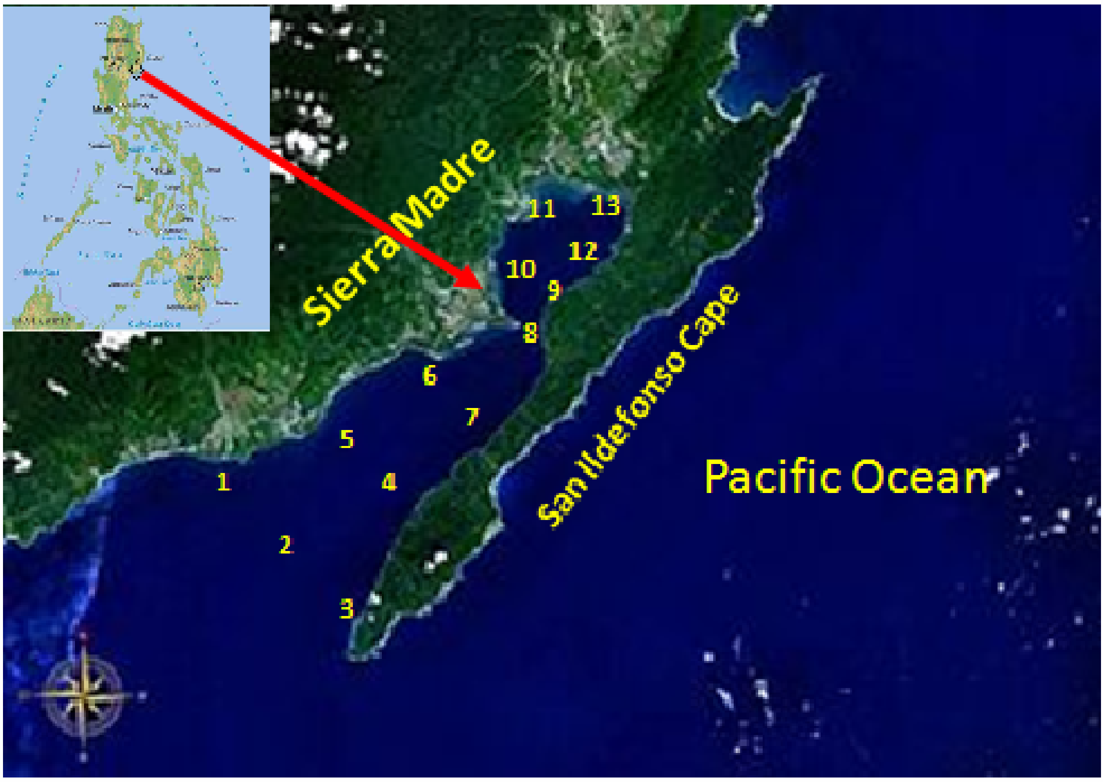

Figure 1. Geographical location of the thirteen sampling stations where zooplankton samples were collected. Inset is Casiguran enclosed in a diamond (http://en.wikipedia.org/wiki/San_Ildefonso_Peninsula).

Results and Discussion. A total of 105 zooplankton taxa belonging to 10 major groups (Protozoa, Cnidarian, Ctenophora, Annelida, Chaetognatha, Protochordata, Arthropoda, Mollusca, Echinodermata and Chordata) were identified in the waters of Casiguran, Aurora (Table 1), with more species occurring during high tide (101) when compared to low tide (98). Of those, 50 species belong to Copepoda (33 from Calanoida, 4 from Cyclopoida, 10 from Poecilostomatoida, and 3 from Harpacticoida); 4 species to Chaetognatha, Cnidaria (Siphonophore) and Protochordata; 3 species to Branchiopoda and Ostracoda; 2 species to Protozoa; 1 species to Mollusca and Decapoda; 1 representative from Ctenophora, Amphipoda, Mysidacea, and Euphausiacea; 26 larval forms and 2 Ichthyoplankters. Majority of these identified species were noted in Casiguran Sound (stations 1-7), with 82 and 90 species for low and high tides, respectively. Out of the 10 major groups, the Arthropoda, particularly crustaceans, were the major components of the zooplankton community in all sampling stations during high and low tides and comprises more than 60% of the total zooplankton population. However, the remaining 10 groups (Protozoa, Cnidarian, Ctenophora, Annelida, Chaetognatha, Protochordata, Mollusca, Echinodermata and Chordata) were low in numbers (<35%) (Figure 2). The importance of crustacean zooplankters in terms of forming the bulk of abundance in the mesozooplankton community was also strongly emphasized and reported in other bodies of coastal, neritic and oceanic waters (Angara et al 2013a; Tseng et al 2012, 2013; Jagadeesan et al 2013; Ka & Hwang 2011; Ogbeibu & Oribhabor 2011; Fernandes & Ramaiah 2009; Etile et al 2009; Robin et al 2009; Onyema & Ojo 2008; Yoshida et al 2006; Webber et al 2005; Uy et al 2006; Irigoien et al 2002; Relox et al 2000; Noda et al 1998; Osore et al 1997; Champalbert 1996; Wiafe &

Frid 1996). Crustacean zooplankters are the key organisms in aquatic ecosystems because they represent an important link in the marine food webs. They transport materials and energy from the primary production of phytoplankton to higher level of consumers, i.e. many fish species in the oceans (Uye 2011; Irigoien et al 2002; Kiorbe 1997). Of these arthropods (Figure 3), the copepods were the most dominant and abundant constituents in both high and low tides, accounting to more than 60% of the total arthropoda population, whereas the rest of the arthropod members attained less than 40% only. As to the copepod-groups, Calanoida was the most species-rich (33) representing >58% of the total copepod abundance on average for all stations in Casiguran Sound and Bay during the 2 tidal cycles. This is followed in order by Poecilostomatoida (10) which represents more than 15%, Cyclopoida (4) accounted to more than 9% and Harpacticoida (3), being the least abundant, was less than 1%. Similarly, looking at the relative abundances of these major copepod groups in each of the sampling stations during the 2 tidal phases (Figures 4 a-b), Calanoida still predominated. The dominance of Copepoda, in particular the calanoids, in constituting the major bulk of abundance in the community is in agreement with earlier reports (Angara et al 2013a; Tseng et al 2012, 2013; Jagadeesan et al 2013; Johan et al 2013; Chou et al 2012; Ka & Hwang 2011; Maiphae & Sa-ardat 2011; Hsiao et al 2011; Chen et al 2010; Jitchum & Wongrat 2009; Tseng et al 2008, 2009; Hwang et al 2007; Dur et al 2007; Lee et al 2006; Rezai et al 2004; Lo et al 2004; Hsieh et al 2004; Uy et al 2006; Hsieh & Chiu 2002) who demonstrated calanoid copepods to be the most dominant contributors in the zooplankton community. Mauchline (1998) added that calanoid species are numerous from 0-100 m depth layer in oceanic waters and are even the most abundant taxa in waters shallower than 100 m in coastal, neritic and oceanic waters (Angara et al 2013a; Tseng et al 2013; Yoshida et al 2006; Irigoien et al 2002). It has been reported that planktonic copepods were considered to be the most abundant group of zooplankton in the pelagic environments of the ocean (Schminke 2007; Lopes et al 2007; Miyashita et al 2009), that is, contributing more than 80% of the plankton assemblage. The reasons for their dominance are attributed to the uniqueness and inherent characteristics of their framework, functions, abilities and rapid life cycle (Schminke 2007). Due to this, their important position in the food web cannot be overlooked since they are considered as source of food of most fishery resources (Mahjoub et al 2011; Dahms & Hwang 2007). Despite the dominance of calanoids in terms of relative abundance and species richness, other dominant copepod species always included some cyclopoids (*Oithona similis* and *O. setigera*) and poecilostomatoids (*Corycaeus affinis, C. andrewsi*). Moreover, the following were the most common and abundant species among the copepod population in terms of the numerical abundances or densities in the waters of Casiguran, namely Casiguran Sound and Bay, during the two tidal phases: in Casiguran Sound, *C. andrewsi* (184 ind m^{-3}), *Clausocalanus arcuicornis* (132.8 ind m^{-3}), *C. affinis* (106.6 ind m^{-3}), *Acrocalanus gracilis* (102.3 ind m^{-3}), *Canthocalanus pauper* (88.9 ind m^{-3}) and *O. similis* (88.3 ind m^{-3}) dominated during low tide, while the appearance of *A. gracilis* (87.35 ind m^{-3}), *Canthocalanus pauper* (71.27 ind m^{-3}), *O. similis* (69.83 ind m^{-3}), *Centropages furcatus* (62.09 ind m^{-3}), *C. andrewsi* (58.86 ind m^{-3}), *C. arcuicornis* (56.14 ind m^{-3}), *C. affinis* (56.02 ind m^{-3}) were prevalent during high tide. In the waters of Casiguran Bay, low tide were observed to be dominated by *C. furcatus* (2393.94 ind m^{-3}), *C. arcuicornis* (794.12 ind m^{-3}), *C. andrewsi* (553.61 ind m^{-3}), *C. affinis* (519.08 ind m^{-3}), *O. similis* (437.48 ind m^{-3}), *O. setigera* (355.03 ind m^{-3}), *Paracalanus parvus* (324.48 ind m^{-3}), *C. pauper* (257.69 ind m^{-3}) and *A. gracilis* (242.59 ind m^{-3}) while high tide was dominated by *C. furcatus* (1277.98 ind m^{-3}), *O. similis* (274.04 ind m^{-3}), *P. parvus* (267.09 ind m^{-3}), *C. arcuicornis* (200.27 ind m^{-3}), *C. affinis* (183.02 ind m^{-3}), *C. andrewsii* (139.64 ind m^{-3}), *O. setigera* (125.51 ind m^{-3}), *C. pauper* (94.85 ind m^{-3}) and *A. gracilis* (87.08 ind m^{-3}). Basically, these species were also present in all thirteen sampling stations during the 2 tidal phases (Table 1, as noted by a black asterisk) except for *P. parvus* and *O. setigera* which were more prevalent and numerous in sampling stations (8-13) in Casiguran Bay (Table 1, as noted by a red asterisk). The reasons for these species' high abundance and frequent occurrence is due to their wide distribution around the worlds' oceans since they are quite thermophilic (that is they are found in tropical and subtropical waters) and euryhaline (can tolerate wide ranges in salinity differences) in nature and have diverse feeding habits (being herbivores, omnivores and carnivores). For instance among poecilostomatoids, *C. andrewsi* was reported to be an indicator of warm-water species, being dominant in Asian waters (Kang et al 1990), particularly in the open sea (Angara et al 2013a; Maiphae & Sa-ardrit 2011) as well as in the neritic areas (Noda et al 1998). Moreover, *C. affinis* was noted to be predominant particularly in coastal (Chen et al 1974; Chen & Zhang 1965) and neritic waters (Noda et al 1998), while the cyclopoid, *O. similis*, was documented to be common in the coastal waters (Maiphae & Sa-ardrit 2011; Hsieh et al 2004; Chen et al 1974; Chen & Zhang 1965), in the open sea, offshore waters (Angara et al 2013a; Maiphae & Sa-ardrit 2011) and even cosmopolitan in the epipelagic waters being euryhaline and eurythermal in nature (Nishida 1985). In addition, the mode of nutrition of this specific cyclopoid is omnivory, that is they consumed different food sources such as phytoplankton, copepod nauplius, ciliates and heterotrophic dinoflagellates (Nakamura & Turner 1997). These wide choices of food could have contributed to the species' successful dominance and survival in the marine waters. Looking at the other copepod group such as the calanoids, the numerical dominance of *C. arcuicornis* may have been attributed to the organisms' wide occurrence in the waters of the coasts (Ka & Hwang 2011; Maiphae & Sa-ardrit 2011), the neritic zone (Campaner 1985), open ocean (Angara et al 2013a; Noda et al 1998), epipelagic zone in the temperate and tropical areas (Lee et al 2006; Chihara & Murano 1998; Frost & Fleminger 1968) having been reported as warm-water indicator species in Asian waters (Hwang et al 2007). On the other hand, *A. gracilis* was noted as warm-water indicator species (Hwang et al 2007; Dur et al 2007; Takahashi & Hirakawa 2001) being high in abundance in inshore waters (Lo et al 2004) as well as in the ocean zone (Angara et al 2013a; Noda et al 1998) and tend to decline in numbers from subtropical to temperate waters (Lo et al 2004). Other dominant calanoids such as *C. furcatus* was reported to commonly occur in coastal, epipelagic zones (Davies & Slotwinski 2012; Achuthankutty et al 1995) and estuaries (Achuthankutty et al 1995 available at http://copepodes.obs-banyuls.fr/en) being able to thrived in waters with salinity that ranges from 27-35 ppt (Achuthankutty et al 1995). Moreover, *C. pauper* was documented to dominate along the coasts of Taiwan (Ka & Hwang 2011), in the inner Gulf of Thailand (Suvavepun & Suwanrumpha 1968) and even in oceanic zone (Noda et al 1998). The much smaller calanoid copepod, *P. parvus*, tend to be cosmopolitan in distribution (Montu & Goleden 1998), being common in warm and temperate waters (Takahasi & Hirakawa 2001; Chen et al 1974; Chen & Zhang 1965); having variable ecological affinities to temperature (thermophilic) and salinity (euryhaline); and being widely recorded in the coastal, neritic and oceanic waters (Angara et al 2013a; Maiphae & Sa-ardat 2011; Vukanic 2010; Peterson et al 2002; Noda et al 1998; Stephen 1984; Chen & Zhang 1974; Chen et al 1965); and able to shift from being herbivorous to omnivorous (Hafferssas & Seridiji 2010) and opportunistic species (Legendre & Legendre 1984). Peterson et al (2002) reported that *P. parvus* is a subtropical neritic species, which is generally found in association with coastal warm-water species.

