AACL BIOFLUX

Aquaculture, Aquarium, Conservation & Legislation
International Journal of the Bioflux Society

Foraminiferal assemblage in Southeast coast of Iligan Bay, Mindanao, Philippines

Maria L. D. G. Lacuna, Shirlamaine I. G. Masangcay, Maria L. S. Orbita, Mark A. J. Torres

Department of Biological Sciences, College of Science and Mathematics, Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines. Corresponding author: M. L. D. G. Lacuna, mileskung@yahoo.com

Abstract. Live foraminiferal composition, diversity, abundance and their relationship with the water quality parameters, organic matter contents and size of the sediments were determined and compared. A total of 62 foraminiferan species belonging to 42 genera under 30 families were identified in the living foraminiferal assemblage in the five sampling stations. Using several diversity indices, results showed maximum differences in the foraminiferan species between the five sampling stations. The results of Two-way ANOVA revealed significant differences ($p<0.05$) in foraminiferan relative abundance between stations. These differences were attributed to the structure of the sediment as reflected from the results of the Canonical Correspondence Analysis. Since the results of the study showed differences in the composition, diversity, abundance and distribution of the species in the five sampling stations, it is suggested that the present conditions of the environment may have affected the community structure of live foraminiferans. In this manner, the foraminiferans may therefore act as indicators of the health of the present environment. Whether these effects may be due to natural or anthropogenic activities, the present records are essentially vital in order to assess further the relationship between anthropogenic impacts and organisms and to evaluate future development towards conservation and management of the said bay.
Key Words: Tropical foraminiferans, community structure, Iligan Bay, Philippines.

Introduction. Knowledge of the microfaunistic assemblage contributes for evaluation of the bottom sediments close to highly polluted areas. The response of benthic foraminiferal assemblages to high input of organic matter and other anthropogenic activities may be a useful tool when evaluating the impact of these substances in the studied areas. Benthic foraminifers respond not only to the natural environmental variability in such parameters as temperature and salinity (Alve 1995b, 1999) but also to anthropogenic stresses such as pollution, eutrophication and hypoxia (Alve 1995a; Murray & Alve 2000).

Analysis of the structure of the foraminiferal assemblage in any area is very important for environmental management, conservation and monitoring. This is because they can be used as biological indicator of coastal and estuarine pollutions (Alve & Nagy 1986; Alve 1991, 1995a; Frontalini et al 2010; Jayaraju et al 2008, 2011; Nagy & Alve 1987; Tsujimoto et al 2006; Valiela 1984) which in turn reflects the ecological changes or health conditions occurring in their present environment. As bio-indicators, foraminifers can be applied in monitoring the health of the environment and act as an early warning indicator. This is possible because foraminifers have short life cycle and are highly sensitive to changes in environmental settings. They are also important among palaeontologists, palaeooceanographers and palaeoclimatologists as palaeoenvironmental indicators because the distribution and abundance of their fossil remains are widely used as tools for palaeoecological reconstruction of past environments The resulting palaeoenvironmental interpretations are therefore useful in knowing ancient environmental conditions, sea water temperatures and sea levels (Alve 2000; Casieri & Carboni 2007; Fiorini & Jaramillo 2007; Patterson et al 2005). Unfortunately, there are few studies carried out on the foraminiferan composition, diversity and abundance in the

Philippines. Despite the important role they promote as bio-indicators as well as their position in the marine benthic food chain as an important link between low (sediments and phytodetritus) and high (benthic metazoans) trophic levels (Nomaki et al 2008), studies on their biodiversity and ecology in the Philippine waters, specifically Mindanao, are quite meager. This lack of interest may be owed to their microscopic size and to the laborious and time-consuming work often associated in handling and handpicking these minute creatures. Such attributes may have probably discouraged most researchers and hence making them uninteresting. But this is not so because foraminifers are very important in the benthic food chain as well as in any conservation, management and monitoring efforts. Therefore, this study was carried out to investigate the composition, diversity and abundance of foraminiferan species and to get a general view of the water quality conditions of the bottom water as well as the sediment contents and structure of the areas. The data generated from this study will not only show the present habitats of live foraminiferal assemblages and the parameters related with their distribution but is important both from geological and from the environmental management view points because the results will represent as baseline needed for monitoring future effects caused by both natural and anthropogenic activities in the bay.

Material and Method. Iligan Bay is located in Mindanao (Figure 1), with a latitude of 8.42 (8° 25' 0 N) and a longitude of 124.08 (124° 4' 60 E). It has an estimated coastline of 170 km with surface area of about 2,390 km^3. It connects with Panguil Bay on the south western part and opens to Bohol Sea in the north (Quiñones et al 2002).

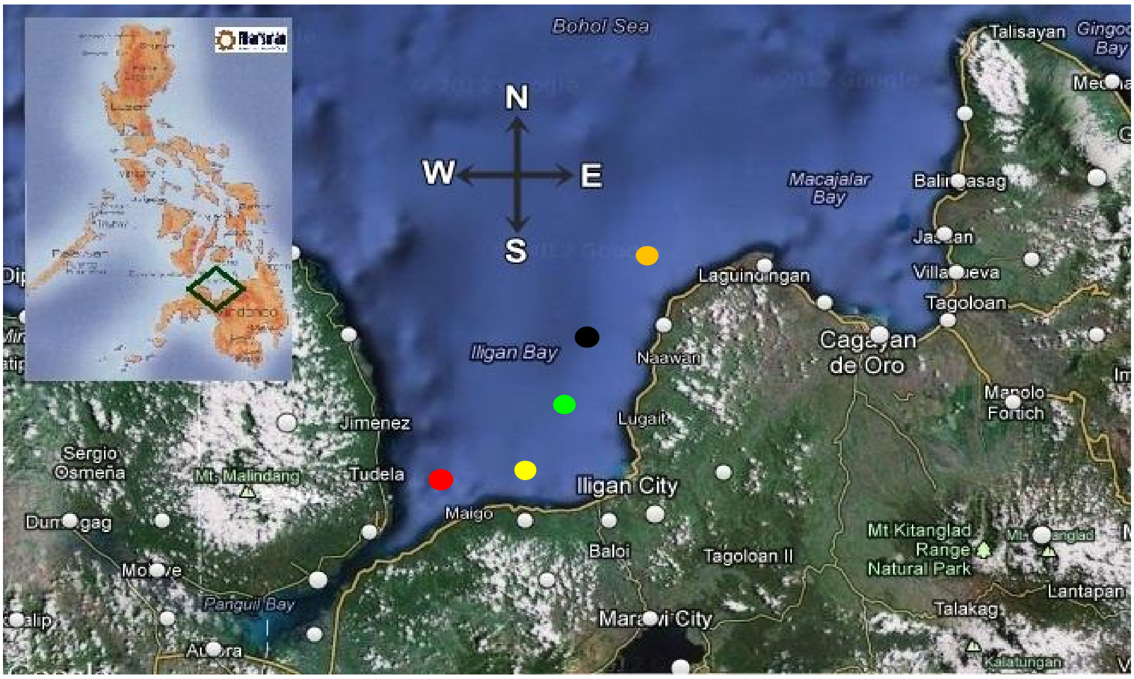

Figure 1. Geographical location of the five sampling stations where foraminifera were collected. Inset is Iligan Bay enclosed in a diamond. Legend: ● Station 1- Maigo, Lanao del Norte; ● Station 2- PGMC, Iligan City; ● Station 3- Lugait, Misamis Oriental; ● Station 4- Maputi, Misamis Oriental; ● Station 5- Laguindingan, Misamis Oriental.

