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Benthic foraminifera in Tantanang Bay, Zamboanga Sibugay, Southern Philippines

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Abstract. Live benthic foraminiferan composition, diversity, abundance and their relationship with the water quality parameters, organic matter content and size of the sediments were determined and compared. A total of 38 foraminiferan species belonging to 25 genera under 23 families were identified in the living benthic foraminiferal assemblage in Tantanang Bay, Zamboanga Sibugay, Southern Philippines. Values for foraminifera diversity and equitability (evenness) were quite low reflecting one species, *viz. Ammonia beccarii* (>65%), solely dominating the living foraminiferal assemblage in all five sampling stations. It is suggested that the the current conditions of the area, *viz.* silty sediments, domestic sewages from local community and freshwater discharges from uplands which carries with it pesticides, fertilizers and sediments, might contribute to the sole dominance of *A. beccarii* in the assemblage. The results of the Canonical Correspondence Analysis further showed that the parameters, *viz.* salinity, temperature, and dissolved oxygen (DO) content of the bottom waters may have also influenced the low abundance of foraminiferal assemblage in the present study. Therefore, the outcome of this work can be used as baseline for future studies in Tantanang Bay, especially in managing and conserving the natural resources of the area.

Key Words: amoeboid protozoa, biodiversity, abundance, Zamboanga Peninsula.

Introduction. Foraminifera came from the Latin words “foramen” or “foramin” which means an opening, a hole, or passage and “ferre” which mean bearing. They are a group of single-celled, heterotrophic, amoeboid protozoa that secrete a test or shell with one or more chambers and reproduce by alternation of sexual and asexual generation (Gooday et al 1992). Benthic foraminifera utilize a wide array of food items, depending on their mode of nutrition (Flach et al 1998). For instance, herbivorous benthic foraminifera graze on algae (diatoms) and bacteria while the carnivorous type preys on small arthropods and other foraminifera. However, majority of the foraminifera are opportunistic omnivores preying on detritus, dissolved organic matter in addition to diatoms and bacteria, hence making them a vital link between the low (sediments and phytodetritus) and high (benthic metazoans) trophic levels (Lipps & Valentine 1970; Gooday et al 1992; Nomaki et al 2008) since they are also food source for of benthic organisms like the worms, crustaceans, echinoderms, gastropods and even fishes (Lipps & Valentine 1970; Lipps 1983; Cedhagen 1988; Hohenegger et al 1989; Goldstein 1999). Aside from the important position they occupy in the marine benthic food chain, they are also considered as an important tool or device in monitoring the health of the environment. For instance, the relative proportion of stress-tolerant taxa and abnormal specimens had been used as evidences to show foraminiferans as suitable indicators of pollution in the estuarine and marine ecosystems (Barras et al 2014; Lacuna & Alviro 2014; Cosentino et al 2013; Foster et al 2012; Martins et al 2011; Frontalini et al 2010; Frontalini & Coccioni 2008; Carboni et al 2009; Ferraro et al 2006; Tsujimoto et al 2006; Alve 1995). Other than the detrimental effects of various types of pollution in controlling the species diversity and abundance of foraminiferans, important environmental parameters like salinity, temperature, dissolved oxygen (DO), pH, nutrition and sediment type have been suggested in influencing the community structure of foraminiferan assemblage (Yahya et al 2014; Lacuna et al 2013; Horton & Murray 2007; Nigam et al 2008, 2006; Lesen 2005).

Few studies on benthic foraminifera in the waters of Iligan Bay, Northern Mindanao, Philippines have provided some information on the environmental parameters that may have influenced the community structure of benthic foraminifera assemblages (Lacuna et al 2013; Lacuna & Alviro 2014; Ganaway & Lacuna 2014; Unsing & Lacuna 2014; Lacuna & Gayda 2014). However, the diversity and abundance of benthic foraminiferal taxa in the waters of Zamboanga peninsula is relatively unknown. To address this gap, this study was carried out to investigate the species diversity and abundance of living foraminifera in the sediments of the eastern coast of Tantanang Bay. Specifically, the study aims to: (1) determine the physical and chemical profiles of the bottom waters and the organic matter contents of the sediments, (2) identify the different species of live (stained) benthic foraminiferans present in the five sampling stations, and to (3) examine the relationship between the environmental condition of bottom waters, organic matter content and grain size of sediments to the abundance of live foraminiferan species in the five sampling areas. The data gathered will be useful because the results will serve as baseline needed for monitoring the future effects caused by both natural and anthropogenic activities in the area.