Table 1

Composition and species richness of zooplankton in Casiguran Sound (CS) and Casiguran Bay (CB) where the thirteen sampling stations were positioned during high and low tides in San Ildefonso Cape, Casiguran, Aurora, Philippines

Zooplankton Taxa	*Low Tide*		*High Tide*	
	CS	*CB*	*CS*	*CB*
HOLOPLANKTON				
Protozoa				
Globigerina	+	+	+	+
Acantharia	+	+	+	+
Cnidaria				
Siphonophora				
Muggiea	+	+	+	+

Diphyes	+	+	+	+
Lensia	-	-	+	-
Chelophyes	+	-	+	-
Ctenophora	+	+	+	+
Mollusca				
Creseis	+	+	+	+
Arthropoda				
Branchiopoda				
Evadne	+	+	+	+
Penelia	-	+	-	+
Lingula	+	+	+	+
Ostracoda				
Macrocypridinia	+	-	+	-
Cypridinia	+	+	+	+
Conchoecia	+	+	+	+
Copepoda				
Calanoida				
Canthocalanus pauper *	+	+	+	+
Undinula vulgaris	+	+	+	+
Eucalanus attenuatus	+	-	+	-
Eucalanus subtenuis	+	+	+	+
Eucalanus elongatus	+	-	+	-
Eucalanus crassus	+	-	+	-
Subeucalanus crassus	+	+	+	+
Euchaeta longicornis	-	-	+	-
Euchaeta plana	+	-	+	-
Sinocalanus sp.	-	+	+	+
Mycenocera clausi	+	-	+	-
Metridia lucens	+	-	+	-
Lucicutia flavicornis	+	-	+	-
Acrocalanus gracilis *	+	+	+	+
Paracalanus aculeatus	+	-	+	-
Paracalanus parvus *	+	+	+	+
Clausocalanus arcuicornis *	+	+	+	+
Clausocalanus furcatus	+	-	+	-
Scolecithrix danae	+	-	+	-
Calocalanus pavo *	+	+	+	+
Centropages furcatus *	+	+	+	+
Centropages abdominalis	-	-	+	-
Temora stylifera	-	+	-	+
Temora discaudata	+	+	+	+
Candacia sp.	-	+	-	+
Candacia catula	+	+	+	+
Candacia discaudata	-	+	-	+
Calanopia elliptica	+	+	+	+
Labidocera detruncata	+	+	+	+
Acartia negligens	+	+	+	+
Acartia erythrea	+	+	+	+
Acartia pacifica	+	-	+	-
Pontellina plumata	-	+	+	+
Cyclopoida				
Oithona similis *	+	+	+	+
Oithona rigida	+	+	+	+
Oithona setigera *	-	+	+	+
Oithona plumifera	+	-	+	-
Poecilostomatoida				
Oncaea venusta	+	+	+	+
Oncaea media	+	-	+	-
Sapphirina angusta	-	-	+	-
Sapphirina intestinata	+	-	+	+

Sapphirina stellata	-	-	+	-
Copilia sp.	-	+	+	+
Copilia mirabilis	+	-	+	-
*Corycaeus affinis**	+	+	+	+
*Corycaeus andrewsi**	+	+	+	+
Corycaeus sp.	-	+	-	+
Harpacticoida				
Microsetella rosea	+	+	-	-
Macrosetella gracilis	+	-	-	-
Clytemnestra rostrata	+	-	-	-
Mysidacea	+	+	+	-
Amphipoda	+	-	+	-
Euphausiacea	+	-	+	-
Decapoda				
Lucifer	+	+	+	+
Chaetognatha				
Sagitta sp.	-	+	-	+
Sagitta crassa	+	+	+	+
Sagitta maxima	+	+	+	+
Sagitta macrocephala	+	+	+	+
Protochordata				
Oikopleura	+	+	+	+
Fritillaria	+	+	+	+
Doliolium	+	+	+	-
Salp	+	+	-	+
MEROPLANKTON/ Larval Forms				
Echinodermata				
Ophiopluteus	+	+	+	+
Echinopluteus	+	+	+	+
Seastar juvenile	-	+	-	+
Bipinnaria	-	+	+	+
Cnidaria				
Hydromedusae	-	+	+	+
Anthomedusae	+	-	+	-
Trachymedusae	+	+	+	+
Leptomedusae	+	-	+	-
Medusae Aegina	+	-	-	-
Mollusca				
Gastropod juvenile	+	+	+	+
Lamellibranch larvae	+	+	+	+
Octopus larvae	-	-	-	+
Chordata				
Fish egg	+	+	+	+
Fish larva	+	+	+	+
Arthropoda				
Decapoda				
Mysis	+	+	+	+
Crab zoea	+	+	+	+
Megalopa	+	-	+	-
Caridean shrimp larvae	+	+	+	+
Gennadas	+	-	+	-
Danaeidea	-	-	+	-
Stomatopoda				
Squilla larvae	+	+	+	+
Copepoda				
Copepod egg	+	+	+	+
Nauplius	+	+	+	+
Cirripedia				
Barnacle larvae	+	+	+	+
Barnacle juvenile	+	-	+	-

Euphausiacea				
Euphausid larvae	+	+	+	+
Annelida				
Polychaete larvae	+	-	+	+
Bryozoa				
Cyphonaute larvae	-	+	-	+
Total number of species	**83**	**69**	**90**	**69**
Grand Total number of species	**98 (LT)**		**101 (HT)**	

CS - Casiguran Sound where stations 1-7 were located; CB - Casiguran Bay where stations 8-13 were established; ***** present in all thirteen sampling stations during the 2 tidal phases; ***** numerous in sampling stations 8-13; LT - Low Tide; HT - High tide.

