ABAH BIOFLUX

Animal Biology & Animal Husbandry
International Journal of the Bioflux Society

Benthic foraminiferal assemblage on a mixed stands of seagrass and macroalgae in Kauswagan, Lanao del Norte, Southern Philippines

Maria L. D. G. Lacuna, Karen A. J. Gayda

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 benthic 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 45 foraminiferan species belonging to 25 genera under 19 families were identified in the living foraminiferal assemblage on the intertidal flat of Kauswagan, Lanao del Norte, Philippines vegetated by mixed stands of seagrass and macroalgae. Using several diversity indices, results showed that the living foraminiferal assemblages in all sampling stations were highly diversified however, the dominance (D) values reflected in these stations were slightly high (0.50 - 0.24). The reason for these can be observed in the high relative abundances of three species, namely *Elphidium crispum* (37 – 57 % or 20 - 36 per 10 cm^3), which strongly dominated the entire living foraminiferal assemblage in all the sites and subordinately by *Neorotalia calcar* (16 – 22 % or 8 - 10 per 10 cm^3) and *Ammonia beccarii* (6 – 11 % or 3 - 6 per 10 cm^3). The results of the Canonical Correspondence Analysis further showed that the parameters, *viz*. Chlorophyll-*a* of the sediment and dissolved oxygen content of the bottom waters, may have influenced the observed low abundance of the benthic foraminiferal assemblage in the present study. The results may imply that the present conditions of the environment may have affected the community structure of live foraminiferans. In this case, the dominance of *E. crispum*, *N. calcar* and *A. beccarii* may imply an environment having gravelly sandy silt bottom sediment vegetated with seagrasses and macroalgae beds. Further, the dominance of *A. beccarii* may likewise suggest potential anthropogenic impacts prevalent in that area. Hence, the results of the present study could be essential in the further assessment in the relationship between anthropogenic impacts and organisms for future development towards conservation and management of the area.
Key Words: Tropical foraminiferans, species diversity, Philippines, water quality, anthropogenic impact.

Introduction. The response of benthic foraminiferal assemblages to the impacts of natural and anthropogenic parameters is considered to be very vital when it comes to monitoring the health of the environment. This is because foraminifers can act as an early warning indicator to any short- and long-term changes in their habitat, especially to coastal ecosystems where human-induced pollutions are quite prevalent. Due to this usefulness, they are now widely used as bio-indicators of coastal and estuarine pollutions (Alve & Nagy 1986; Alve 1991; Alve 1995; Frontalini et al 2010; Jayaraju et al 2008, 2011; Nagy & Alve 1987; Tsujimoto et al 2006; Valiela 1984). Their role as bio-indicator is made possible since foraminiferans have short life cycle and are highly sensitive to changes in environmental settings. Several ecological studies had documented the influence of environmental parameters, such as substrate texture, bathymetry, temperature, organic content, dissolved oxygen, salinity, light, sedimentation rate, organic carbon, and toxins, to benthic foraminiferal assemblage (*e.g.*, Jorissen et al 1992, 1995, 1998; Debenay & Redois 1997; Yanko et al 1999; Mendes et al 2004; Diz & France´s 2008; Pascual et al 2008; Armynot du Chatelet et al 2009a,b; Mojtahid et al 2009). These reports have revealed a variety of dominant environmental influences on benthic foraminiferal fauna. Despite the increased numbers in the studies of benthic foraminiferal ecology, no study had previously been conducted in the Philippine setting on foraminiferal assemblages on the intertidal flat vegetated by mixed stands of seagrass and macroalgae. To address this gap, 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 area. The data generated from this study will represent as baseline needed for monitoring future effects caused by both natural and anthropogenic activities in the area. Hence, knowledge of the ecological parameters that influence distributions of benthic foraminiferans in natural environments is therefore a necessary prerequisite to the promotion of foraminifera as useful tools for ecological and environmental interpretations.

Material and Method. The study area is located on the intertidal flat of Kauswagan, Lanao del Norte, Philippines which is famous for its abundance in coastal resources such as fresh fish and shells. The study area although important as a major fishing ground, is also exposed to human-induced pollutions such as domestic sewage discharges. The area is part of the well-known Iligan Bay in Mindanao.

Within the intertidal flat of Kauswagan, Lanao del Norte vegetated by mixed stands of seagrasses (*Cymodocea, Thalassia, Enhalus)* and green (*Halimeda*, *Laurencia*) and red macroalgae (*Chaetomorpha* and *Gracillaria*), two transect lines with a length of 50 m, were established. Each of the transect lines were positioned perpendicular to the shoreline and parallel to each other with a distance of 100 m apart (Figure 1).

