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Abundance of benthic foraminifera in Balangan Bay, Zamboanga Sibugay, western Mindanao

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Abstract. Live benthic foraminiferan composition, diversity and abundance and their relationship with the water quality parameters, organic matter content and size of the sediments were determined in the five established stations in Balangan Bay. A total of 46 living benthic foraminiferan species belonging to 23 genera under 20 families were identified in the five sampling stations of Balangan Bay, Zamboanga Sibugay, Southern Mindanao. Variations in the water quality parameters and the organic matter content of the sediments between sampling stations were observed. The grain size analysis of the sediments showed that the sedimentary structures of the benthic zone in the five sampling stations are predominantly made up of silt. The observed living foraminiferal assemblages in all sampling stations were highly diversified with low dominance values indicating that living foraminiferans are evenly distributed in all the sampling stations. This may indicate that Balangan bay is still pristine and harbours diverse marine flora and fauna. Results in the Canonical Correspondence Analysis (CCA) revealed that the abundance of the benthic foraminiferan assemblages is influenced by total organic matter (TOM), salinity and temperature. Hence, the results of this study will serve as baseline required for future monitoring on effects cause by both natural and anthropogenic activities in the area further promoting foraminiferans as tools for ecological and environmental interpretations.
Key Words: Protozoa, physico-chemical parameters, *Ammonia beccarii*, Zamboanga Peninsula.

Introduction. Foraminiferans are widely used as environmental indicators (since they are niche specific and are restricted to particular types of sediment, temperature, or salinity) aside from being vital organisms in the marine food web (Al-Zamel et al 2009; Aloulou et al 2012). Being small, numerous and often well preserved in shallow marine sediment, foraminifera provides the best record of human impacts on coastal marine environment (Hayward et al 2008). These minute creatures are very important as their distributional patterns provide key information for paleoclimatic, paleoecologic and paleoceanographic studies (Alve & Goldstein 2003). They have been known in geological records since the Cambrian period (540 MYA) and are the most useful microfossil for dating and reconstructing paleoenvironments (Pascual et al 2002). According to Hayward et al (2008), benthic organisms such as foraminifera have the potential to provide the best record of their former occurrence and abundance as their hard parts can be preserved in accumulating sea floor sediment and their study provide insights into biotic changes (both natural and anthropogenically induced) that have occurred at a locality, at a decadal to millennial scales. Foraminifers are not only vital in reconstructing the marine environment of the past and as bio-indicators of pollution but they are also used to study the relationship between biotic and abiotic parameters which govern their distribution all over the world. Studies have shown that organic carbon, salinity, substratum type, and substratum pH were factors determining their distribution (Arnal et al 1980).

Despite the increasing number of studies on foraminiferal ecology worldwide, studies on benthic foraminiferans in the Philippines are already slowly gaining popularity among researchers. These local studies often focuses on diversity and abundance of benthic foraminiferans (Lacuna & Gayda 2014; Lacuna et al 2013) with few dealing on influence of heavy metals to foraminiferal assemblages (Lacuna & Alviro 2014; Ganaway & Lacuna 2014; Unsing & Lacuna 2014). In order to address this gap, this study was done to determine the composition, diversity and abundance of benthic foraminifera in Balanngan Bay, Zamboanga Sibugay, Southern Philippines and to determine the physico-chemical parameters that may influence the abundance of foraminiferal assemnblages. The data generated will serve as baseline required for future monitoring on effects cause by both natural and anthropogenic activities in the area. Furthermore, knowledge on foraminiferans in natural environment is consequently a necessary prerequisite to the promotion of forams as tools for ecological and environmental interpretations.