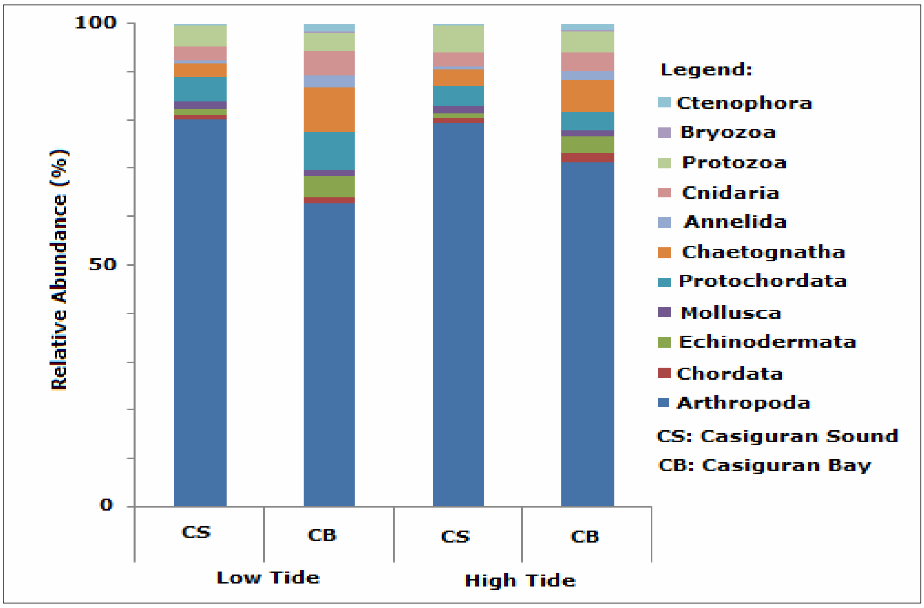

Figure 2. Relative abundance (%) of the members of arthropoda in each sampling stations during low tide and high tide in Casiguran waters, Aurora, Northern Philippines.

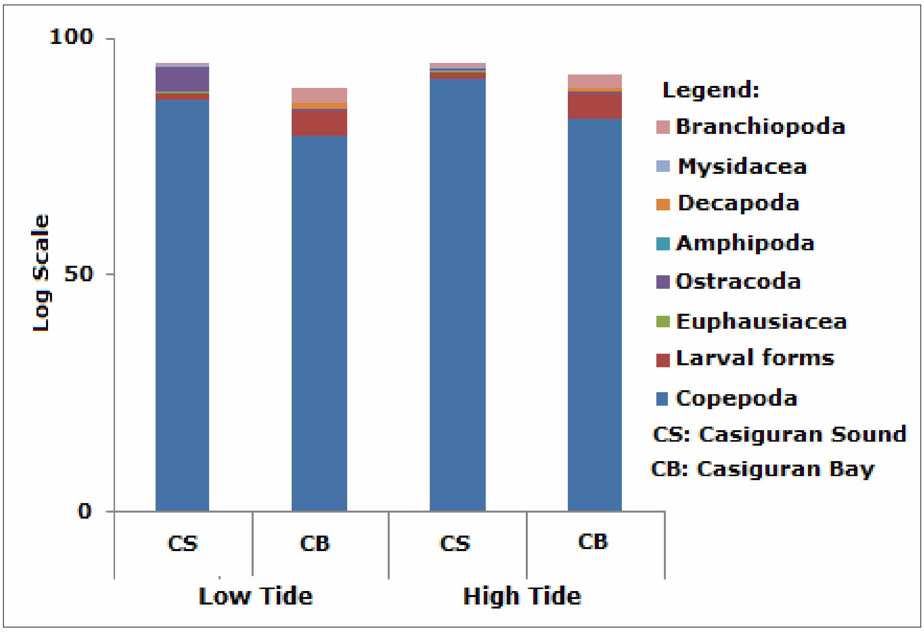

Figure 3. Relative abundance (Log Scale) of the members of arthropoda in each sampling stations during low tide and high tide in Casiguran waters, Aurora, Northern Philippines.

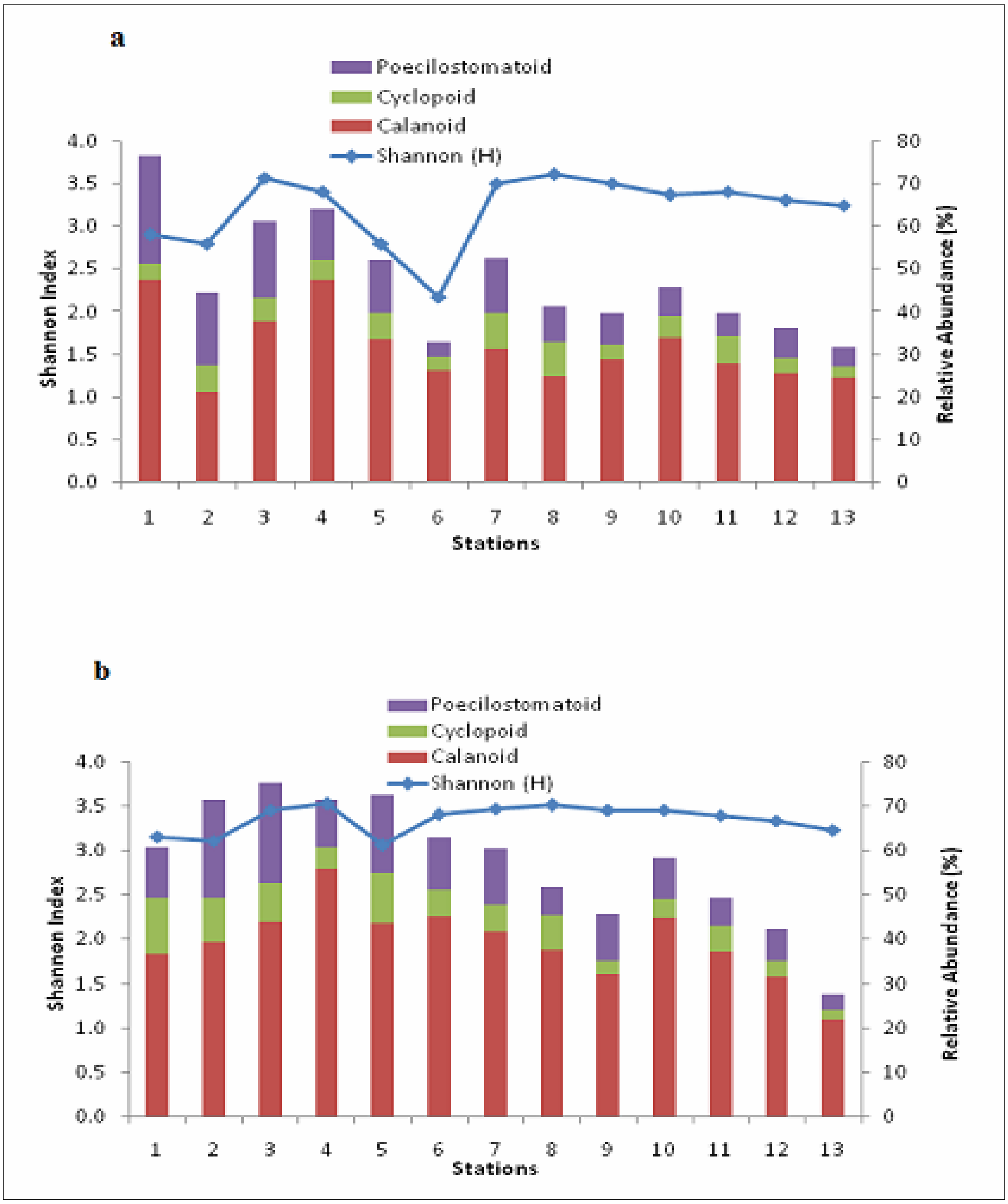

Figure 4. Relative abundance and diversity profile of copepod-groups in each sampling station during (a) high tide and (b) low tide in Casiguran Sound and Bay, Aurora, Northern Philippines.

To compare the numerical abundances or densities of individual copepod species among the thirteen sampling stations during and between high and low tides, NPMANOVA (Non-Parametric Multivariate Analysis of Variance) did not show any significant differences ($p > 0.05$). This would imply that the distribution of copepods did not vary all throughout the thirteen sampling stations during the 2 tidal phases as reflected in Figure 5.

The water quality parameters assessed in the thirteen sampling sites have shown variations (Figures 6a-c). For instance, the mean water temperature during high tide was highest in station 10 and lowest in station 9 with mean values of 29.47°C and 26.10°C, respectively (Figure 6a). During low tide, the mean water temperature was high in station 9 and low in station 1 with mean values of 29.67°C and 28.7°C, respectively. Variations in the surface water temperatures among the stations were due to differences in light intensity since temperatures were measured at different times of the day. During high tide, surface water temperatures were taken around 12:05-12:39 and 12:39-12:57 noon in stations 9 and 10, respectively. During low tide, these were measured late in the afternoon (4:28-4:42 PM in station 9 and 6:00-6:14 PM in station 1). For salinity values, high tide values were high in stations 1, 2, 3, 4, 5, 6, 7, 9, 10, 11 (35 ppt) but lowest in station 13 (30 ppt) (Figure 6a). During low tide, salinity was highest in stations 1, 2, 3, 4, 5, 8, 9, 10, 11 at 35 ppt and lowest in station 13 at 30 ppt. Low salinity values in station 13 might be attributed to inflow of freshwater from the four rivers present near the station resulting to dilution of the waters. High values in salinity are expected in most of the stations that are located furthest from the inner bay due to the influence and mixing of more saline waters of the Pacific Ocean. High alkaline pH range values (8.88-9.36) have been recorded in all stations for both high and low waters (Figure 6b), much higher than the slightly alkaline seawater (pH 7.5-8.5). This may imply the influence of the intrusion of the waters of the neighboring Pacific Ocean which may contain high concentrations of calcium carbonate. It has been reported that the alkaline pH values are almost always determined by the buffering effect of dissolved salts or seawater (Schmieglow 2004; Costa et al 2009) and from a high concentration of free CO_2, carbon-based mineral molecules suspended in the water, specifically calcium carbonate that comes from rocks like limestone or can be leached from calcite in the soil (George et al 2012).

