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Molluscan (Gastropoda and Bivalvia) diversity and abundance in rocky intertidal areas of Lugait, Misamis Oriental, Northern Mindanao, Philippines

Shirlamaine Irina G. Masangcay[1], Maria Lourdes Dorothy G. Lacuna[*2]

[1]*Department of Biology, College of Arts and Sciences, Caraga State University, Ampayon Campus National Highway, NH1, Butuan City, Philippines*

[2]*Department of Biological Sciences, College of Science and Mathematics, Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines*

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Key words: *Cerithium stercusmuscarum*, *Drupella margariticola*, total organic matter, calcium carbonate, density.

Abstract

Composition, diversity and abundance of rocky intertidal mollusks and their relationship with the environmental parameters, *viz*. water quality, total organic matter and calcium carbonate were determined. A total of 43 species were identified, of which 41 species belong to Class Gastropoda under 18 families and 2 species were categorized under Class Bivalvia from 2 families. Using several diversity indices, results revealed high diversity and equitability values in the 2 sampling sites. Moreover, comparison of the mollusks abundance between the 2 sampling stations showed station 2 to be dominantly abundant with *Cerithium stercusmuscarum* comprising almost one-third of the total population. Canonical Correspondence Analysis showed that total organic matter and calcium carbonate in the sediment may have influenced the abundance of mollusk assemblage in station 2. The results obtained from the study are vital in order to strongly support the need to continue monitoring the Lugait marine sanctuary and its nearby surroundings.

***Corresponding Author:** Maria Lourdes Dorothy G. Lacuna ✉ mileskung12@gmail.com

Introduction

Rocky intertidal zone is one of the most hostile and demanding region among the marine ecosystems on the globe. For one, this area is regularly uncovered during low tide and therefore exposed to air such that large variations in environmental factors (*i.e* temperature, salinity, pH and oxygen) are often experienced. In addition, constant bombardment brought about by the wind and breaking waves, the drying effect as a result to exposure to sunlight (Sørensen, 2012; Alyakrinskaya, 2004), wind and high salinity as well as the presence of large terrestrial organisms acting as predators are but contributory factors that lead to the unpredictable and intense conditions of this environment (Smith, 2013). Notwithstanding these harsh situations, rocky shores are always teeming with diverse population of benthic invertebrate animals since they offer shelters (such as cracks between rocks and protection under boulders) for these fauna to live on in addition to large availability of food choices (Smith, 2013; Sørensen, 2012; Alyakrinskaya, 2004).

Among the littoral benthic invertebrate animals frequently abundant in rocky shores are mollusks. They display a wide range of feeding habits such as particle feeders, herbivory, carnivory and predatory (Todd *et al.,* 2002). Gastropods in particular feed on living and decaying algae and plant materials (Kelaher *et al.,* 2007; Nagelkerken *et al.,* 2008), while bivalves are regarded as filter-feeders. In turn, predators like large crustaceans (*i.e.* crabs and lobsters) fish, starfishes, birds and other mammals also feed on mollusks (Gosling, 2003). Not only are these mollusks important in the marine food web, they are also exploited to supply the high demand for human consumption. Other mollusks are also used for ornamental purposes (Gomez and Chavez, 1986) in shellcraft industries and jewelry, and even as potential source of pharmaceuticals (Lin *et al.,* 2013). Owing to the vital position these organisms occupy in the ecosystem, understanding their distribution patterns and ecology is of immense importance. According to previous studies, the degree of exposure to wave action (Zamprogno *et al.,* 2012; Crowe *et al.*, 2000; Mc Quaid and Lindsay 2000), variations in temperature (Harley *et al.*, 2006), topography of the shore (Sorensen 2012; Zamprogno *et al.,* 2012; Crowe *et al.,* 2000), organic contents in the sediment (de Arruda and Amaral, 2003; Snelgrove and Butman, 1994), predation (Morton and Blackmore, 2009; Moerland *et. al.,* 2016) and human disturbances (Deepananda and Macusi, 2013) are some parameters affecting the extent of distribution of rocky intertidal communities.