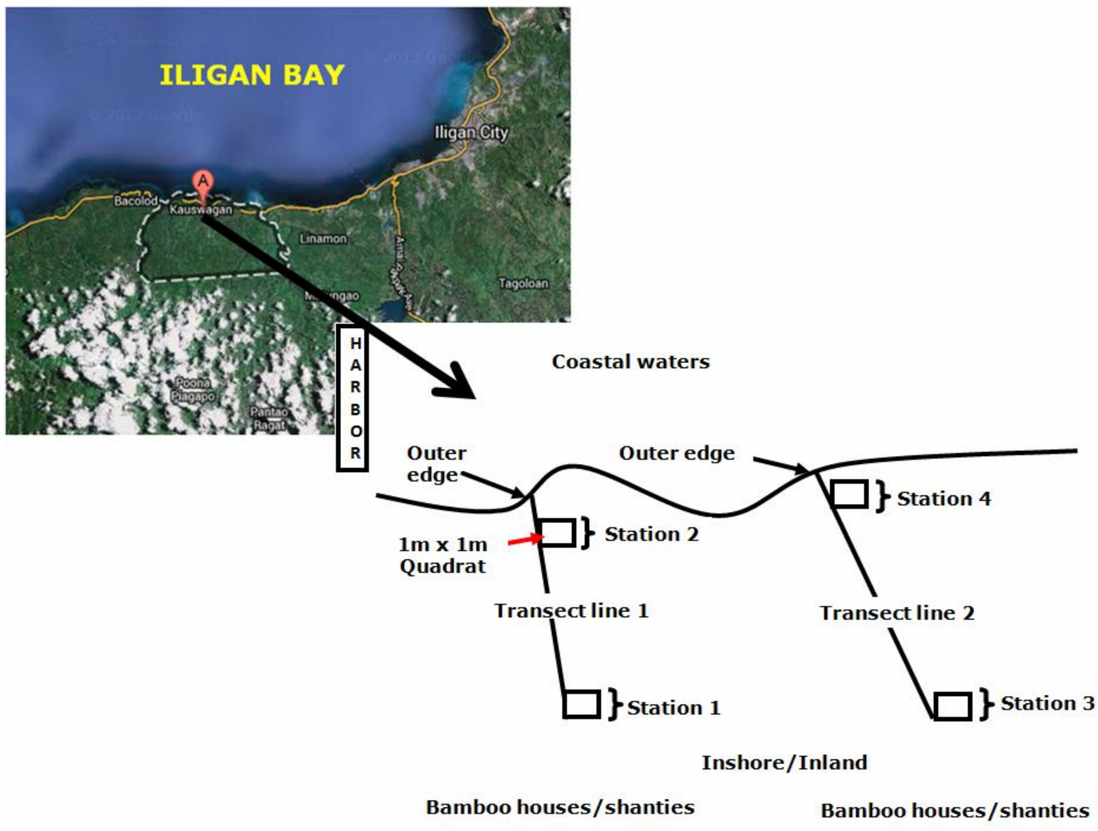

Figure 1. Satellite image of Kauswagan, Lanao del Norte with a schematic diagram of the four sampling stations that were set up strategically on the study area.

The transect line was laid down starting from the inshore where a mixed stand of seagrass beds and macroalgae first appeared until the outer edge of the bed going towards the sea. Along each transect line, two sampling stations were set up at 50 m intervals: (a) transect line 1 with stations 1 (0 m) and 2 (50 m); (b) transect line 2 with stations 3 (0 m) and 4 (50 m). At each station, a 1 m x 1 m quadrat was laid down and sediment samples for the analyses of foraminiferans and environmental parameters were collected. Methods for the field collections and laboratory analyses employed in the present study were patterned from those of Lacuna et al (2013). 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 during low tide level using a syringe with its tip being cut off (4 cm inner diameter; 10 cm length). 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 four 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 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 & 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. 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 2.17 (http://folk.uio.no/ohammer/past/) (Hammer et al 2001).

Results and Discussion. A total of 45 foraminiferan species belonging to 25 genera under 19 families were identified in the living foraminiferal assemblage in the intertidal flat of Kauswagan, Lanao del Norte associated with the presence of seagrasses (*Cymodocea, Thalassia, Enhalus*) and algae (*Halimeda*, *Laurencia*, *Chaetomorpha* and *Gracillaria*) (Table 1). Of those, 16 species prefer an attached lifestyle *i.e.* epiphytic both permanently and temporarily attached (as indicated by an asterisk in table 1), while the rest of the species are benthic epifauna in nature.

Table 1

Composition of live foraminiferan species in the four sampling stations established in the intertidal flat of Kauswagan, Lanao del Norte, Southern Philippines

Foraminiferal species	*Stations*			
	1	*2*	*3*	*4*
Rotaliidae				
Ammonia beccarii	+	+	+	+
Neoratalia calcar	+	+	+	+
Soritidae				
Amphisorus hemprichii•	+	+	+	-
Amphisteginidae				
Amphistegina lessonii	+	+	-	-
Peneroplidae				
*Peneroplis pertusis**	+	-	-	-
Calcarinidae				
Calcarina mayori	+	+	+	+
Calcarina spengleri	+	+	+	+
Calcarina hispida	+	+	+	+
Cibicididae				
Cibicides cushmani	+	+	-	-
Elphidiidae				
Elphidium crispum	+	+	+	+
Elphidium subcrispum	+	+	+	+
Elphidium hamburg	-	-	+	-
Elphidium macellum	+	-	+	-
Textulariidae				
*Textularia agglutinans**	+	+	+	+
Hauerinidae				
Massilina granulocostata	+	+	+	+
Miliolinella circularis	+	-	+	-
*Quinqueloculina bicostata**	-	+	+	-
*Quinqueloculina candeiana**	-	+	-	-
*Quinqueloculina laevigata**	+	+	+	+
*Quinqueloculina vulgaris**	+	-	-	-
*Quinqueloculina lata**	+	+	-	-
*Quinqueloculina parkeri**	+	+	+	+
*Quinqueloculina goesi**	+	+	+	-
*Quinqueloculina pertensi**	-	+	-	-
*Quinqueloculina pseudoreticulata**	-	+	-	-
*Quinqueloculina seminulum**	+	+	-	-
*Quinqueloculina costata**	-	+	-	-
*Quinqueloculina ludwigi**	-	-	+	-
Nonionidae				
Pseudononion trececum	+	-	-	-
Pseudononion sp.	-	+	-	-
Astrononion sp.	+	+	+	+
Planorbulinidae				
Planorbulina difformis•	-	+	-	-
Spiroloculinidae				
Spiroloculina angulata	+	+	+	-
Miliolidae				
Triloculina trigonula	+	+	+	-
Triloculina poeyana	+	-	-	-
Triloculina barnardi	+	-	-	-

Foraminiferal Species	Stations			
	1	*2*	*3*	*4*
Triloculina linneiana	-	+	-	-
Triloculina granolusa	-	-	-	+
Triloculina terquemiana	-	-	+	-
Valvulinidae				
Clavulina multicamerata	+	+	+	+
Bagginidae				
Valvulineria floridana	-	+	-	-
Strainforthiidae				
Cassidelina aspisenscens	-	+	-	-
Epistomarridae				
Epistomaria yabei	-	-	-	+
Vaginulinidae				
Lenticulina submalligera	+	+	-	-
Rosalinidae				
Neoconobina pacifica	+	-	-	-
Total number of species	30	32	23	15

+ present, - absent, • permanent attachment, • temporary attachment, * permanent motile grazing epiphytes.