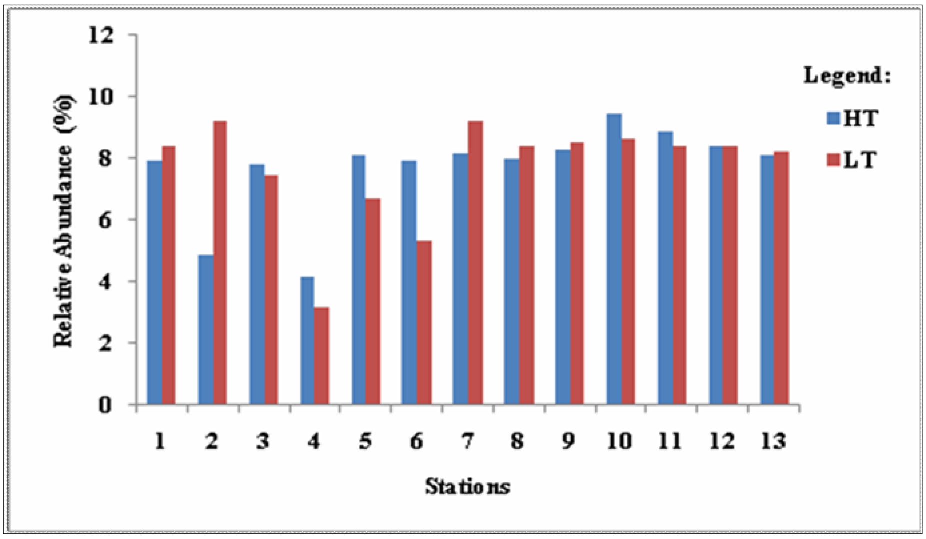

Figure 5. Relative abundance (%) of copepods in the thirteen sampling stations during high tide and low tide in San Casiguran Sound (stations 1-7) and Casiguran Bay (stations 8-13), Aurora, Northern Philippines.

Dissolved oxygen is the amount of oxygen dissolved in the water. It is an important constituent of water and its concentration is an indicator of prevailing water quality and ability of water body to support a well-balanced aquatic life (George et al 2012). Among the 13 stations during high tide, station 3 recorded the highest DO value of 7.05 mg L^{-1}, but low DO (5.77 mg L^{-1}) was observed in station 5. During low tide, station 1 registered the highest DO value of 7.4 mg L^{-1}, however lowest in station 8 (5.9 mg L^{-1}). Turbidity (total suspended solids) is a measure of the attentuation of light in the water column and can be caused by the light adsorption properties of the water, the number of planktonic organisms in the water, and with the amount of suspended particulate organic and inorganic matter (Parr et al 1998). It has been stressed out that suspended particulate matter is often the primary cause of turbidity of the water (Dawes 1981). TSS value (Figure 6c) during high tide was highest in station 4 (12.93 mg L^{-1}) but lowest in station 2 (5.40 mg L^{-1}). During low tide, stations 4 (12.40 mg L^{-1}) showed the highest value, whereas lowest value was observed in station 9 (6.23 mg L^{-1}). Despite such differences reflected in Figures 6 a-c, the values for all surface water quality parameters in all thirteen sampling stations are within the range for any marine faunistic assemblage to thrive and be fairly abundant (DENR DAO 34 1990).

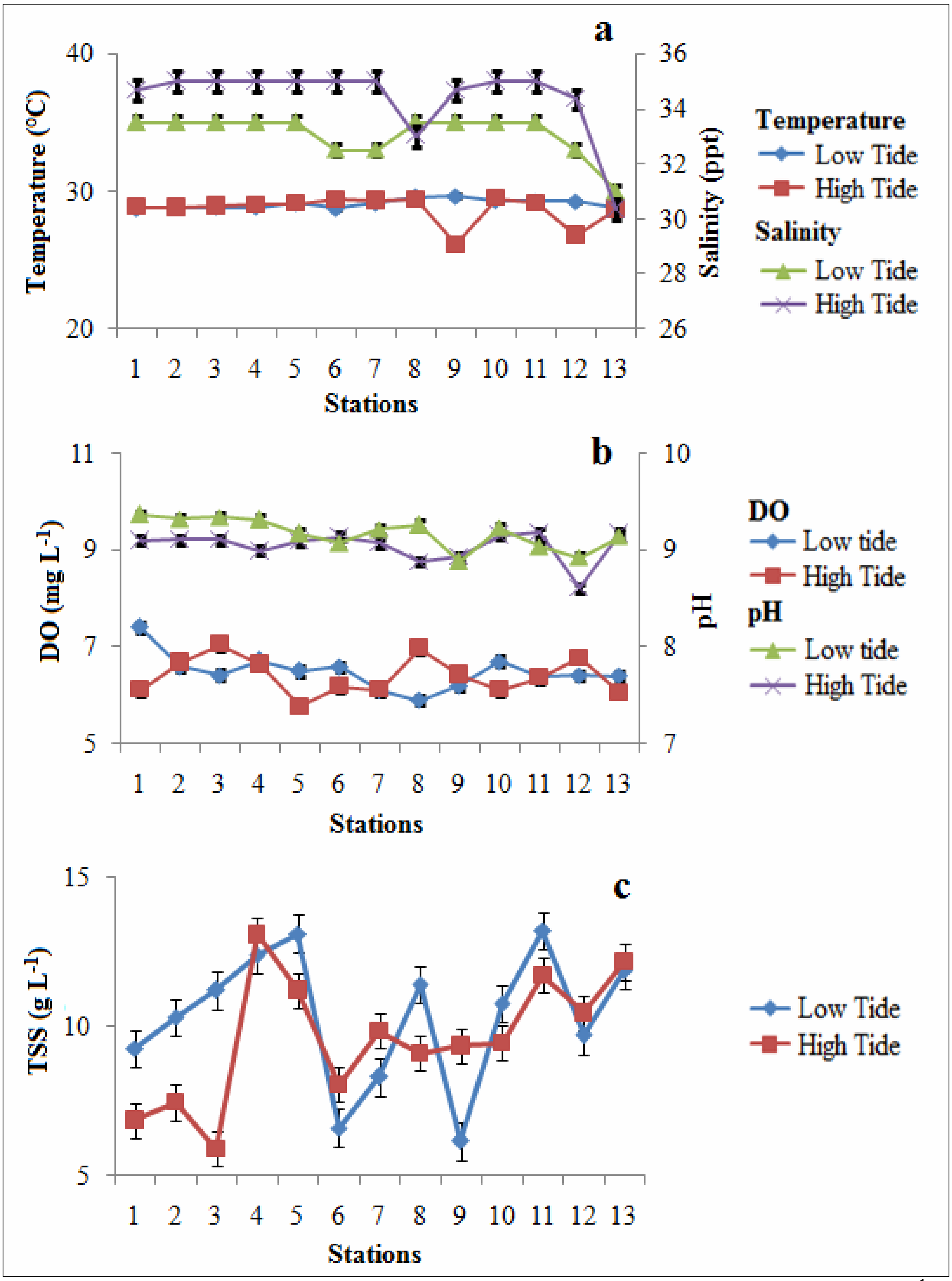

Figure 6. Mean values of (a) water temperature (°C) and salinity (ppt); (b) DO (mg L^{-1}) and pH; (c) TSS (g L^{-1}) in the thirteen sampling stations during low and high tides in Casiguran Sound and Bay, Aurora, Philippines.

Looking at the level of diversity and species richness of zooplankton taxa in Casiguran waters during high tide and low tide, minimal variations were observed as reflected in Table 2. A difference of only three taxa was apparent when comparing the two tidal phases, of which high tide was more species-rich. Results further revealed minimal difference in the diversity of zooplankton taxa between the two tidal phases as reflected in the Shannon-Weaver (H), where both have high species diversity values of 3.773 and 3.804 at low and high tides, respectively. Conversely, looking at the level of species richness of zooplankton between stations during the two tidal phases, it can be seen that differences in the number of taxa were quite large in low and high tides, with stations 1-7 in Casiguran Sound having much lower values in the two tidal phases (range: 41-62) when compared to Casiguran Bay (range: 59-64). Moreover, when comparing the diversity between stations, H' values were still lower in stations 1-7 in Casiguran Sound (H' ranges: 2.1-3.5) than those noted in Casiguran Bay (H' ranges: 3.2-3.6). Despite these variations, the H' values reflected in all sampling stations were still high. Since copepods constituted the major bulk of the total zooplankton population, the levels of copepod diversity were therefore calculated. Data revealed high levels of copepod diversity values (H' ranges from 2.2-2.9) in each sampling stations during and between high tide (Figure 4a) and low tide (Figure 4b), while the number of species ranges between 18-29. When comparing the number of taxa between stations during low and high tides, results showed minimal variations, although stations 1-7 in Casiguran Sound were slightly lower (range: 18-25) than those recorded in Casiguran Bay (26-29). Similarly, when comparing the diversity between stations, minimal differences in the H' values were also observed during the two tidal phases (CS range: 2.2-2.9, CB range: 2.3-2.6). Hence, the high H' values reflected in the present study therefore supports the dominance of copepod groups as major contributor in the mesozooplankton community. Several studies had shown that the levels of diversity for mesozooplankton, particularly those of the copepods, were usually high in oceanic waters (H'values ranged: 2.50-5.16) when compared to those in the neritic and coastal zones (H' values <2.50) (Angara et al 2013a; Tseng et al 2013; Marin & Delgado 2009; Fernandes & Ramaiah 2009; Tseng et al 2008; Lee et al 2006; Hsieh et al 2004; Yang et al 1999; Lopes et al 1999; Noda et al 1998; Shih & Chiu 1998; Champalbert 1996; Kang & Hong 1995). In the case of Casiguran Sound and Bay, the H' values recorded during low and high tides in the thirteen sampling stations fall within the ranges reported for neritic and oceanic waters suggesting that both coastal, neritic and oceanic species may occur in the copepod assemblage in the said area and thus forming an intermediate assemblage.

