AES BIOFLUX

**Advances in Environmental Sciences -
International Journal of the Bioflux Society**

Assemblages of benthic foraminifera in front of three industries along the coast of Iligan City, Southern Philippines and its relation to some environmental parameters

Hannah M. C. Unsing, Maria L. D. G. Lacuna

Mindanao State University - Iligan Institute of Technology, Andres Bonifacio Avenue,
Iligan City 9200, Philippines. Corresponding author: M. L. D. G. Lacuna,
mileskung@yahoo.com

Abstract. Live benthic foraminiferan composition, diversity, abundance and their relationship with the water and sediment quality parameters and some heavy metal contents were determined and compared in the three sampling stations of Iligan Bay where nearby industries are situated. A total of 28 foraminiferan species belonging to 18 genera under 14 families were identified in the living foraminiferal assemblage. Values for foraminiferal abundance, density, diversity and equitability (evenness) showed variations between sites. High species diversity and equitability but low dominance observed in station 1 showed even distribution of foraminiferan species. Conversely, low species diversity and equitability but high dominance values revealed dominance of *Calcarina gaudichaudii* – *Neorotalia calcar* assemblage in station 2 and *Quinqueloculina laevigata* – *N. calcar* assemblage in station 3. Canonical Correspondence Analysis showed that the sediment type played a major influence in characterizing the community structure in station 2. Results further revealed the influence of temperature, Pb and Zn in the community structure of station 3. Although these trace elements were detected, the values recorded were still below the ER-L values set by the USEPA. Nonetheless, their mere presence may imply the possibility of the area to progress from its present health condition into a highly polluted/stressed environment if conservation measures and biomonitoring will not be strictly implemented. Hence, the present result showed that benthic foraminiferans are suitable indicators of early warning signs of probable anthropogenic pollution of the marine environment.

Key Words: protista, diversity, abundance, heavy metals, Southeast Asia.

Introduction. Population growth and the consequential acceleration of domestic, municipal, industrial, agricultural and recreational activities are the primary causes of anthropogenic pollution of the marine realm. The marine environment, as the ultimate destination of virtually all terrestrial runoff, is especially affected by pollution, and the shallow near shore marine environment is particularly subject to frequent and extensive industrial and municipal pollution (Kravchuk 2006). Most often, it is the quality of sediments that are frequently influenced by harbor activities and release of untreated sewage wastewaters (Mikulic et al 2008). Habitat loss and degradation as well as man-made pollution were to blame for the steep decline in the quality of marine waters (Al-Zamel et al 2009).

In the local scale, Iligan City, considered to be a highly urbanized industrial city had majority of big industries, corporations, harbors/docklands and depots located along the southeast coast of Iligan Bay. According to Vilela et al (2004), coastal areas where docklands and harbors are predominant, have been described as typical locations where sediment-associated pollutants can accumulate. Ecological and environmental consequences of contamination may produce complex problems and these need to be resolved in order that exposed habitats will be protected. Among these contaminants, are metals which are non-bioavailable and can bioaccumulate in the sediments through various mechanisms (Bruland et al 1991; Bryan & Langston 1992) thus making them strong and toxic pollutants. Besides the natural process, metals may enter into aquatic system due to anthropogenic factors such as mining operations, disposal of industrial wastes and application of biocides for pest control (Jain et al 2011). Heavy metals discharged in aquatic systems are immobilized within sediment through adsorption, flocculation and co-precipitation (Barakat et al 2012). In fact, several studies have noted the location where sedimentary metals are linked with organic matter (Emery & Rittenberb 1952; Van Straaten 1954; Moretti 1957; Love & Murray 1963). Microfauna test (shell) contains cellular structure allowing the formation of micro-environments within an overall environment, and when oxidized, organic matter is rapidly consumed by bacteria. Hence, when the sediment reaches the reducing zone the microfauna test will become locus of organic material which will act as nuclei for heavy metal precipitation in the sediment. Furthermore, Erez (2003) stated that these elements present in seawater could co-precipitate with the calcite and are thus incorporated into the shell of microfauna. Physicochemical parameters such as pH, temperature, salinity or pressure may also influence in the incorporation of elements. Further, Hg, Cd, and Pb, besides Cu, Zn, Ag, and Cr, are the most hazardous metal elements from the ecotoxicological as well as the public health point of view (Lay & Zsolnay 1989). Their persistence and toxicity at unwanted and undesirable metal levels adversely affect the ecosystems which eventually may affect food quality and safety (Barakat et al 2012; Jain et al 2011). Hence, it is very important to assess their impacts on the microfauna inhabiting the surface sediment. In order to contribute to the knowledge on how benthic foraminiferans may respond to these contaminants, this study was therefore conducted. Specifically, it aims to investigate the diversity and abundance of these microfauna where nearby industries are situated in relation to selected physico-chemical parameters of the water and organic matter contents and heavy metals in the sediments.

Material and Method. Iligan is a highly urbanized city in the province of Lanao del Norte located in the northeastern coast of Mindanao. It is surrounded by the towns of Baloi and Linamon of Lanao del Norte on the south, on the north is Lugait, Misamis Oriental, Lanao del Sur and Bukidnon on the east and Iligan Bay on the west. It has latitude of 8° 13' 0.1" (8.2167°) N and a longitude of 124° 13' 59.9" (124.2333°) E (http://mapcarta.com/). It has a total land area of 81,337 hectares with 44 barangays with a Type C climate characterized by short, low sun dry season for one to three months. Rainfalls are evenly distributed throughout the year and are located outside the typhoon belt. The City of Iligan has been so lucky with industrialization, which came with the city’s conversion from a small municipality into a city in the 1950s. It started with the construction of Mindanao‘s first hydroelectric plant at the foot of the majestic Maria Cristina Falls. Shortly after, heavy industries, attracted by the low electricity rates, arrived among them were a giant steel mill (Global Steel Philipines Inc.), cement (Iligan Cement Corporation), chemical (Platinum Group Metals Corporation), flour industries (PILMICO Foods Corp) and the coconut oil mills (GRANEX, SAN MIGUEL CORPORATION – ILIGAN COCONUT OIL). Wastes produced by these industries all drained out into Iligan Bay, which has ben 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.

