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Benthic marine gastropods and bivalves on the intertidal zones of Butuan Bay, Agusan del Norte, Northeastern Mindanao, Philippines

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Abstract

Benthic molluscs inhabiting the intertidal zones have always been vulnerable to anthropogenic activities, most specifically the edible ones, because they are often harvested as sources of food and additional income. Due to this, there is a dire need in monitoring and obtaining information regarding the diversity, abundance and distribution of intertidal molluscs in Butuan Bay, Philippines. Assessments were done using the transect-quadrat methods. Twenty seven molluscan species were identified, with 11 species classified under Class Bivalvia, while 16 species are categorized as Class Gastropoda. All identified bivalves were edible, while only 4 of the gastropod species were of commercial value. Results of the diversity profiles and abundance showed station 3 to be highly diverse and abundant, although half of the population were considered non-edible. On the contrary, low species diversity and low abundance were observed in stations 1 and 2. It is suggested that heavy anthropogenic activities may be responsible for the dominance of non-edible molluscs assemblage in station 3, whereas the impact of uncontrolled gleaning activities may result to low species diversity in stations 1 and 2. The spatial distribution of each mollusc species exhibits preference to a specific stratum in the intertidal zones of the 3 sampling stations and it is believed that this may be related to their mode of feeding.

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Introduction

Intertidal zone is one of the marine habitats where it is considered as the most productive place on Earth (MacKinnon *et al.*, 2012).Various biological components can be found in this area and by far the most diverse and abundant population are the marine molluscs (Quintas *et al.*, 2013; Aji and Widyastuti, 2017; Kaullysing *et al.*, 2017).These organisms are one of the constituents of macroinvertebrate group which are very significant as links in the marine food web (Castell and Sweatman, 1997; Burkepile, 2007) aside as source of food for humans and as natural resources for ornamentals and fertilizers (Del Norte-Campos *et al.*, 2003; Schoppe *et al.*,1998). Recently, molluscs are now considered as one of the marine resources that can be a prospect for antiviral and antimicrobial drugs (Chatterji *et al.*, 2002; Defer *et al.*, 2009; Dang *et al.*, 2011). Owing to their importance and the fact that they are within reached by humans, they are without doubt the most heavily exploited invertebrate in the intertidal zones. Shore gleaning, diving, snorkeling and reef-walking are some forms of human activities which often affects the diversity, abundance and survival of the molluscan fauna (Vaghela *et al.*, 2010). Interactions between environmental (i.e. organic matter contents of the sediment, sediment size) and biological parameters (i.e. competition and predation) may also modify the diversity and abundance of molluscan population (Flores-Rodríguez *et al.*,2014;Esqueda-Gonzalez *et al.*, 2014; Bula *et al.*, 2017; Masangcay and Lacuna, 2017) in addition to the aforementioned anthropogenic pressures. Studies on intertidal communities have been well documented in other parts of the globe (van der Meij *et al.*, 2009; Vaghela *et al.*, 2010; Esqueda-Gonzalez *et al.*, 2014) because these organisms are easily obtained, however information on benthic marine population along the intertidal shores of Butuan Bay is nil. To address this issue, the study attempts to contribute baseline data on the diversity, abundance and spatial distribution of intertidal benthic molluscs under different abiotic conditions and substrate contents in the three sampling stations along the said bay.

Materials and methods

Study area and sampling stations

Butuan Bay, which is part of Bohol Sea, is situated in the northeast section of Mindanao. It is famous as an essential fishing ground for tuna and sardines (Wernsted and Spencer, 1967) and receives freshwater from Agusan River, the longest river in Mindanao. Within the intertidal flats of Butuan Bay, 3 sampling stations were established (Fig. 1).