Material and Method. Tantanang bay located in Zamboanga Sibugay, Zamboanga Peninsula in Mindanao has a latitude of 7.5° (7° 30' 3.31" N) and a longitude of 122.91° (122° 54' 35.83" E) (Figure 1). Its coastal area measures for about 1,005 hectare and is considered as the largest fish sanctuary in the province. It is enclosed by five communities or barangays with three major rivers identified namely, Bomba River, Lambouyan River and Lutiman River that carry freshwater and transport nutrients into the bay (LGU - ALICIA 2010). Within the eastern portion of the bay, the study was carried out in May 4, 2014 in the five sampling sites established near the coastline with a depth of 7-10 m (Figure 1).

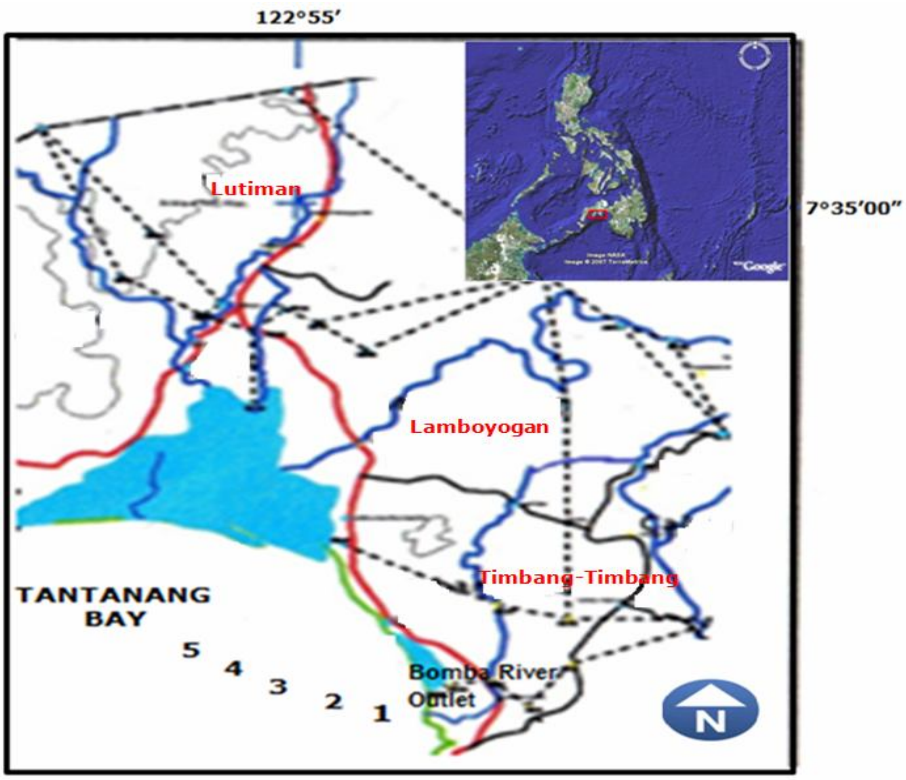

Figure 1. Geographical locations of the five sampling stations where foraminífera were collected. Inset is the map of the Philippines with Tantanang Bay enclosed in a red rectangle (LGU - Alicia 2010).