The present study was carried out in September 2012 in the three sampling stations within the coastal waters in Iligan City. These sampling stations were established near the coastline with a depth of 7-10 meters (Figure 1). Station 1 was established in front of Holcim Philippines Incorporated. It is one of the cement and aggregates distributor located between the boundaries of Dalipuga, Iligan City and Lugait, Misamis Oriental. Station 2 was situated in front of Pilmico Foods Corporation at Kiwalan, Iligan City. It is primarily engaged in the manufacture of wheat flour and related products such as feeds and feed ingredients, yeast, powdered sugar and baking powder. Station 3 was located in front of Iligan Cement Corporation (ICC). It is also a cement manufacturer located at Kiwalan, Iligan City. In each of the sampling stations, water quality determination and sediment collections were done following the methods described by Lacuna et al (2013, 2014). For instance, field data such as bottom water temperature, pH, salinity and dissolved oxygen were measured “in situ” in each of the three 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).

Figure 1. Geographical location of the three sampling stations where foraminifera were collected. Inset is Iligan Bay with Iligan City enclosed in a red circle.
Legend: ● Station 1 - Holcim Philippines Incorporated, Lugait, Misamis Oriental;
● Station 2 – Pilmico Foods Corporation, Kiwalan, Iligan City;
● Station 3 – Iligan Cement Corporation, Kiwalan, Iligan City.

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 a 100 g oven-dried sediment using a series of sieves of 2.00 mm, 0.841 mm, 0.595 mm, 0.31 mm, 0.149 mm, 0.074 mm 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 USDA (United States Department of Agriculture) Soil Texture Triangle. Separate core samples from the top 1 cm of the sediment were also collected in the three sampling stations for foraminiferan analysis. The sample was placed into a properly labeled bottle and preserved and stained with a Rose Bengal-ethanol solution (1 g Rose Bengal in 1 L ethanol). 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 sediment samples for foraminifera analysis were stored for 3-4 weeks to allow effective staining with Rose Bengal. Each foraminiferal samples 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 & Venec-Peyre (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. Cluster analysis using Ward's method was employed to deternine the major groupings of foraminiferans present between the three sites. Canonical Correspondence Analysis (CCA) was employed to determine the physico-chemical parameters and sediment contents that influenced the relative abundance of foraminiferans. All statistical analyses were done using the software PAST version 2.17 (http://folk.uio.no/ohammer/past/) (Hammer et al 2001).

Results and Discussion. A total of 28 living benthic foraminiferan species belonging to 18 genera under 14 families were identified in nearshore sediments where three industries are located (Table 1). Further, looking at the level of diversity of benthic foraminiferans in the three sampling stations revealed high values in stations 1 and 2, viz. with 17 and 18 living individuals, respectively. Conversely, low diversity was observed in station 3 with fewer number of living individuals, viz. 14, being recorded. Results further showed a much higher Shannon index (H') and equitability (J) values in station 1 followed in decreasing trend by station 3 and then station 1 having the lowest values (Table 2). Although station 2 recorded the highest number of living individuals (18), it did not have the highest H' and J values. Instead, station 1, with 17 living individuals, showed the highest H' and J values but with the lowest dominance value (0.1451). This is further justified by the even distribution in the abundance or density among the 17 foraminiferan species in station 1 as reflected in Figure 2. The present result did not seem to agree with those reported by Lacuna et al (2013), who assessed foraminiferal assemblage in the same area/station, where the cement plant (Holcim) is located, in the year 2011. Their results showed sole dominance of *A. beccarii* (60%) in the nearshore waters facing Holcim industry but in the present study this species was very low in number (4.64% or 4 individuals per cm^3). The difference in the diversity and dominance of foraminiferans in this specific sampling station between the year 2011 as reported by Lacuna et al (2013) and the present study (which was 2012) might be attributed to the organisms' being patchy in distribution as well as the different degrees of sensitivity of the foraminiferans to spatial and temporal changes in their environment.

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, several studies documented patchiness occurring between the two dominant species (*Ammonia tepida* and *Haynesina germanica*) at a scale of decimeter and even >50 meters (De Nooijer et al 2007) and to a scale of a few centimeters in monthly samplings in an intertidal zone (Murray & Alve 2000).

Table 1

Species composition of live benthic foraminiferan in the three sampling stations wherenearby industries are present

Family	*Foraminiferal species*	*Stations*		
		1	*2*	*3*
Amphisteginidae	*Amphistegina lessonii*	+	+	-
Calcarinidae	*Baculogypsina sphaerulata*	-	+	-
	Calcarina gaudichaudii	+	+	-
Elphidiidae	*Elphidium hanzawai*	+	+	-
	Elphidium collinsi	+	+	-
	Elphidium jenseni	-	+	+
Fischerinidae	*Planispirina exigua*	+	+	-
Hauerinidae	*Quinqueloculina poeyana*	-	-	+
	Quinqueloculina seminulum	+	+	-
	Quinqueloculina sulcata	-	-	+
	Quinqueloculina tropicalis	+	-	+
	Quinqueloculina parkeri	-	+	-
	Quinqueloculina laevigata	+	+	+
Miliolidae	*Triloculina trigonula*	+	+	+
Nonionidae	*Nonionellina labradorica*	-	+	-
Nubeculariidae	*Nodobacularia pacifica*	-	-	+
Peneroplidae	*Coscinospira hemprichii*	-	-	+
	Peneroplis carinatus	+	-	-
	Peneroplis pertusus	+	+	+
Rotaliidae	*Ammonia beccarii*	+	-	-
	Ammonia tepida	+	+	+
	Neorotalia calcar	+	+	+
Soritidae	*Sorites marginalis*	+	-	-
Spiroloculinidae	*Spirolina acicularis*	+	-	-
	Spiroloculina antillarum	+	-	+
Textulariidae	*Textularia agglutinans*	-	+	+
Vaginulinidae	*Amphicoryna scalaris*	-	+	-
Total Number of Species		17	18	14

Legend: + presence; - absence.