Material and Method. Balangan bay (Figure 1), which is part of the Zamboanga Peninsula, is located in the western part of Mindanao, Philippines with the coordinates of 07°58’ N and 122°58’ E. Its coasts (excluding the mangrove area) measures about 221 hectares and is enclosed by the following communities or Barangays namely, Tandiong Muslim, Bagong Buhay, Bella and Pandan-Pandan. The bay receives fresh water from Binuangan River where it carries or transports with it sediments, pesticides, fertilizers and effluents from small-scale mining activities located in Barangays Payongan and Calades and from agricultural and fishpond activities uplands (LGU-ALICIA 2010). Within the eastern part of the bay, the study was carried out in May 3, 2014 in the five sampling stations established near the coastline with a depth of 7-10 m. The five sampling stations were positioned within the vicinity of the influence of Binuanngan River with station 1 located nearest to the mouth of the river (about 500 m away) while station 5 as the farthest (about 2 km away from the river mouth). Anthropogenic wastes such as domestic discharges from houses (made of bamboo) visible along the shoreline as well as river run-offs which carries with it effluents from agriculture and fishpond activities occurring upland exits into the bay.

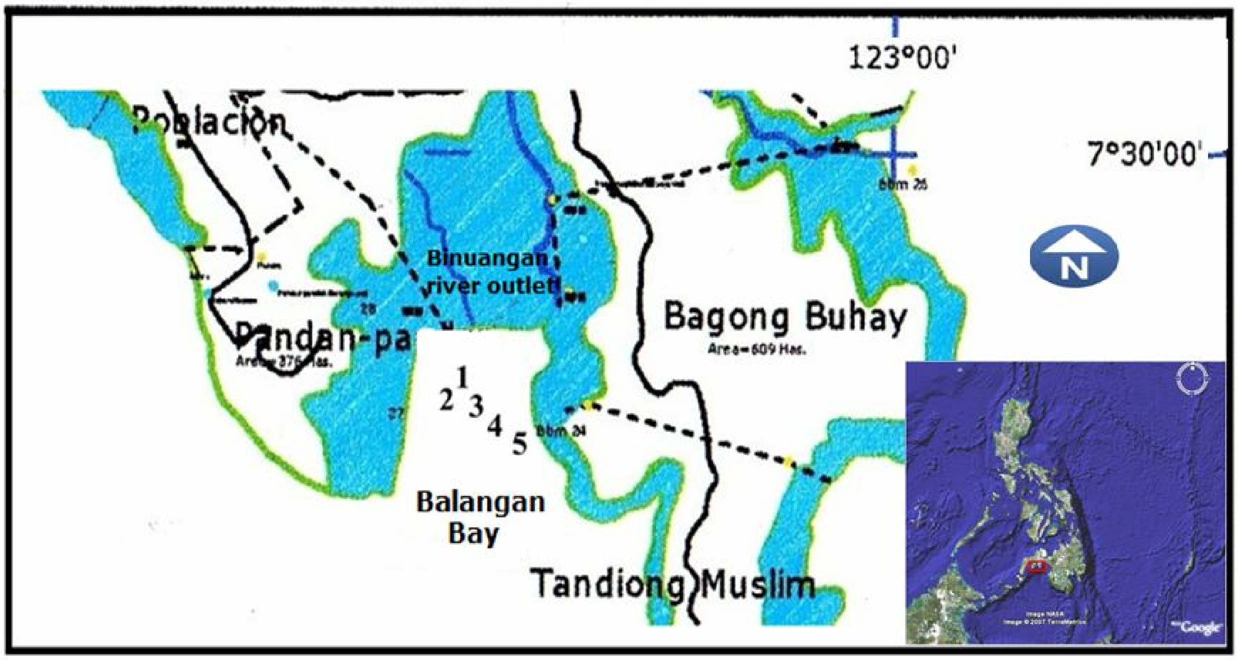

Figure 1. Geographical locations of the five sampling stations where foraminifera were collected. Inset is the map of the Philippines with Balangan Bay enclosed in a red rectangle (LGU-Alicia 2010).