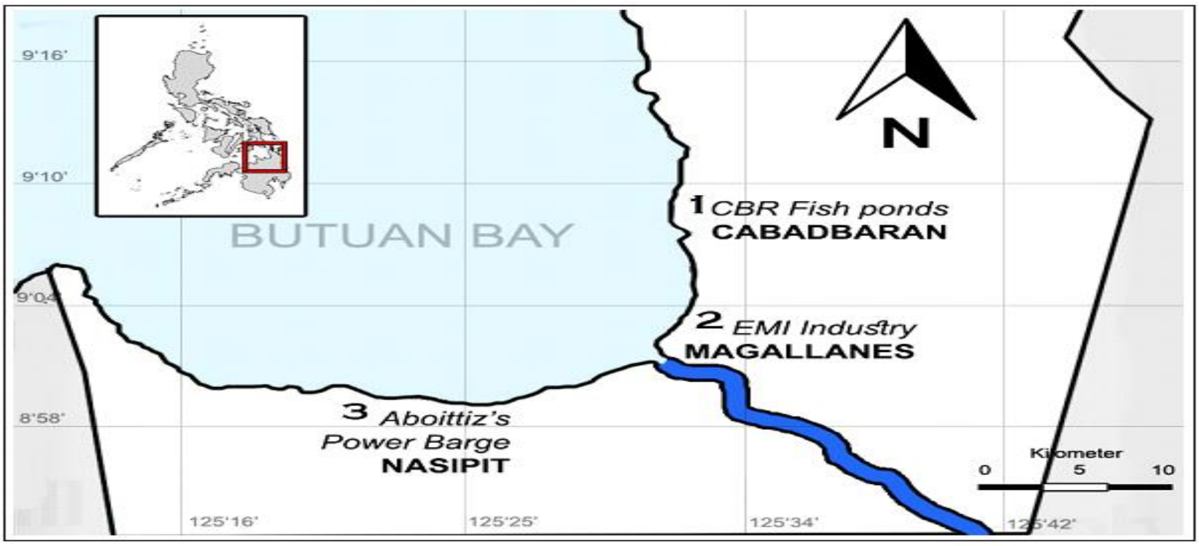

Fig. 1. Sampling sites established on the littoral zones of Butuan Bay, Northeastern Mindanao, Philippines where benthic mollusks were assessed.
(www.maphill.com/philippine/region-13/agusan-del-norte/simpe-maps/silver-styly-map)

Station 1 was positioned in Barangay La Union, Cabadbaran City where numerous fish ponds are operational. The presence of damaged corals and a foul smell was highly conspicuous in the area. Station 2 was situated in Barangay Marcos, Magallanes where EMCO Plywood Corporation and the leading producer of matches (Eurasia Match Inc. or EMI) were present. Approximately less than 300 meters away from the site, freshwater run-offs carried by the Agusan River mixes with the seawater.

It has been reported that the freshwaters transported by Agusan River contained residues of mercury and cyanide supposedly originated from Mt. Diwalwal, one of the biggest mining site in Mindanao (www.bar.gov.ph/digest-home/digest-archives/94-2003-4th-quarter/3282-oct-dec03-mercury-contamination-in-agusan-river). Station 3 was located at Barangay Sta. Ana, Nasipit where fishing and gleaning activities were rampant. Fish pens and a floating power barge owned by Aboitiz, one of the largest shipping corporation in the country, were put up in this site. The barge, which was fuelled with gasoline, was engaged to supply energy during summer months where extended periods of power shortage were experienced in the entire province of Agusan del Norte. The area is characterized with muddy sediments where mangrove stands were visible along the shoreline.

Establishment of Transects, Quadrats and assessment of molluscs and abiotic factors

On the intertidal flat in each station, 3 transects were arranged perpendicular to the shore. Each transect measures approximately 50 meters and were positioned 50 meters away from each other. Down the length of each transect, four quadrats of 1m^{2}size were laid down. The distance between quadrats was 10 meters. Transect 1 which represents the high stratum of the intertidal flat, was nearest to the coastline, whereas transect 3 signifying the low stratum was positioned 1-2 meters before the subtidal or sublittoral zone. Transect 2 or the intermediate/middle stratum was arranged in between transects 1 and 3. Within each quadrat, epifaunal molluscs encountered were collected by means of picking up live organisms. Conversely, infauna species were obtained from a 15-cm depth sediments which were sieved through a 2mm mesh opening screen. Molluscs that remained on the sieve represents the infaunal species. A solution of 10% formalin-seawater was used as preservative for all live organisms collected. Abiotic factors namely, temperature, salinity and pH were measured three times in each quadrat using a field thermometer, refractometer (ATAGO) and portable pen type pH meter (PH-009), respectively. For the sediment contents, such as total organic matter and calcium carbonate, soil samples of about 50 grams were gathered by means of a plastic corer, whereas sediment samples of around 200 grams were collected for the grain size analysis. Triplicate soil samples were collected from each quadrat for the analysis of the sediment contents. All assessments for the entire sampling sites were done during low tide between the months of June and July 2015. The coordinates of each stations were measured using a GPS (Garmin GPSMAP 76S).

Laboratory analysis of biological and sediment samples

Collected molluscs were washed thoroughly in order to remove all dirt attached to the shell. Afterwards, each individuals were identified to species level, counted, measured and then photos were obtained with the aid of a digital camera (Sony Cyber-Shot, 16 MP).

The book of Springsteen and Leobrera (1986) and the illustrated images of marine gastropods (www.gastropods. com.) and seashells (www.seashellhub.com, www.jaxshells.com.) were employed as guides for identification. Raw counts were expressed as density and relative abundance. Density was expressed as number of individuals per m^2 and was computed as the total number of species A over the total area assessed. Whereas relative abundance for each species was calculated by dividing the abundance of species A with the abundance of all species and then multiplied by 100. Determination of calcium carbonate concentration and total organic matter were quantified using the method described by Moghaddasi *et al.* (2009). Calcium carbonate were done by drying the sediment samples inside an oven at 70°C for about 8 hours. Then, around twenty-five grams (25 g) was weighed (W_1), with HCl (0.1 N) added and then stirred until no CO_2 bubbles appeared and were stored. After 24 hours, the sample was filtered and the upper liquid phase was disposed. The retained sediments were oven-dried at 70ºC for 8 hours and reweighed again (W_2). Calcium carbonate percentage was measured by the following formula:

$$CaCO3(\%)=\frac{100\ (W_1-W_2)}{W_1}$$

Analysis of the total organic matter (TOM) was done by oven drying at 70ºC for 24 the pre-weighed crucible (C) which contained the collected sediments. After the designated time, the sediment-filled crucible was reweighed (A) and immediately transferred into a furnace set at 550ºC for about 12 hours. The crucibles were reweighed again (B) until the constant weight was obtained. The total organic matter was computed as follows:

$$TOM\ (\%)=\frac{100\ (A-B)}{A-C}$$

To test for the sizes of the sediments, the method described by Das (2009) was followed using series of sieves with mesh opening of 3.35 mm, 0.841 mm, 0.595 mm, 0.31 mm, 0.149 mm, and 0.074 and 0.053 mm. A 100 grams oven-dried sediments were sieved and soil particles that remained on each specific sieve were removed and weighed.