A total of 27 rivers and 42 minor tributaries are identified which carry freshwater and transport nutrients and sediments into the bay. Iligan Bay is recognized by the Philippine Bureau of Fisheries and Aquatic Resources (BFAR) as a major fishing ground for its rich in fishery resources such as fish, algae and mollusks and serves as an important food producer and as a living space for wildlife assemblages.

Within the southeast portion of the bay, the study was carried out in April 27-29, 2011, and July 17, 2011 in the five sampling stations established near the coastline with a depth of 5-7 meters (Figure 1). Station 1 was located outside the vicinity of a marine sanctuary in Barangay Segapod in the Municipality of Maigo, Lanao del Norte. Station 2 was established facing the Platinum Group Metals Corporation (PGMC), a ferro-nickel smelting plant which was formerly known as Maria Cristina Chemical Industries Inc. (MCCI) at Barangay Maria Cristina, Iligan City. Station 3 was located in front of Holcim Philippines Inc. It is one of the cement corporations in Iligan City, formerly known as Alsons Cement Corp. Station 4 was situated in Barangay Maputi of the Municipality of Naawan, Misamis Oriental. The area is devoid of industries and beach resorts. Station 5 was established in Laguindingan, Misamis Oriental which will be the future site of an International Airport in Northern Mindanao. But as of now, the airport is still yet to be operational and parts of the area are still undergoing rapid reconstruction. Field data like 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), handheld refractometer (ATAGO) and DO meter (Eutech Instruments Ecosan DO6), respectively. Likewise, sediments for organic matter content (such as calcium carbonate, total organic matter and chlorophyll a) determination were collected using a syringe with its tip being cut off (4 cm inner diameter; 10 cm length). Employing the aid of a diver, the corer was pushed into the top 1-2 cm of the sediment. Calcium carbonate and total organic matter concentration were measured following the method described by Moghaddasi et al (2009). Chlorophyll a was extracted in acetone following the method described by Liu et al (2007) and read on a spectrophotometer. Grain size was collected from each sampling station using a grab sampler and was analyzed by sieving 100 g oven-dried sediment using a series of sieves of 3.35 mm, 0.841 mm, 0.595 mm, 0.31 mm, 0.149 mm, and 0.074 and 0.053 mm mesh opening. The remaining soil particles in each sieve were carefully removed and weighed separately. The percentage of each particle fraction was calculated and classified based on the Wentworth grade classification of particle size.

Separate core samples from the top 1 cm of the sediment were also collected in the five sampling stations for foraminiferan analysis. The sample was placed into a properly labeled bottle and preserved and stained with a solution of 10% formalin (buffered with sodium borate) already added with Rose Bengal stain to a concentration of 2.0 g/L. Rose Bengal stain was used in order to determine the presence of live foraminifera during the time of collection. The stained sediment samples were gently mixed so that the foraminiferans within the interstitial spaces of the sediments were properly preserved and stained. Since foraminiferas exhibited spatial patchiness, core sediment samples were deployed twice in each sampling station in order to avoid bias in information on abundance (Murray & Alve 2000). The entire wet volume of sediment collected for the analysis of foraminifera in each core sample was 12.56 cm^3. The sediment samples for foraminifera analysis were stored for 3-4 weeks to allow effective staining with Rose Bengal. Each foraminiferal sample were gently washed with tapwater through a 1000 μm sieve in order to remove pebbles and then washed through a 150 μm sieve. The fraction of sediments remaining on the 150 μm sieve were transferred to a petri dish, allowed to air dry and were weighed afterwards. All individuals were hand-picked using an artists' brush (Sakura, tip size 3/0) moistened with distilled water, under a dissecting microscope (Optech). Live (stained) and dead (unstained) individuals were separated, identified and counted to species level. Foraminiferal data were represented as relative abundance. Identification of foraminifera were done using the Illustration guides of Javaux & Scott (2003), Murray (2003), Riveiros & Patterson (2007), Patterson et al (2010), Scott et al (2000), Clark & Patterson (1993), Montaggioni & Vénec-Peyré (1993) and the illustrated foraminifera gallery (http://www.foraminifera.eu). All encountered species were documented using a digital camera (Sony Cyber-Shot, 16 MP) 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. Nearest-neighbor joining method was used to deternine the major groupings of foraminiferans present between the five sites. Canonical Correspondence Analysis (CCA) was employed to determine the physico-chemical parameters and sediment contents that influenced the relative abundance of foraminiferans. Two-way ANOVA was used to determine the differences in foraminiferan relative abundance between stations. All statistical analyses were done using the software PAST version 2.14 (http://folk.uio.no/ohammer/past/) (Hammer et al 2001).

Results and Discussion. A total of 62 foraminiferan species belonging to 42 genera under 30 families were identified in the living foraminiferal assemblage in the five sampling stations established in Southeast portion of Iligan Bay (Table 1). Fifty-eight (58) species are under the category of benthic foraminiferans while the remaining four (4) (*i.e. Globigerina bulloides*, *Globigerinoides trilobus, Orbulina universa* and *Globorotalia continuosa*) are planktonic species. The level of the diversity of foraminiferal species in the five sampling stations is presented in Table 2. It can be seen from the results that there were differences in the number of taxa between the five sampling stations, with station 4 showing the highest number of foraminiferal taxa (38) followed in decreasing order by Station 1 (23), Station 3 (21), Station 5 (17) and with Station 2 having the lowest number of taxa (15). Results further revealed maximum difference in the diversity of foraminiferan species between the five sampling sites as reflected in the Shannon-Weaver (H) values. Generally, a high Shannon Weiner diversity index of 2.918 was obtained for station 4, while Station 2 has the lowest diversity (1.619). The evenness value showed a highest value of 0.487 in Station 4, but a lowest value of 0.3365 in Station 2. Therefore, Station 4 has the highest number of taxa that showed high diversity in species abundance and at the same time indicating that the abundance is likewise evenly distributed among all the species. In contrast, Station 2 has the lowest number of species (15) and lowest diversity and evenness values indicating that the abundance is not that evenly distributed among all the species, thus it has a high dominance value (0.3437) compared to the other stations. The reason for the high dominance value in Station 2 can be observed in the high relative abundance (55%) of one species, namely *Ammonia beccarii*, which solely dominated the living foraminiferal assemblage. 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 not expected under such oligotrophic stress-free conditions (Kouwenhoven 2000; Drinia et al 2004). The level of low diversity with high dominance is expected in Station 2 since it is categorized as a disturbed area where it receives effluents from the Platinum Group Metals Corporation (PGMC), a ferro-nickel smelting plant in Iligan City. Further, it is suggested that the high dominance of *A. beccarii* observed in station 2 might be associated with the outputs coming from the smelting plant. It has been reported that *A. beccarii*, it is an euryhaline species which is widely distributed in intertidal and subtidal zones (Alve & Murray 1999), survives under a wide range of values of dissolved oxygen (Moodley & Hess 1992), salinity and temperature (Murray 1991) as well as heavily polluted waters (Alve 1995a). Tsujimoto et al (2006) observed the dominance of three species such as *A. beccarii*, *Verneuilinulla advena* and *Trochammina hadai* in the foraminiferal assemblage in a polluted marine area and concluded that all three dominant species are tolerant of anthropogenic impacts. Further, it has been stressed out that *A. beccarii* is highly tolerant to different ecosystems (Walton & Sloan 1990). Frontalini et al (2009) observed high abundance of *Ammonia tepida* (which was reported by Zampi & D'Onofrio in 1984 as *A. beccarii*), to occur in the middle-innermost part of a lagoon which is severely influenced by industrial discharges. This species has been known for its great tolerance to chemical and thermal pollution, fertilizing products, hydrocarbons (Setty & Nigam 1982; Coccioni 2000) and even capable of supporting very polluted environments and high concentrations of trace elements (Ferraro et al 2006). Burone & Pires-Vanin (2006) suggested that the sole dominance of *A. tepida* may be an indicative of unstable conditions caused by both natural and anthropogenic effects. Several studies also showed foraminiferal assemblages in the vicinity of sewage outfalls to be characterized by a large number of specimens and low diversity (Alve 1995b; Thomas et al 2000). They stressed out that human-induced organic material caused oxygen depletion and bottom water hypoxia which has led to a negative effect on foraminiferal diversity but a positive one on the population of opportunistic species (Alve 2000).