Water quality determination and sediment collections were carried out in each station. *In situ* determination of pH, temperature, salinity, and dissolved oxygen (DO) of the bottom waters in each of the five stations were done using the handheld refractometer (ATAGO), handy pH meter (Eutech Instruments) and the modified Winkler Titration Method (Bruckner 2013), respectively. On the other hand, the organic matter contents of the sediments, namely chlorophyll a, calcium carbonate and total organic matter, were collected employing a plastic corer (inner diameter: 4 cm, length: 10 cm) which was made of a syringe where its tip was cut off. Using the plastic corer, the top 1 cm of the sediments were collected by the diver and then were immediately put inside a Ziploc bag once the diver was on board of the motorboat. All collected sediment samples were stored in a freezer prior to the laboratory analyses. Measurements of calcium carbonate and total organic matter were done using the method employed by Moghaddasi et al (2009), while chlorophyll a was read using a spectrophotometer following the technique of Liu et al (2007). For the grain size determination, a grab sampler was utilized to collect the sediments and then the sizes were evaluated by the sieving process using several sieves with mesh opening of 2.00 mm, 0.841 mm, 0.074 mm and 0.053 mm. The soil particles retained in each sieve were weighed separately and afterwards each particle fraction was computed and classified based on the Wentworth grade classification of particle size. For the foraminiferan analysis, 1 cm depth of core samples were gathered from the sediments of the five stations and immediately deposited into properly labeled plastic bottles. All core sediment samples for foraminiferan analysis were preserved and stained with a Rose Bengal - 10% formalin solution (2 g Rose Bengal in 1 L buffered formalin). The presence of live foraminifera during the time of collection were determine by the stain (Rose Bengal) since alive foraminifera absorbs the Rose Bengal stain and renders them pink in coloration. The samples were then gently mixed in order for the foraminiferans to be well-preserved and well-stained. Core sediment samples were collected twice in each sampling station. For the stain to be effective, foraminifera sediment core samples were kept in the dark for two weeks. Volume of the wet sediment in each core sediment sample collected for foraminifera was 12.56 cm^3. Each foraminiferans were extracted by pouring the sediment sample into a 149 µm sieve and then were gently washed with tap water until no more fine-grained sediments were left. The residues from the sieve were transferred into a petri dish and added with 10 mL distilled water. The samples were gently mixed and three sub-samples of 1 mL were retrieved using a pipette. The sub-samples were air-dried and then all live individuals (stained) in each of the replicate samples were hand-picked using an artist's brush (Sakura, tip size 3/0) moistened with distilled water under a dissecting microscope (Optech). All live individuals were separated, identified to species level and then counted. Three 1-mL sub-samples were used for counting and the average was taken. Abundance for each species was expressed as the number of individuals per mL, whereas relative abundance for each species was expressed as a percent of total foraminifera present. Illustration guides of Patterson et al (2010), Murray (2003), Riveiros & Patterson (2007), Haig (1997), Scott et al (2000), Clark & Patterson (1993) and the illustrated foraminifera gallery (http://www.foraminifera.eu) were used in identifying individual. Using a digital camera (Sony Cyber-Shot, 16 MP), all encountered species was documented and measured using an eyepiece micrometer whose scale division appears together with the image of the foraminifera to be measured. Diversity indices were computed using Shannon-Weaver Index, Margalef Index and Menhinick index. The difference in the abundance of live foraminiferan species between sampling stations and between replicates was determined using One-way ANOVA. The relationship between physico-chemical parameters and the abundance of live foraminiferal assemblage was determined using the Canonical Correspondence Analysis (CCA). All analyses were done using PAST (Paleontological Statistical) software version 2.17 (http://folk.uio.no/ohammer/past/) (Hammer et al 2001).

Results and Discussion. The mean values of the physical and chemical parameters of the bottom waters and the organic matter content of the sediments in Balangan Bay are presented in Table 1. Differences in the mean values of the environmental parameters were observed in the five sampling stations. For instance, station 1 showed the lowest value for the bottom water temperature (28.65°C) when compared to the four sampling stations. Although temperature is an important factor in coastal environments (Culver & Buzas 1999), it is relatively uniform and if not, within the range of standard value in most parts of the ocean and therefore probably not a major parameter for foraminifera, at least in modern oceans (Gooday & Jorissen 2012).