The percentage of each particle fraction were computed as shown below:

$$Percentage\ Weight=\frac{Dry\ weight\ of\ sediments}{Total\ dry\ weight\ of\ sediments}\times 100$$

Statistical analyses

Diversity profiles were calculated using Shannon-Weaver Index. Difference of molluscan abundance among stations were computed using One-way ANOVA.

To determine which of the abiotic factors and sediment contents that may control the molluscan abundance, the Canonical Correspondence Analysis (CCA)was utilized.Statistical analyses were done by using the PAST (PAleontologicalSTatistical) software version 2.17 (www.folk.uio.no/ohammer/past) (Hammer *et al.*, 2001).

Results and discussion

Live molluscan species composition

Species of molluscs recorded on the intertidal flats of Butuan Bay is reflected in Table 1.

Twenty-seven (27) molluscan species were identified, with 11 species classified under Class Bivalvia from 9 families, while 16 species are categorized as Class Gastropoda under 10 families.

All of the bivalves (9 species) recorded in all stations are edible, while only 4 gastropod species are of commercial value based on the reports of the gleaners interviewed in the sites. Further, all gastropods species and 2 bivalves (i.e.*Pinctada margaritifera* and *Spondylus nicobaricus*) are epifauna (as indicated by a single asterisk), whereas the rest of the bivalve molluscs are categorized as infauna (as indicated by a double asterisks).The intertidal zones of the present areas were chiefly dominated by gastropods and this is comparable with previous reports done in most intertidal flats where gastropods were the most dominant group among intertidal animals (Marina *et al.*, 2012; Quintas *et al.*, 2012; Veras *et al.*, 2013; Leopardas *et al.*, 2016; Galenzoga, 2016; Masangcay and Lacuna, 2017).

The physical-chemical parameters, total organic content, calcium carbonate and sediment size

All the physical and chemical parameters, sediment analysis, calcium carbonate and total organic matter of the intertidal flats of each sampling stations in Butuan bay are expressed in mean values (Table 2). Temperature ranges from 24.45°C to 29.83°C.

Table 1. List of intertidal molluskan species in the 3 sampling stations of Butuuan Bay, Northeastern Mindanao, Philippines.

Class	Family	Species name	Station		
			1	2	3
Bivalvia	Arcidae	*Anadara granosa***e	-	-	+
	Cardiidae	*Cerastoderma pinnulatum***e	-	-	+
	Pinnidae	*Atrina vexillum***e	-	-	+
	Pteriidae	*Pinctada margaritifera**e	-	-	+
	Spondylidae	*Spondylusnicobaricus**e	-	-	+
	Glycymerididae	*Glycymeris flammea***	-	-	+
	Lucinidae	*Ctena bella***e	+	-	+
	Psammobiidae	*Soletllina diphos***	+	-	-
		*Gari maculosa***e	+	-	-
	Veneridae	*Paphia ambilis***e	-	+	-
		*Paphia rhomboides***e	-	+	-
	Angariidae	*Angaria dephinus**e	-	-	+
	Cerithiidae	*Cerithium coralium**	-	-	+
		*Clypeomorus patulum**	-	-	+
	Cypraeidae	*Monetaria annulus**	-	-	+
		*Cypraea tigris**	-	-	+
	Muricidae	*Hexaplex trunculus**	-	-	+
		*Chicoreus microphyllus**	-	-	+
	Nassariidae	*Nassa mustelinai**	-	-	+
		*Nassarius reeveabus**	-	-	+
	Naticidae	*Polinices flemingianus**e	-	-	+
	Strombidae	*Canarium labiatum**e	-	-	+
		*Lambis lambis**e	-	-	+
		*Strombus luhuanusii**	-	-	+
	Tegulidae	*Trochus niloticus**	-	-	+
	Trochidae	*Cantharidus suarezensis**	-	-	+
	Turbinidae	*Astralium calcar**	-	-	+
Total number of species			3	2	23

Legend: + present; - absent; *infauna **epifauna eedible.

It shows that station 1 has the lowest sediment temperature while station 3 records the highest value (29.7°C). One factor that can greatly affect the temperature is the intensity of the sun. Sampling was done in station 1 from early morning to almost noon, while measurements of temperature in stations 2 and 3 were performed between 2PM to 6 PM. pH ranges between 7.2 to 8.38, showing a slightly alkaline pH in these stations. This is expected because of the buffering capacity of seawater that allows seawater to resist drastic pH changes even after the addition of weak bases and acids (Giere, 2009). Salinity content from all stations ranges from 19.06ppt to 31.72ppt. It is highly noticeable that station 1 has the lowest salinity value, while the rest of the stations depicts salinity values that falls within the Philippine Standard for Marine and Waste Waters (DENR Administrative Order No. 2016-08).