Station 1 was positioned 60 m away from the outlet of Bomba River while stations 2 and 3 were 95 m and 130 m away from the river outlet, respectively. Station 5 was positioned farthest from the outlet of Bomba River. All sampling stations received domestic sewages discharged directly from houses (made of bamboo) visible along the shoreline in addition to the run-offs coming from the agriculture and fishpond activities occurring upland. In each of the sampling stations, water quality determination and sediment collections were done following the method described by Lacuna et al (2013). For instance, field data such as bottom water temperature, pH, salinity and dissolved oxygen were measured *in situ* in each of the five sampling stations using portable pH meter (Eutech Instruments) and handheld refractometer (ATAGO), and modified Winkler Titration Method (Bruckner 2013), respectively. On the other hand, by means of a syringe (inner diameter: 4 cm, length: 10 cm) which was cut at its tip, calcium carbonate, total organic matter and chlorophyll *a* were analyzed. Employing the aid of a diver, the corer was pushed into the top 1-2 cm of the sediment and were placed in a Ziploc bag and stored in a freezer until analysis. The procedure of Moghaddasi et al (2000) was employed to assess for calcium carbonate and total organic matter concentration, whereas the method depicted in Liu et al (2007) was followed for the analysis of chlorophyll *a* which was determined by spectrophotometry using an acetone. For the grain size test, sieving technique was applied to the sediments which were gathered with the aid of a grab sampler in each sampling stations. The sieving process involved the use of screen sieves (with the mesh openings of 2.00 mm, 0.84 mm, 0.59 mm, 0.31 mm, 0.14 mm, and 0.07 and 0.05 mm) where the 100 g dried sediment was being sieved in order to separate soil particles of different sizes. After sieving, the soil particles that were retained on the individual sieve screen were separated and weighed. Each grain portion was calculated to get the percentage and then was categorized using the Wentworth grade scheme of classification. Subsequently, another set of core samples were taken from the uppermost 1 cm of the sediment to be used for foraminifera assessments in each stations. The sediment sample was preserved and stained with 10% Buffered Formalin-Rose Bengal solution. The purpose of using Rose Bengal was to assure that live foraminiferans were collected at the time of its gathering.

Immediately, the preserved-stained soil samples inside the sampling bottle were slowly agitated in order for the preservative and stain to be properly absorbed by the organisms. Duplicate core sediment samples were collected in the five sampling stations to guarantee elimination of any possible discrimination on abundance data since these microfauna display patchy in its distribution (Murray & Alve 2000). Individual core sediment sample for the quantitative analysis of foraminifera has a total wet volume of 12.56 cm^3). The sediment samples for foraminifera analysis were stored for 2 weeks to allow effective staining with Rose Bengal. Each foraminiferan 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 were then added with 10 mL distilled water. Using a pipette, a 1 mL subsample was taken from the 10 mL residue and then was air-dried. All live (stained) and dead (unstained) individuals in this 1 mL subsample were separated, identified to species level and then counted. Three 1 mL subsamples were used for counting and then the average was taken. Abundance of each foraminiferan species was then expressed as individuals per mL while relative abundance 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), Montaggioni & Vénec-Peyré (1993) and the illustrated foraminifera gallery (http://www.foraminifera.eu) were used in identifying individual foraminifera. 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, the organic matter contents of the sediments and grain size in the eastern portion of Tantanang Bay is presented in Table 1. The values for all bottom water quality parameters (*i.e.* temperature, pH, salinity and DO) in all five sampling stations are within the range for any marine faunistic assemblage to thrive and be fairly abundant (DENR-DAO 34 2008; Bradshaw 1957).

Table 1

Mean values of environmental parameters of the bottom waters and organic matter contents in the Eastern part of Tantanang Bay

Environmental parameters	*Stations*				
	1	*2*	*3*	*4*	*5*
Water temp (°C)	28.9	29.25	29.5	29.1	29.05
pH	7.805	7.78	7.695	7.845	7.76
Salinity (ppt)	31	34	32.5	32.5	35
DO (mg L^{-1})	5.2	5.8	6.8	6.4	5.8
$CaCO_3$ (%)	49.987	48.9282	50.1814	51.8116	49.0858
TOM (%)	17.4396	19.58925	18.3516	15.7854	17.79665
Chlorophyll *a* (μL^{-1})	0.689975	0.633115	0.942435	0.92505	0.875045
Medium sand (%)	4	7	4	2	4
Fine sand (%)	10	11	11	15	12
Very fine sand (%)	19	18	24	20	16
Silt (%)	67	64	61	63	68

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 >5 mg L^{-1}; Salinity 34-45 ppt (Philippine waters standard values from DENR-DAO 2008), TOM - total organic matter.