Table 2

Diversity profiles of live benthic foraminiferan species in the three sampling stations where nearby industries are located

Diversity index	*Station*		
	1	*2*	*3*
Taxa (S)	17	18	14
Individuals	93	325	79
Dominance (D)	0.1451	0.3161	0.2617
Simpson (1-D)	0.8549	0.6839	0.7383
Shannon (H)	2.33	1.662	1.843
Evenness (e^H/S)	0.6045	0.2927	0.4509
Menhinick	1.763	0.9985	1.575
Margalef	3.53	2.939	2.975
Equitability (J)	0.8223	0.575	0.6982
Fisher alpha	6.097	4.106	4.943
Berger-Parker	0.3118	0.5138	0.4557

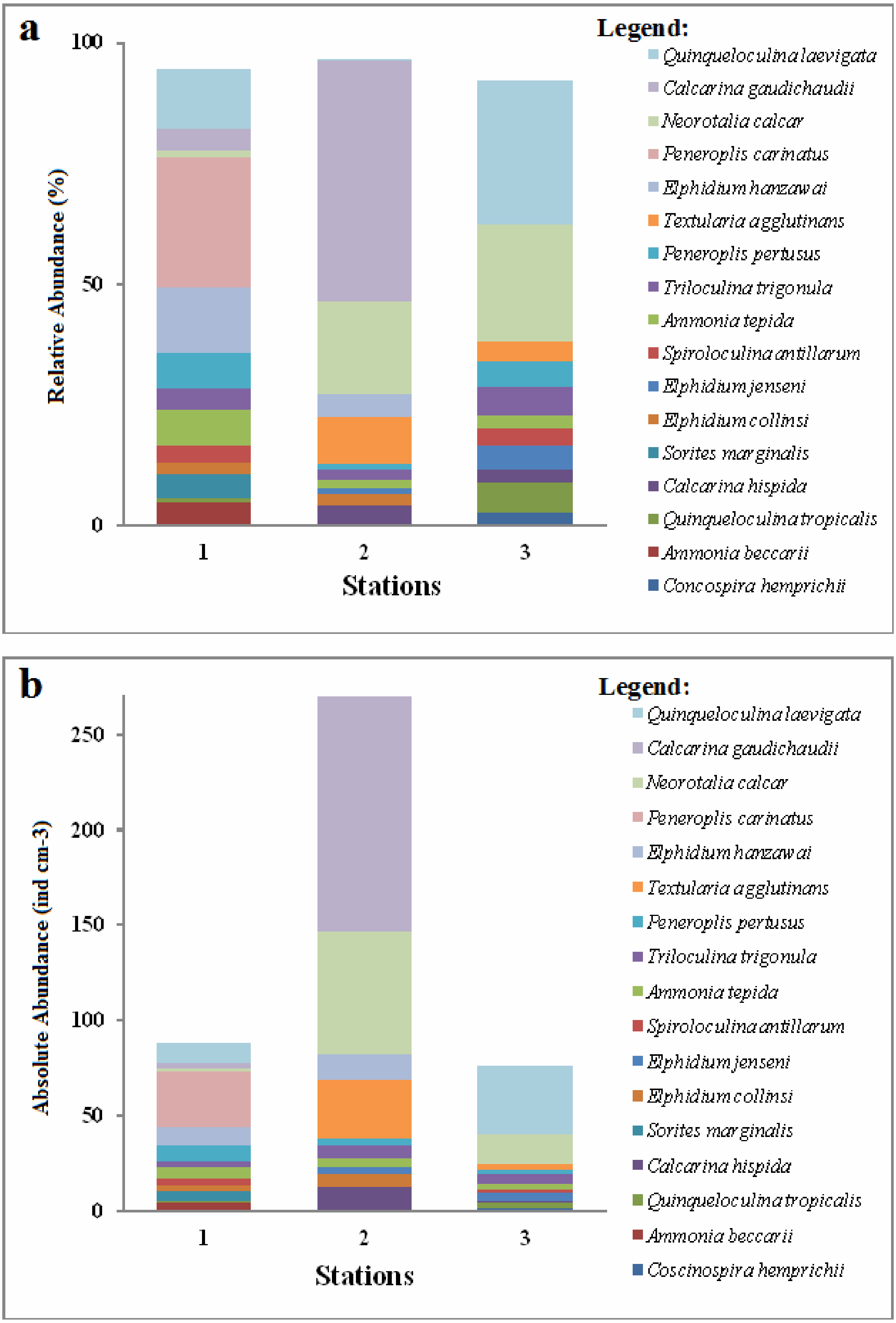

Figure 2. a) Relative abundance (%) and b) absolute abundance (ind cm^{-3}) of live benthic foraminiferan species in the three sampling stations in Iligan Bay.

It is argued that the patchiness (i.e. organisms distributed unevenly or aggregated) in the spatial distribution and abundances of benthic foraminifera may be due to factors like grazing and predation aside from local changes in the environment (Valiela 1995). It is therefore assumed that the arguments suggested by these studies might be responsible to the differences in the diversity and abundance of foraminiferans when comparing the years 2011 and 2012 in the same sampling area. On the other side, station 2, despite having more living individuals, showed lowest H' and J values but the dominance value (0.3161) was high. The reason for the high dominance value in station 2 can be observed in the high relative abundance of two species, namely *Calcarina gaudichaudii* (49.95%, 167 individuals per cm^3) and *Neorotalia calcar* (19.09%, 64 individuals per cm^3) that solely dominated the living foraminiferal assemblage (Figure 2). It is quite clear that the abundance of *C. gaudichaudii* was relatively high (167 individuals per cm^3) than those of *N. calcar* (86 individuals per cm^3). In fact, extreme densities of *C. gaudichaudii* can be found on most NW Pacific coral reef crests (Sakai & Nishihira 1981; Hohenegger 1994). This species was classified as a large symbiont bearing foraminiferan (Natsir et al 2012) which maintains themselves only in oligotrophic environments because they are housing symbionts (Hallock 1985). Further study in Okinawa and Hawaii (Hallock 1984; Hohenegger 1994) showed the occurrence of *C. gaudichaudii* and *N. calcar* to be predominantly present in the shallowest seaward slope where both species obtained their optimum niche. It is probable that the high dominance and abundance of *C. gaudichaudii* might be associated with the presence of corals since all foraminiferan samples were collected in shallow waters having a depth of between 7-10 meters and the fact that some patches and scattered living assemblage of corals as well as coral rubbles were observed in station 2. Renema & Troelstra (2001) who studied carbonate shelf reported *C. gaudichaudii* and *N. calcar* as eurytopic species, which means that they may exhibit wide range of tolerance to variations in environmental factors. In contrast, station 3, which exhibited the lowest number of individuals, had also low H' and J values with slightly high dominance value, indicating that the abundance is not that evenly distributed among all the species. In particular, *Quinqueloculina laevigata* (30% or 36 individuals per cm^3) and *N. calcar* (24.12% or 16 individuals per cm^3) dominated the living assemblage in station 3 (Figure 2). However, despite the relative abundance of *Q. laevigata* and *N. calcar*, both their numbers were very low. Previous studies (Pascual et al 2002; Vanicèk et al 2000; Aloulou et al 2001; Frontalini et al 2009; Nigam & Chaturvedi 2000) detected *Q. laevigata* as an accessory species in their samples with no remarkable or significant information on the assemblage. Accessory or secondary species are species that occur in very low abundance and have less value than the dominant or principal species. For instance, *Q. laevigata* showed <10% relative abundance (Buosi et al 2013) and even as low as 0.32% (Frontalini et al 2009). In addition, Mendes et al (2004) described *Q. laevigata* as part of the assemblage present in the shallow water depth up to 12 meters having characteristics of littoral environments differentiated by muddy to sandy benthic zone. As mentioned, *N. calcar* is an eurytopic species which may have wide range of tolerance to variations in environmental factors. Hence, the dominace but low abundances of *Q. laevigata* and *N. calcar* could be related to their response to the present condition in station 3. Images of these 3 dominant foraminiferans are shown in Figures 3-5.