Table 2. Mean values of the environmental parameters in the 3 sampling stations in Butuan Bay, Northeastern Mindanao, Philippines.

Environmental Parameters	Station		
	1	2	3
Temperature (°C)	24.45	28.59	29.07
pH	7.2	7.96	7.57
Salinity (ppt)	19.06	29.83	31
$CaCO_3$ (%)	12.7	6.99	19.36
TOM (%)	9.85	6.84	11.33
Sediment Size			
Gravel (%)	45.41	1.7	13.43
Sand (%)	54.31	92.07	84.94
Silt (%)	0.45	6.53	1.63
Sediment Texture	Sandy	Sandy	Sandy

Standard values for marine and coastal water: water temperature 26-30°C; pH range from 6.0 to 8.5; salinity 34-35ppt (Philippine water standard values of DENR-Administrative Order No. 2016-08).

The reason behind station 1 showing the lowest salinity is due to the dilution effect of freshwater coming from the uplands. Data on calcium carbonate and total organic matter contents of the sediment showed higher values in station 3 when compared to the rest of the stations. For the sediment structure, station 1 is made up of medium to fine sands mixed with loose assorted stones, while station 2 is dominantly fine sands, and station 3 comprises mainly of fine sands mixed with a few small pebbles.

Table 3. Diversity profile of the 3 sampling stations in Butuan Bay, Northeastern Mindanao, Philippines.

Diversity	Station		
Index	1	2	3
Taxa (S)	3	2	23
Individuals	114	40	107
Dominance (D)	0.61	0.545	0.155
Shannon (H)	0.605	0.647	2.485
Equitability (J)	0.5509	0.9341	0.792

Live Molluscan Diversity, Density and Relative Abundance

The results of molluscan diversity in the three sampling stations is presented in Table 3. A considerable difference in the species diversity (H), number of taxa (S) and equitability (J) values were clearly observed among the three stations, where station 3 showed the highest numbers in all of the diversity profiles or parameters determined. High species diversity is expected in station 3 considering that sea grass beds and mangroves are present in this area. Sea grass beds serve as food source and as refuge among marine organisms (Edgar and Robertson, 1992). On the other hand, stations 1 and 2 reflected very low species diversity and very low number of taxa.

The abundance of edible and non-edible molluscs recorded in station 3 is reflected in Fig. 2. Among the 23 taxa or molluscan species observed, eleven (11) were edible, while the remaining twelve (12) were non-edible species. Further, of these 11 edible species noted in station 3 (Fig.2a) *Canarium labiatum* was the most abundant representing 3.17 ind m^{-2} or 35% of the total population in the said station. This is followed by *Angaria delphinus* at 0.5 ind m^{-2} (5.61%), whereas *Spondylus nicobaricus* garnering 0.42 ind m^{-2} (4%) of the whole assemblage.