Table 1
Composition of live foraminiferan species in the five sampling stations in Southeast part of Iligan Bay

Foraminiferal Species	*Station*				
	1	*2*	*3*	*4*	*5*
Rotaliidae					
Ammonia beccarii	+	+	+	+	-
Ammonia sp.	-	-	+	-	-
Neorotalia calcar	-	+	-	+	+
Pararotalia batavensis	-	-	+	+	-
Pararotalia sp.	+	+	+	+	+
Soritidae					
Amphisorus hemprichii	-	-	-	+	+
Amphisteginidae					
Amphistegina hauerina	-	-	-	+	-
Amphistegina lobifera	-	-	-	+	+
Peneroplidae					
Coscinospira arietina	-	-	-	+	-
Peneroplis carinatus	+	-	-	-	-
Peneroplis pertusus	-	+	+	+	-
Peneroplis planatus	+	-	-	+	-
Bagginidae					
Baggina bradyi	-	-	+	+	-
Bolivinidae					
Bolivina sp.	-	+	+	-	+
Brizalina convallaria	+	-	-	-	-
Brizalina subspinescens	-	-	-	+	-
Calcarinidae					
Calcarina sp.	+	-	-	-	-
Calcarina spengleri	+	+	-	+	+
Siderolites calcitrapoides	-	-	-	-	+
Reussellidae					
Reussella atlantica	+	+	-	+	-
Reussella spinulosa	-	+	+	-	-
Cibicididae					
Cibicides cushmani	+	+	+	+	-
Haplophragmoididae					
Conglophragmium coronatum	-	-	+	-	-
Nodosariidae					
Cribrebella obtusa	-	-	+	-	-
Nodosaria sp.	+	-	-	-	+
Elphidiidae					
Cribrononion miyakoense	+	-	+	+	-
Elphidium craticulatum	+	-	-	-	-

Foraminiferal species	Station				
	1	2	3	4	5
Elphidiidae					
Elphidium crispum	-	-	-	+	-
Elphidium hanzawai	-	+	-	-	-
Elphidium fichtellianum	-	-	+	-	-
Elphidium kusiroense	+	-	-	-	-
Elphidium novozealandicum	-	-	+	-	-
Elphidium taiwanum	+	-	-	+	+
Elphidium somaense	+	-	+	+	-
Cymbaloporidae					
Cymbaloporetta bradyi	-	-	-	+	+
Ophthalmidiidae					
Edentostomina cultrata	-	-	-	+	-
Textulariidae					
Textularia agglutinans	-	-	-	-	+
Alfredinidae					
Epistomaroides punctulata	-	-	-	+	-
Eponididae					
Eponides repandus	-	-	-	+	+
Globigerinidae					
Globigerina bulloides	-	-	+	-	-
Globigerinoides trilobus	-	-	+	-	-
Orbulina universa	-	-	+	-	-
Globorotaliidae					
Globorotalia continuosa	-	-	+	-	-
Siphogenerinoididae					
Hopkinsina pacifica	+	-	-	+	-
Vaginulinidae					
Lenticulina submamilligera	-	-	-	-	+
Hauerinidae					
Pseudotriloculina granulocostata	-	-	-	-	+
Miliolinella subrotunda	-	-	-	+	-
Polysegmentina circinata	-	-	-	+	-
Siphonaperta agglutinans	-	-	-	+	+
Quinqueloculina bicostata	+	-	-	+	-
Quinqueloculina candeiana	+	-	-	-	-
Adelosina laevigata	-	-	-	+	-
Quinqueloculina parkeri	-	-	-	+	+
Quinqueloculina poeyana	-	-	-	+	-
Quinqueloculina seminula	-	+	-	-	-
Quinqueloculina sp.	-	-	-	+	+
Quinqueloculina tropicalis	-	-	-	+	-
Nubeculariidae					
Nodobaculariella convexiuscula	-	+	-	+	-
Nonionidae					
Nonionella japonica	+	+	+	+	-

Foraminiferal species	*Station*				
	1	*2*	*3*	*4*	*5*
Nummulitidae					
Operculina ammonoides	+	-	-	-	-
Planorbulinidae					
Planorbulina difformis	-	-	+	-	-
Rosalinidae					
Rosalina globularis	+	+	-	+	-
Turrilinidae					
Sitella laevis	-	-	+	-	-
Spiroloculinidae					
Spiroloculina angulata	-	-	-	+	-
Spiroloculina communis	+	+	-	-	-
Spiroloculina depressa	-	-	-	+	-
Spiroloculina henbesti	+	-	-	-	-
Miliolidae					
Triloculina trigonula	-	+	-	+	-
Total number of species	23	15	21	38	17

Legend: + presence, - absence.

Table 2

Diversity profiles of the five sampling stations for live foraminiferan species

Diversity Index	*Station*				
	1	*2*	*3*	*4*	*5*
Taxa (S)	23	15	21	38	17
Individuals	177	146	174	710	123
Dominance (D)	0.1985	0.3437	0.2222	0.0837	0.2561
Simpson (1-D)	0.8015	0.6563	0.7778	0.9163	0.7439
Shannon (H)	2.108	1.619	2.089	2.918	1.904
Evenness (e^H/S)	0.358	0.3365	0.3845	0.487	0.3947
Brillouin	1.936	1.481	1.922	2.818	1.723
Menhinick	1.729	1.241	1.592	1.426	1.533
Margalef	4.25	2.809	3.877	5.636	3.325
Equitability (J)	0.6724	0.5978	0.6861	0.8022	0.6719
Fisher alpha	7.051	4.191	6.245	8.583	5.35
Berger-Parker	0.3559	0.5548	0.431	0.207	0.4634

Jorissen et al (1992) reported differences in the foraminiferal composition based on the flux of organic matter and oxygen levels and concluded that areas with high organic matter are characterized by opportunistic species. Although, the total organic matter recorded in Station 2 was higher (12.18%) compared to the four sampling stations, it may not be enough to cause anoxic condition of the water since the mean dissolved oxygen value reflected in Station 2 is still within the normal range that can support propagation and reproduction of marine fauna. These results would therefore imply the strong potential of the marine waters in Station 2 to develop into a eutrophic condition as well as an ecologic stress environment in the near future if environmental management and monitoring will not be implemented. In contrast, Station 4 which is located in Maputi and is known for its pristine waters is expected to show low dominance, high eveness and diversity in foraminiferal assemblage. This high diversity was probably due to reduced influence of urban discharges around the vicinity of the area. Frontalini et al

(2009) observed high diversity of foraminiferal assemblages in the outermost part of a lagoon that is less exposed from urban discharges.

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 1990; Bradshaw 1957) (Table 3).