In the Philippines, early works done on intertidal mollusks were focused mainly on soft bottom intertidal (Herceda *et al.,* 2016; Jumawan, 2015; Manzo *et al.*, 2014; Batomalaque *et al.,* 2010) and reef areas (Picardal and Dolorosa, 2014; Dolorosa and Jontila, 2012; Dolorosa *et al.,* 2011; Dolorosa and Schoppe, 2005), but less attention was given on rocky shores or substratum. It is in this context that the present study was materialized in order to address this gap. To attain this goal, the specific objectives are as follows: (1) to measure the temperature, pH, salinity of the substrate and the sediment organic matter contents, *i.e.* calcium carbonate and total organic matter; (2) to identify the benthic mollusks present in the area; (3) to determine and compare the diversity and abundance of benthic mollusks among sampling stations established, and (4) to correlate the environmental parameters of the sediments and the organic matter contents in the sediment to the abundance of benthic mollusks. The data generated from this study will not only describe the present habitats of benthic mollusks and the parameters related with their distribution but it can be a baseline for studying the biology and ecology and conservation management of mollusks in this area.

Materials and methods

Description of the Study Area and Sampling Stations

Lugait is a coastal municipality located along Iligan Bay with a geographical coordinates of 8°20'13” (8.34) North and 124°15'37” (124.26) East (Fig. 1) which consists of 3 coastal barangays, namely Poblacion, Biga and Calangahan. A marine sanctuary often guarded by sea patrollers and is also known as Lugait Marine Sanctuary lies within the coast of Biga.

Along the shoreline of Poblacion are major industrial establishments like Holcim Philippines Inc., and Petronas Energy Phil. Inc., which dumped its industrial waste matters into the sea. On the other hand, the coastline of Calangahan is lined with residential houses and commercial establishments such as beach resorts and restaurants.

Two sampling stations were established within the intertidal flat of Lugait, Misamis Oriental with station 1 positioned inside the marine sanctuary of barangay Biga which is characterized with rocky substrates mixed with corals. Station 2 was located in barangay Calangahan which consist of rocky substratum interspersed with coarse sands and boulders.

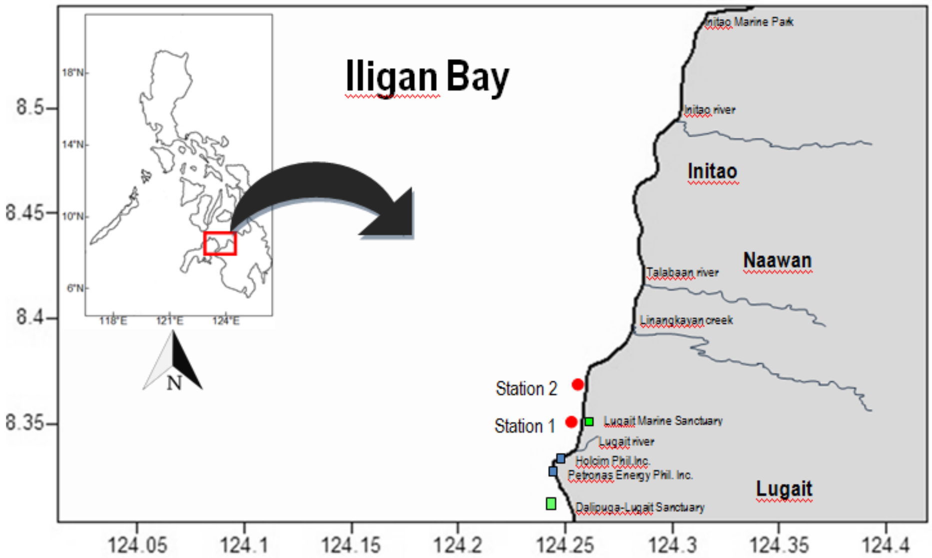

Fig. 1. Geographical location of the two sampling stations where mollusks were collected. (Surfer Golden Software version 8.0).

Field samplings of samples and "in situ" determination of physico-chemical parameters

The sampling technique described by Medrano *et al.* (2015) and Paulay (2000) was used for the collection of mollusks, with some modifications. All samples were collected in the intertidal areas during low tide in November 2015. In each station, a total of three (100m) transects were deployed parallel to the shore with each transect separated by a distance of 20m. Ten 0.25m² (0.5mx0.5m) quadrats were placed in each transect with an interval of 10m from each other. In each quadrat, live epifaunal mollusks found on the sediment surface were obtained by hand-picking and scraping the surface of rocks and crevices. Further, sediments at each quadrat were dug using a digging tool down to approximately 20cm deep for infauna collection and these sediments were then passed through a 2mm mesh opening sieve screen. All live mollusks were preserved in a 10% formalin-seawater solution.