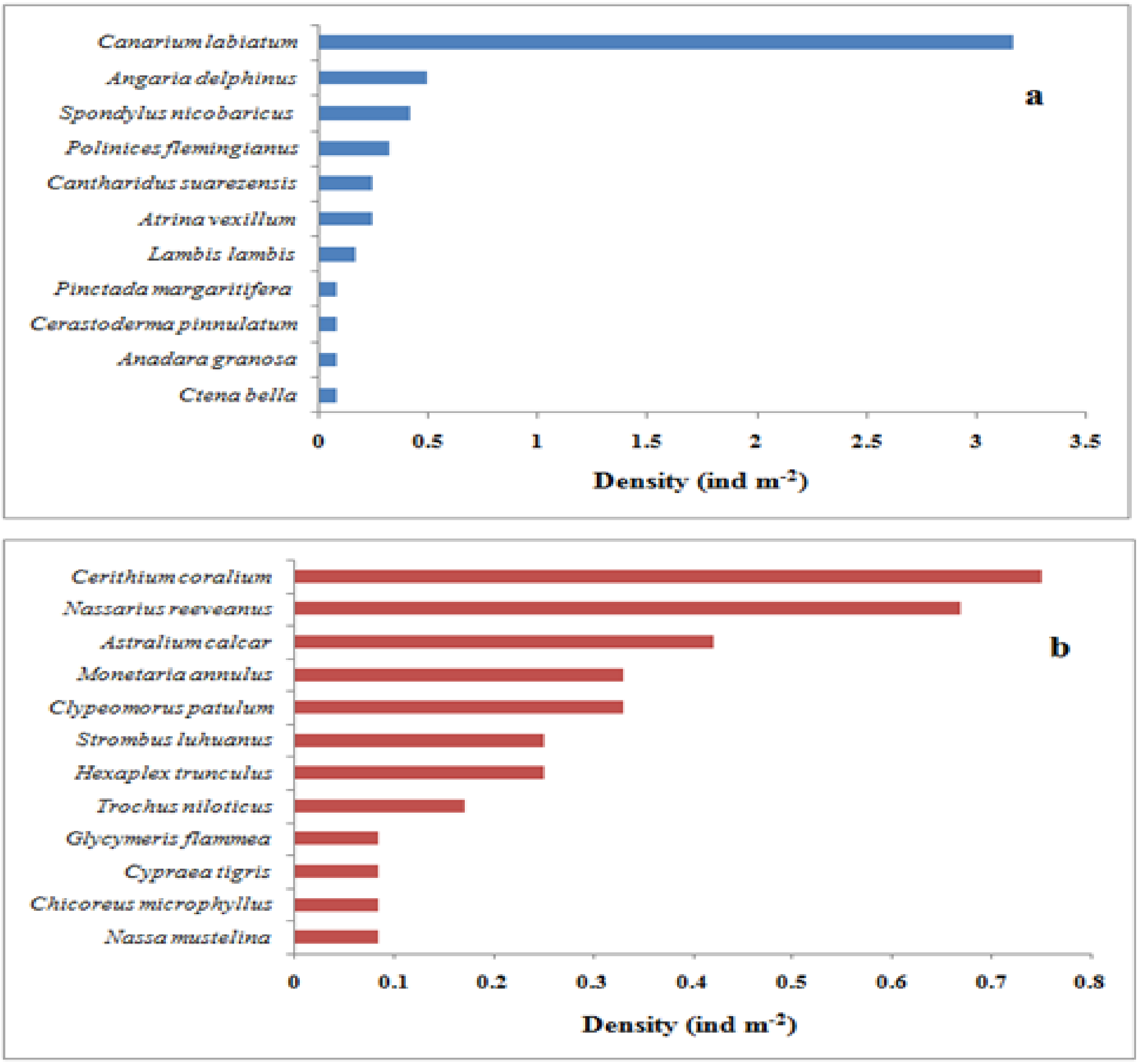

Fig. 2. Density of (a) edible and (b) non-edible mollusks in station 3, Barangay Nasipit, Butuan Bay, Northeastern Mindanao, Philippines.

The rest of the edible molluscs were quite low and recorded to be <4% of the total molluscs population in this station. For non-edible species (Fig.2b), *Cerithium coralium* was observed to be the most dominant with an abundance of 0.75ind m^{-2} or 8% while trailing behind was *Nassarius reeveanus* with 0.67 ind m^{-2} or 5%, then next in rank was *Astralium calcar* obtaining 0.42 ind m^{-2} or 4% of the whole assemblage. The remaining non-edible species in stations 3 were <4% of the total molluscan group. Conversely, station1 recorded three (3) species with *Soletllina diphos*, a non-edible species, as the most abundant (74.56% or 7.08 ind m^{-2}), while the remaining two (2) species which are edible such as *Gari maculosa* (2.33ind m^{-2} or 24.56%) and *Ctenabella* (0.083 ind m^{-2} or 0.885%) trails behind. In station 2, only two (2) species were recorded which are both edible, with the species *Paphia ambilis* as the most dominant at 2.17 ind m^{-2} or 65%, whereas *P. rhomboides* was noted at 1.17 ind m^{-2} or 35%. Although station 3 reflected high abundance and diverse molluscan assemblage when compared with stations 1 and 2, half of the assemblage are categorized as non-edible. As reported by the gleaners we interviewed in the field, they spent between once to twice in a week gleaning and that each time they gleaned, they spent around 1 to 3 hours in a day collecting.

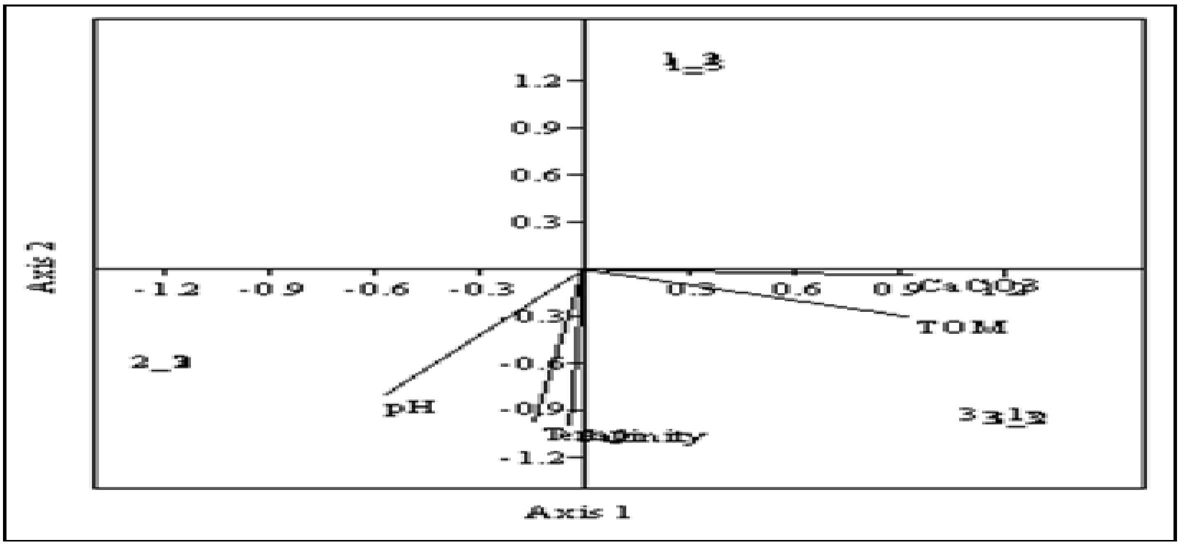

Fig. 3. Canonical Correspondence Analysis (CCA) biplot of the distanceamong the sampling stations and the physico-chemical factors that influencethe distribution and abundance of intertidal mollusks.