Table 3

Mean values of environmental parameters of the bottom waters and organic matter contents and size of sediments in Southeast part of Iligan Bay

Environmental Parameters	*Station*				
	1	*2*	*3*	*4*	*5*
Water Temp (°C)	25	25	25	25	27.85
pH	8.23	8.70	8.83	8.87	8.67
Salinity (ppt)	31	34	35.50	34	34.50
DO (mg L^{-1})	8.29	5.15	5.16	7.07	7.18
$CaCO_3$ (%)	18.20	19.26	20.20	20.32	23.48
TOM (%)	6.79	12.18	4.23	5.50	5.99
Chlorophyll a (μL^{-1})	0.267	0.251	0.259	0.428	0.545
Gravel (%)	0.21	0.07	0.05	2.14	4.8
Coarse sand (%)	0.11	0.28	0.26	9.73	54.62
Medium sand (%)	0.75	12.94	11.81	35.38	39.49
Fine sand (%)	39.46	44.72	43.05	22.36	0.26
Very Fine sand (%)	26.55	33.02	29.13	22.17	0.07
Silt/Mud (%)	32.92	8.97	15.70	8.22	0.04
Sediment Type	Fine sandy silt	Fine-very fine sand	Fine-very fine sand	Medium-very Fine sand	Coarse-medium sand

Standard values for marine and coastal waters: Water temperature minimum rise of 3°C; TSS <30 mgL^{-1} increase; pH range from 6.0 to 8.5; DO >5mg L^{-1}; Salinity 34-45 ppt (Philippine waters standard values from DENR 1990).

However, the mean values reflected variations between the five sampling stations and might be responsible for differences in their relative abundances. For instance, bottom water temperature values were all similar for stations 1-4 (25°C) but showed an increased in station 5 (27.85). For pH and salinity, Station 1 showed decreased in values (8.23 and 31 ppt, respectively) when compared to the four sampling stations. In the marine biome, pH plays only a minor role for benthic microfauna since the slightly alkaline seawater (pH 7.5-8.5) is well buffered against pH fluctuations. On the other hand, it has been shown that salinity preference may also occur in various meiofaunal species (Giere 2009). The much lower salinity in Station 1 might have been due to the mixing of waters coming from Panguil Bay that exits into this station. Lacuna et al (2012) reported salinity values in areas near the mouth of Panguil Bay that ranges from 27-30 ppt. The DO values recorded in all five sampling stations are within the standard limits set by the Philippine Department of Environment and Natural Resources (DENR 1990), however, fairly large variations occurred between these stations. Station 1 exhibited the highest value (8.29 mgL^{-1}), whereas stations 2 and 3 had the lowest values of 5.15 mgL^{-1} and 5.16 mgL^{-1}, respectively. Van der Zwann et al (1999) noted that species of benthic foraminifera have a strong response to changes in oxygen concentration. Giere (2009) further showed that oxygen is the predominant factor among the abitoic parmeters determining the habitat conditions and the presence of meiofaunal assemblage. This is because they have relatively large surface areas and high oxygen demands so that their distribution can be correlated to the oxygen supply of the pore water. On the other hand, the organic matter contents of the sediment showed slight differences between sampling stations. For example, the calcium carbonate content and chlorophyll-a were highest in stations 5 and 4 but low in stations 1, 2 and 3 while, total organic matter was highest in

Station 2 but low in stations 3, 4 and 5. The grain size analysis of the sediments showed that the sedimentary structure of the benthic zone in the five sampling stations are predominantly made up of sands but in varying degrees of sizes. Station 1 consisted of fine sands to very fine sands and silt sediments; stations 2 and 3 were made up of fine sands to very fine sands; Station 4 was made up of medium to fine sands while Station 5 consisted of coarse to medium sands. Based on the results, it showed that the sediment structure in Station 5 was made of much larger grains of sand as compared to the four sampling stations.

The relative abundance of the 58 identified benthic foraminiferan species varies from station to station, with 21 species showing relative abundances greater than 2% in at least one replicate core sample (Figure 2).

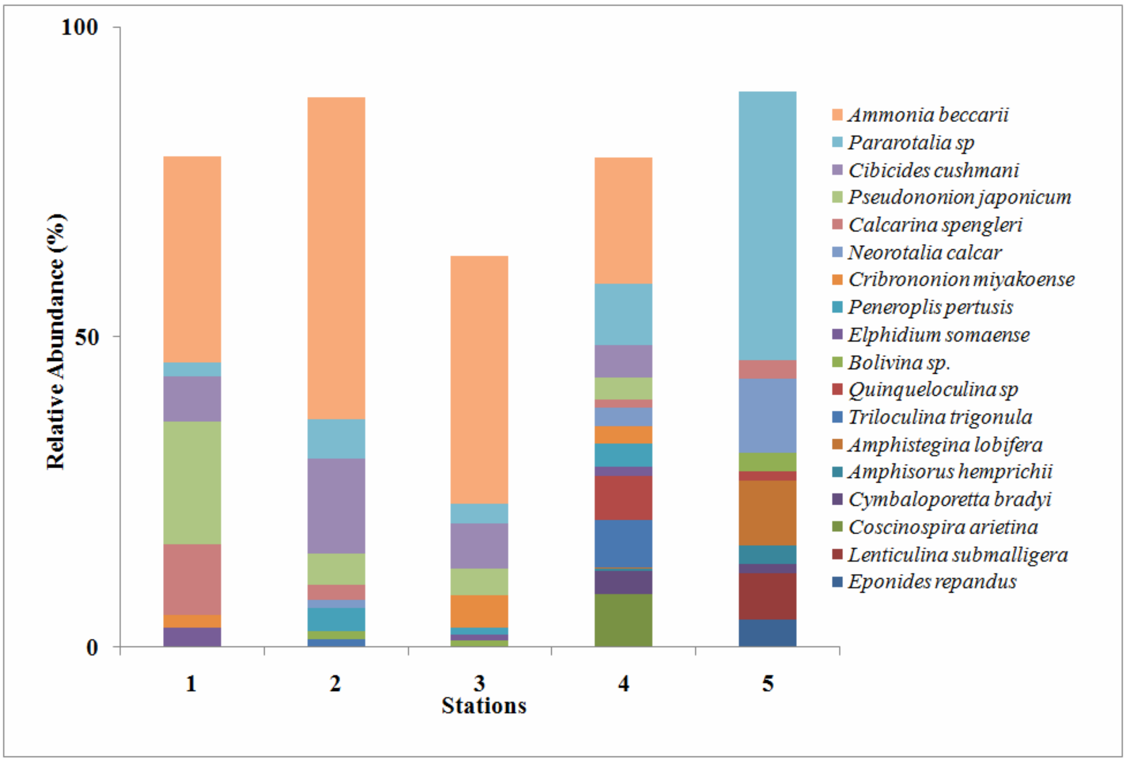

Figure 2. Relative abundance (%) of selected foraminiferan species in the five sampling stations in Southeast Iligan Bay.

Living assemblage was largely dominated by 4 species namely, *A. beccarii*, *Pararotalia* sp., *Cibicides cushmani* and *Nonionella japonica* in the five sampling stations. Images of these 4 dominant foraminiferans are shown in figures 3-6.

The result further showed that *A. beccarii* was the most abundant (>30%) among these 4 dominant species in stations 1, 2, and 3 while *Pararotalia* sp. was most abundant in stations 4 (11%) and 5 (48%).

It is interesting to mention that *A. beccarii* was very low in abundance (2%) in Station 4 and was even absent in Station 5. Likewise, *C. cushmani* and *N. japonica* exhibited varying degrees of abundance from station to station except for Station 5 where both species were absent. 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).

On the other hand, relative abundance of planktonic foraminifera, such as *G. bulloides* (8.42%), *G. trilobus* (10.53%) and *G. continuosa* (4.21%), were considerably high but are only distributed in Station 3 and absent in the rest of the sampling stations.