Table 2

Diversity profiles of zooplankton taxa in Casiguran Sound and Bay during low and high tide

Diversity Index	*Tide*	
	Low	*High*
Taxa (S)	98	101
Individuals	22885	22465
Dominance (D)	0.03353	0.03314
Simpson (1-D)	0.9665	0.9669
Shannon (H)	3.773	3.804
Evenness (e^H/S)	0.4442	0.4445
Brillouin	3.761	3.791
Menhinick	0.6478	0.6739
Margalef	9.663	9.98
Equitability (J)	0.823	0.8243
Fisher alpha	13.13	13.63
Berger-Parker	0.08377	0.1051
Chao-1	98.5	102

Based on these findings, it is apparent that abundance, richness and diversity among copepods were the same and therefore did not fluctuate with changes in the tide phases. This would mean that the mesozooplankton, particularly the copepod species, were thus uniformly distributed by the alteration of high and low tides that may have transported or brought in water masses by horizontal displacement from the Pacific Ocean into the Casiguran waters, namely Casiguran Sound and Bay, during spring tide. Hsiao (1992) reported that the tides had a double beneficial effects, that is (1) they not only flush in water masses from nearby areas during flooding or high tide but (2) also generates an upward mixing particularly when ebbing or low tide.

In order to know if zooplankton species and their abundances are similar between the thirteen sampling sites during high and low tides, cluster analysis using Ward's method was employed. The dendrogram results (Figure 7) showed the stations that are similar on the basis of species composition and density. The presence of two major groups or clusters that separates the stations (1-7) in Casiguran Sound with those of the stations in Casiguran Bay (9-13) were apparent. Group I comprises of stations 1, 2, 3, 4, 5, 6, 7, 8 at both low and high tides and station 11 at high tide only. Group II consists of stations 9, 10, 12, 13 at both low and high tides and station 11 at low tide only. It is noteworthy that stations 8 and 11 although both located within Casiguran Bay, did not cluster with the rest of the stations (9, 10, 12, 13) in Casiguran Bay, but instead clustered together with all the stations that are located in Casiguran Sound (1-7).

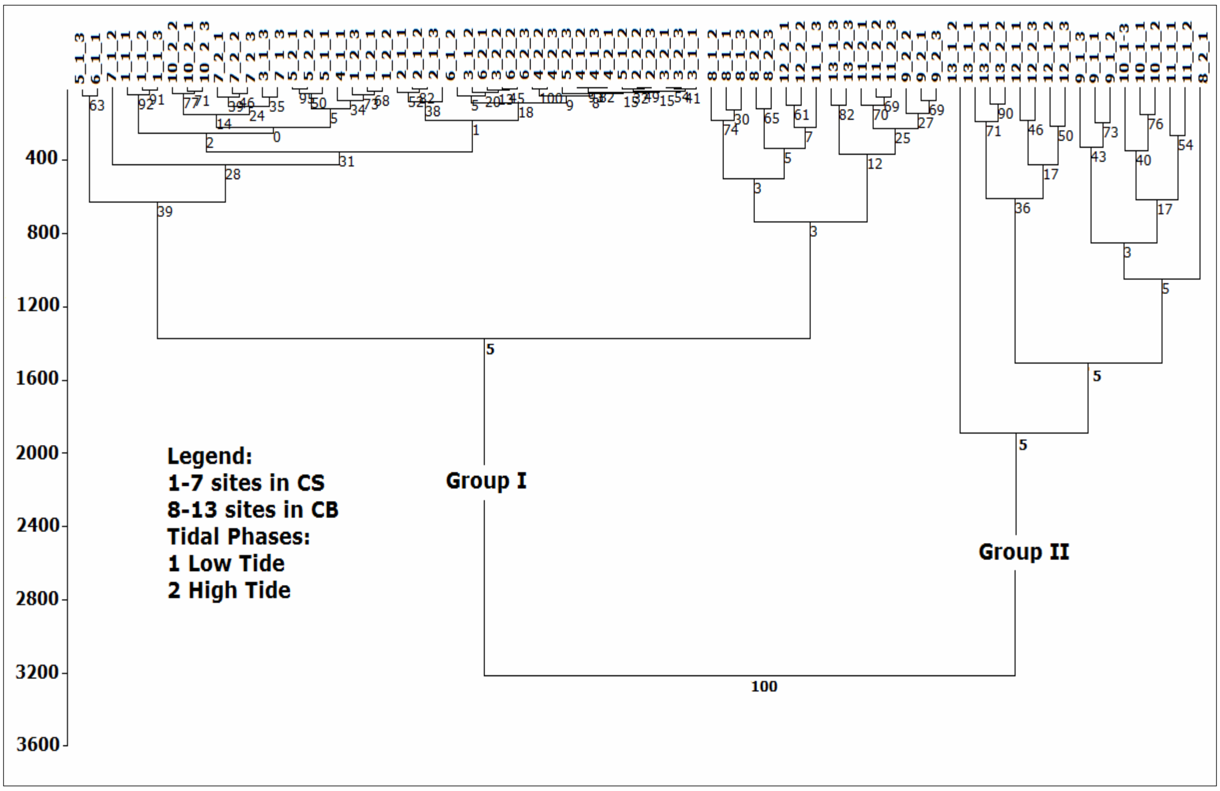

Figure 7. Cluster diagram showing similarities in the composition of zooplankton species between the thirteen sampling sites. The diagram was computed using Ward's method of analysis using Euclidean distance measure (Boot N:1000).

Casiguran waters in Aurora comprises of Casiguran Sound where stations 1-7 are established, which directly connects itself into the open sea or Pacific Ocean, and Casiguran Bay (stations 8-13), which is located in the innermost part of the area where it often receives freshwater runoffs from the nearby rivers. The result revealed the dominant species that occurred in Group I were *A. gracilis, O. similis, C. andrewsii, C. affinis, C. furcatus, P. parvus, C. arcuicornis, Cypridina, Globigerina, Acantharia, Sagitta crassa*, *Muggiae* and a shrimp larva or mysis. The abundant species in Group II were *A. gracilis, O. similis, O. setigera, C. andrewsii, C. affinis, C. furcatus, P. parvus, C. arcuicornis, Evadne, Acantharia,* mysis, crab zoea, polychaete larva, nauplius, ophiopluteus, *Sagitta crassa*, *Oikopleura, Frittilaria* and *Muggiae*. Although data showed the 2 clusters, viz. Groups I and II, having almost the same zooplankton community structure, differences were quite clear by the dominance of a pelagic ostracod, *Cypridinia*, and a pelagic protozoa, *Globigerina*, in Group I, and the dominance of a cyclopoid copepod, *O. setigera*, a pelagic ostracod, *Evadne*, two chordates, viz. *Oikopleura, Frittilaria*, and some larval forms that are adapted for pelagic life, viz. ophiopluteus, crab zoea, nauplius, polychaete larva in Group II. The dominance of these zooplankton taxa in the two clusters were believed to be brought along by the incoming high water during high tide from the neighboring open seas (i.e. Taiwan Strait, Japan Sea and China Sea) via ocean current considering that Casiguran is directly facing the Pacific Ocean. Hence, the similarities in the composition and density of the dominant mesozooplankton in Casiguran Sound and Bay as evidenced by the results of the cluster analysis further showed that other factors might have been responsible for such variations rather than the two tidal phases.

In order to determine the specific physical and chemical parameters of the water that may influence the relative abundance and diversity of mesozooplankton, Canonical Correspondence Analysis was used. The plots of the sites or stations along the first two canonical axes are shown for samples collected during (a) low tide and (b) high tide (Figures 8 a-b). The plot includes a vector plot that could be used to pinpoint important variables that can explain the differences in the density of zooplankton community structures among the thirteen sampling stations during high and low tides. During low tide, stations 1 to 7 consisted of several species of zooplankton that were different from stations 8 to 13. The differences between these stations can be seen in the variations of the species composition and density which may be explained by the observed disparity in the pH, DO and temperature of the waters. As presented in Figure 8a, stations 1 to 7 had the highest pH and DO but lowest temperature values. Among these sampling stations, site 1 registered the highest pH (9.36), DO (7.4 mg L^{-1}) and lowest water temperature (28.7°C), but recorded low mesozooplankton density (Figure 9a). Low zooplankton density is expected with the lowering of water temperature since these organisms reproduced successfully at an optimum temperature between 29-30°C. On the other side, the low zooplankton density reflected in station 1 despite high pH and DO values might be attributed to other possible biological factors, viz. presence of predators and less food sources. Changes in the community structure can also be seen during high tide (Figure 8b) but with lesser differences in the density and composition of zooplankton present among the stations except for station 13 which recorded a much higher mesozooplankton density (Figure 9b). Although, the present data suggests the influence of pH, dissolved oxygen and water temperature to the diversity and density of mesozooplankton community structure in Casiguran waters, Aurora, during high and low tides, other factors like transport of water masses by currents (Gomez et al 2000; Lopes et al 1999; Gowen et al 1998), characteristics of water masses (Tseng et al 2011), seasonal monsoon effects (Yoshida et al 2006), diverse feeding habits (Turner 2004), vertical migration (Lo et al 2004), sampling time (Hwang et al 2009) and mesh-size effects (Tseng et al 2011) may have played an important role in shaping the mesozooplankton community.