The foraminiferan species in the study area is characterized by medium in size, extremely well-preserved and undeformed specimens implying that the species are free from all signatures of pollution effects on their test morphology. Further, out of the 45 identified species, around 19 species have already been reported from other areas in the Philippines by Lacuna et al (2013), and Lacuna & Alviro (2014) in Iligan Bay, and by Brobo (2010) in Murcielagos Bay. From a thorough review of these existing literatures in the Philippine Archipelagic waters, it appears that the remaining 27 species have been mentioned and recorded first time in the southwest portion of Iligan Bay. Images of some of the common and dominant foraminiferan species is presented in figures 2 - 7.

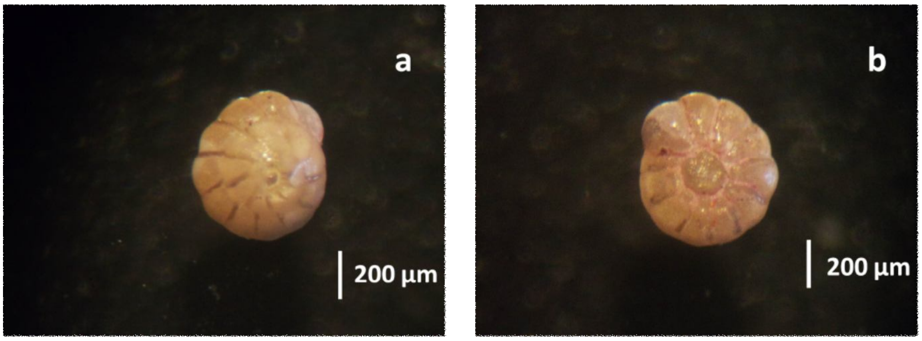

Figure 2. Dorsal (a) and ventral (b) view of *Ammonia beccarii*.

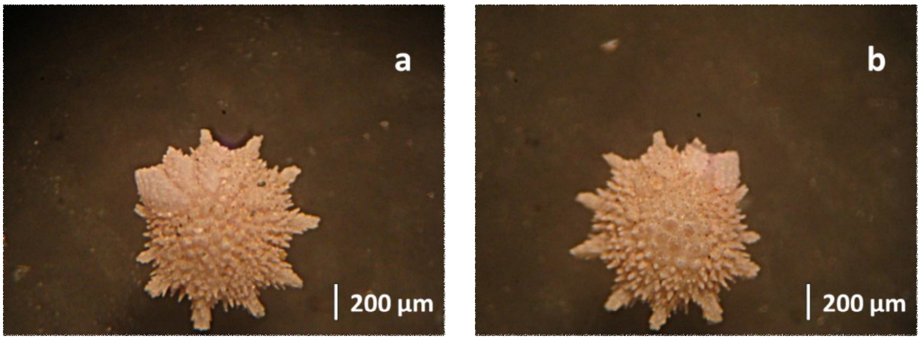

Figure 3. Dorsal (a) and ventral (b) view of *Neorotalia calcar*.