Table 1

Mean values of the environmental parameters of the bottom waters and organic matter content of sediments from the five sampling stations in Balangan Bay

Environmental parameters	*Stations*				
	1	*2*	*3*	*4*	*5*
Water temp (°C)	28.65	29.2	29.35	29.3	29.25
pH	7.95	7.98	7.795	8.01	7.97
Salinity (ppt)	27.5	30	28.5	33	30
DO (mg L^{-1})	8.4	5.9	7.3	7.4	7.6
$CaCO_3$ (%)	36.179	34.173	25.4142	28.0141	38.8572
TOM (%)	22.241	21.133	24.205	44.217	19.158
Chlorophyll a (μgL^{-1})	0.487	0.867	0.594	0.694	0.545

Standard values for marine and coastal waters: Water temperature minimum rise of 3°C, TSS <30 mg L^{-1} increase, pH range from 6.0 to 8.5, DO >5mg L^{-1}, Salinity 34-45 ppt (Philippine waters standard values from DENR-DAO 2008), TOM - total organic matter.

For pH, all five sampling stations showed slightly alkaline values (7.7–8.01) with station 4 exhibiting the highest value. The pH is an important indicator of chemical conditions of the depositional environment and is a critical environmental factor which influences the production of calcareous microfauna. Hydrogen ion concentrations are expected to affect the production of calcareous tests of foraminiferans at pH approximately <7, where they may not be able to survive (Phleger 1960). Salinity values in all five sites were <35 ppt with stations 1 and 4 showing the lowest (27.5 ppt) and highest (33 ppt) values, respectively. The lower values reflected in all stations might be due to the influence of freshwater coming from Binuangan river. According to Giere (2009), salinity preference may also occur among meiofauna. The recorded DO values in all of the five sampling stations in Balangan Bay are within the standard values set by the Philippine Department of Environment and Natural Resources (DENR-DAO 34 2008), however large variations occurred between these stations. Station 1 showed the highest value (8.9 mg L^{-1}), while station 2 has the lowest value of 5.9 mg L^{-1}. On the other hand, the organic matter contents of the sediment showed large differences between sampling stations. For example, $CaCO_3$ was highest in station 5 (38.8572%), but lowest in station 3 (25.4142%), while total organic matter was highest in station 4 (44.217%) but lowest in station 5 (19.016%). The grain size analysis of the sediments showed that the sedimentary structure of the benthic zone in the five sampling stations is predominantly made up of silt in almost uniform degrees of sizes.

A total of 46 living benthic foraminiferan species belonging to 23 genera under 20 families were indentified in the five sampling stations of Balangan Bay (Table 2).

The level of the diversity of foraminiferal species in the five sampling stations is presented in Table 2. Results revealed a highly diversified assemblage of living benthic foraminiferan species in the five sampling stations with station 4 showing the highest number of foraminiferal taxa (37), followed in decreasing order by station 2 (36), station 5 (32), station 3 (29) and with station 1 having the lowest number of taxa (24). Further, high diversity indices (H': between 2.723-2.569) and equitability (J: between 0.8083-0.7293) values were noted in all sampling stations (between 2.723-2.569) with low dominance (D: 0.09654-0.1227) values. This may indicate that foraminiferan species were evenly distributed in terms of abundance in the 5 sampling sites and that no certain species tend to dominate as shown in Figure 3. It has been reported that high diversity with low dominace values are characteristics of oligotrophic, stress-free environment with low levels of ecological stress (Kouwenhover 2000). It is probable that Balangan Bay can be categorized as having pristine waters able to support highly diversified benthic foraminiferal species.

Table 2

Composition of live benthic foraminiferan species in the five sampling stations of Balangan Bay, Zamboanga Sibugay, western Mindanao