The mean values of the physical and chemical parameters of the bottom waters, the organic matter and some heavy metal contents and the grain size of the sediments in the southeast sector of Iligan Bay is presented in Table 3. In the three sampling stations, differences in the mean values of the environmental parameters were observed. For bottom water temperature, station 1 (29.6°C) was lowest, whereas station 3 (30.85°C) had the highest value recorded. 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 (6.69) and highest (7.87) values were recorded in stations 1 and 3, respectively. This parameter plays 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, salinity did not show any variations in the three stations since all areas have values between 34-35 ppt. For the dissolved oxygen content, the lowest value (5.18 mg L^{-1}) was recorded at station 1 while stations 2 and 3 were 5.20 mg L^{-1} and 5.52 mg L^{-1}, respectively. The environmental conditions of the marine environment are the limiting factors in the occurrence and abundance of benthonic foraminifera (Hariri 2008) although in general, all bottom water environmental parameters recorded in the three sampling stations are within the standard limits set by DENR (DAO 34 1990). The grain size analysis of the sediments showed that the sedimentary structures of the benthic zone in the three sampling stations are predominantly made up of loamy to gravelly sand.

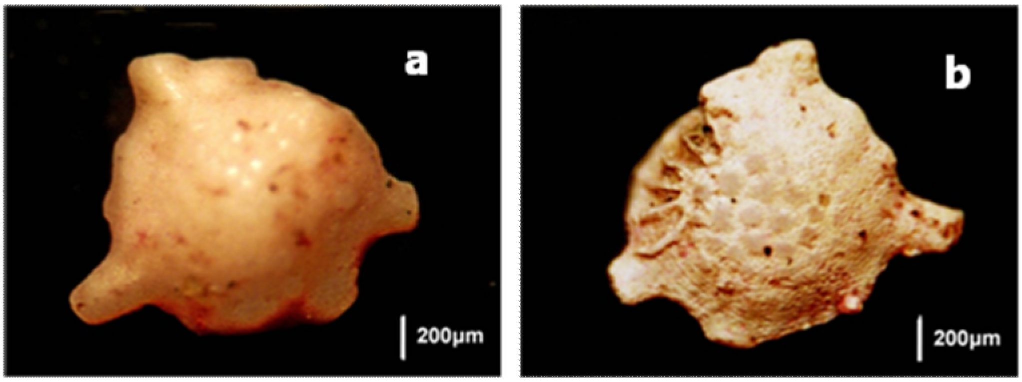

Figure 3. Dorsal (a) and ventral (b) view of *Calcarina gaudichaudii*.

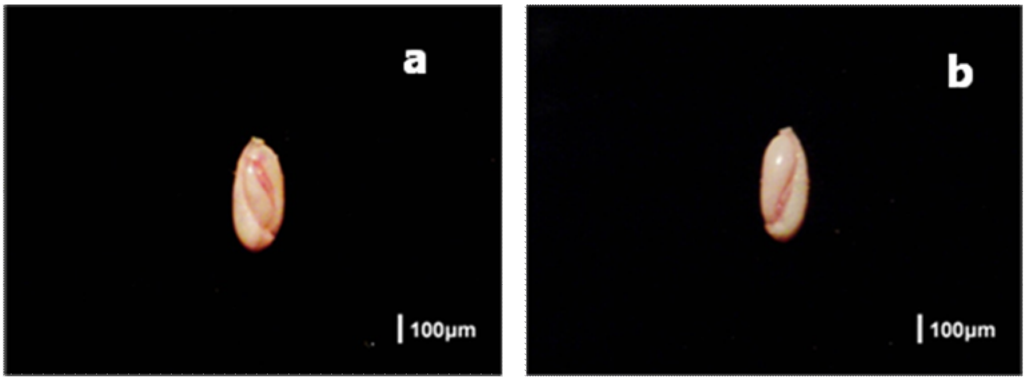

Figure 4. Dorsal (a) and ventral (b) view of *Quinqueloculina laevigata*.

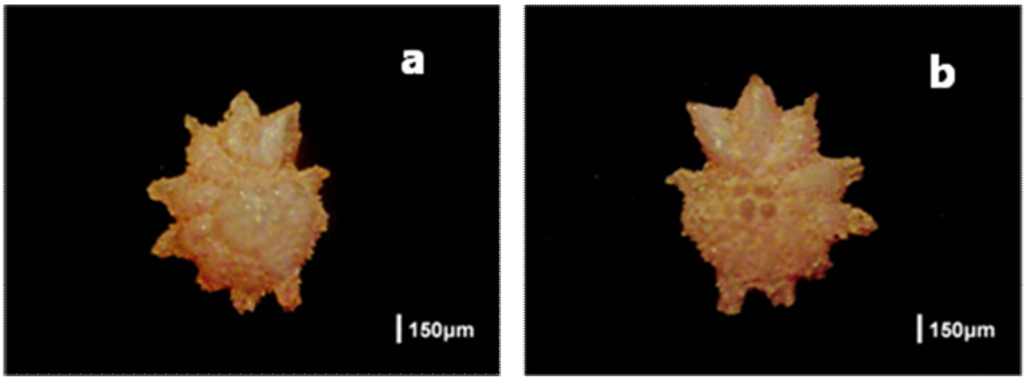

Figure 5. Dorsal (a) and ventral (b) view of *Neorotalia calcar*.