In spite of this, there were still disparity in the mean values of the physical, chemical parameters of the water and those of the sediment contents among the stations which may be accountable for the discrepancy in the abundances of foraminiferans. For instance, the highest bottom water temperature value was regarded in station 3 (29.5°C) whereas station 1 (28.9°C) had the lowest water temperature value. 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). For pH, the lowest (7.695) and the highest (7.845) values were recorded in stations 3 and 4, respectively. pH have an insignificant effect on foraminiferans because the pH in seawater is slightly alkaline (pH 7.5-8.5) and therefore is protected against any change in the pH (Giere 2009). The recorded salinity value in station 1 (31 ppt) is the lowest value while the highest value was recorded in station 5 (35 ppt). Even though fluctuations of salinity values were observed, these are still within the suitable range for marine organisms to flourish. For the DO content, the lowest value (5.2 mg L^{-1}) was recorded at station 1 while station 3 (6.8 mg L^{-1}) had the highest value. Giere (2009) showed that oxygen is the predominant factor among the abiotic parameters determining the habitat conditions and the presence of meiofaunal assemblage. Generally, foraminiferans have strong needs for oxygen because they have large surface area so that any changes in the supply of this important parameter can affect their distribution and abundance. The environmental conditions of the marine environment are the limiting factors in the occurrence and abundance of benthic foraminifera (Hariri 2008) although in general, all bottom water environmental parameters recorded in the five sampling stations are within the standard limits set by DENR (DAO 34 2008). Furthermore, it is important to note that sedimentary structures of the benthic zone in the five sampling stations are predominantly made up of silt. On the other hand, the organic matter contents of the sediment (i.e. $CaCO_3$, TOM, Chlorophyll *a*) showed slight differences between sampling stations. For example, the calcium carbonate content was highest in station 4 (51.8116%) and lowest in station 2 (48.9282%). For the chlorophyll-*a* content, station 3 was the highest with the value of 0.942435 μL^{-1} and lowest in station 2 with a value of 0.633115 μL^{-1} while, total organic matter was highest in station 2 (19.58925%) but low in station 4 (15.7854%).

A total of 38 species belonging to 25 genera under 23 families were identified in the living benthic foraminiferal assemblage in the five sampling stations in Tantanang Bay (Table 2). Most of the foraminiferan species in the study area is characterized mostly by small in size specimens (<100 μm), majority of which are well-preserved and did not exhibit morphological defects except for few samples showing tests deformities and even tend to be broken easily when handled. This may imply the possible effects of pollution occurring in the said area as manifested on their deformed test morphology and sensitivity.

Table 2

Composition of live foraminiferan species in the five sampling stations in the Eastern part of Tantanang Bay, Zamboanga Sibugay

Foraminiferal species	*Stations*				
	1	*2*	*3*	*4*	*5*
Rotaliidae					
Ammonia beccarii	+	+	+	+	+
Ammonia tepida	+	+	+	+	+
Amphisteginidae					
Amphistegina lessonii	-	+	+	+	-
Alfredinidae					
Epistomaroides punctulatus	+	+	-	-	-
Epistomaroides polystomelloides	+	-	+	-	-
Bagginidae					
Baggina bradyi	-	-	-	-	+
Bolivinidae					
Brizalina alata	-	-	-	+	-
Calcarinidae					
Siderolites tetraedra	-	+	-	-	-
Chrysalogoniidae					
Amphimorphina crassa	+	+	+	-	+
Amphimorphina haueriana	-	-	+	-	-
Cibicididae					
Cibicides cushmani	+	-	+	+	+
Elphidiidae					
Elphidium cripsum	+	+	+	+	+
Elphidium fichtellianum	+	+	+	+	+
Elphidium lessonii	-	+	+	+	+
Elphidium somaense	-	+	+	-	-
Gavelinellidae					
Hanzawai concentrica	-	-	-	-	+