All physico-chemical parameters were measured thrice for each transect. Salinity, pH, and temperature of the sediment pore waters were determined "in situ" using refractometer (ATAGO), pH meter (Eutech Instruments) and field thermometer, respectively. Likewise, sediments for determination of calcium carbonate and total organic matter were collected in each transect using a digging tool. All samples were placed separately in a Ziploc bag and stored in a freezer until analysis.

Laboratory analyses of the samples

In the laboratory, all mollusks specimens collected in the field were washed with sea water and the epiphytes attached on the shells were carefully removed and then preserved with 70% ethanol (Rueda *et al.*, 2009). Specimens were then identified to species level and counted. The works of Springsteen and Leobrera (1986), Dolorosa and Galon (2014), Picardal and Dolorosa (2014), Poppe *et al.* (2006), and the illustrated guides to mollusks (www.nmr-pics.nl/, www.idscaro.net/sci/.) and marine gastropods (www.gastropods). Voucher specimens for each identified mollusk organism were prepared by removing the animal from the shell and immediately the shell was thoroughly cleaned and sun dried. The shells were then measured and photographed using a digital camera (Olympus, 16 MP).

Calculation on mollusks abundance is represented as relative abundance and density. Relative abundance was expressed as a percent of total mollusk present for each species and was calculated using the equation:

$$\text{Relative abundance} = \frac{\text{Abundance of a species}}{\text{Abundance value of all species}} \times 100$$

Density, on the other hand, was expressed as ind/m² and was computed using the following equation:

$$\text{Density (ind/m}^2\text{)} = \frac{\text{Total no. of species A}}{\text{Total area examined}}$$

The procedure stated by Moghaddasi *et al.* (2009) on total organic matter and calcium carbonate content analyses were followed. TOM was measured using a pre-weighed crucible (C), half-filled with sediment samples and dried (70°C) in an oven for 24 hours. After this, samples were removed and weighed (A), placed in a furnace at 550°C overnight, allowed to cool and weighed again (B). The total organic matter was calculated as follows:

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

$CaCO_3$ sediment samples were oven dried (70°C) for 8 hours and about 25g of it were weighed (W_1), mixed with HCL (0.1N) and stirred until no CO_2 bubbles appeared. This was then allowed to soak for 24 hours. Afterwards, the samples were filtered and then the upper liquid phase was disposed so that the residue left behind was oven dried at 70°C for 8 hours. The oven dried residue was reweighed (W_2). Calcium carbonate percentage was measured by the following formula:

$$CaCO_3\,(\%) = \frac{100\,(W_1-W_2)}{W_1}$$

Statistical Analyses

Species diversity index was estimated using the Shannon-Weaver (H) and equitability (J) indices. To know which of the physico-chemical parameters might affect the relative abundance of benthic mollusk, the Canonical Correspondence Analysis (CCA) was employed. All analyses were done using PAST (PAleontological STatistical) software version 2.17c (http://folk.uio.no/ohammer/past/) (Hammer *et al.,* 2001). Surfer Golden Software version 8.0 was used to draw the map.

Results and discussion

Physico-Chemical parameters, Organic matter and Grain size

The mean values of the physical and chemical profile of interstitial waters and organic matter contents in the sediments of the two sampling stations are shown in Table 1. Different values are observed for the interstitial water quality parameters (temperature, pH and salinity) and organic matter contents of the sediments (calcium carbonate and total organic matter) in the two sampling stations, with station 1 showing low values for all these environmental parameters with the exception of pH when compared to station 2. The high values of water temperature and salinity in station 2 may be attributed to the time of data collection since sampling was done early in the morning in station 1, while data was gathered during noontime in station 2 where light intensity was extremely high. According to Geng *et al.* (2016), high salinity within the intertidal zone is the result of the rapid removal of pore water from the sediment due to intense evaporation brought about by high air temperature and low humidity during noon so that salts were left behind, while insignificant or no evaporation from the intertidal zone during early morning hours resulted to a much lower salinity. On the other hand, although pH value was slightly high in station 1 when compared to that in station 2, these values still fall within the standard values common in any marine biome because seawater is always slightly alkaline (pH: 7.5-8.5). For calcium carbonate and total organic matter content of the sediment, a much higher values were noted in station 2.