Table 3

Mean values of environmental parameters of the bottom waters, organic matter and heavy metal contents and size of sediments in the three sampling stations where nearby industries are present

Environmental parameters	*Stations*			*Standard values*	*ER-L ($mg\ kg^{-1}$)*	*ER-M ($mg\ kg^{-1}$)*
	1	*2*	*3*			
Temperature (^oC)	29.6	29.8	30.85	min. rise of < 3^oC		
pH	6.69	7.79	7.87	6 to 8.5		
Salinity (ppt)	34	35	35	34 to 35		
DO (mg L^{-1})	5.18	5.20	5.52	> 5		
$CaCO_3$ (%)	15.19	21.92	25.54			
TOM (%)	6.25	6.72	20.97			
Chlorophyll-*a* (mg L^{-1})	0.37	0.41	0.14			
Lead (mg kg^{-1})	13.5	16.4	20		46.7	218
Copper (mg kg^{-1})	21.1	12.9	55.4		34	270
Zinc (mg kg^{-1})	35.6	19.2	74.4		150	410
Chromium (mg kg^{-1})	14.4	14.8	15		81	370
Gravel (%)	0.03	48.39	1.97			
Coarse sand (%)	7.78	34.08	14.38			
Medium sand (%)	3.48	4.35	15.73			
Fine sand (%)	14.75	6.6	10			
Very fine sand (%)	59.09	5.06	47.42			
Silt/mud (%)	7.77	0.54	6.73			
Clay (%)	7.1	0.97	3.78			
Sediment type	Loamy sand	Gravelly sand	Loamy sand			

Standard values for marine and coastal waters (Philippine waters standard values from DENR 1990);
ERL (Effect range low in mg kg^{-1}) and ERM (Effect range median in mg kg^{-1}) values reported for the marine sediment quality standards of the USEPA by Long et al (1995).

Station 1 consisted of fine sands to very fine sands and station 3 was made up of medium to very fine sands while stations 2 was made up of gravel to coarse sands. The foraminifera, which constituted the major bulk of the benthic communities (Gooday et al 1992), can be considered as an excellent tool to characterize both abiotic conditions and environmental quality of marine ecosystems. It has been demonstrated that the community structure and the distribution of foraminiferal assemblages are often associated with abiotic variables such as salinity, granulometry, organic matter content, and dissolved oxygen deserving a meaningful interpretation of the complex ecosystem conditions (Aloulou et al 2001). Since the Philippines had no established sediment quality guidelines, the Sediment Quality Guidelines (SQG) of the USEPA (United States Environmental Protection Agency) were instead used as basis in assessing whether the concentrations of heavy metal in the sediments could have adverse biological impacts. The SQG of the USEPA introduced the Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values for chemical concentrations in marine and estuarine sediments. These values represent potential for occasional detrimental effects to the aquatic environment. For instance, ER-L value represents the concentrations below which adverse effects rarely occur, whereas ER-M value represents the concentrations above which such effects frequently occur (Long et al 1995). For the heavy metal contents of the sediment in the three sampling stations, results showed that the sediments in station 3 contained copper that was above the ER-L value, however lead, chromium and zinc were below ER-L values. On the other side, all trace elements or heavy metals in the sediment in stations 1 and 2 were below ER-L values. Although the concentrations recorded for lead, chromium and zinc were not high, it may still have some influenced in the species composition and the foraminiferal assemblage dominating in each sampling stations.

In order to distinguished benthic foraminiferal assemblages in the study area, hierarchial cluster analysis was employed. The dendrogram revealed the following assemblages (Figure 6): *P. carinatus – E. hanzawai – Q. laevigata* assemblage represents station 1 with *P. carinatus* dominating at 27.07%, followed in decreasing trend by *E. hanzawai* at 13.46% and *Q. laevigata* constituting 12.44% of the total foraminifera assemblage of the bottom sediments; *C. gaudichaudii – N. calcar* assemblage represents station 2, with *C. gaudichaudii* being most abundant (49.95%), while *N. calcar* constituted 19.09% of the total living assemblage; and *Q. laevigata – N. calcar* assemblage represents station 3 with *Q. laevigata* garnering the highest abundance of 30%, while *N. calcar* constituted 24.12% of the total foraminifera assemblage. The results reflected in the cluster diagram (Figure 6) are supported by the results of the Canonical Correspondence Analysis (Figure 7).