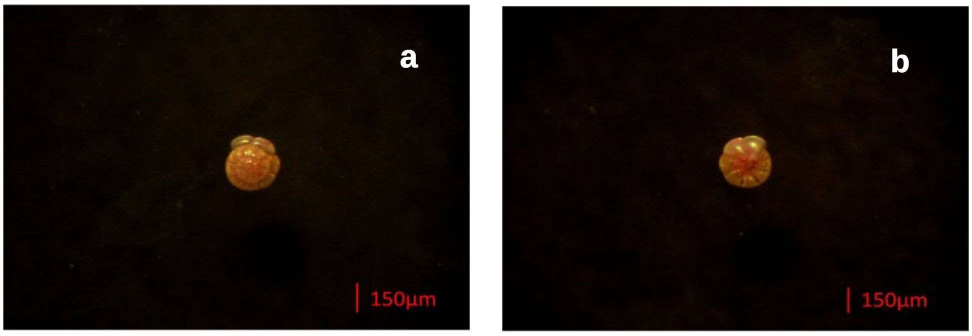

Figure 3. Dorsal (a) and ventral (b) view of *Ammonia beccarii.*

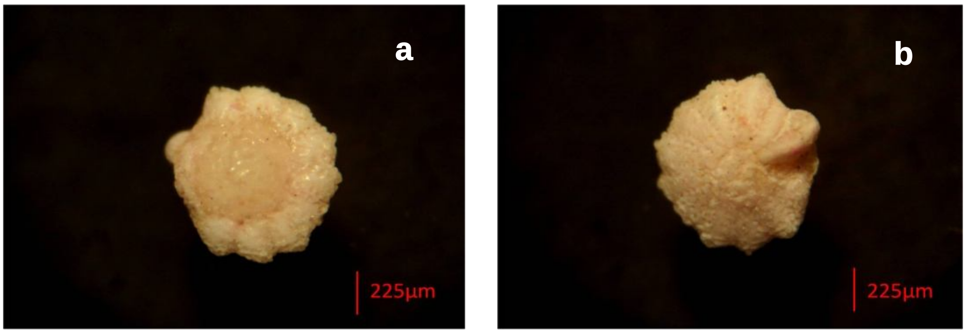

Figure 4. Dorsal (a) and ventral (b) view of *Pararotalia* sp.

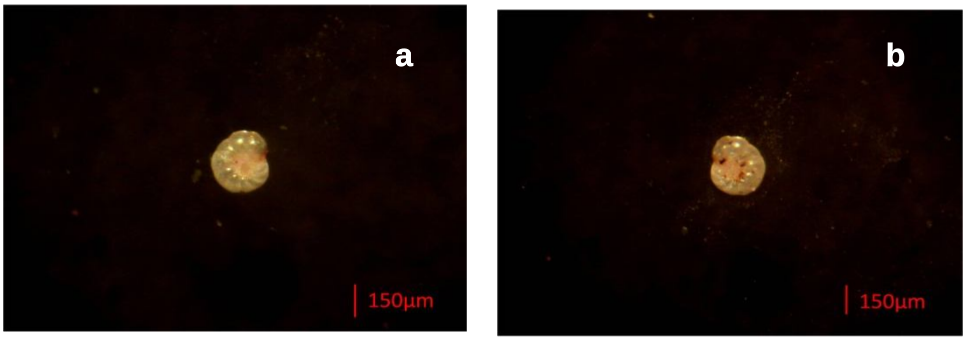

Figure 5. Dorsal (a) and ventral (b) view of *Cibicides cushmani.*

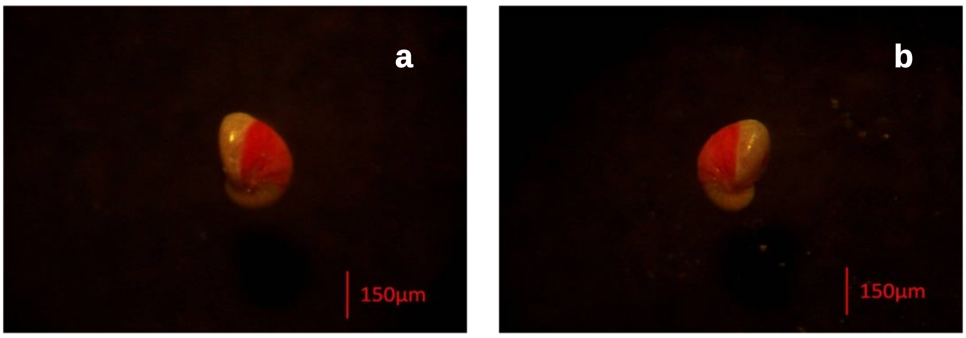

Figure 6. Dorsal (a) and ventral (b) view of *Nonionella japonica.*

The results of the comparison (Two-way ANOVA) of the abundance of foraminiferans between the five sampling stations showed that the stations or areas had a significant effect on the abundance ($p<0.05$) where this effect or difference was manifested in the high abundance of foraminiferans occurring in Station 4 but low in Station 5 (Figure 7). This is further supported by the results of the Canonical Correspondence Analysis reflected in Figure 8 where it showed a plot of the sampling stations across the first two canonical axes.

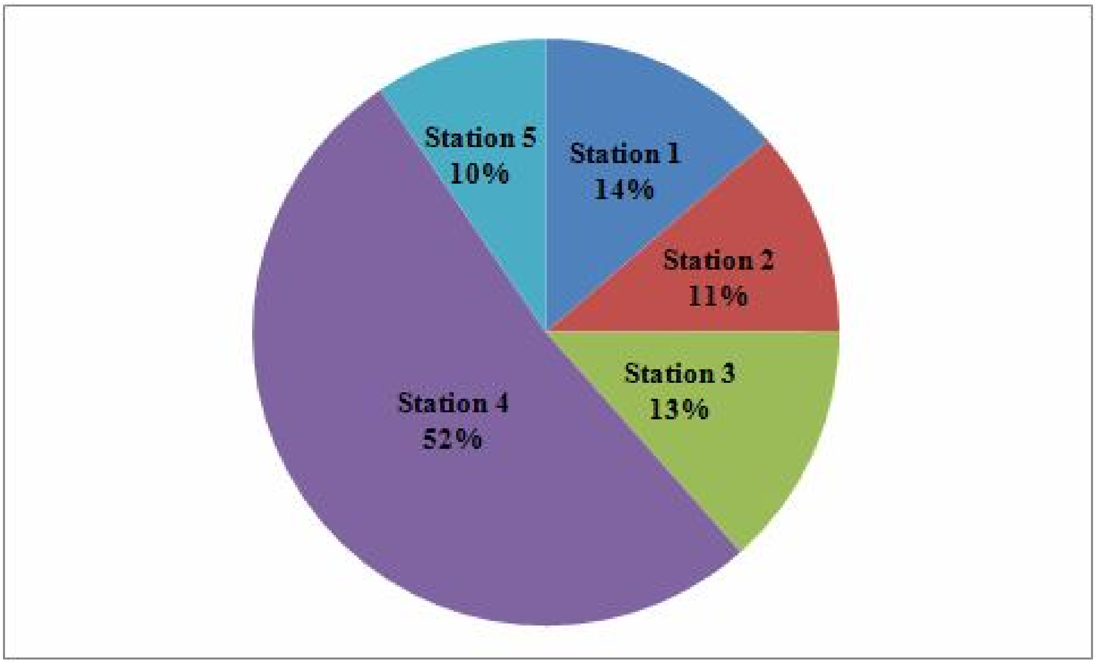

Figure 7. Total relative abundance (%) of foraminiferans in the five sampling stations in Southeast Iligan Bay.