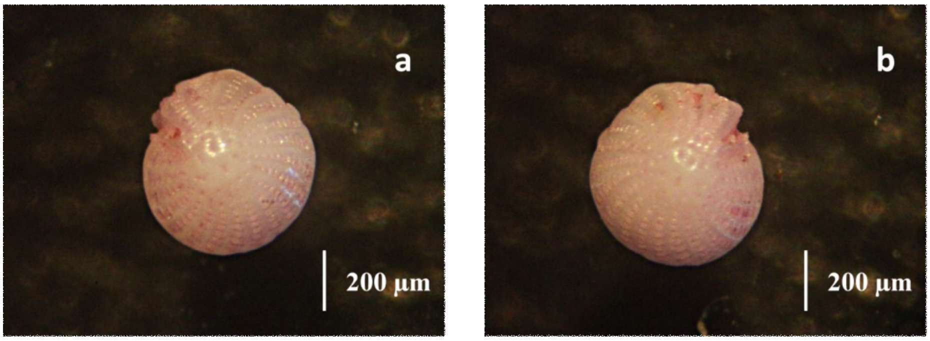

Figure 4. Dorsal (a) and ventral (b) view of *Elphidium crispum.*

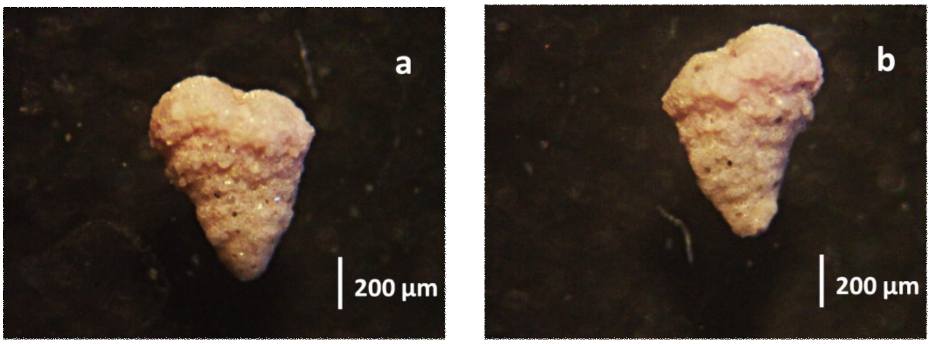

Figure 5. Dorsal (a) and ventral (b) view of *Textularia agglutinans.*

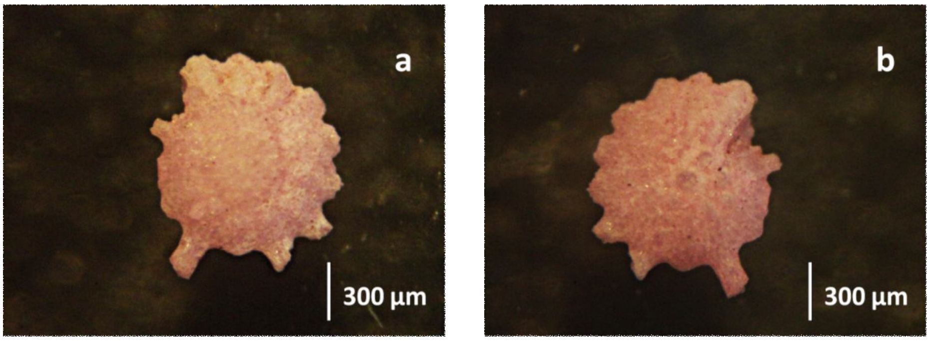

Figure 6. Dorsal (a) and ventral (b) view of *Calcarina spengleri.*

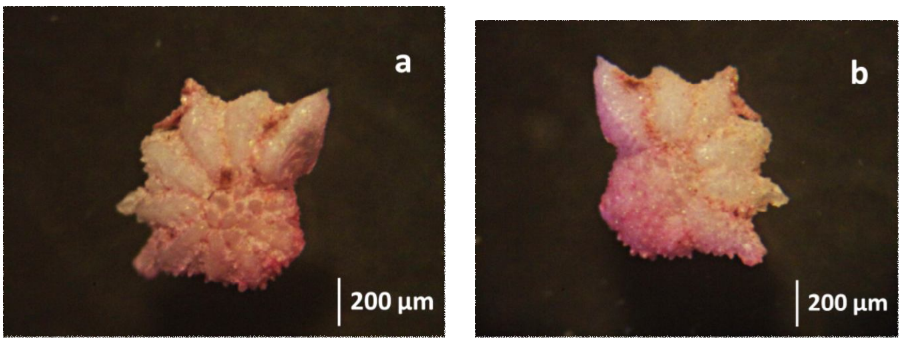

Figure 7. Dorsal (a) and ventral (b) view of *Astrononion sp*.

The mean values of the physical and chemical parameters of the bottom waters and the organic matter contents of the sediments in the seagrass bed of Kauswagan, Lanao del Norte is presented in table 2. The values for all bottom water quality parameters (*i.e* temperature, pH, salinity and DO) in all four sampling stations are within the range for any marine faunistic assemblage to thrive and be fairly abundant (DENR-DAO 34 1990; Bradshaw 1957). However, the mean values showed variations between the four sampling stations and might be responsible for differences in their relative abundances.

Table 2
Mean values of environmental parameters of the bottom waters, organic matter and size of sediments in the four sampling stations in the intertidal flat of Kauswagan, Lanao del Norte

Environmental parameters	*Stations*			
	1	*2*	*3*	*4*
Temp (°C)	26.5	27.9	27.8	29.05
pH	7.35	7.83	8.42	8.45
Salinity (ppt)	30	30	30	30
DO (mg L^{-1})	6.22	6.45	6.49	7.3
$CaCO_3$ (%)	44.66	40.46	45.24	41.56
TOM (%)	7.16	7.67	9.05	10.03
Chlorophyll *a* (µL^{-1})	0.287	0.251	0.259	0.428
Gravel (%)	4.18	6.4	5.9	5.5
Sand (%)	92.21	88.93	90.92	90.22
Silt (%)	3.61	4.67	3.18	4.28
Sediment type	Slightly gravelly sandy silt	Slightly gravelly sandy silt	Slightly gravelly sandy silt	Slightly gravelly sandy silt

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-DAO 1990).

It is noteworthy that all the bottom water quality parameters (*i.e.* temperature, pH, salinity and DO) were constantly highest in station 4 and lowest in station 1. Salinity contents in the four sampling stations did not exhibit any fluctuations and are within the values (30 ppt) recorded for a typical marine environment. 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 fluctuation (Lacuna et al 2013). The pH of the area is an important indicator of chemical conditions of the depositional environment. It is a critical environmental factor which influences the production of calcareous microfauna. Hydrogen ion concentrations are expected to affect the production of calcareous tests of foraminiferans at pH approximately <7, where they may not be able to survive (Phleger 1960). On the other side, Giere (2009) 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. Moreover, dissolved oxygen is one of the most important environmental gradients in the system and is frequently impacted by human activity (Bouchet et al 2012). In terms of the organic matter contents of the sediment, slight differences were observed between sampling stations. For instance, the calcium carbonate content was highest in station 3 but lowest in station 2, whereas the total organic matter and chlorophyll *a* were highest in station 4 but lowest in stations 1 and 2, respectively. In terms of grain size, the bottom sediments are primarily composed of sand (~88 %), with an average percentage of silt of 3.9 % and coarser fraction that is made up of gravel of 5.5 %. With these data, the sedimentary structure of the intertidal flat of Kauswagan, Lanao del Norte that are often associated with the presence of seagrasses (*Cymodocea,* *Thalassia, Enhalus*) and green and red algae (*Halimeda*, *Laurencia*, *Chaetomorpha* and *Gracillaria*) are therefore composed of slightly gravelly sandy silt.

The level of diversity of foraminiferal species showed variations in the four sampling stations established in the intertidal flat of Kauswagan, Lanao del Norte where seagrasses and algae are associated (Table 3).