It is most likely that when we did our sampling trips the gleaners in station 3 may have already collected and depleted the edible molluscs so that we were left with abundant (>50%) non-edible species in the said station, an indication of uncontrolled gleaning activities. Likewise, since the data we gathered from the interviewed gleaners in stations 1 and 2 suggested frequent gleaning or collections of edible molluscs in these 2 areas, we expected to encounter few edible species along with abundant non-edible molluscs. However, this was not the case because we recorded only very few edible species (*i.e.* 3 and 2 species in stations 1 and 2, respectively) and even no non-edible molluscs, except in station 1 where *Soletllina diphos* was quite abundant.

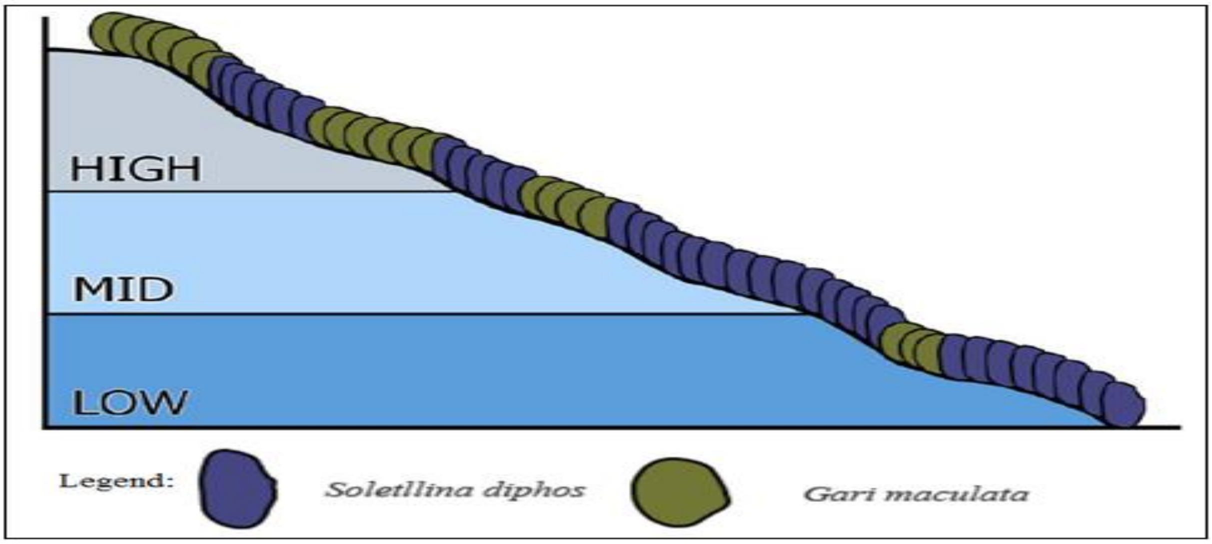

Fig. 4. Spatial distribution of mollusks in the 3 strata on the littoral zones of station 1 (Cabadbaran City), Butuan Bay, Northeastern Mindanao, Philippines.

There is a possibility that the presence of heavy anthropogenic activities going on in stations 1 and 2 such as fishpond operations and effluents released from EMI industry and traces of mercury residues carried by Agusan River may have caused a negative impact on the molluscan population, hence the extremely poor and very low molluscan species diversity in these 2 areas. Further, the presence of these specific taxa in stations 1 and 2 may indicate that these are the only molluscs that can endure the pressure brought about by these anthropogenic /pollution activities. Several studies had shown the dominance of one or two taxa, such as bivalves, as an indication of tolerance to stress and pollution (Gray *et al.*, 2002; Leopardas *et al.*, 2016).