Foraminiferal species	Stations				
	1	2	3	4	5
Globotextulariidae					
Globotextularia anceps	-	-	-	-	+
Haurinidae					
Ammamassilina alveoliniformis	-	-	-	-	+
Haurinidae					
Quinqueloculina bicostata	+	+	+	-	+
Quinqueloculina boueana	+	+	+	-	+
Quinqueloculina costata	+	-	-	-	-
Quinqueloculina seminula	+	+	+	+	+
Quinqueloculina subrotunda	+	-	-	-	-
Quinqueloculina vulgaris	+	+	-	-	-
Heterohelicidae					
Heterohelix striata	+	-	-	-	-
Miliolidae					
Triloculina tricarinata	+	+	-	-	-
Triloculina trigonula	+	-	+	+	-
Nonionidae					
Nonionellina labradorica	+	-	+	-	-
Pseudononion japonicum	-	-	+	-	-
Cornuspiridae					
Cornuspira involvens	-	-	+	-	-
Opthalmidiidae					
Edentostomina cultrata	+	-	-	-	-
Edentostomina rupertiana	+	-	-	-	-
Penerolplidae					
Coscinospira hemprichii	-	-	+	+	+
Planorbulinidae					
Planorbulina difformis	-	-	+	+	+
Rosalinidae					
Rosalina bradyi	+	+	-	-	-
Reusselidae					
Reusella spinulosa	+	-	+	-	+
Textulariidae					
Textularia agglutinans	+	+	+	+	+
Vaginulinidae					
Lenticulina submalligera	+	+	+	-	-
Total number of species	24	19	23	13	18

+ presence, - absence.

The level of the diversity of foraminiferal species in the five sampling stations is presented in Table 3. There were differences in the number of taxa between the five sampling stations, with station 1 showing the highest number of foraminferal taxa (24) followed in decreasing order by station 3 (23), station 2 (19), station 5 (18) and with station 2 having the lowest number of taxa (13). Generally, a much lower diversity (H': between 0.84-1.37) and evenness (0.09-0.20) values were noted in all 5 stations, but with high dominance (D: 0.47-0.66) values. These results indicate that the abundance is not that evenly distributed among all the foraminiferans but certain species tend to dominate in numbers. In this case, one foraminiferan species, *viz*. *Ammonia beccarii*

(>65%), solely dominated the living foraminiferal assemblage in all 5 sampling stations as reflected in Figure 2. Aside from *A. beccarii*, the abundance of other benthic foraminiferan species showing relative abundances of at least 1% in one replicate core sample is presented in a decreasing order: *A tepida* with a relative abundance of 11% followed by *Cibicides cushmani* (5.2%), *Elphidium fichtellianum* (4.8%) and 1% for the remaining foraminiferan species (i.e. *Textularia agglutinans, Reusella spinulosa, Planorbulina difformis, Coscinospira hemprichii, Triloculina trigonula, T. tricarinata, Quinqueloculina seminula, Q. bicostata, Elphidium lessonii, E. crispum, Amphimorphina crassa*, and *Amphestigina lessonii*).

Table 3

Diversity profiles of the five sampling stations for live foraminiferans in Tantanang Bay, Zamboanga Sibugay

Diversity index	*Stations*				
	1	*2*	*3*	*4*	*5*
Taxa (S)	24	19	23	13	18
Individuals	2241	1133	1341	543	1449
Dominance (D)	0.6651	0.6259	0.4743	0.6077	0.6403
Shannon (H)	0.8411	0.9956	1.371	0.9938	0.8851
Simpson (1-D)	0.3349	0.3741	0.5257	0.3923	0.3597
Evenness (e^H/S)	0.09662	0.1424	0.1713	0.2078	0.1346
Menhinick	0.507	0.5645	0.6281	0.5579	0.4729
Margalef	2.981	2.559	3.055	1.906	2.336
Equitability (J)	0.2646	0.3381	0.4372	0.3875	0.3062
Fisher alpha	3.754	3.243	3.944	2.395	2.895
Berger-Parker	0.8077	0.7855	0.6756	0.7735	0.7916