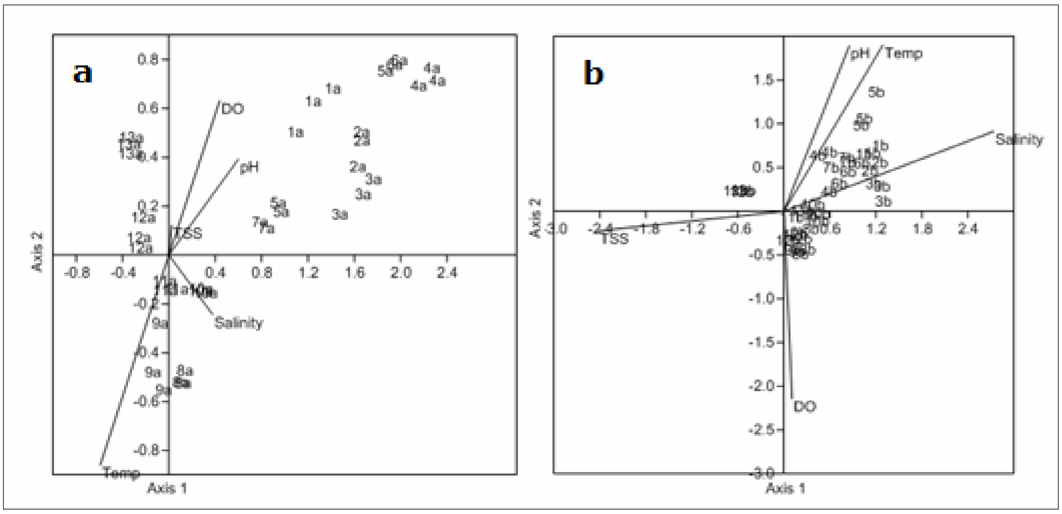

Figure 8. Results of the Canonical Correspondence Analysis- biplot showing the distance among the sampling stations during (a) low tide and (b) high tide and the physico-chemical factors that influence the abundance (ind m^{-3}) of zooplankton in Casiguran Sound and Bay, Aurora, Northern Philippines.

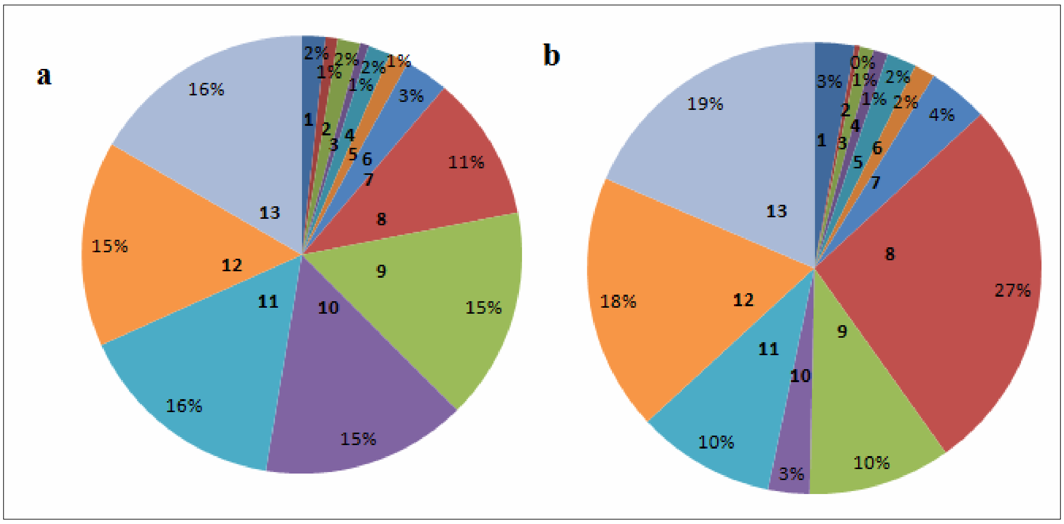

Figure 9. Relative abundance (%) of zooplankton taxa in the thirteen sampling stations during (a) low tide and (b) high tide in Casiguran Sound and Bay, Aurora, Northern Philippines.

Conclusions. The level of mesozooplankton diversity and abundance did not fluctuate with changes in the tidal phases, suggesting that mesozooplankton species were thus uniformly distributed by the alteration of low and high tides that may have transported or brought in water masses by horizontal displacement from the Pacific Ocean into Casiguran waters. Further, the mesozooplankton assemblage, copepods in particular, in Casiguran waters, Aurora, Northern Philippines, consisted of a mixture of coastal, neritic, and oceanic warm-water species to subtropical species thereby reflecting the high diversity of the said community. Although, hydrological condition, viz, pH, dissolved oxygen and water temperature, may have influence the abundance of zooplankton community, other factors such as transport of water masses by currents, characteristics of water masses, seasonal monsoon effects, diverse feeding habits, vertical migration, sampling time, and even mesh-size effects may have played an important role in shaping the mesozooplankton community. Considering the importance of copepods as major component of the marine zooplankton and its function in marine food webs, the present records are therefore crucial in understanding the dynamics of marine ecosystems and are necessary for purposes of management and conservation of marine resources. Moreover, the major role of ocean current in the general circulation and transport of large masses of water is therefore highly recommended for future studies in order to describe in greater detail its influence in shaping mesozooplankton community structure.

Acknowledgements. The study was supported by Senator Edgardo J. Angara, Aurora Provincial Government, the Philippines Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR) Region III, Mindanao State University-Iligan Institute of Technology (MSU-IIT), Aurora State College of Technology (ASCOT), Zabali Campus, Aurora Province and University of the Philippines-Marine Science Institute (UP-MSI). M.L.D.G. Lacuna would like to acknowledged Ms. Arri Adajar and Mr. Rolly Caballero for assisting in the collections of the zooplankton samples.

References

Achuthankutty C. T., Ramaiah N., Padmavati G., 1995 Salinity ranges for *Centropages furcatus* in coastal and estuarine waters of Goa India. In: Pelagic biogeograpgy ICoPB II. Proc. 2nd Intern. Conf. Final report of SCOR/IOC working group 93, 9-14 July 1995. Workshop Report No. 142, Unesco, 1998. [p.8, Fig.6]. Available at: http://copepodes.obs-banyuls.fr/en/fichesp.php?sp=42.

Al-Yamani F. Y., Skryabin V., Gubanova A., Khvorov S., Prusova I., 2011 Marine Zooplankton Practical Guide for the Northwestern Arabian Gulf. Vol 2. Kuwait Institute for Scientific Research, Safat Kuwait, 197 pp. Available at: http://www.kisr.edu.kw/Data/Site1/images/kisr_publications/978-99966-95-07-0-2.pdf

Angara E. V., Rillon G. S., Carmona M. L., Ferreras J. E. M., Vallejo M. I., Jamodiong E., Lacuna M. L. D. G., 2013a Mesozooplankton composition and abundance in San Ildefonso Cape, Casiguran, Aurora, Northern Philippines. AACL Bioflux 6(6):539-559.

Angara E. V., Rillon G. S., Carmona M. L., Ferreras J. E. M., Vallejo M. I., Amper A. C. G. G., Lacuna M. L. D. G., 2013b Diversity and abundance of phytoplankton in Casiguran waters, Aurora Province, Central Luzon, Northern Philippines. AACL Bioflux 6(4):358-377.

Bradford-Grieve J. M., 1999 The marine fauna of New Zealand: pelagic Calanoid Copepoda: Bathypontidae, Arietellidae, Augaptilidae, Heterorhabdidae, Lucicutiidae, Metridinidae, Phyllopodidae, Centropagidae, Pseudodiaptomidae, Temoridae, Candaciidae, Pontellidae, Sulcanidae, Acartiidae, Tortanidae. Mem New Zealand Oceanogr Inst 111:1-268.

Boucher M., Ibanez F., Prieur L., 1987 Daily and seasonal variations in the spatial distribution of zooplankton populations in relation to the physical structure in the Ligurian Sea Front. Journal of Marine Research 45:133-173.

Campaner A. F., 1985 Occurrence and distribution of copepods (crustacea) in the epipelagial off southern Brazil. Bolm Inst Oceanogr 33(1):5-27.

Champalbert G., 1996 Characteristics of zooplankton standing stock and communities in the Western Mediterranean Sea: relations to hydrology. Scientia Marina 60(2):97-113.

Chen Q. C., Zhang S. Z., 1965 The planktonic copepods of the Yellow Sea and the East China Sea, I. Calanoida. Studia Marina Sinica 7:20-131.

Chen Q. C., Zhang S. Z., Zhu C. S., 1974 On planktonic copepods of the Yellow Sea and the East China Sea, II. Cyclopoida and Harpacticoida. Studia Marina Sinica 9:27-76.

Chen M. R., Ka S., Hwang J. S., 2010 Diet of the copepod *Calanus sinicus* Brodsky, 1962 (Copepoda, Calanoida, Calanidae) in northern coastal waters of Taiwan during the northeast monsoon period. Crustaceana 83:851–864.

Chihara M., Murano M., 1997 An illustrated guide to marine plankton in Japan. Tokai University Press, Tokyo, 1004 pp.

Chou C., Tseng L. C., Ou C. H., Chen Q. C., Hwang J. S., 2012 Seasonal succession of planktonic copepods in bight environments of north-eastern Taiwan. Zoological Studies 51:1380–1396.

Costa R. M., Leite N. R., Pereira L. C. C., 2009 Mesozooplankton of the Curuca estuary (Amazon coast, Brazil). Journal of Coastal Research 56:400-404.