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 from the different stations. Results in Figure 8a showed that low abundance of foraminiferans observed in Station 5 might be influenced by the type or size of sediments, bottom water temperature and $CaCO_3$. It is noticeable that the sediment structure in Station 5 is mainly coarse to medium sand while Station 4 consisted of medium to very fine sand whereas stations 1, 2, 3 are made up of fine to very fine sand grains. It has been reported that foraminiferans are normally common in fine-grained sediments and less abundant in coarse sands and with some occurring in silt and clay sediments than in muds. The reason behind this is presumably due to scarcity in food sources. Many sediment-dwelling foraminifera live on or near the sediment surface where the nutrients are concentrated and the pore-water are well aerated (Gooday 1988). Nigam & Chaturvedi (2000) also suggested that fine sand mixed with shelly fragments and silt or clay substratum support the richest standing crop of foraminifera. Likewise, Setty & Nigam (1982) observed that the foraminiferal population and diversity are highest in very fine grained sediments. Aside from grain size, other factors, namely higher concentration of calcium carbonate and bottom water temperature can explained the low foraminiferal abundance in Station 5. Although it is expected that high amount of $CaCO_3$ in the sediment maybe attributed to high numbers of foraminiferan shells as reported by Sadough et al (2012), it is not the case in the present study. Instead, the high concentration of $CaCO_3$ in the sediment might be due to the presence of appreciable broken gastropod shells and coral fragments which were observed to be mixed up in the collected sediment samples in Station 5.

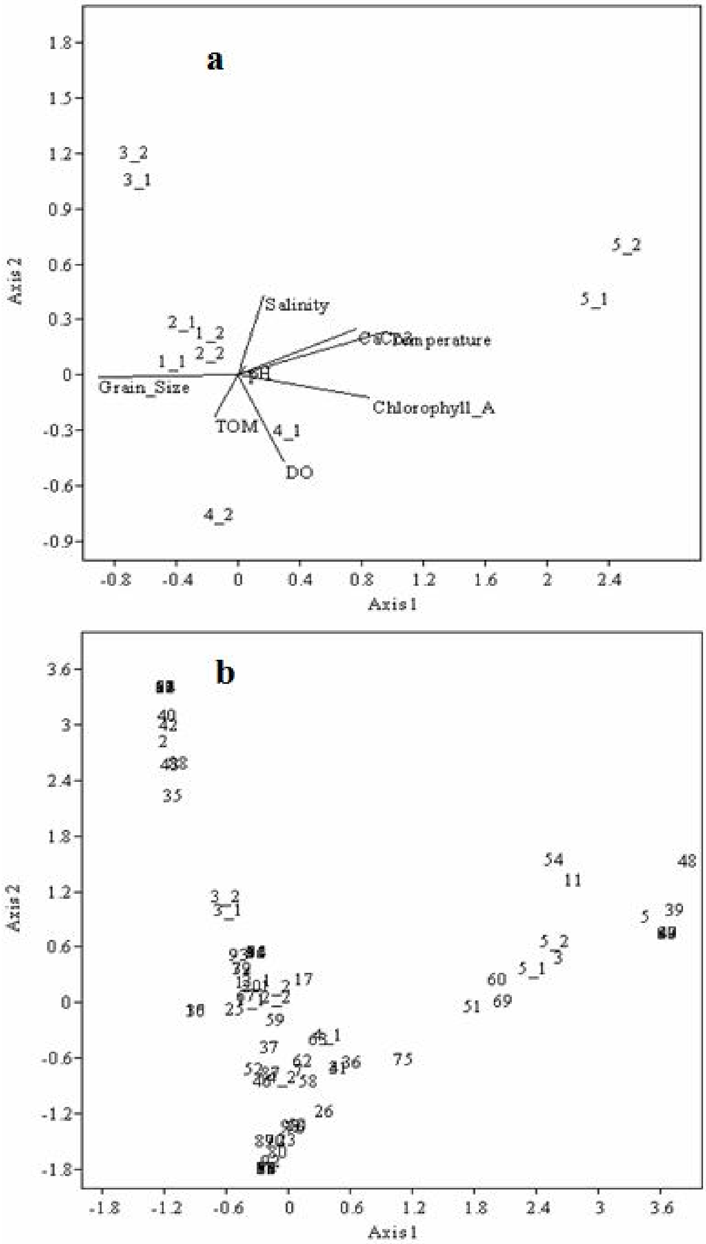

Figure 8. Results of the Canonical Correspondence Analysis - (a) biplot showing the distance among the sampling stations and the physico-chemical factors that influence the distribution and abundance of live foraminiferans and (b) relationships among the live foraminferan species across the first two canonical axes.

It is suggested that the undergoing rapid reconstruction (for the future site of an International Airport in Northern Mindanao) occurring in the area might have brought in these mixtures by dumping into the sea more sediments containing broken shell and coral debris as terrigenous contributions. The present data is in accordance with Suresh Gandhi & Rajamanickam (2004) who argued that the high $CaCO_3$ content in the sediment of Palk Strait, India is probably due to the accumulation of high order broken shell debris dumped through the creek as terrigenous contributions. Further, the accumulation of these sediments might also be the reason for an increased in bottom water temperature experienced in Station 5 which may influenced low foraminiferal abundance. On the other hand, Figure 8a further shows that stations 1, 2 and 3, which are found on the negative x-axis, have a mixture of fine to very fine grains of sand when compared to that of stations 5 (coarse to medium sand) and 4 (medium to very fine sand). Hence, the results reflected in Figure 8a is an indicative of the influence of the sizes of the grains of sand or sediment structure on the distribution and abundance of foraminiferans. Results reflected in Figure 8b further showed water pH to have an influenced on the eight species in Station 3 where these species can tolerate this condition of the water. These species includes *Ammonia* sp., *Conglophragmium coronatum, Elphidium fichtellianum, Elphidium novozealandicum, G. bulloides, G. trilobus, G. continuosa* and *O. universa* which were observed to occur only in Station 3.

In order to know if foraminiferan species and their abundances are similar between the five sampling sites, nearest-neighbor joining method was employed. Results revealed similarities in the community structures of foraminiferans or similarities in the types and abundance of foraminiferan species between stations 1, 4, and 5 and between stations 2 and 3 (Figure 9). The cluster diagram presented in figure 9 is suggestive of the effect of the conditions of the environment on the community structure of live foraminiferans from five different sampling stations in surrounding Iligan Bay. Stations 1 and 4, which are relatively characterized by pristine waters because of the absence of any industries, hosts species that are different from those that were collected from stations 2 and 3, which are characterized as disturbed waters were a number of industries release their effluents into the sea. On the other hand, Station 5, which will be the future site of an International Airport in Northern Mindanao, is still operational and parts of the area are still undergoing rapid reconstruction. This means that the waters in its coast could still be relatively pristine. This explains why some of the foraminiferan species are similar to those from the pristine waters of stations 1 and 4.