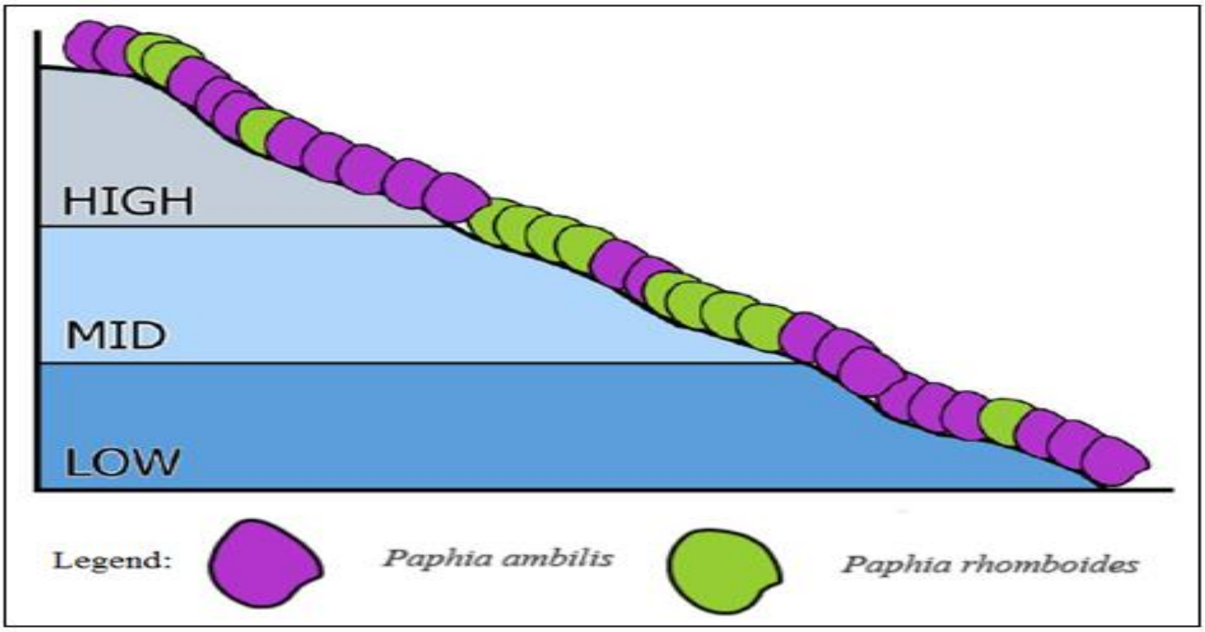

Fig. 5. Spatial distribution of mollusks in the 3 strata on the littoral zones of station 2 (Magallanes), Butuan Bay, Northeastern Mindanao, Philippines.

Comparison of the molluscs abundance between the 3 stations were performed by employing the Kruskall-Wallis Test and results showed only station 3 as significantly different from station 1 (p=3.89E-06) and station 2 (p=2.57E-06). The result of CCA (Fig. 3) revealed that total organic matter or TOM and calcium carbonate may be the reason behind the high relative abundance of molluscan fauna in station 3. Total organic matter (TOM) and calcium carbonate contents in the sediments of station 3 were much higher than those in stations 1 and 2 (Table 2). The higher values of total organic matter may be attributed to the presence of sea grass beds in station 3 since these meadows usually contained high supply of organic matter. Previous studies showed epiphytic algae present on sea grass leaves and organic matter on the sediments of sea grass beds as endless supply of food among animals that are herbivores, omnivores and deposit/detritus grazers (Fredriksen and Christie 2003; Fredriksen *et al.*, 2004; Hily *et al.*, 2004).

It is highly probable that the high supply of total organic matter in station 3 may have supported the required physiological wants of the molluscan population in this station such that they were able to reproduce in high numbers when compared to stations 1 and 2.

Spatial Distribution of benthic molluscs

Benthic molluscs often positioned themselves on different strata within the intertidal zone. In station 1 (Fig. 4), although both species were observed and scattered on all 3 strata, the frequency of occurrence between the 2 molluscs differs. For instance, the abundance of *Gari maculata* follows a decreasing trend from the high stratum towards the low zone, while *Solettlina diphos* follows an increasing order from high mark zone towards the low stratum.

In station 2 (Fig. 5), the 2 edible species, *Paphia ambilis* and *P. rhomboides*, were likewise seen and encountered within the 3 strata but their frequency of appearance varies from each other. For example, *P. ambilis* prefers the middle/intermediate level of the intertidal zone, while *P. rhomboides* favors the high and lower strata. Further, it was noticed that if one *Paphia* species was abundant in a particular stratum, the other *Paphia* species was least dominant. In station 3 (Fig. 6), it is clearly seen that *Canarium labiatum* dominated the whole intertidal zone by occurring in high numbers in all 3 strata, whereas majority of the mollusks choose a particular stratum to occupy. For instance, the least abundant species namely, *Atrina vexillum*, *Cerastoderma pinnulatum*, *Ctena bella*, *Glycemeris flammea* and *Pinctada margaritifera* were noted to lived exclusively in the high stratum of the intertidal zone. On the contrary, the following uncommon species favors the middle/intermediate and low strata: *Cantharidus suarezensis*, *Conomurex luhuanus*, *Polinices flemingianus* and *Lambis lambis*, while *Trochus niloticus* was restricted in the low stratum. *Angaria delphinus* on the other hand prefers the high and middle strata.