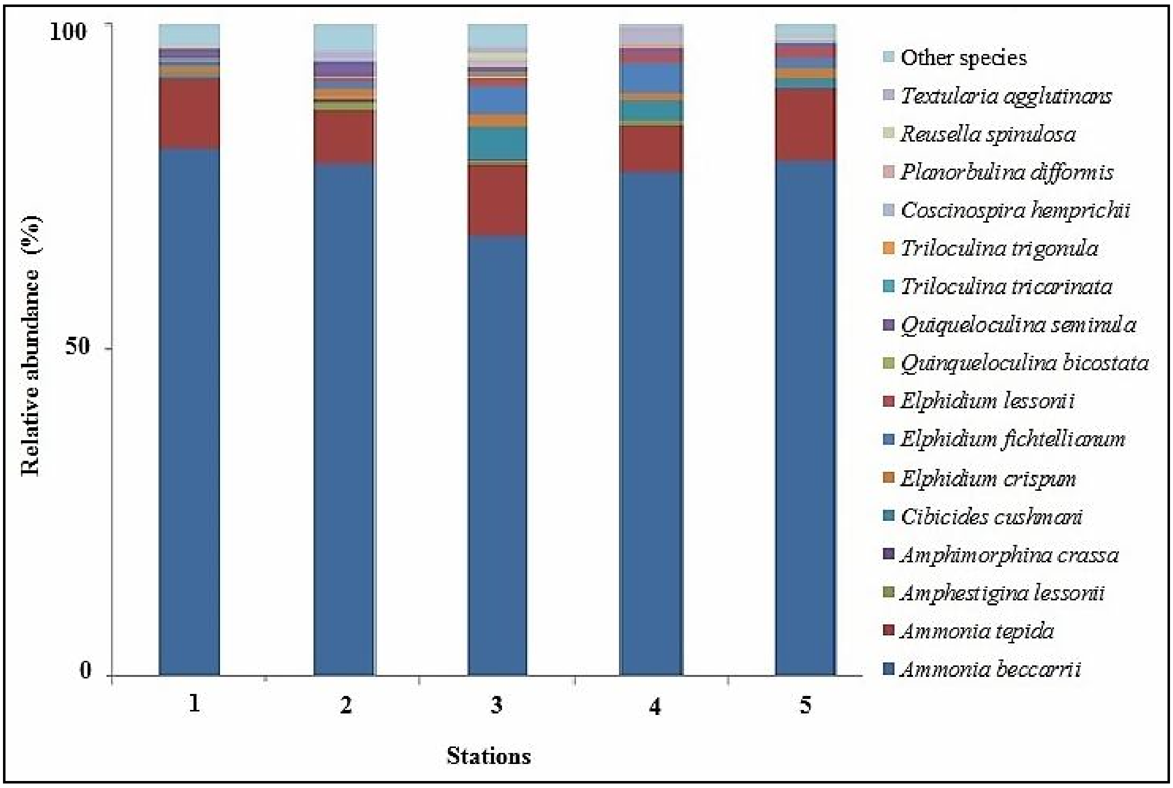

Figure 2. Relative abundance (%) of selected benthic foraminiferan species in five sampling stations in Tantanang Bay, Zamboanga Sibugay.