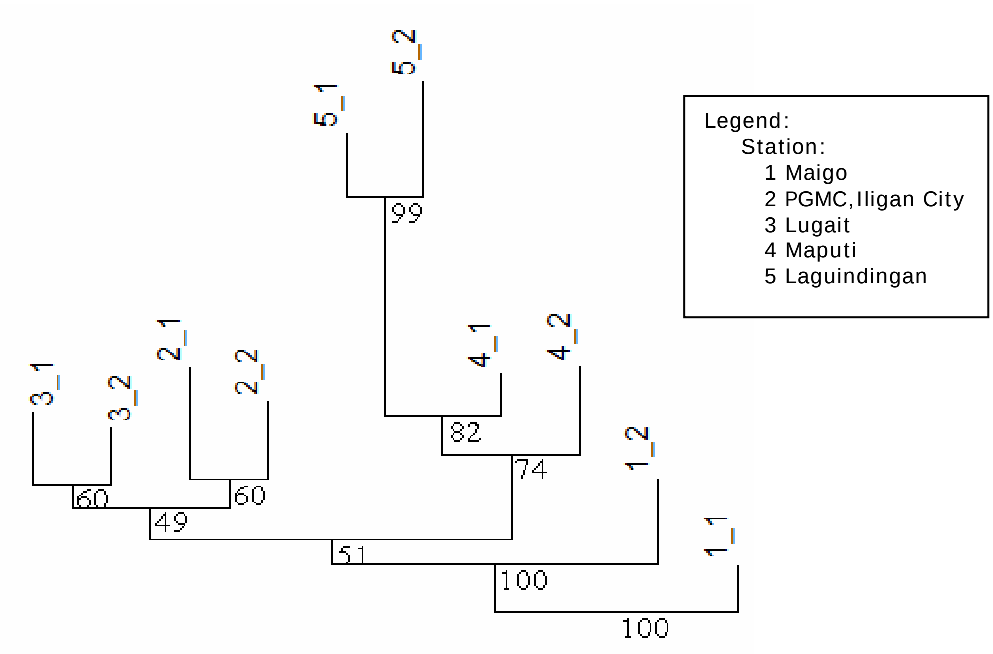

Figure 9. Cluster diagram showing similarities in the relative abundance of live foraminiferans from five sampling sites in Iligan Bay.

Conclusions. Since the results of the study showed differences in the composition, diversity, abundance and distribution of the foraminiferan species in the five sampling stations, it is suggested that the present conditions of the environment may have affected the community structure of live foraminiferans. Specifically, the sedimentary structure of the sampling areas was the most important parameter that influences the distribution pattern of live foraminiferans. Whether these effects may be due to natural or anthropogenic activities, the present records are essentially vital in order to assess further the relationship between anthropogenic impacts and organisms and to evaluate future development towards conservation and management of the said bay. It is recommended that the period of the study will be made in annual basis to observe the trend and compare the distribution of live froaminiferan communities during dry and wet months in these particular areas. Further study is needed to know the relationship between changes in the benthic foraminiferal assemblages and in the food supply, hence other organic matter contents in the sediments such as total organic carbon, total organic nitrogen, and total amino acids are recommended as additons to the assessed parameters in the present study.

References

Alve E., Nagy J., 1986 Estuarine foraminiferal distribution in Sandebukta, a branch of the Oslo Fjord. J Foraminiferal Res 16(4):261-284.

Alve E., 1991 Benthic foraminifera in sediment cores reflecting heavy metal pollution in Sorfjord, Western Norway. J Foraminiferal Res 21(1):1-19.

Alve E., 1995a Benthic foraminiferal responses to estuarine pollution: A review. J Foraminiferal Res 25(3):190-203.

Alve E., 1995b Benthic foraminiferal distribution and recolonization of formerly anoxic environments in Drammensfjord, southern Norway. Mar Micropaleontol 25:169-186.

Alve E., 1999 Colonization of new habitats by benthic foraminífera: A Review. Earth-Science Reviews 46:167-185.

Alve E., 2000 A ase study reconstructing bottom water oxygen conditions in Frierfjord, Norway, over the past five centuries. Environmental statigraphy. In: Environmental Micropaleontology. Martin R. E. (ed), vol. 15 of Topics in Geobiology.

Alve E., Murray J. W., 1999 Marginal marine environments of the Skagerrak and Kattegat: a baseline study of living (stained) benthic foraminiferal ecology. Palaeogeogr Palaeoclimatol Palaeoecol 146:171–193.

Bradshaw J. S., 1957 Laboratory studies on the rate of growth of the foraminífera, *"Strebus beccarii"* (Linne). J Paleontol 31:1138-1147.

Burone L., Pires-Vanin A. M. S., 2006 Foraminiferal assemblages in Ubatuba Bay, south-eastern Brazilian coast. Sci Mar 70(2):203-217.

Buzas M. A., Hayek L. C., Reed S. A., Jett J. A., 2002 Foraminiferal densities over five years in the Indian river lagoon, Florida: A model of pulsating patches. J Foraminiferal Res 32:68-93.

Clark F. E., Patterson T., 1993 An illustrated key to the identification of unilocular genera of calcareous foraminifera. J Paleontol 67(1):20-28.

Casieri S., Carboni M. G., 2007 Late-quaternary paleoenvironmental reconstruction of San Benedetto Del Tronto Coast (Central Adriatic Sea) by benthic foraminiferal assemblages. Geologica Romana 40:163-173.

Coccioni R., 2000 Benthic foraminifera as bioindicators of heavy metal pollution. In: EnvironmentalMicropaleontology: The Application of Microfossils to Environmental Geology. Martin R. E. (ed), pp. 71-103, Kluwer Academic/Plenum Publishers, New York.

DENR-Administrative order No. 34. 1990 "Revised water usage and classification of water quality criteria amending section No. 68 and 69, Chapter III of the 1978 Rules and Regulations", Manila.

Drinia H., Antonarakou A., Tsaparas N., 2004 Diversity and abundance trends of benthic foraminifera from the southern part of the Iraklion basin, Central Crete. Bulletin of the Geological Society of Greece 36:772-781.

Ferraro L. M., Sproviera M., Alberico I., Lirer F., Prevedello L., Marsella E., 2006 Benthic foraminífera and heavy metals distribution: a case from the Naples harbour (Tyrrhenian Sea, Southern Italy). Environ Pollut 142:274-287.

Fiorini F., Jaramillo C. A., 2007 Paleoenvironmental reconstruction of the Oligocene-Miocene deposits of southern Caribbean (Carmen de Bolivar, Colombia) based on benthic foraminifera. Boletin de Geologia 29(2):47-55.

Frontalini F., Buosi C., Da Pelo S., Coccioni R., Cherchi A., Bucci C., 2009 Benthic foraminífera as bio-indicators of trace element pollution in the heavily contaminated Santa Gilla lagoon (Cagliari, Italy). Mar Pollut Bull 58:858-877.

Frontalini F., Coccioni R., Bucci C., 2010 Benthic foraminiferal assemblages and trace element contents from the lagoons of Orbetello and Lesina. Environ Monit Assess 170:245–260.

Giere O., 2009 Meiobenthology: The microscopic motile fauna of aquatic sediments. 2nd ed. Springer-Verlag Berlin Heidelberg, pp. 513.

Gooday A. J., 1988 Introduction to the study of meiofauna. Smithsonian Institution Press, Washington DC, pp. 465

Hammer O., Harper D. A. T., Ryan P. D. 2001 PAST: paleontological statistics software package for education and data analysis. Palaeontol Electronica 4:1-9.

Javaux E. J., Scott D. B., 2003 Illustration of modern benthic foraminifera from Bermuda and remarks on distribution in other subtropical/tropical areas. Palaeontol Electronica 6(4):1-29.

Jayaraju N., Sundara B. C., Reddy R., Reddy K. R., 2008 The response of benthic foraminifera to various pollution sources: A study from Nellore Coast, East Coast of India. Environ Monit Assess 142:319–323.

Jayaraju N., Sundara B. C., Reddy R., Reddy K. R., 2011 Anthropogenic impact on Andaman coast monitoring with benthic foraminifera, Andaman Sea, India. Environ Earth Sci 62(4):821-829.