The type of substrate in both stations is classified as gravel which is made up of granules but often mixed with fine sands and loose assorted stones in station 1, while those in station 2 these granules are mixed with a much coarser sand as well as loose assorted stones.

Table 1. Mean values of environmental parameter, organic matter contents of the sediments in the two stations in Lugait, Misamis Oriental.

Environmental Parameters	Station	
	1	2
Water Temperature (°C)	27.67	28.44
pH	8.20	7.78
Salinity (ppt)	31.44	34.11
$CaCO_3$ (%)	6.96	10.06
TOM (%)	4.50	9.21

*Standard values for marine and coastal waters: Water temperature minimum rise of 3°C, pH range from 6.0 to 8.5, Salinity 34-45 ppt (Philippine waters standard values from DENR-DAO 2008).

Species Composition

A total of 43 mollusks species were collected in the rocky intertidal flat of Lugait, Misamis Oriental with 41 species belonging to Class Gastropoda under 18 families, while 2 species are bivalves (Class Bivalvia) belonging to 2 families (Table 2). Moreover, 39 of these gastropods are categorized as epifauna, while 4 species (2 gastropods: *Polinices mammilia*, *Syrnola fasciata*; 2 bivalves: *Barbatia foliata*, *Tapes sulcarius*) are infauna. Some infaunal species were collected since the loose rocks of the two stations are often mixed with sands allowing these species to burrow. Generally, the present result is comparable to those reported in most intertidal rocky shores where more gastropods were observed compared to bivalves and other molluscan classes (Galenzoga, 2016; Flores-Rodríguez *et al.*, 2014; Veras *et al.*, 2013; Flores-Rodriguez *et al.*, 2012; Rahman and Barkati, 2012; Sørensen, 2012).

Table 2. Species composition of intertidal mollusk species in Lugait, Misamis Oriental.

Class	Family	Species name	Station	
			1	2
Bivalvia	Arcidae	*Barbatia foliata** (Forsskål in Niebuhr, 1775)	+	+
	Veneridae	*Tapes sulcarius** (Lamarck, 1818)	+	-
Gastropoda	Buccinidae	*Engina mendicaria** (Linnaeus, 1758)	+	+
		*Pollia fumosa** (Dillwyn, 1817)	+	+
	Bursidae	*Bursina nobilis** (Reeve, 1844)	-	+
	Cerithiidae	*Cerithium atratum** (Born, 1778)	+	+
		*Cerithium columna** (Sowerby I, 1834)	+	+
		*Cerithium punctatum** (Bruguière, 1792)	+	-
		*Cerithium stercusmuscarum** (Mörch, 1876)	-	+
		*Clypeomorus petrosa chemnitziana**(Pilsbry, 1901)	+	-
		*Rhinoclavis sinensis** (Gmelin, 1791)	+	+
	Chilodontidae	*Euchelus atratus** (Gmelin, 1791)	-	+
	Columbellidae	*Cosmioconcha helenae** (Costa, 1983)	+	-
		*Pyrene obtusa** (Sowerby I, 1832)	-	+
		*Pyrene testudinaria** (Link, 1807)	+	+
	Conidae	*Conus coronatus** (Gmelin, 1791)	+	+
		*Conus ebraeus** (Linnaeus, 1758)	+	+
		*Conus musicus** (Hwass in Bruguière, 1792)	+	+
	Costellariidae	*Vexillum plicarium** (Linnaeus, 1758)	+	+
		*Vexillum semifasciatum** (Lamarck, 1811)	+	-
	Liotiidae	*Liotina peronii** (Kiener, 1839)	-	+
	Mitridae	*Mitra chrysalis** (Reeve, 1844)	+	-
		*Mitra litterata** (Lamarck, 1811)	+	+
		*Mitra tabanula** (Lamarck, 1811)	+	+
	Muricidae	*Drupella margariticola** (Broderip, 1833)	+	+
		*Morula anaxares** (Kiener, 1835)	+	+
		*Tenguella granulata** (Duclos, 1832)	+	+
	Nassariidae	*Hebra corticata** (A. Adams, 1852)	-	+
		*Nassarius albescens** (Dunker, 1846)	+	+
		*Nassarius elegantissimus** (Shuto, 1969)	+	+
		*Nassarius luridus** (Gould, 1850)	+	+
		*Nassarius subspinosus** (Lamarck, 1822)	-	+
	Naticidae	*Polinices mammilla** (Linnaeus, 1758)	+	-