Dahms H. U., Hwang J. S., 2007 Krill-tracking by ROV in the Antarctic. J Ocean Underw Technol 17:3–8.

Davies C. H., Slotwinski A. S., 2012 *Centropages furcatus*. Integrated Marine Observing System (IMOS). Available at: http://www.imas.utas.edu.au/__data/assets/pdf_file/0004/394870/Centropages_furcatus_atlas.pdf.

Dawes C. J., 1981 Marine botany. A Wiley-Interscience Publication, USA, 480 pp.

DENR - Administrative Order No. 34. 1990 “Revised Water Usage and Classification of Water Quality Criteria Amending Section Nos. 68 and 69, Chapter III of the 1978 Rules and Regulations”, Manila, 11 pp.

Dur G., Hwang J. S., Souissi S., Tseng L. C., Wu C. H., Hsiao S. H., 2007 An overview of the influence of hydrodynamics on the spatial and temporal patterns of calanoid copepod communities around Taiwan. J Plankton Res 29:97-116.

Etile R. N., Kouassi A. M., Aka M. N., Pagano M., N’douba V., Kouassi N. J., 2009 Spatio temporal variations of the zooplankton abundance and composition in a West African tropical coastal lagoon (Grand-Lahou, Côte d’Ivoire). Hydrobiologia 624:171–189.

Fernandes V., Ramaiah N., 2009 Mesozooplankton community in the Bay of Bengal (India): spatial variability during the summer monsoon. Aquat Ecol 43(4):951-963.
Frost B., Fleminger A., 1968 A revision of the genus *Clausocalanus* (Copepoda: Calanoida) with remarks on distributional patterns in diagnostic characters. Bulletin of the Scripps Institution of Oceanography 12:1-235.
George B., Nirmal Kumar J. I., Kumar R. N., 2012 Study on the influence of hydrochemical parameters on phytoplankton distribution along Tapi estuarine area of Gulf of Khambhat, India. Egyptian Journal of Aquatic Research 38:157-170.
Gomez F., Echevarria F., Garcia C. M., Prieto L., Ruiz J., Reul A., Jimenez-Gomez F., Varela M., 2000 Microplankton distribution in the Strait of Gibraltar: coupling between organisms and hydrodynamics structures. Journal of Plankton Research 22:603–617.
Goswami S. C., 2004 Zooplankton methodology, collection and identification: a field manual. National Institute of Oceanography, Goa, 26 pp.
Gowen R. J., Raine R., Dickey-Collas M., White M., 1998 Plankton distributions in relation to physical oceanographic features on the southern Malin Shelf, August 1996. ICES Journal of Marine Science 55:1095-1111.
Hafferssas A., Seridji R., 2010 Relationships between the hydrodynamics and changes in Copepod structure on the Algerian Coast. Zoological Studies 49(3):353-366.
Hammer O., Harper D. A. T., Ryan P. D., 2001 PAST: paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4:1-9.
Hsiao S. L. C., 1992 Diel, tidal and vertical variations of phytoplankton and its environment in Frobisher Bay. Arctic 45(4):327-337.
Hsiao S. H., Fang T. H., Hwang J. S., 2006 The bioconcentration of trace metals in dominant copepod species off the northern Taiwan coast. Crustaceana 79:459-474.
Hsiao S. H., Fang T. H., Shih C. T., Hwang J. S., 2011 Effects of Kuroshio Current on copepod assemblages in Taiwan. Zoological Studies 50(4):475-490.
Hsieh C. H., Chiu T. S., 2002 Summer spatial distribution of copepods and fish larvae in relation to hydrography in the Northern Taiwan strait. Zoological Studies 41(1):85-98.
Hsieh C. H., Chiu T. S., Shih C. T., 2004 Copepod diversity and composition as indicators of intrusion of the Kuroshio Branch Current into the Northern Taiwan Strait in spring 2000. Zoological Studies 43(2):393-403.
Huys R., Boxshall G., 1991 Copepod evolution. The Ray Society, London, ISBN 0903874210.
Hwang J. S., Wang C. H., Chan T. Y., 2000 Proceedings of the international symposium on marine biology in Taiwan-crustacean and zooplankton taxonomy, ecology and living resources. Natl Taiwan Mus Spec Publ Ser 10:1-200.
Hwang J. S., Chen Q. C., Wong C. K., 2003 Taxonomic composition, density and biomass of free-living copepods in the coastal waters of southwestern Taiwan. Crustaceana 76:193-206.
Hwang J. S., Souissi S., Tseng L. C., Seuront L., Schmitt F. G., Fang L. S., 2006 A 5-year study of the influence of the northeast and southwest monsoons on copepod assemblages in the boundary coastal waters between the East China Sea and the Taiwan Strait. Journal of Plankton Research 28:943-958.
Hwang J. S., Dahms H. U., Tseng L. C., Chen Q. C., 2007 Intrusions of the Kuroshio Current in the northern South China Sea affect copepod assemblages of the Luzon Strait. Journal of Experimental Marine Biology and Ecology 352:12-27.
Hwang J. S., Souissi S., Dahms H. U., Tseng L. C., Schmitt F. G., Chen Q. C., 2009 Rank abundance allocations as a tool to analyze planktonic copepod assemblages off the Danshuei river estuary (northern Taiwan). Zoological Studies 48:49-62.
Hwang J. S., Kumar R., Dahms H. U., Tseng L.C., Chen Q. C., 2010 Interannual, seasonal, and diurnal variation in vertical and horizontal distribution patterns of 6 *Oithona* spp. (Copepoda: Cyclopoida) in the South China Sea. Zoological Studies 49:220-229.

Irigoien X., Harris R. P., Verheye H. M., Joly P., Runge J., Starr M., Pond D., Campbell R., Shreeve R., Ward P., Smith A. N., Dam H. G., Peterson W., Tirelli V., Koski M., Smith T., Harbour D., Davidson R., 2002 Copepod hatching success in marine ecosystems with high diatom concentrations. Nature 419:387–389.
Jagadeesan L., Jyothibabu R., Anjusha A., Mohan A. P., Madhu N. V., Muraleedharan K. R., Sudheesh K., 2013 Ocean currents structuring the mesozooplankton in the Gulf of Mannar and the Palk Bay, southeast coast of India. Progress in Oceanography 110:27-48.
Jitchum P., Wongrat L., 2009 Community structure and abundance of epipelagic copepods in Shallow Protected Bay, Gulf of Thailand. Kasetsart University Fisheries Research Bulletin 33(1):28-40.
Johan I., Abu Hena M. K., Ildris M. H., Arshad A., 2013 Taxonomic composition and abundance of zooplankton copepoda in the Coastal Waters of Bintulu, Serawak, Malaysia. Journal of Fisheries and Aquatic Sciences 8(3):472-479.
Ka S., Hwang J. S., 2011 Mesozooplankton distribution and composition on the Northeastern coast of Taiwan during autumn: effects of the Kuroshio Current and hydrothermal vents. Zoological Studies 50(2):155-163.
Kang Y. S., Hong S. Y., 1995 Occurrences of oceanic warm-water calanoid copepods and their relationship to hydrographic conditions in Korean waters. Bull Plankt Soc Jpn 42(1):29-41.
Kang Y. S., Huh S. H., Lee S. S., 1990 Taxonomy and distribution of Corycaeidae (Copepoda: Cyclopoida) in the Korean waters in summer. The Journal of the Oceanological Society of Korea 25:49-61.
Kasturirangan L. R., 1963 A key for the identification of the more common planktonic Copepoda of Indiana Coastal Waters. Coun Scien Ind Res, New Delhi, 87 pp.
Kiorbe T., 1997 Population regulation and role of mesozooplankton in shaping marine pelagic food webs. Hydrobiologia 363:13-27.
Lan Y. C., Lee M. A., Liao C. H., Lee K. T., 2009 Copepod community structure of the winter frontal zone induced by the Kuroshio branch current and the China coastal current in the Taiwan Strait. Journal of Marine Science and Technology 17(1):1-6.
Lee C. Y., Shih C. T., Hsu C. C., 2006 Community structure of planktonic copepods in I-lan bay and adjacent Kuroshio waters off northeastern Taiwan. Crustaceana 79:1223-1240.
Legendre L., Legendre P., 1984 Ecologic numerique, 2e ed. Tome 2: La structure des don & esecologiques. Collection d'Ecologie, 12 et 13, Masson, Paris el les Presses de l'Universite du Quebec.
Lo W. T, Chung C. L, Shih C. T., 2004 Seasonal distribution of copepods in the Tapong Bay, south-western Taiwan. Zoological Studies 43:464–474.
Lopes E., Viesca L., Anadon R., 2007 Seasonal variation in abundance and feeding rates of the first stages of copepods in a temperate sea. Marine Ecology Progress Series 352:161–175.
Lopes R. M., Brandini F. P., Gaeta S. A., 1999 Distribution patterns of epipelagic copepods off Rio de Janeiro (SE Brazil) in summer 1991/1992 and winter 1992. Hydrobiologia 411:161-174.
Mahjoub M. S., Souissi S., Schmitt F. G., Nan F. H., Hwang J. S., 2011 Anisotropy and shift of search behavior in Malabar grouper (*Epinephelus malabaricus*) larvae in response to prey availability. Hydrobiologia 666:215–222.
Maiphae S., Sa-Ardrit P., 2011 Marine copepods at Mo Ko Thale Tai, Gulf of Thailand. Songklanakarin J Sci Technol 33(6):641-651.
Marin V. H., Delgado L. E., 2009 Diversity and spatial distribution of surface (0-10 m) copepods in the nearshore zone of Chiloé's inland sea cimar 10 fiordos. Cienc Tecnol Mar 32(1):93-98.
Mauchline J., 1998 The biology of calanoid copepods. Advances in Marine Biology 33:1-710.
Miyashita L. K., de Melo M. Jr., Lopes R. M., 2009 Estuarine and oceanic influences on copepod abundance and production of a subtropical coastal area. Journal of Plankton Research 31(8):815-826.