Foraminiferal species	*Stations*				
	1	*2*	*3*	*4*	*5*
Alfredinidae					
Epistomaroides punctulatus	+	+	+	+	+
Bolivinidae					
Bolivina compacta	+	-	-	+	-
Brizalina convallaria	+	-	-	+	-
Chrysalogoniidae					
Amphimorphina crassa	-	+	-	+	+
Amphimorphina lirata	+	-	-	-	-
Cibicididae					
Cibicides cushmani	-	-	+	+	+
Elphidiidae					
Elphidium advenum	+	+	+	+	+
Elphidium collinsi	-	-	-	+	-
Elphidium crispum	+	+	+	+	+
Elphidium jenseni	+	+	+	+	+
Elphidium lessonii	-	+	-	-	-
Elphidium macellum	+	-	+	-	-
Hauerinidae					
Quinqueloculina agglutinans	-	+	+	+	+
Quinqueloculina bicostata	-	+	+	+	+
Quinqueloculina boueana	+	-	-	+	+
Quinqueloculina laevigata	+	+	+	+	+
Quinqueloculina lamarckiana	-	+	-	-	-
Quinqueloculina lata	+	+	-	-	-
Quinqueloculina poeyana	-	+	-	+	+
Quinqueloculina seminulum	+	+	+	+	+
Quinqueloculina tropicalis	-	+	+	+	+
Quinqueloculina vulgaris	-	+	+	+	+
Heterohelicidae					
Heterohelix straiata	+	+	+	+	+
Hippocrepinidae					
Jacullela acuta	+	+	+	+	+
Lituolidae					
Ammobaculites agglutinans	+	+	+	+	+
Miliolidae					
Triloculina trigonula	+	+	+	+	+
Nonionidae					
Nonionellina labradorica	+	+	+	+	+
Pseudononion japonicum	-	+	+	+	+
Ophthalmidiidae					
Edentostomina cultrate	-	+	-	+	-
Edentostomina rupertiana	+	+	+	+	+
Peneroplidae					
Peneroplis carinatus	-	+	-	-	-
Planorbulinidae					
Planorbulina difformis	+	+	+	+	+
Planorbulina mediterranensis	-	+	-	+	-
Reusellidae					
Reusella spinulosa	+	+	+	+	+

Foraminiferal species	Stations				
	1	2	3	4	5
Rotaliidae					
Ammonia beccarii	+	+	+	+	+
Ammonia tepida	+	+	+	+	+
Pararotalia batavensis	+	-	+	+	+
Pararotalia venusta	-	-	-	+	-
Valvulineria floridana	-	+	+	+	+
Rosalinidae					
Rosallina globularis	-	+	-	-	-
Soritidae					
Sorites marginalis	+	+	+	+	+
Spiroloculinidae					
Spiroloculina angulata	-	+	+	+	+
Spiroloculina antillarum	-	+	-	-	-
Spiroloculina communis	-	+	+	+	+
Spiroloculina depessa	-	+	+	-	+
Textulariidae					
Textularia agglutinans	-	-	-	+	+
Total number of species	24	36	29	37	32

+ = presence, - = absence.

Table 3

Diversity profiles of the five sampling stations for live foraminiferans in Balangan Bay, Zamboanga Sibugay, western Mindanao

Diversity indices	*Stations*				
	1	*2*	*3*	*4*	*5*
Taxa (S)	24	36	29	37	32
Individuals	746	1575	1312	3101	1605
Dominance (D)	0.1151	0.1153	0.1227	0.1102	0.09654
Shannon (H)	2.569	2.614	2.534	2.652	2.723
Simpson (1-D)	0.8849	0.8847	0.8773	0.8898	0.9035
Evenness (e^H/S)	0.5437	0.3791	0.4345	0.3832	0.4757
Menhinick	0.8787	0.9071	0.8006	0.6644	0.7988
Margalef	3.477	4.754	3.9	4.478	4.2
Equitability (J)	0.8083	0.7293	0.7524	0.7343	0.7856
Fisher alpha	4.738	6.564	5.249	5.905	5.663
Berger-Parker	0.2373	0.2222	0.2515	0.2409	0.195

The relative abundance of the 46 identified living forams varies form station to station with 13 species showing relative high abundances greater than 2% in at least one replicate core samples (Figure 2). Among these 13 living foraminifera species, *Ammonia becccarii*, *Heterohelix striata*, *Ammonia tepida*, *Nonionellina labradorica*, *Triloculina trigonula* and *Reusella spinulosa* were abundant in the five sampling stations. The results further showed that *A. beccarii* was the most abundant (<26%) in all stations followed in decreasing order by *H. striata* (<23%), *A. tepida* (<17 %), *N. labradorica* (<14%), *T. trigonula* (<9%), and *R. spinulosa* (<6%). It has been reported that *Triloculina* spp. and *Ammonia* spp. (*A. beccarri* and *A. tepida*) are opportunistic species in coastal regions that were constantly exposed by anthropogenic pollution (Kfouri et al 2005). *A. beccarii* is a widely accepted shallow water species (Alve & Goldstien 2003) primarily confined to water depths of <10 m. It is also an euryhaline organism, widely distributed from estuarine to lagoonal zones to intertidal to subtidal zones (Alve & Murray 1999; Alve &

Goldstien 2003) able to survive under wide range of values of DO (Moodley & Hess 1992), salinity and temperature (Murray 1991) as well as in heavily polluted and stressed waters (Alve 1995; Lacuna & Alviro 2014; Lacuna & Masangcay 2013).