Class	Family	Species name	Station	
			1	2
	Neritidae	*Nerita albicilla** (Linnaeus, 1758)	+	+
		*Nerita maxima** (Gmelin, 1791)	-	+
		*Nerita peloronta** (Linnaeus, 1758)	+	+
		*Nerita plicata** (Linnaeus, 1758)	+	-
	Olividae	*Oliva oliva** (Linnaeus, 1758)	+	-
	Pyramidellidae	*Syrnola fasciata** (Jickeli, 1882)	+	-
	Strombidae	*Canarium maculatum** (G.B. Sowerby II, 1842)	+	+
		*Canarium mutabile** (Swainson, 1821)	+	-

Species Richness, Diversity and Density

A slight variation in the total number of species (Taxa or S), species diversity (Shannon index or H) and equitability (J) values were noted between the 2 sampling stations, with station 1 displaying higher values when compared to station 2 (Table 3).

High species diversity in station 1 is expected since this site was positioned inside the established marine sanctuary where fishing and gleaning activities are strictly prohibited. In fact 2 marine sanctuary guards were regularly posted within the vicinity of the sanctuary who are commissioned to implement strictly these local ordinances or laws (pers com).

Gleaning or collection of edible mollusks are common practices in the Philippines since these organisms are used either for personal consumption (as food source) or as additional earnings (Napata and Andalecio, 2011; Nieves *et al.,* 2010; del Norte-Campos *et al.,* 2005).

Table 2 (cont'd). Species composition of intertidal mollusk species in Lugait, Misamis Oriental.

Class	Family	Species name	Station	
			1	2
Gastrpoda	Triviidae	*Trivirostra oryza** (Lamarck, 1810)	+	-
	Turinidae	*Lunella cinerea** (Born, 1778)	+	+
Total number of individuals			178	367

Legend: + present; - absent; *infauna, *epifauna

Despite these differences, high equitability and diversity values were clearly observed in both stations indicating that mollusk community in intertidal areas of Lugait, Misamis Oriental are incredibly rich, highly diverse and uniformly distributed where no certain species tend to dominate.

Mollusks associated with rocky substrates are expected to have rich and diverse communities (Galenzoga, 2016; Medrano, 2015; Flores-Rodriguez *et al.,* 2014; Flores-Rodriguez *et al.,* 2012; Jaiswar and Kulkarni, 2001). since they inhabit areas.

Between rocks and crevices using them as hiding place and protection against desiccation which is usually caused by extreme heat during low tide (Sørensen, 2012; Alyakrinskaya, 2004).

Species Density and Relative Abundance

A total of 178 and 367 individuals were counted in stations 1 and 2, respectively. In station 1, the most abundant species was *Drupella margaritcola* representing 14.61% (3.47ind m^{-2}) of the total number of organisms (Fig. 2).

This is followed in order by *Tenguella granulata* at 10.67% (2.53ind m^{-2}), *Conus coronatus* and *Syrnola fasciata* both accounted to 8.43% (2.00ind m^{-2}), *Nassarius albescens, Mitra tabanula, Morula anaxares* and *Nerita peloronta* garnering 5.62% (1.33ind m^{-2}) and *Canarium maculatum* at 5.06% (1.20ind m^{-2}).

Moreover, in station 2, species with highest abundance was *Cerithium stercusmuscarum* consisting of 34.60% (16.93 ind m^{-2}) of the total number of organisms, while *Nassarius subspinosus* trailed behind by 15.26% (7.47ind m^{-2}). *T. granulata* followed next with 8.72% (4.27ind m^{-2}), whereas *N. albescens* and *Cerithium atratum* were 6.54% (3.20ind m^{-2}) and 5.45% (2.67ind m^{-2}) of the total number of organisms, respectively. The remaining molluscs species which were least abundant in both stations consisted <5% of the entire molluscan fauna.