Table 3

Diversity profiles of the four sampling stations for live foraminiferans in Kauswagan, Lanao del Norte

Diversity index	*Stations*			
	1	*2*	*3*	*4*
Taxa (S)	30	32	23	15
Individuals	677	575	545	516
Dominance (D)	0.4575	0.3192	0.2491	0.5008
Shannon (H)	1.523	1.883	2.034	1.268
Simpson (1-D)	0.5425	0.6808	0.7509	0.4992
Evenness (e^H/S)	0.1529	0.2053	0.3324	0.2369
Menhinick	1.153	1.334	0.9852	0.6603
Margalef	4.449	4.879	3.492	2.241
Equitability (J)	0.4478	0.5432	0.6487	0.4682
Fisher's alpha	6.429	7.31	4.865	2.89
Berger-Parker	0.6677	0.5391	0.4697	0.6977

Data revealed that the living assemblages were highly diversified in the study sites with differences in the number of taxa being very apparent when the four sampling stations were compared. It can be seen from the result that station 2 showed the highest number of foraminiferal taxa (32) followed in decreasing order by station 1 (30), station 3 (23) and station 4 (15). Results further revealed a much higher Shannon index (H') and equitability (J) values in station 3 followed in decreasing trend by station 2, station 1 and then with station 4 having the lowest values. Despite the highest number of living individuals (32) recorded in station 2, it did not have the highest H' and J values. Instead, station 3, with 23 living individuals, showed the highest H' and J values but with the lowest dominance value (0.2491). Conversely, station 4, which recorded the lowest number of living individuals (15) showed low Shannon and equitability values but the highest dominance value. In general, the dominance (D) values reflected in all the sampling stations were slightly high (0.50 - 0.24). The reason for these can be observed in the high relative abundances of three species, namely *Elphidium crispum* (37 – 57 % or 20 - 36 per 10 cm^3), which strongly dominated the entire living foraminiferal assemblage in all the sites and subordinately by *Neorotalia calcar* (16 – 22 % or 8 - 10 per 10 cm^3) and *Ammonia beccarii* (6 – 11 % or 3 - 6 per 10 cm^3) (Figure 8). Toth & Gorog (2008) observed the predominance of keeled elphidiids (*i.e*. *E. crispum* and *E. aculeatum*) in the rhizomes of the mediterranean seagrass *Posidonia oceanicus*. The appearance of *A. beccarii* in greater abundance beside the keeled elphidiids was also observed. They argued that the high abundance of the keeled elphidiids and *A. beccarii* could be connected with the phytal microhabitats and high detrital content in the area. According to Buosi et al (2012) and Venec-Peyre (1984), the seagrass *Posidonia* meadows provide abundant niche for fixed and mobile foraminiferal species because the rhizomes act as sediment traps and the leaves are often colonized by sessile foraminifera. In this sense, the meadow would support a diversity of taxa (*viz*. epiphytic and epibenthic foraminiferal species) by providing a diversity of niches relative to both food supply and physical habitat. Similarly, Abu-Zied et al (2011) reported dominance of a symbiont-bearing species, *Neorotalia calcar*, in sediments that is characterized by muddy sand, and the presence of seagrasses and green filamentous algae. Since *N.*

calcar have several spines projected from its body (Figure 3), it is probable that these spines may provide a means of stabilization on the algal mat (Hohenegger 1994; Lobegeier 2002) thereby contributing to the species' dominance and high abundance in the bottom sediments in the present study. Moreover, aside from the presence of vegetation, the substrate type may have also been responsible for the dominance of these three benthic foraminiferans.

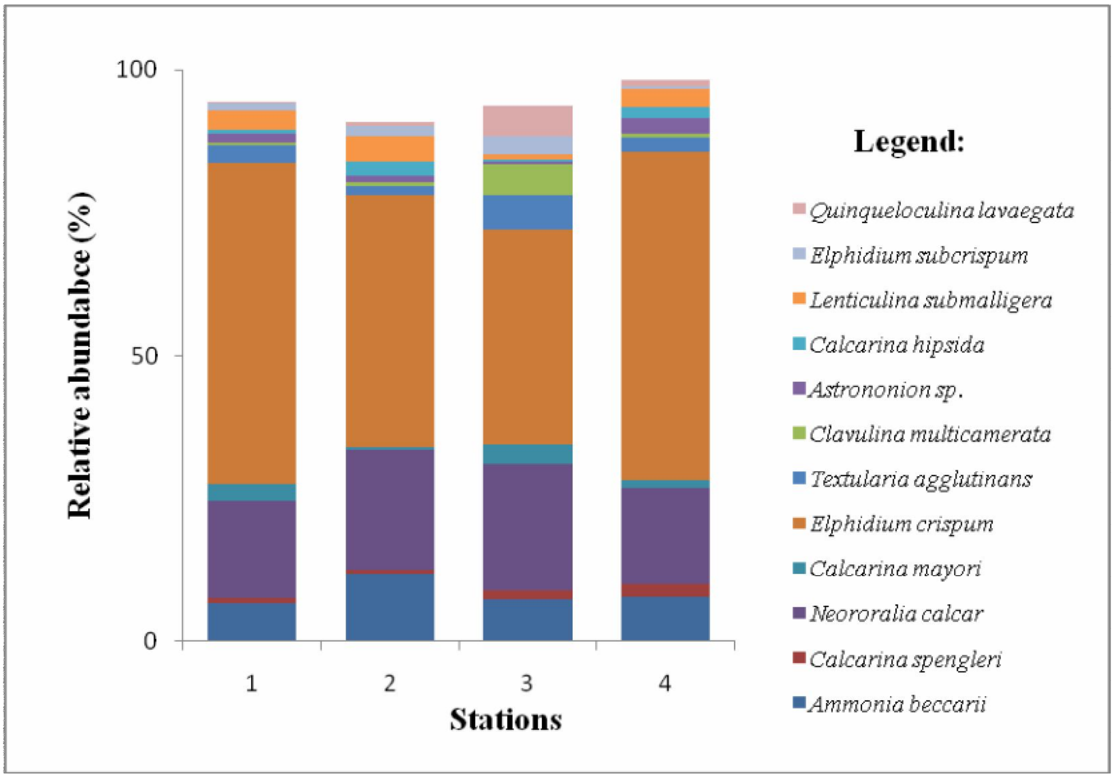

Figure 8. Foraminiferan species with relative abundances >2 % in the four sampling stations in the intertidal flat of Kauswagan, Lanao del Norte.