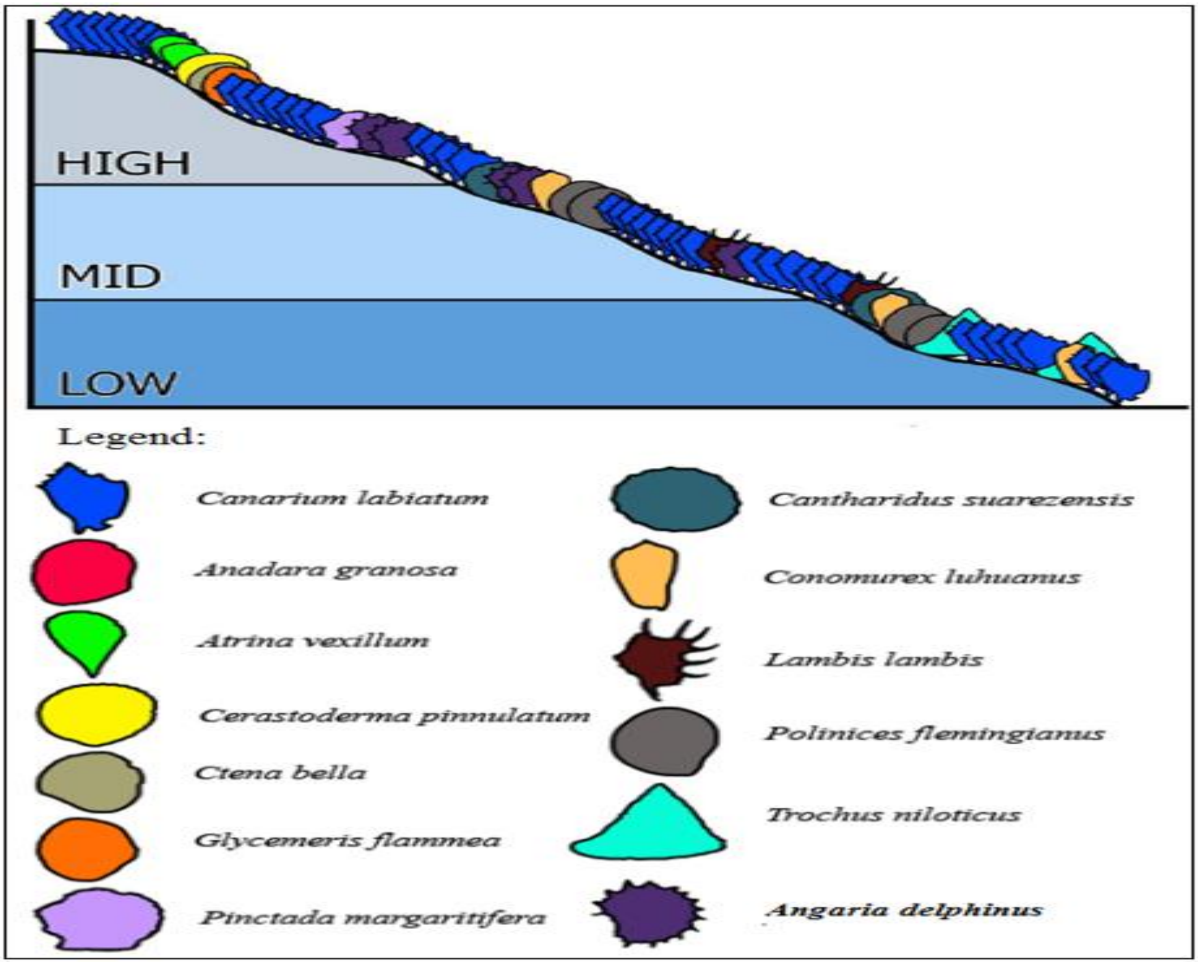

Fig. 6. Spatial distribution of mollusks in the 3 strata on the littoral zones of station 2 (Nasipit), Butuan Bay, Northeastern Mindanao, Philippines.

The spatial distribution of individual mollusc species favors a certain stratum in the littoral zones of the 3 sampling stations and it is suggested this may be related to their feeding habits. For example, the distribution of gastropods, either as carnivores, herbivores or detritivores, is directly affected by the pattern of food. That is, the preferential distribution of some of the species in the lower stratum of the flats is probably due to a greater submersion time and more availability of detritus which is brought along by the incoming tide, when compared to the upper stratum.

Concerning the bivalves, they tend to occupy a much broader strata because of their filtration feeding preference where they just simply filter the water for the extraction of food (Rhoads and Young, 1970).

Conclusion

Variations in species diversity (H), number of taxa (S) and equitability (J) values were quite evident among the three stations, with station 3 exhibiting the highest numbers in all of the diversity profiles determined. In spite of its rich diversity, half of the molluscan population in station 3 were non-edible and it is suggested that the uncontrolled gleaning activities occurring in the said area may have been responsible for these scenario. On the contrary, stations 1 and 2 reflected extremely poor and low molluscan species diversity and this may be attributed to the negative impacts caused by anthropogenic activities (*i.e.* fishpond operations, effluents released directly to the coast from EMI Industry and mercury residues carried by Agusan River) rather than the over gleaning activities in these 2 areas. Comparison on the relative abundance among these 3 stations revealed high molluscan assemblage in station 3 and it is assumed that the high amounts of total organic matter (TOM) and calcium carbonate in station 3 may be responsible for the high abundance considering the significant importance of TOM as the chief source of food for many marine organisms. The spatial distribution of each mollusc species exhibits preference to a specific stratum in the intertidal zones of the 3 sampling stations and it is suggested that this may be related to their mode of feeding. Since it could not be argued that benthic molluscs occupy a vital position in the marine food web, the present information can be employed for the sustainable management of these locally important invertebrates in order to ensure their continued survival. Further, conservation efforts in these areas must commenced in order to avoid extensive reduction of natural stocks of commercially important and edible molluscs in the said intertidal areas. Since the sampling period of the present study was done only once, it is highly recommended that these areas must be assessed every month for a period of one year to acquire information on the impacts of changes in seasons (i.e. NE and SW monsoons) to the diversity, abundance and distribution of benthic littoral molluscs community.

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