It is suggested that the sole dominance of the small-sized *A. beccarii* in all five sampling stations in the present study might be attributed to the current conditions prevalent in area. It is noteworthy that the 5 sampling stations were established about 50 m away from houses or shanties made of bamboos. These houses are visible along the shore and often local people, fishermen and their families occupied these houses where their domestic sewages or wastes are often discharged directly into the sea thereby contributing to human-induced pollutions. Moreover, Bomba River that carries freshwater and nutrients and sediments directly into these five sampling stations may have also transported wastes discharged from small scale minings as well as pesticides and fertilizers coming from agricultural lands and fishponds uplands. It has been reported that high diversity with low dominance values are common in oligotrophic, stress-free environment and low levels of ecological stress while high dominance, low diversity fauna are expected under stressed conditions (Kouwenhover 2000; Drinia et al 2004) which were brought about by human-induced activities. Some studies showed the response of benthic foraminiferans, specifically *A. beccarii*, to anthropogenic-induced pollutions in Iligan Bay, Mindanao, Southern Philippines. For instance, high dominance of *A. beccarii* were reported in areas that receives effluents from industries suggesting that the present environmental conditions may have influenced the community structure of live foraminiferans (Lacuna et al 2013). Further, the high abundance of *A. beccarii* exposed to several pollutants (i.e. copper, lead and chromium) from industrial effluents confirmed the capacity of this species to tolerate at least moderately-polluted waters (Lacuna & Alviro 2014). Other reports also documented the highly adaptive quality of *A. beccarii* in heavily polluted waters (Cosentino et al 2013; Martinez-Colon & Hallock 2010; Tsujimoto et al 2006; Alve 1995), in high-energy waves and turbulent environments (Ghosh et al 2014), in wide range of dissolved oxygen values (Moodley & Hess 1992), and in different ecosystems in the intertidal and subtidal zones (Alve & Murray 1999; Walton & Sloan 1990; Javaux & Scott 2003). Aside from the high tolerance of *A. beccarii* to the human-induced activities occurring in its environment, the type of sediment may also influence their abundance. In the present study, the sedimentary structures of all five sampling stations comprised of silt. It has been observed that silt and clay sedimentary profiles support high abundance of only few dominant foraminiferan species including *A. beccarii* (Gayathri et al 2014; Elakkiya & Manivannam 2013; Issa et al 2009; Sohrabi-Mollayousefy et al 2006; Ferraro & Molisso 2000). Moderately well-sorted medium sands provide the habitat with the most diverse meiofauna, while coarser sand are characterized by high species richness but low density population whereas silty/muddy sediments, which are more chemically controlled, support population that have limited number of species or less diverse population (Giere 2009). Since the sedimentary structure of Tantanang Bay is predominantly silted, it is expected that few species may tend to dominate the foraminiferal assemblage of the said area, and in this case, the small-sized *A. beccarii* population dominated the community structure of foraminiferans. Further, the presence of some morphologically deformed tests of *A. beccarii* and *Elphidium fichtellianum* and the fragile forms of some *Quinqueloculina* spp., that is easily broken when handled, may suggest that Tantanang Bay are already experiencing some signs of pollution effects and that this may progress into a more serious situation if conservation actions will not be implemented.

The results of the comparison (One-way ANOVA) of the abundance of foraminiferans between the five sampling stations showed that there is a significant difference ($p<0.5$) in the abundance of foraminiferans between stations and replicates. This is reflected in Figure 3 where station 5 exhibited highest foraminiferan abundance (33%) followed in decreasing order by station 4 (27%), station 3 (20%), station 2 (17%), and station 1 (7%) having the lowest abundance. This is further supported by the results of the Canonical Correspondence Analysis reflected in Figure 5 where it showed a plot of the sampling stations across the first two canonical axes.

The plot includes a vector plot that could be used to pinpoint important variables that can explain the differences in the community structures of live foraminiferans between the five stations. Results in Figure 4 showed that high abundance of foraminiferans observed in station 5 might be influenced by bottom water salinity.

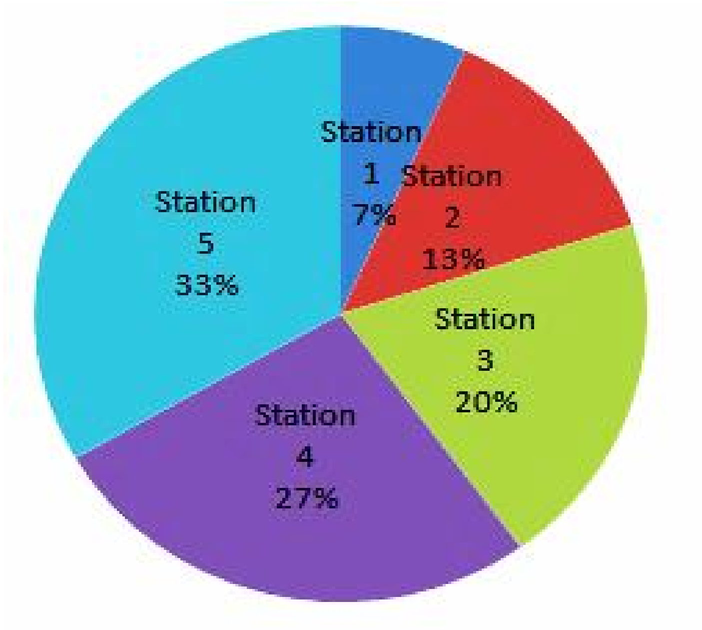

Figure 3. Relative abundance (%) of all benthic foraminiferans in the five sampling stations in Tantanang Bay, Zamboanga Sibugay.