Buosi et al (2013) have observed that in sandy sediments, the dominant biocenosis would comprise of epifaunal and epiphytic species belonging to *A. beccarii, Peneroplis pertusis* and *Rosalina bradyi*, respectively. Similarly, Sgarrella & Moncharmont Zei (1993) documented *A. beccarii* to be widespread and generally abundant in the entire infralittoral zone that has sandy bottom, whereas Abu-Zied et al (2011) reported dominance of *N. calcar* in muddy sand substrate. Conversely, Buosi et al (2012) recorded positive correlation of *E. crispum* and other keeled elphidiids with coarse sediments and strong bottom currents. They emphasized that under coarse sands and gravels, foraminifera assemblage is dominated by *E. crispum* and *Textularia agglutinans*, with the later species preferring sandy-gravelly sediments. Several studies had also reported *A. beccarii*, a euryhaline species, to be widely distributed in intertidal and subtidal zones (Alve & Murray 1999), able to survive under a wide range of values of dissolved oxygen (Moodley & Hess 1992), salinity and temperature (Murray 1991) as well as heavily polluted waters (Alve 1995). Lacuna et al (2013) reported the sole dominance of *A. beccarii* in the benthic foraminiferal assemblage in moderately polluted marine waters and suggested that *A. beccarii* might be associated with the outputs coming from the ferro-nickel smelting plant. In fact, Lacuna & Alviro (2014) reported the capacity of *A. beccarii* and *T. trigonula* in tolerating the presence of pollutants in moderately stressed coastal environment. Tsujimoto et al (2006) also observed the dominance of three species such as *Ammonia beccarii*, *Eggerella 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.

It is noteworthy that within the vicinity (around 50 m away from the intertidal flat of Kauswagan, Lanao del Norte) of the four established sampling stations, houses or shanties made up of bamboo are visible. Local people most often fishermen and their families occupied those bamboo shanties/houses. Their domestic wastes or effluents are often being discharged directly into the area thereby contributing more human-induced pollutions. Since the sedimentary structure of the intertidal flat of the present study is composed of slightly gravelly sandy silt vegetated by seagrasses (*Cymodocea, Thalassia, Enhalus*) and green and red macroalgae (*Halimeda*, *Laurencia*, *Chaetomorpha* and *Gracillaria*), it is suggested that these two factors might be responsible for the dominance of *E. crispum*, *N. calcar* and *A. beccarii* in the entire living foraminiferal assemblage. Further, anthropogenic inputs can also be one of the reasons (aside from the type of substrate and presence of vegetations) leading to the dominance of *A. beccarii* in the present study as reported by the above-mentioned authors. Hence, the dominance of *E. crispum, P. calcar* and *A. beccarii* recognized in the present study may appear to be related to sedimentary structure and the presence of associated macrophytes in addition to the stress conditions (*i.e*. human-induced) occurring there.

The relative abundance of the benthic foraminiferan community varies from station to station (Figure 9), with station 1 being highly abundant while station 4 being lowest in relative abundance.

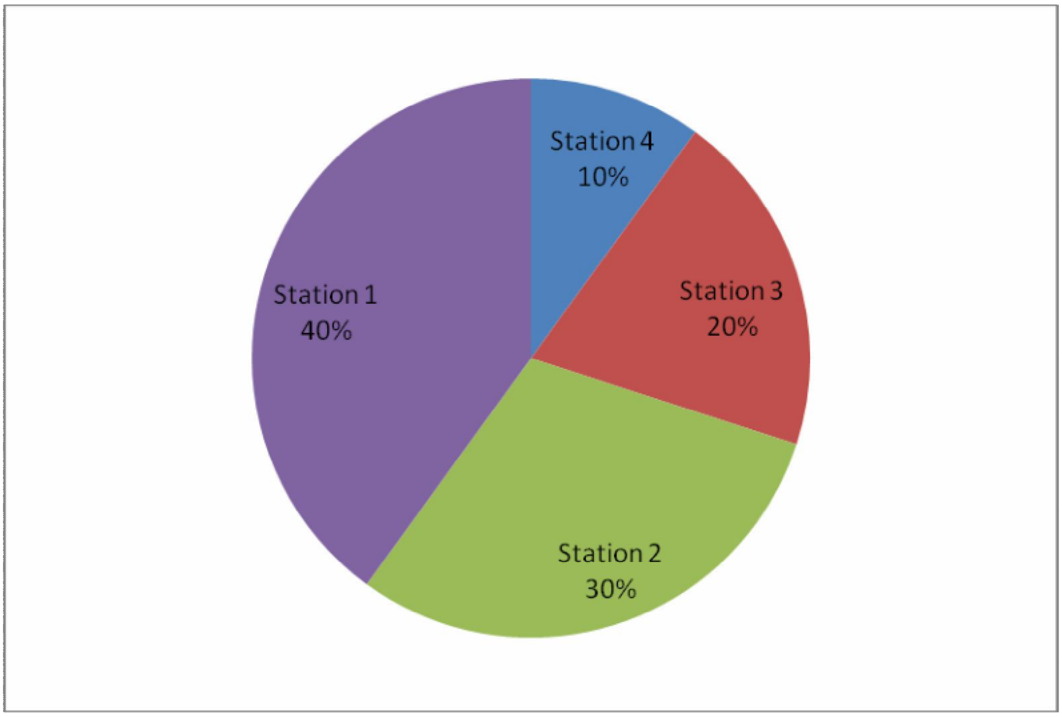

Figure 9. Relative abundance of the benthic foraminiferal community in the four sampling stations in the intertidal flat of Kauswagan, Lanao del Norte.