Jorissen F. J., Barmavidjaja D. M., Puskaric S., Van Der Zwaan G. J., 1992 Vertical distribution of benthic foraminifera in the northern Adriatic Sea: The relation with the organic flux. Mar Micropaleontol 19:131-146.

Kouwenhover T. J., 2000 Survival under stress: benthic foraminiferal patterns and Cenozoic biotic crises. Geologica Ultraiectina 186:206.

Lacuna M. L. D. G., Esperanza M .R. R., Torres M. A. J., Orbita M. L. S., 2012 Phytoplankton diversity and abundance in Panguil Bay, Northwestern Mindanao, Philippines in relation to some physical and chemical characteristics of the water. AES Bioflux 4(3):122-133.

Liu X. S., Zhang Z. N., Huang Y., 2007 Sublittoral meiofauna with particular reference to nematodes in the southern Yellow Sea, China. Estuarine Coastal and Shelf Science 71:616-628.

Moghaddasi B., Nabavi S. M. B., Vosoughi G., Fatemi S. M. R., Jamili S., 2009 Abundance and distribution of benthic foraminifera in the Northern Oman Sea (Iranian Side) continental shelf sediments. Res J Environ Sci 3(2):210-217.

Montaggioni L. F. Vénec-Peyré M. T., 1993 Shallow-water foraminiferal tapochoenoses at site 821: Implications for the Pleistocene evolution of the central Great Barrier Reef Shelf, Northeastern Australia. In: Proceedings of the ocean drilling program. Scientific Results 133:365-378.

Moodley L., Hess C., 1992 Tolerance of infaunal benthic foraminifera for low and high oxygen concentrations. Biol Bull 183:94-98.

Murray J. W., 1991 Ecology and palaeoecology of benthic foraminifera. John Wiley & Sons Inc., New York, pp. 397.

Murray J. W., Alve E., 2000 Major aspects of foraminiferal variability (standing crop and biomass) on a monthly scale in an intertidal zone. J Foraminiferal Res 30(3):177–191.

Murray J. W., 2003 An illustrated guide to the benthic foraminifera of the Hebridean Shelf, West of Scotland, with notes on their mode of life. Palaeontol Electronica 5(1):1-31.

Nagy J., Alve E., 1987 Temporal changes in foraminiferal faunas and impact of pollution in sandebukta, Oslo Fjord. Mar Micropaleontol 12:109-128.

Nigam R., Chaturvedi S. K., 2000 Foraminiferal study from Kharo creek, Kachchh (Gujarat), northwest coast of India. Indian J Mar Sci 29:133-138.

Nomaki H., Ogawa N. O., Ohkouchi N., Suga H., Toyofuku T., Shimanaga M., Nakatsuka T., Kitazato H., 2008 Benthic foraminifera as trophic links between phytodetritus

and benthic metazoans: carbon and nitrogen isotopic evidence. Mar Ecol Prog Ser 357:153–164.
Patterson R. T., Dalby A. P., Roe H. M., Guilbault J. P., Hutchinson I., Clague J. J., 2005 Relative utility of foraminifera, diatoms and macrophytes as high resolution indicators of paleo-sea level in coastal British Columbia, Canada. Quat Sci Rev 24:2002-2014.
Patterson R. T., Haggart J. W., Dalby A. P., 2010 A guide to late Albian-Cenomanian (Cretaceous) foraminifera from the Queen Charlotte Islands, British Columbia, Canada. Palaeontol Electronica 13(2):1-28.
Quiñones M. B., De Guzman A. B., Moleño E. P., 2002 Iligan Bay. In: Atlas of the Philippine coral reefs. Aliño P. et al (eds), pp. 164-166, Goodwill Trading Co., Inc, Philippines.
Riveiros N. V., Patterson T. R., 2007 An illustrated guide to fjord foraminifera from the Seymour-belize Inlet Complex, Northern British Columbia, Canada. Palaeontol Electronica 11(1):1-45.
Sadough M., Ghane F., Hamed M., Moghaddasi B., Beikaee H., 2012 Identification and abundance of benthic foraminifera in the sediments from Fereidoonkenar to Babolsar of Southern Caspian Sea. Turkish J Fish Aquat Sci 12:1-8.
Scott D. B., Takayanagi Y., Hasegawa S., Saito T., 2000 Illustration and reevaluation of affinities of neogene foraminifera described from Japan. Palaeontol Electronica 3(2):1-41.
Setty M. G. A. P., Nigam R., 1982 Foraminiferal assemblages and organic carbon relationship in benthic marine ecosystem of western Indian continental shelf. Indian J Mar Sci 11:225-232.
Stubbs S. A., 1940 Studies of foraminifera from seven stations in the vicinity of Biscayne Bay. Proceedings of the Florida Academy of Sciences for 1939 4:225-230.
Suresh Gandhi M. S., Rajamanickam G. V., 2004 Distribution of certain ecological parameters and foraminiferal distribution in the depositional environment of Palk Strait, east coast of India. Indian J Mar Sci 33(3):287-295.
Thomas E., Gapotchenko T., Varekamp J. C., Mecray E. L., Buchholz M. R., 2000 Benthic foraminífera and environmental changes in Long Island Sound. Journal of Coastal Research 16:641-655.
Tsujimoto A., Nomura R., Yasuhara M., Yamazaki H., Yoshikawa S., 2006 Impact of eutrophication on shallow marine benthic foraminifers over the last 150 years in Osaka Bay, Japan. Mar Micropaleontol 60:258–268.
Valiela I., 1984 Marine ecology process. Springer-Verlag, New York.
Van Der Zwaan G. J., Duijnstee I. A. P., Den Dulk M., Ernst S. R., Jannink N. T., Kouwenhoven T. J., 1999 Benthic foraminifers: Proxies or problems? A review of paleoecological concepts. Earth-Science Reviews 46:213–236.
Walton W. R., Sloan B. J., 1990 The genus *Ammonia* Brünnich 1772: Its geographic distribution and morphologic variability. J Foraminiferal Res 20:128-156.
Zampi M., D'Onofrio S., 1984 Foraminiferi dello stagno di S. Gilla (Cagliari). Atti Societa Toscana Scienze Naturali Memorie 91:237-277.
***www.foraminifera.eu
***http://folk.uio.no/ohammer/past

Received: 21 February 2013. Accepted: 15 March 2013. Published online: 15 April 2013.
Authors:
Maria Lourdes Dorothy Garcia Lacuna, Mindanao State University-Iligan Institute of Technology, College of Science and Mathematics, Department of Biological Sciences, Philippines, Iligan City 9200, Bonifacio Avenue, e-mail: mileskung@yahoo.com
Shirlamaine Irina Gundaya Masangcay, Mindanao State University-Iligan Institute of Technology, College of Science and Mathematics, Department of Biological Sciences, Philippines, Iligan City 9200, Bonifacio Avenue, e-mail: alrihs023@yahoo.com
Maria Luisa Sasil Orbita, Mindanao State University-Iligan Institute of Technology, College of Science and Mathematics, Department of Biological Sciences, Philippines, Iligan City 9200, Bonifacio Avenue, e-mail: mlwsasil@yahoo.com
Mark Anthony Jariol Torres, Mindanao State University-Iligan Institute of Technology, College of Science and Mathematics, Department of Biological Sciences, Philippines, Iligan City 9200, Bonifacio Avenue, e-mail: torres.markanthony@gmail.com

How to cite this article:
Lacuna M. L. D. G., Masangcay S. I. G., Orbita M. L. S., Torres M. A. J., 2013 Foraminiferal assemblage in Southeast coast of Iligan Bay, Mindanao, Philippines. AACL Bioflux 6(4):303-319.