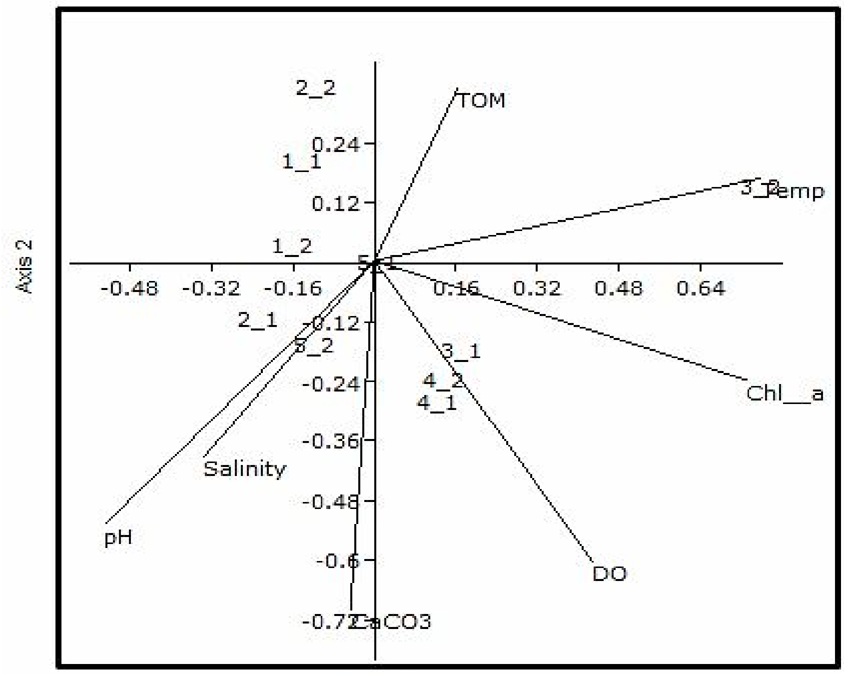

Figure 4. Results of the Canonical Correspondence Analysis – Biplot showing the distance among the sampling stations and the physico-chemical factors that influence the distribution and abundance of live benthic foraminiferans.

It is noticeable that the bottom water salinity was highest (35 ppt) in station 5 which was probably attributed to the station being farthest from the influence of Bombariver. According to Murray (1991), *A. beccarii* is often common in environments where high salinity and temperature prevails. Koubova & Hudackova (2010) emphasized the genera *Ammonia* and *Elphidium* as euryhaline speciesable to tolerate fluctuating salinities, while

Quinqueloculina flourished in increasing salinity. Conversely, low foraminiferal abundance observedin station 1 might be affected by a much lower DO (5.2 mg/L) and temperatura (28.9°C) values. Although these values are still within the standard limit set by the Philippine Department of Natural Resources (DENR) water classification (DENR DAO 2008), these results may reveal that the environmental conditions in station 1 were not within the optimum level to support high foraminiferal assemblage. Kumar & Manivannan (2001) pointed out that the optimum conditions for abundance of foraminferans are between 31.5-32.6°C for water temperature and 6.0 mg/L for DO.

Conclusions. The level of the diversity (H': 0.8–1.3) and equitability (J: 0.2–0.4) were quite low in the coastal areas of Tantanang Bay where one species, viz. *A. beccarii,* solely dominating the living foraminiferal assemblages in these five study areas. It is suggested that the current conditions in the area, i.e. silty sediment, domestic sewages from the local community residing along the coast, and freshwater discharges from the uplands which transport with it pesticides, fertilizers, and sediments might have contributed to the sole dominance of the small-sized *A. beccarii* in the assemblage. Moreover, the presence of some morphologically deformed tests of *A. beccarii* and *Elphidium fichtellianum* and the fragile forms of *Quinqueloculina* spp. may indicate that Tantanang Bay may have already experienced some signs of pollution impacts and that this may progress into a more serious situation if conservation actions will not be implemented. Hence, it is recommended that yearly assessment and monitoring must be conducted in the area and in order to promote and develop plans toward conservation and management of Tantanang Bay.

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