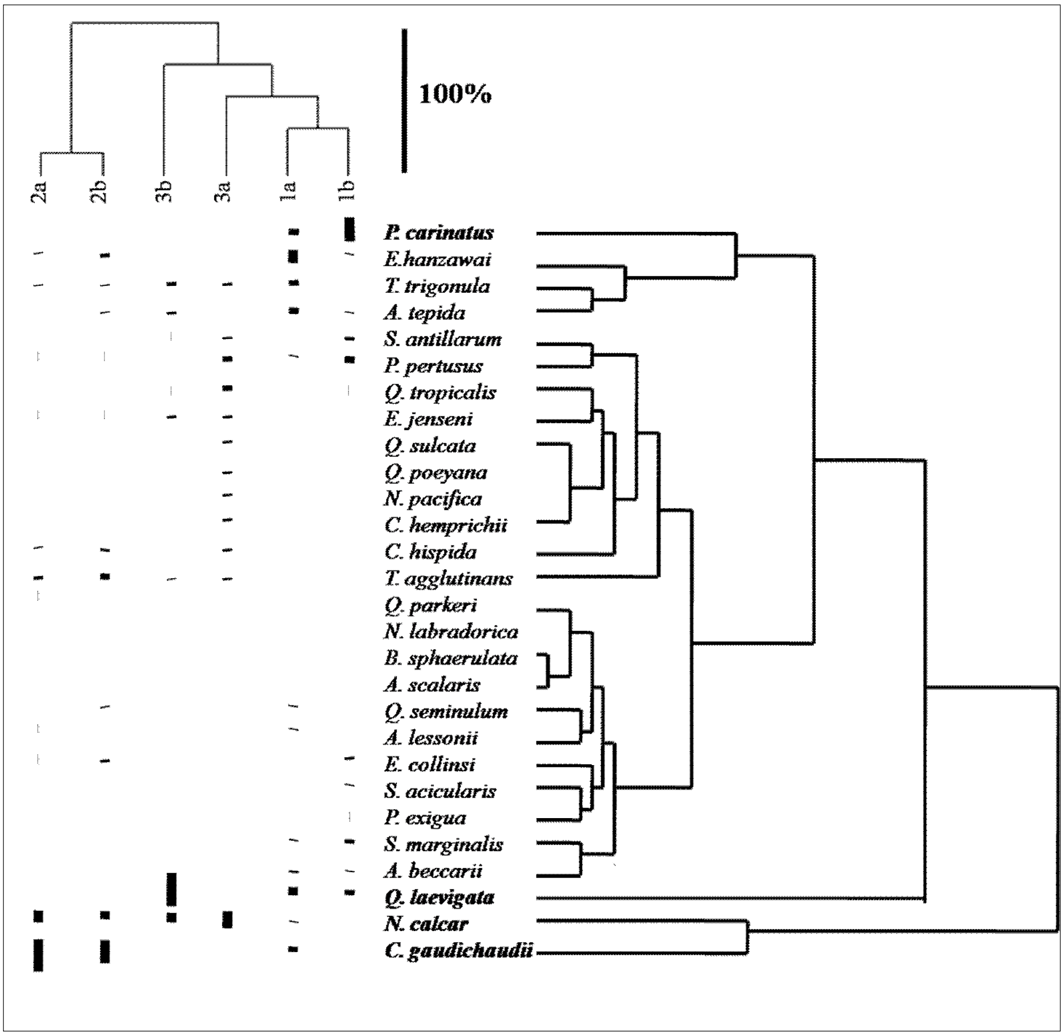

Figure 6. Two-way cluster analysis showing the top four live foraminiferan species that dominates in the three sampling stations in the Iligan Bay.

The CCA showed the 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 three stations. Moreover, results reflected in Figure 7 showed substrate to have an effect on the foraminiferal community structure in station 2. In particular, the gravelly sands favored the dominance of *C. gaudichaudii* which flourished at high abundance (49.95% or

167 individuals per cm^3) in this station. According to the reports of Hohenegger (1994), *C. gaudichaudii* are found on hard substrates represented by the coarse-gravel sediment fraction. *C. gaudichaudii* was even observed to attached to coral rubbles forming dense patches (Renema & Troelstra 2001). As described by some authors (Lacuna et al 2013; Natsir et al 2012; Rao & Balasubramanian 1996), the foraminiferal distribution in an area could be related not only to the surrounding water conditions but also to the type of bottom sediment which mainly influences the ability of benthic foraminifera to dwell in. Hence, sediment type in this case played a major role in characterizing the community structure in the current station. Although the results of CCA manifested in Figure 7 showed an influenced of lead (Pb) and zinc (Zn) to the abundance of foraminifera in station 3, the concentrations of these 2 trace elements were below the ERL values (Pb: 46.7 mg kg^{-1} or ppm; Zn: 150 mg kg^{-1} or ppm) set by USEPA. Lead and zinc, in trace levels are essential for growth but levels beyond the threshold level may become toxic to marine organisms (Kennish 1992). Lead and zinc are also common contaminants that exert strong toxicity to marine organisms in industrialized coastal areas. Inputs of these trace elements into natural water come from different sources including alloys, batteries, anti-corrosive coatings, pharmaceuticals, fertilizers, mining, smelting, paints, petroleum refining and plastics with an additional sources of pipes, sheets, pulp and paper and fossil fuel combustion for lead (Sundara Raja Reddy et al 2012). In addition, these trace elements or heavy metals are known to form organometallic substances. For example, Pb would appear to have different toxicological properties when present in the aquatic ecosystem, while Zn at increasing levels would lead to ecological damage since zinc has long residence time in the marine environment (Madkour & Ali 2009).

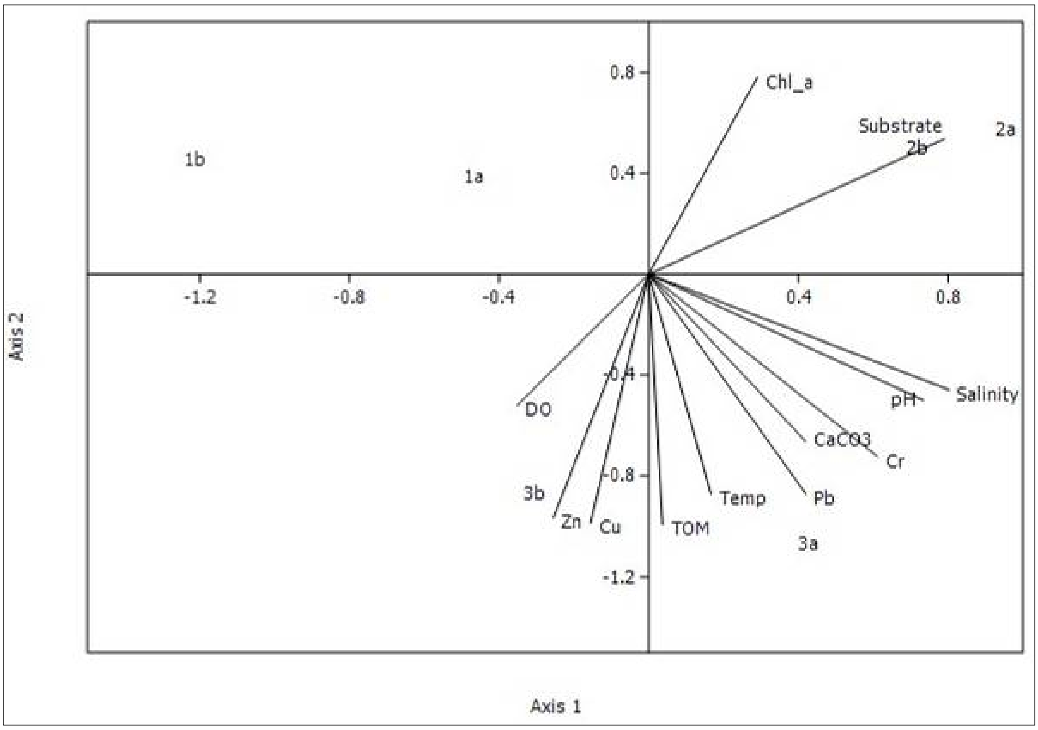

Figure 7. Results of the Canonical Correspondence Analysis – Biplot showing the distance among the sampling stations and the physico-chemical factors that influence the distribution and abundance of live benthic foraminiferans.