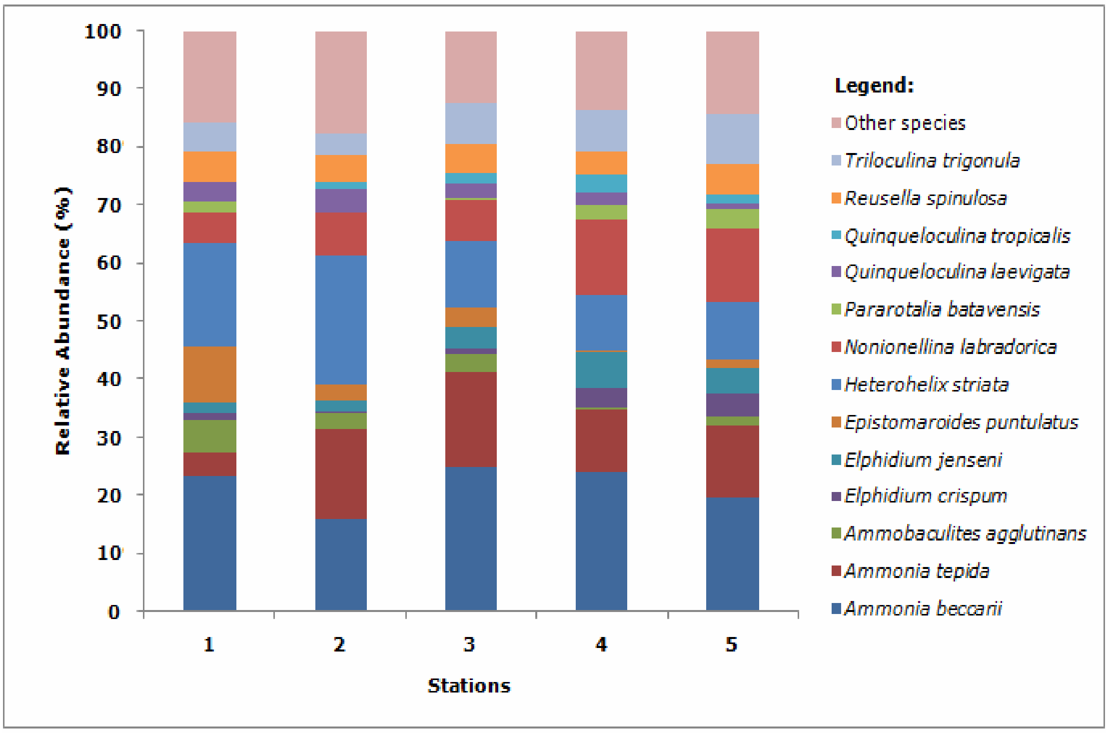

Figure 2. Relative abundance (%) of selected benthic foraminiferan species in five sampling stations in Balangan Bay, Zamboanga Sibugay, western Mindanao.

Further, it has been observed that *A. beccarii* is highly tolerant to different ecosystems (Walton & Sloan 1990). *A. tepida* had been observed to occur in lagoon severely influenced by industrial discharges (Frontalini et al 2009) and is known to tolerate chemical and thermal pollution, fertilizing products, hydrocarbons and even capable of supporting very polluted environments and high concentrations of trace elements (Setty & Nigam 1982; Coccioni 2000; Ferraro et al 2006). Further, Burone & Pires–Vanin (2006) observed that the dominance of *A. Tepida* may be an indication of notable conditions as a result of both natural and anthropogenic effects. *N. labradorica* is found to tolerate environmental variations such as changes in substrate composition, more pollution, greater oxygen depletion, and higher turbidity (Alve & Nagy 1986).