Montu M. A. Goleden I. M., 1998 Maxillopoda - Copepoda. MarinePlanktonic Calanoida. In: Catalogue of Crustacea of Brazil. Young P. S. (ed.), Museu Nacional, Série Livros no. 6., Rio de Janeiro, pp. 167-200.

Mulyadi, 2004 Calanoid Copepods in Indonesian waters. Research Center for Biology, Institute of Sciences, Jakarta, 195 pp.

Nakamura Y., Turner J. T., 1997 Predation and respiration by the small cyclopoid copepod *Oithona similis*: how important is feeding on ciliates and heterotrophic flagellates? Journal of Plankton Research 19:1275-1288.

Nishida S., 1985 Taxonomy and distribution of the family Oithonidae (Copepoda, Cyclopoida) in the Pacific and Indian Oceans. Bulletin of the Ocean Research Institute, University of Tokyo 20:1-167.

Noda M., Ikeda I., Ueno S., Hashimoto H., Gushima K., 1998 Enrichment of coastal zooplankton communities by drifting zooplankton patches from the Kuroshio front. Marine Ecology Progress Series 170:55-65.

Ogbeibu A. E., Oribhabor J., 2011 Environmental factors influencing the distribution of marine zooplankton in Buguma Creek, Niger Delta, Nigeria. Int J Ecol Environ Sci 37:27-36.

Onyema I. C., Ojo A. A., 2008 The zooplankton and phytoplankton biomass in a tropical creek, in relation to water quality indices. Life Science Journal 5(4):75-82.

Osore M. K. W., Tackx M. L. M., Daro M. H., 1997 The effect of rainfall and tidal rhythm on the community structure and abundance of the zooplankton of Gazi Bay, Kenya. Hydrobiologia 356:117–126.

Owre H. B., Foyo M., 1967 Copepods of the Florida Current. Fauna Caribaea, No. 1, Crustacea, Part 1: Copepoda. Institute of Marine Science, University of Miami, 137 pp.

Parr W., Clarke S. J., Van Dijk P., Morgan N., 1998 Turbidity in English and Welsh tidal waters. Report prepared for English Nature, Report no. Co 4301/1., Water Research Centre, Marlow, 116 pp.

Peterson W. T., Gomez-Gutierrez J., Morgan C. A., 2002 Cross-shelf variation in calanoid copepod production during summer 1996 along the Oregon coast, USA. Marine Biology 141:353–365.

Relox J. R., Furio E. F., Borja V. M., 2000 Abundance and distribution of zooplankton in the South China Sea, Area III: Western Philippines. In: Proceedings of the Third Technical Seminar on Marine Fishery Resources Survey in the South China Sea, Area III: Western Philippines. SEAFDEC Special Paper No. SEC/SP141, pp. 164-176, Southeast Asian Fisheries Development Center, Bangkok, Thailand.

Rezai H., Yusoff F. M., Arshad A., Kawamura A., Nishida S., Ross O. B. H., 2004 Spatial and temporal distribution of copepods in the straits of Malacca. Zoological Studies 43(2):486-497.

Robin R. S., Srinivasan M., Chandrasekar K., 2009 Distribution of zooplankton from Arabian Sea, along Southern Kerala (Southwest Coast of India) during the Cruise. Current Research Journal of Biological Sciences 1(3):155-159.

Schmieglow J. M. M., 2004 O planeta azul: uma introducao as ciencias marinhas. Ed. Interciencia, Rio de Janeiro, 202 pp.

Schminke H. K., 2007 Entomology for the copepodologist. Journal of Plankton Research 29(1):149-162.

Shih C. T., Chiu T. S., 1998 Copepod diversity in the water masses of the southern East China Sea north of Taiwan. J Mar Systems 15:533-542.

Stephen R., 1984 Distribution of calanoid copepods in the Arabian Sea and Bay of Bengal. Mahasagar-Bulletin of the National Institute of Oceanography 17(3):161-171.

Suvavepun S., Suwanrumpha W., 1968 Distribution of copepods in the inner Gulf and western coast of the Gulf of Thailand. Proceedings of the Indo-Pacific Fisheries Council 13(2):1-19.

Takahashi T., Hirakawa K., 2001 Day–night vertical distribution of the winter and spring copepod assemblages in ToyamaBay, Southern Japan Sea, with special reference to *Metridia pacifica* and *Oithona atlantica*. Bull Plankton Soc Jap 48:1–13.

Todd C. D., Laverack M. S., 1991 Coastal marine zooplankton: a practical manual for students. Cambridge University Press., U.K., 106 pp.
Tseng L. C., Kumar R., Dahms H. U., Chen Q. C., Hwang J. S., 2008 Monsoon-driven succession of copepod assemblages in coastal waters of the Northeastern Taiwan strait. Zoological Studies 47(1):46-60.
Tseng L. C., Dahms H. U., Chen Q. C., Hwang J. S., 2009 Copepod feeding study in the upper layer of the tropical South China Sea. Helgoland Marine Research 63:327-337.
Tseng L. C., Dahms H. U., Hung J. J., Chen Q. C., Hwang J. S., 2011 Can different mesh sizes affect the results of copepod community studies? J Exp Mar Biol Ecol 398:47-55.
Tseng L. C., Dahms H. U., Chen Q. C., Hwang J. S., 2012 Mesozooplankton and copepod community structures in the southern East China Sea: the status during the monsoonal transition period in September. Helg Mar Res 66:621–634.
Tseng L. C., Dahms H. U., Chen Q. C., Hwang J. S., 2013 Geospatial variability in the autumn community structure of epipelagic zooplankton in the upper layer of the northern South China Sea. Zoological Studies 52:1-12.
Turner J. T., 2004 The importance of small planktonic copepods and their roles in pelagic marine food webs. Zoological Studies 43(2):255-266.
Uy W. H., Bacaltos D. G. G., Freire F. F., Avenido P. M., Roa E. C., Seronay R. A., Lacuna D. G., Rollon R. N., Van Stevenick De Ruyter, Coronado R. M., 2006 A comprehensive analysis of the ecological factors for the development of strategies to sustain coastal biodiversity and to improve fish stock management. Biodiversity Research Programme for Development in Mindanao: Focus on Mt. Malindang and Environs. SEAMEO SEARCA, College, Laguna, 58 pp.
Uye S., 2011 Human forcing of the copepod–fish–jellyfish triangular trophic relationship. Hydrobiologia 666:71–83.
Vukanic V., 2010 Studies of copepod in the Bay of Kotor-Coastal waters of Southern Adriatic. Natura Montenegrina, Podgorica 9(3):457-467.
Webber M., Edwards-Myers E., Campbell C., Webber D., 2005 Phytoplankton and zooplankton as indicators of water quality in Discovery Bay, Jamaica. Hydrobiologia 545:177–193.
Wiafe G., Frid C. L. G., 1996 Short-term temporal variation in coastal zooplankton communities: the relative importance of physical and biological mechanisms. Journal of Plankton Research 18(8):1485-1501.
Yamaji I., 1962 The plankton of Japanese coastal waters. Hoikusha publishing Co., Ltd., Japan, 189 pp.
Yang G. M., He D. H., Wang C. S., Miao Y. T., Yu H. H., 1999 Study on the biological oceanographic characteristics of planktonic copepods in the waters north of Taiwan, I. Abundance distribution. Acta Oceanol Sin 21:78-86.
Yoshida T., Toda T., Yusoff F. M., Othman B. H. R., 2006 Seasonal variation in zooplankton community in the coastal waters of the Straits of Malacca. Coastal Mar Sci 30:320-327.
*** http://folk.uio.no/ohammer/past/ [last view: 02 October 2013]
*** http://www.imas.utas.edu.au/zooplankton/references
*** http://copepodes.obs-banyuls.fr/en
*** http://www.edangara.com/apeco/
*** http://en.wikipedia.org/wiki/San_Ildefonso_Peninsula

Received: 13 May 2014. Accepted: 09 June 2014. Published online: 10 June 2014.
Authors:
Maria Lourdes Dorothy Garcia Lacuna, Department of Biological Sciences, College of Science and Mathematics, Mindanao State University - Iligan Institute of Technology, Andres Bonifacio Avenue, Iligan City 9200, Philippines, e-mail: mileskung@yahoo.com
Eusebio Villar Angara, Aurora State College of Technology, Zabali Campus, Aurora Province, Philippines, e-mail: sebangara@gmail.com
Gerardo Serna Rillon, Aurora State College of Technology, Zabali Campus, Aurora Province, Philippines, e-mail: gerardo.rillon@yahoo.com
Marvelisa Laput Carmona, Aurora State College of Technology-Aurora Marine Research and Development Institute, Zabali Campus, Aurora Province, e-mail: tala_sa_baler@yahoo.com
Joer Ef Molina Ferreras, Aurora State College of Technology-Aurora Marine Research and Development Institute, Zabali Campus, Aurora Province, Philippines, e-mail: ferrerasjoeref@yahoo.com
Myra Inoc Vallejo, Aurora State College of Technology-Aurora Marine Research and Development Institute, Zabali Campus, Aurora Province, Philippines, e-mail: myra_vallejo@yahoo.com
Christar Ree Merano, Mindanao State University - Iligan Institute of Technology, Andres Bonifacio Avenue, Iligan City 9200, Philippines, e-mail: christaree14@gmail.com

How to cite this article:
Lacuna M. L. D. G., Angara E. V., Rillon G. S., Carmona M. L., Ferreras J. E. M., Vallejo M. I., Merano C. R., 2014 Community structure of mesozooplankton in Casiguran waters, Aurora, Northern Philippines. AES Bioflux 6(2):136-156.