Aside from trace elements, temperature also showed influence in the community structure of station 3 as shown in the CCA. Increase in temperature may be suggested from cumulative effects of several other factors present in an area. Horton & Murray (2007) identified temperature as an important factor for distribution of foraminiferal species in shallow water environments. Most organisms principally are associated to a given range where in survival is possible over which reproduction and repopulation could be completed. Langer (2008) added that tropical foraminiferan exhibit distributional limitation affected by temperature. It has been shown that temperatures greater than 30°C appeared to stress the foram-diatom endosymbiosis indicated by colour changes associated with the effects of bleaching (Schmidt et al 2011). It should be noted that the foraminiferal assemblage in this station, showed low abundance of dominant species (*Q. laevigata* and *N. calcar*). However, no related reports have shown occurrence of these species as indicators of stressed conditions. This could indicate that station 3 has strong possibilities to progress into a highly polluted environment if conservation measures and biomonitoring will not be strictly followed. Hence, the present result showed that benthic foraminiferans are suitable indicators of early warning signs of probable anthropogenic pollution of the marine environment as suggested by Kramer & Botterweg (1991).

Conclusions. In general, foraminiferal abundance, diversity, equitability and density clearly showed variations between the three sampling areas of Iligan Bay where complex industries were located near the coast. These significant changes of foraminifera community structure at the different sites illustrate the complexity of factors controlling their distribution and abundance. In particular, living foraminiferal assemblages in station 1 and 2 were quite diversified while station 3 was less diversified. The low species abundance, diversity, equitability but slightly high dominance values observed in station 3 further revealed the dominance of *Q. laevigata* and *N. calcar* in the foraminiferal community structure. Conversely, the high diversity and equitability but low dominance values recorded in station 1 further explained the even distribution of the abundance of foraminiferan species. Although trace element (Pb and Zn) concentrations were detected in station 3, the values recorded were still below the ER-L values set by the USEPA. Nonetheless, their mere presence may imply the possibility of the area to progress from its present health condition into a highly polluted/stressed environment if conservation measures and biomonitoring will not be strictly implemented.

References

Aloulou F., Elleuch B., Kallel M., 2012 Benthic foraminiferal assemblages as pollution proxies in the northern coast of Gabes Gulf, Tunisia. Environ Monit Assess 184:777-795.

Al-Zamel A. Z., Al-Sarawi M. A., Khader S. R., Al-Rifaiy I. A., 2009 Benthic foraminifera from polluted marine environment of Sulaibikhat Bay (Kuwait). Environ Monit Assess 149:395–409.

Barakat A., El Baghdadi M., Rais J., Nadem S., 2012 Assessment of heavy metal in surface sediments of Day River at Beni-Mellal region, Morocco. Research Journal of Environmental and Earth Sciences 4(8):797-806.

Bruland K. W., Donat J. R., Hutchins D. A., 1991 Interactive influences of bioactive trace metals on biological production in oceanic waters. Limnol Oceanogr 36:1555-1577.

Bryan G. W., Langston W. J., 1992 Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: a review. Environ Poll 76:89-131.

Buosi C., Cherchi A., Ibba A., Marras B., Marrucci A., Schintu M., 2013 Benthic foraminiferal assemblages and sedimentological characterisation of the coastal system of the Cagliari area (southern Sardinia, Italy). Bollettino della Società Paleontologica Italiana 52(1):1-9.

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. Journal of Foraminiferal Research 32:68-93.

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

Culver S. J., Buzas M. A., 1999 Biogeography of Neritic benthic foraminifera. In: Modern Foraminifera. Sen Gupta B. K. (ed), Kluwer Academic Publishers, The Netherlands, pp. 93-102.

DENR-ADMINISTRATIVE ORDER NO. 34, 1990 Revised Water Usage and Classification of Water Quality Criteria Amending Section Nos. 68 and 69, Chapter III of the 1978 Rules and Regulations. Manila, 11 pp.

De Nooijer L. J., Duijnstee I. A. P., Bergman M. J. N., Van Der Zwaan G. J., 2007 The ecology of benthic foraminifera across the Frisian Front (Southern North Sea). Estuarine, Coastal and Shelf Science 78:715-726.

Emery K. O., Rittenberb S. C., 1952 Early diagenesis of California basin sediments in relation to origin of oil. Bull Am Assoc Pet Geol 38:735-806.

Erez J., 2003 The source of ions for biomineralization in foraminifera and their implications for paleoceanographic proxies. Reviews in Mineralogy and Geochemistry 54:115–149.

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

Gooday A. J., Jorissen F. J., 2012 Benthic foraminiferal biogeography: controls on global distribution patterns in deep-water settings. Ann Rev Mar Sci 4:237-262.

Gooday A. J., Levin L. A., Linke P., Heeger T., 1992 The role of benthic foraminifera in deep sea food webs and carbon cycling. In: Deep-sea food chains and the global carbon cycle. Rowe G. T., Pariente V. (eds), Kluwer Academic Publishers, the Netherlands, pp. 63-91.

Hallock P., 1984 Distribution of selected species of living algal symbiont-bearing foraminifera on two Pacific coral reefs. Journal of Foraminiferal Research 14:250–261.

Hallock P., 1985 Why are larger Foraminifera large? Paleobiology 11:195–208.

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

Hariri M. S. B., 2008 Effect of hydrographic conditions on the ecology of benthic foraminifera in two different hypersaline lagoons, Eastern Red Sea Coast, Kingdom of Saudi Arabia. JKAU:Mar Sci 19:3-13.

Hohenegger J., 1994 Distribution of living larger foraminifera NW of Sesoko-Jima, Okinawa Japan. Marine Ecology 15:291–334.

Horton B. P., Murray J. W., 2007 The roles of elevation and salinity as primary controls on living foraminiferal distributions: Cowpen Marsh, Tees Estuary, UK. Marine Micropaleontology 63:169–186.

Jain M. K., Dadhich L. K., Kalpana S., 2011 heavy metals contamination in sediments of the River Parbati, Baran, Rajasthan. Journal of Chemical, Biological and Physical Sciences 2(1):54-60.

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

Kennish M. J., 1992 Ecology of estuaries: anthropogenic effects. CRC Press Inc., Boca Raton, 494 pp.