The results of One-way ANOVA showed that the abundance (i.e. total count) of live benthic foraminiferal assemblage in Balangan Bay differs between stations ($p<0.05$) and between replicates ($p<0.05$) as manifested in Figure 3, where station 4 showed the highest foraminiferan abundance while lowest in station 1. According to Buzas et al (2002), no two stations showed the same degree of abundance of individuals because foraminifers are sensitive to even a very slight ecologic difference (Stubbs 1940). Further, the disparity in the abundance of foraminiferans between the two replicates eventhough collected just a few centimeters apart from each other may be attributed to the spatial patchiness commonly exhibited among benthic foraminifers. Several studies had documented that patchiness (i.e. organisms distributed unevenly or aggregated) in the spatial distribution and abundances of benthic foraminifera may be due to factors like absence/presence of high amount of food sources (Gooday 1988; Valiela 1995), asexual reproduction (Buzas 1968; Murray 1973) and local disturbances such as presence of predators (Gooday 1988; Valiela 1995).

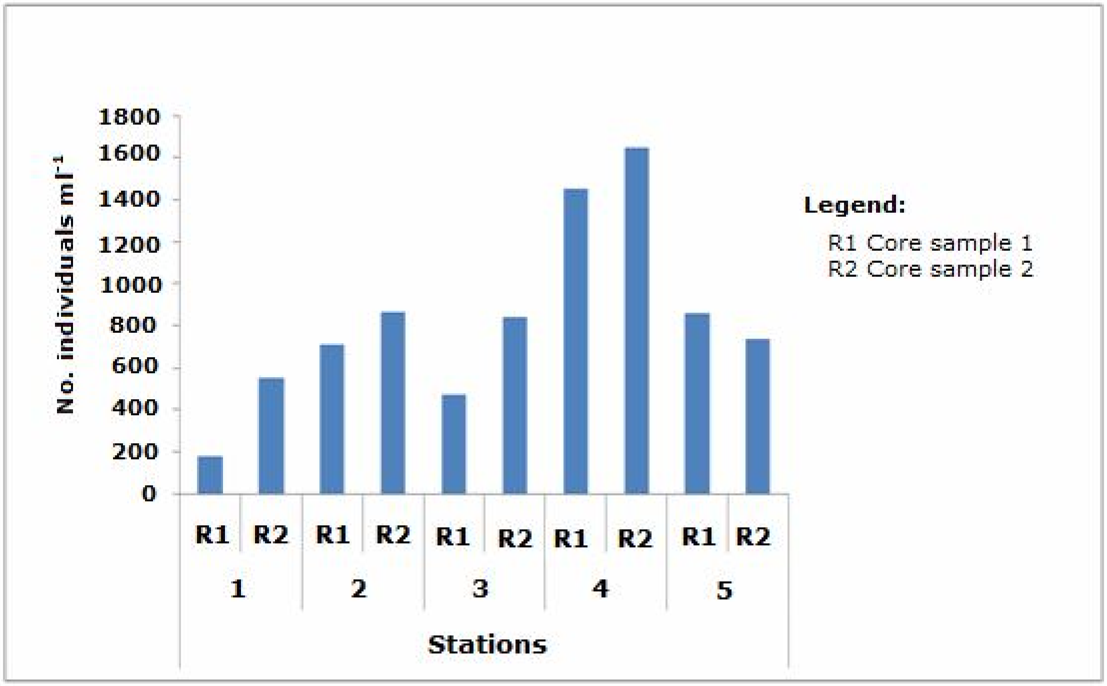

Figure 3. Total count of foraminiferans (no. individuals mL^{-1}) in the five sampling stations in Balangan Bay, Zamboanga Sibugay, western Mindanao.

The results of the Canonical Correspondence Analysis reflected in Figure 4 can explain the differences in the community structures of live foraminiferans between the stations.