The results of the Canonical Correspondence Analysis (Figure 10) further showed that the parameters, *viz*. chlorophyll *a* of the sediment and dissolved oxygen content of the bottom waters, may have influenced the observed low abundance of the benthic foraminiferal assemblage in the present study. Results in figure 10 showed that the sparse abundance of foraminiferal assemblage in station 4, which was predominated by *E. crispum* and subordinately with *N. calcar* and *A. beccarri*, might be affected by an increase in chlorophyll *a* and dissolved oxygen. It has been reported that foraminiferal biomass and standing stocks are directly related to the amount of food available and many workers have suggested that measuring sediment chlorophyll may be the best proxy for food supply or as a measure of food availability (Erskian & Lipps 1987; Murray & Alve 2000). In general, foraminifera mostly favoured pennate diatoms, small chlorophytes and certain bacteria (Gooday et al 1992). Lesen (2005) have shown that total foraminiferal standing crop was positively correlated with water column chlorophyll and suggests that all the chlorophyll *a* in the sediments is the result of sedimentation from the water column following phytoplankton bloom rather than *in situ* production by benthic microalgae. Despite earlier documents showing the positive effect of chlorophyll *a* to foraminiferal community, the present study particularly in station 4, is not in agreement with these earlier reports, instead increased chlorophyll *a* may have influenced low foraminiferal assemblage.

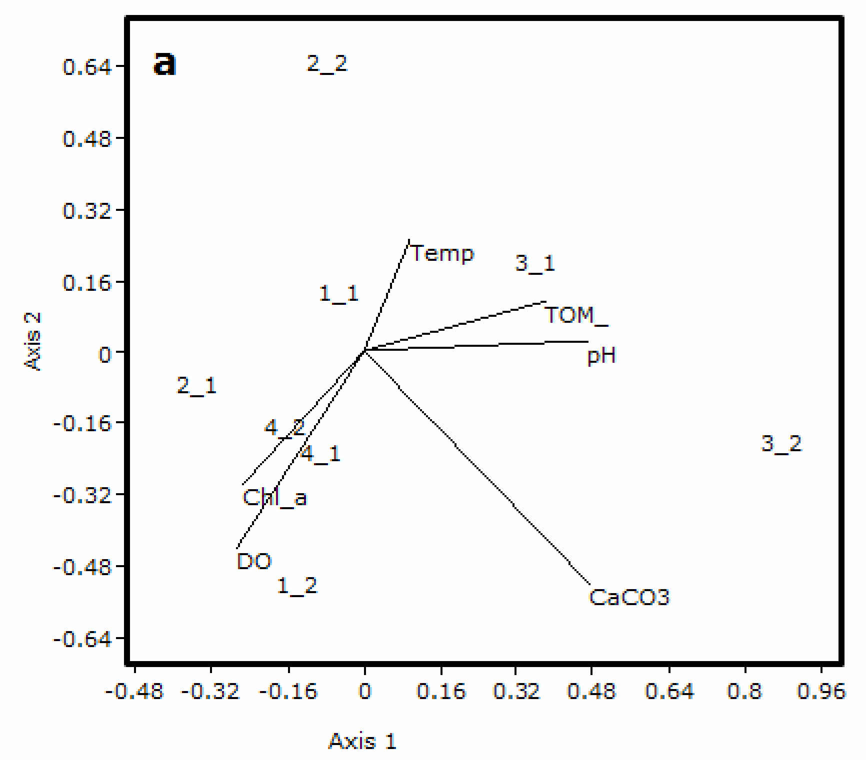

Figure 10. Canonical Correspondence Analysis - biplot showing the distance among the sampling stations and the physico-chemical factors that influence the distribution and abundance of live benthic foraminiferal community.

On the other side, Giere (2009) 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. Although the mean values of dissolved oxygen in station 4 are within the range for any marine faunistic assemblage to thrive and be fairly abundant (DENR-DAO 34 1990; Bradshaw 1957), the present result reflected in figure 9 may imply that other factors may have controlled the benthic foraminifera community structure rather than the presence of high food sources (*viz*. in the form of chlorophyll *a*) and appropriate amount of dissolved oxygen in that station.

Conclusions. In general, the living foraminiferal assemblages in all sampling stations were highly diversified however, the dominance (D) values reflected in these stations were slightly high (0.50 - 0.24). The reason for these can be observed in the high relative abundances of three species, namely *Elphidium crispum* (37 – 57 % or 20 - 36 per 10 cm^3), which strongly dominated the entire living foraminiferal assemblage in all the sites and subordinately by *Neorotalia calcar* (16 – 22 % or 8 - 10 per 10 cm^3) and *Ammonia beccarii* (6 – 11 % or 3 - 6 per 10 cm^3). It is suggested that the dominance of *E. crispum, P. calcar* and *A. beccarii* in the intertidal flat of Kauswagan, Lanao del Norte vegetated with seagrasses (*Cymodocea, Thalassia, Enhalus*) and green ((*Halimeda*, *Laurencia*) and red (*Chaetomorpha* and *Gracillaria*) macroalgae may appear to be related to the sedimentary structure and the presence of associated macrophytes in addition to the stress conditions (*i.e*. human-induced) occurring there. On the other side, the relative abundance of the whole benthic foraminiferan community varies from station to station, with station 1 being highly abundant while station 4 being lowest in relative abundance. Although results of the Canonical Correspondence Analysis showed that the parameters, *viz*. Chlorophyll *a* of the sediment and dissolved oxygen content of the bottom waters, may have influenced the observed low abundance of the benthic foraminiferal assemblage in the present study, it is probable that other factors may have controlled these assemblage.

Since the results of the study showed differences in the composition, diversity and abundance of the benthic foraminiferan species in the sampling stations, it is suggested that the present conditions of the environment may have affected the community structure of live foraminiferans. In this case, the dominance of *E. crispum*, *N. calcar* and *A. beccarii* may imply an environment having gravelly sandy silt bottom sediment vegetated with seagrasses and macroalgae beds. Further, the dominance of *A. beccarii* may likewise suggest potential anthropogenic impacts prevalent in that area. Hence, the results of the present study could be essential in the further assessment in the relationship between anthropogenic impacts and organisms for future development towards conservation and management of the area. It is therefore recommended that the period of the study will be made in an annual basis to observe the trend and compare the distribution of live benthic foraminiferal communities during dry and wet months.