Kramer K. J. M., Botterweg J., 1991 Aquatic biological early warning system: an overview. In: Bioindicators and environmental management. Jeffrey D. W., Mudden B. (eds), Accademic Press, London, pp. 95-126.

Kravchuk A., 2006 Benthic foraminifera as indicators of pollution in the north-western shallow part of the Black Sea. Geophysical Research Abstracts vol. 8, 00518.

Lacuna M. L. D. G., Alviro M. P., 2014 Diversity and abundance of benthic foraminifera in nearshore sediments of Iligan City, Northern Mindanao, Philippines. ABAH Bioflux 6(1):10-26.

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.

Langer M. R., 2008 Assessing the contribution of foraminiferan protists to global ocean carbonate production. J Eukaryot Microbiol 55:163-169.

Lay J. P., Zsolnay A., 1989 Effects in marine ecosystems. In: Ecotoxicology and climate. Bourdeau P., Haines J. A., Klein W., Krihsna Murti C. R. (eds), John Wiley & Sons Ltd., USA, pp. 195-218.

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.

Long E. R., MacDonald D. D., Smith S. L., Calder F. D., 1995 Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19:81-97.

Love L. G., Murray J. W., 1963 Biogenic pyrite in recent sediments of Christchurch Harbour, England. American Journal of Science 261:433–448.

Madkour H. S., Ali M. Y., 2009 Heavy metals in the benthic foraminifera from the coastal lagoons, Red Sea, Egypt: indicators of anthropogenic impact on environment. Environ Geol 58:543–553.

Mendes I., Gonzalez R., Dias J. M. A., Lobo F., Martins V., 2004 Factors influencing recent benthic foraminifera distribution on the Guadiana shelf (southwestern Iberia). Marine Micropaleontology 51:171–192.

Mikulic N., Orescanin V., Elez L., Pavicic L., Pezelj D., Lovrencic I., Lulic S., 2008 Distribution of trace elements in the coastal sea sediments of Maslinica Bay, Croatia. Environ Geol 53:1413-1419.

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. Research Journal of Environmental Sciences 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.

Moretti F. J., 1957 Observations on limestones. J Sediment Petrol 27:282-292.

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. Palaeontologia Electronica 5(1):1-31.

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

Natsir S. M., Subkhan M., Wardhani V. I., 2012 The distribution of benthic foraminiferal assemblages in Tambelan Islands of Riau Islands. Proc Soc Indon Biodiv Intl Conf 1:107-112.

Nigam R., Chaturvedi S. K., 2000 Foraminiferal study from Kharo creek, Kachchh (Gujarat), north west coast of India. Indian Journal of Marine Sciences 29:133-138.

Pascual A., Rodriguez-Lazaro J., Weber O., Jouanneau J. M., 2002 Late Holocene pollution in the Gernika estuary (southern Bay of Biscay) evidenced by the study of Foraminifera and Ostracoda. Hydrobiologia 475/476:477–491.

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. Palaeontologia Electronica 13(2):1-28.

Rao K. K., Balasubramanian T., 1996 Distribution of foraminifera in the Cochin Estuary. Journal of Marine Biological Association of India 38(1&2):50-57.

Renema W., Troelstra S. R., 2001 Larger foraminifera distribution on a mesotrophic carbonate shelf in SW Sulawesi (Indonesia). Palaeogeography, Palaeoclimatology, Palaeoecology 175:125-146.

Riveiros N. V., Patterson T. R., 2007 An illustrated guide to fjord foraminifera from the Seymour-belize Inlet Complex, Northern British Columbia, Canada. Palaeontologia Electronica 11(1):1-45.

Sakai K., Nishihira M., 1981 Population study of the benthic foraminifer *Baculogypsina sphaerulata* on the Okinawan reef flat and preliminary estimation of its annual production. Proceedings of the Fourth International Coral Reef Symposium, Manila 2:763–766.

Schmidt C., Heinz P., Kucera M., Uthicke S., 2011 Temperature-induced stress leads to bleaching in larger benthic foraminifera hosting endosymbiotic diatoms. Limnol Oceanogr 56:1587–1602.

Scott D. B., Takayanagi Y., Hasegawa S., Saito T., 2000 Illustration and reevaluation of affinities of Neogene foraminifera described from Japan. Palaeontologia Electronica 3(2):1-41.

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.

Sundara Raja Reddy B. C., Jayaraju N., Reddy K. R., 2012 Anthropogenic impact on the Pulicat Lagoon monitoring with foraminifera, East coast of India. Marine Science 2(5):66-76.

Valiela I., 1995 Marine ecological processes. Second edition, Springer Verlag, New York, 686 pp.

Vanicèk V., Juracic M., Bajraktarevic Z., Cosovic V., 2000 Benthic foraminiferal assemblages in a restricted environment - an example from the Mljet Lakes (Adriatic Sea, Croatia). Geol Croat 53:269–279.

Van Straaten L. M. J. U., 1954 Sedimentology of recent tidal flat deposits and the psammites du Condroz (Devonian). Geologie en Mijnbouw 16:25-47.

Vilela C. G., Batista D. S., Baptista-Neto J. A., Crapez M., McAllister J. J., 2004 Benthic foraminifera distribution in high polluted sediments from Niteroi, Harbor (Guanabara Bay) Rio de Janeiro, Bay. Annals of the Brazilian Academy of Sciences 76(1):161-171.

*** http://folk.uio.no/ohammer/past/.

*** http://www.foraminifera.eu.

*** http://mapcarta.com/.

Received: 30 May 2014. Accepted: 12 June 2014. Published online: 13 June 2014.

Authors:
Hannah Mae Cagaan Unsing, Department of Biological Sciences, College of Science and Mathematics, Mindanao State University - Iligan Institute of Technology, Andres Bonifacio Avenue, Iligan City 9200, Philippines, e-mail: han7154nah@gmail.com
Maria Lourdes Dorothy Garcia Lacuna, Department of Biological Sciences, College of Science and Mathematics, Mindanao State University - Iligan Institute of Technology, Andres Bonifacio Avenue, Iligan City 9200, Philippines, e-mail: mileskung@yahoo.com

How to cite this article:
Unsing H. M. C., Lacuna M. L. D. G., 2014 Assemblages of benthic foraminifera in front of three industries along the coast of Iligan City, Southern Philippines and its relation to some environmental parameters. AES Bioflux 6(2):168-182.