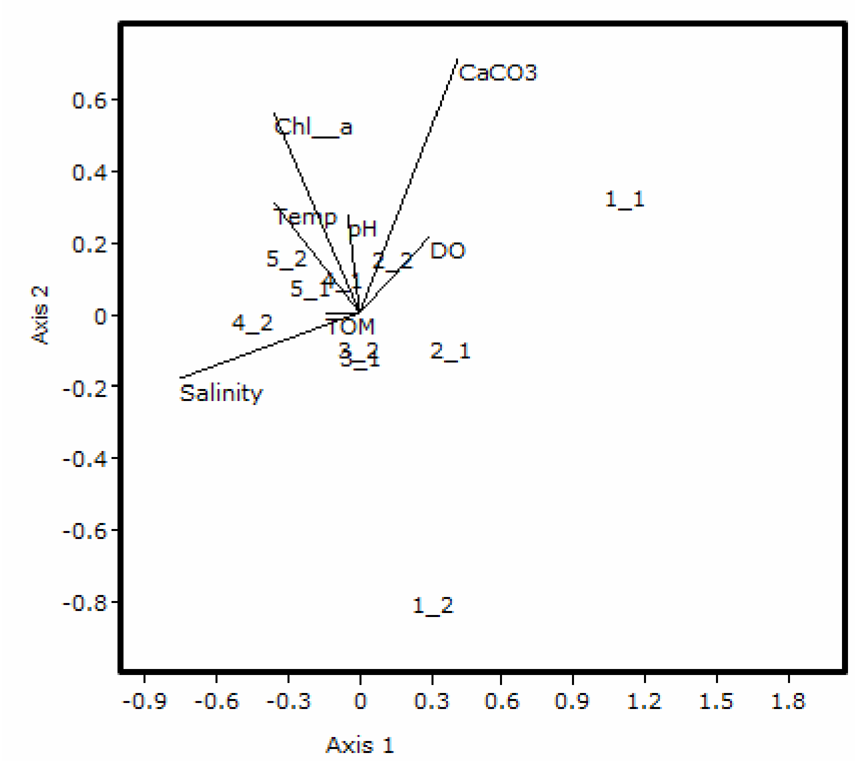

Figure 4. Results of the Canonical Correspondence Analysis - biplot showing the distance among the sampling stations and the physico-chemical factors that influence the distribution and abundance of live benthic foraminiferans.

Figure 4 shows that high abundance of foraminiferans observed in station 4 might be influenced by total organic matter (TOM), salinity and temperature. It is noticeable that total organic matter content (59.6802%) was highest in station 4, and it is suggested that high foraminiferal abundance are supported by elevated food availability. Moghadassi et al (2009) noted that high concentration of organic matter was related to the sinking of primary productivity or dead phytoplankton which resulted to the accumulation of organic particles on the seafloor. Many shallow-water benthic foraminifera utilizes on microalgae and bacteria that settles on the sediment (Moodley et al 2002; Heinz et al 2001). Aside from TOM content of the sediment, it is possible that high abundances of foraminifera in station 4 are partly due to factors that may influence microphytobenthic and bacterial biomass. Montagna et al (1983) showed that occurences of diatoms and other meiofauna were partly caused by physical factors like salinity and temperature. In the present study, high salinity and temperature were noted in station 4 and it is suggested that these factors could have influenced high diatom productionn resulting to elevated food availability once these diatoms sink to the seafloor as phytodetritus. Hence, the downward flux of organic matter and the associated influence of salinity and temperature to primary productivity may have been responsible for the high abundance of benthic foraminiferal assemblages in station 4.

Conclusions. In general, the living foraminiferal assemblages in all sampling stations were highly diversified with low dominance (D) values indicating that living benthic foraminiferans are evenly distributed in all the sampling stations. This may indicate that Balangan bay is still pristine and harbours diverse marine flora and fauna. The relative abundance of the whole foraminiferan community varies from station to station with station 4 with the highest abundance and station 1 with the lowest. Results in the Canonical Correspondence Analysis (CCA) revealed that the abundance of the benthic foraminiferan assemblages is influenced by total organic matter (TOM), salinity and temperature. Hence, the results of this study will serve as baseline required for future monitoring on effects cause by both natural and anthropogenic activities in the area further promoting foraminiferans as tools for ecological and environmental interpretations.

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