References

Abu-Zied R. H., Bantan R. A., Basaham A. S., El Mamoney M. H., Al-Washmi H. A., 2011 Composition, distribution, and taphonomy of nearshore benthic foraminifera of the Farasan Islands, southern Red Sea, Saudi Arabia. J Foraminiferal Res 41(4):349–362.

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

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.

Armynot du Chatelet E., Bout-Roumazeilles V., Riboulleau A., Trentesaux A., 2009a Sediment (grain size and clay mineralogy) and organic matter quality control on living benthic foraminifera. Rev Micropaleontol 52:75–84.

Armynot du Chatelet E., Degre D., Sauriau P. G., Debenay J. P., 2009b Distribution of living benthic foraminifera in relation with environmental variables within the guillon cove (Atlantic coast, France): improving knowledge for paleoecological interpretation. Bull Soc Geol Fr 180:131–144.

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

Bouchet V. M. P., Alve E., Rygg B., Telford R. J., 2012 Benthic foraminifera provide a promising tool for ecological quality assessment of marine waters. Ecol Indic 23:66-75.

Brobo R., 2010 Meiofauna as an indicator of mercury pollution in Baranggay Libay, Sibutad, Zamboanga del Norte. Undergraduate Thesis, MSU-IIT, 65 pp.

Buosi C., Armynot du Chatelet E., Cherchi A., 2012 Benthic foraminiferal assemblages in the current-dominated strait of Bonifacio (Mediterranean Sea). J Foraminiferal Res 42(1):39–55.

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 Societa Paleontologica Italiana 52(1):1-9.

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

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

Coccioni R., 2000 Benthic foraminifera as bioindicators of heavy metal pollution. In: Environmental micropaleontology: The application of microfossils to environmental geology. Martin R. E. (ed), pp. 71–103, Kluwer Academic/Plenum Publishers, New York.

Debenay J. P., Redois F., 1997 Recent foraminifera of the northern continental shelf of Senegal. Rev Micropaleontol 40:15–38.

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.

Diz P., France S. G., 2008 Distribution of live benthic foraminifera in the Rıa de Vigo (NW Spain). Mar Micropaleontol 66:165–191.

Erskian M. G., Lipps J. H., 1987 Population dynamics of the foraminiferan *Glabratella ornatissima* (Cushman) in northern California. J Foraminiferal Res 17:240–256.

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.

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, 513 pp.

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

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.

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

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.

Jorissen F. J., De Stigter H. C., Widmark J. G. V., 1995 A conceptual model explaining benthic foraminiferal microhabitats. Mar Micropaleontol 22:3–15.

Jorissen F. J., Wittling I., Peypouquet J. P., Rabouille C., Relexans J. C., 1998 Live benthic foraminiferal faunas off Cap Blanc, NW Africa: community structure and microhabitats. Deep Sea Res Part 1 Oceanogr Res Pap 45:2157–2188.

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.

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.

Lesen A. E., 2005 Relationship between benthic foraminifera and food resources in South San Francisco Bay, California, USA. Mar Ecol Prog Ser 297:131–145.

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

Lobegeier M. K., 2002 Benthic foraminifera of the family Calcarinidae from Green Island reef, Great Barrier Reef province. J Foraminiferal Res 32(3):201-216.

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). Mar Micropaleontol 51:171–192.

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.

Mojtahid M., Jorissen F. J., Lansard B., Fontanier C., Bombled B., Rabouille C., 2009 Spatial distribution of live benthic foraminifera in the Rhone prodelta: faunal response to a continental–marine organic matter gradient. Mar Micropaleontol 70:177–200.

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, 397 pp.

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.

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.

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

Pascual A., Rodriguez-Lazaro J., Martin-Rubio M., Jouanneau J. M., Weber O., 2008 A survey of the benthic microfauna (Foraminifera, Ostracoda) on the Basque shelf, southern Bay of Biscay. J Mar Syst 72:35–63.

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.

Phleger F. B., 1960 Ecology and distribution of recent foraminifera. The Johns Hopkins Press, Baltimore.

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.

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.
Sgarrella F., Moncharmont Zei M., 1993 Benthic foraminifera of the Gulf of Naples (Italy): systematics and autoecology. Bollettino della Societa Paleontologica Italiana 32:145–264.
Toth E., Gorog A., 2008 Sarmatian foraminifera fauna from Budapest (Hungary). In: 125th Anniversary of the Department of Palaeontology at Budapest University – A Jubilee Volume Hantkeniana 6. Galácz A. (ed), pp. 187-217, Budapest, Hungary.
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 ecological processes. Springer-Verlag, New York, 546 pp.
Venec-Peyre M., 1984 Etude de la distribution des foraminiferes vivant dans la Baie de Banyuls-Sur-Mer. In: Ecologie des microorganismes en mediterranee occidentale. Bizon J. J., Burollet P. F. (eds), pp. 60–80, Ecomed, Association Francaise des Techniciens du Petrole, Paris.
Walton W. R., Sloan B. J., 1990 The genus *Ammonia* Brünnich 1772: Its geographic distribution and morphologic variability. J Foraminiferal Res 20:128-156.
Yanko V., Arnold A. J., Parker W. C., 1999 Effects of marine pollution on benthic Foraminifera. In: Modern foraminifera. Sen Gupta B. K. (ed), pp. 217–235, Kluwer Academic Publishers, Dordrecht.
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: 02 February 2014. Accepted: 04 May 2014. Published online: 06 May 2014.
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, Andres Bonifacio Avenue, e-mail: dollygarcialacuna12@gmail.com
Karen Antonette Jakosalem Gayda, Mindanao State University - Iligan Institute of Technology, College of Science and Mathematics, Department of Biological Sciences, Philippines, Iligan City 9200, Andres Bonifacio Avenue, e-mail: karen08_gayda@yahoo.com

How to cite this article:
Lacuna M. L. D. G., Gayda K. A. J., 2014 Benthic foraminiferal assemblage on a mixed stands of seagrass and macroalgae in Kauswagan, Lanao del Norte, Southern Philippines. ABAH Bioflux 6(1):102-116.