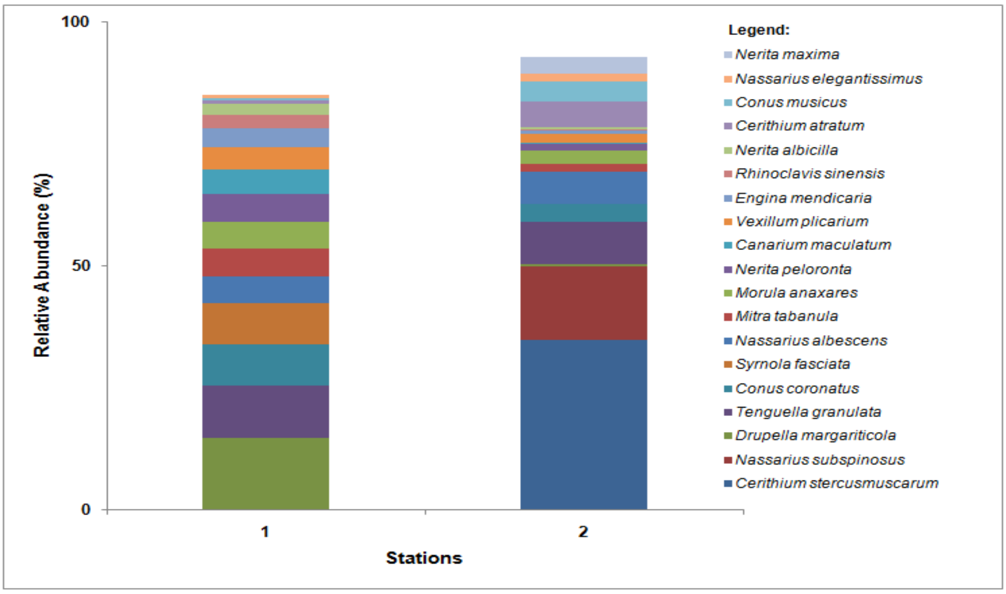

Fig. 2. Mollusk species with relative abundance ≥2% in the two sampling stations in the rocky intertidal flats of Lugait, Misamis Oriental.

Cerithium stercusmuscarum and *C. atratum*, are both herbivorous gastropods which are among the frequently encountered mollusk species on rocky intertidal shores (de Arruda and Amaral, 2003; Fursich and Schödlbauer, 1991; Fursich and Flessa, 1987). *C. stercusmuscarum* was observed to aggregate on hard substrates (*i.e.* rock grounds) where food (algae) is largely available (Fuersich and Flessa, 1987). Benthic algae often attached itself to hard substrates to ensure their survival and growth (Fursich and Schödlbauer, 1991). In our study, we noticed thick algal mats attached on rocks in station 2 and it is most likely that *C. stercusmuscarum* may have grazed on these algae which possibly lead to their dense aggregation or high population in the said area. On the other hand, *C. atratum* was quite common on rocky and soft bottom shores where seaweeds were present (de Arruda and Amaral, 2003), while *Nassarius albescens* was reported to occur in rocky substrate but in less abundance (Batolamaque *et al.*, 2010; Callea, 2005; Chelazzi and Vannini, 1980) since this species is normally a sandy-substrate organism (Taylor and Reid, 1984).

The species *D. margariticola* and *T. granulata* synonymously named *Morula margaticola/Cronia margariticola/Ergalatax margariticola* and *Morula granulata* respectively, *Morula anaxares* and *Conus coronatus* are common molluscan species found on rocky intertidal shores and beaches (Rahman and Barkati, 2012; Chelazzi and Vannini, 1980; Taylor, 1976). It has been demonstrated that the species *D. margariticola* and *Morula granulata* usually co-exist at the same time and preyed on similar type of food such as small-sized gastropods (Taylor, 1976). *Rhinoclavis sinensis* and *Nerita albicilla* were among these small-sized gastropods described by Taylor (1976) as diets of *M. margariticola* and *M. granulata*, which also occurred in the present study but in less abundance (2% of the entire molluscan population).

It is probable that *D. margariticola* and *T. granulata* may feed on *R. sinensis* and *N. albicilla* thereby resulting to their large numbers among the entire molluscan population in station 1. Further, the much higher densities of *D. margariticola* observed in station 1 may be attributed to their being corallivorous in nature since presence of small coral patches were observed in this site. Studies showed that *D. margariticola* tend to aggregate on corals of the genera *Acropora*, *Astreopora* and *Montipora* suggesting that the organism may have been feeding on these corals (Morton and Blackmore, 2009; Moerland *et al.*, 2016).

Comparison of mollusk abundance between the two stations revealed station 2 to be highly abundant (Fig. 3). The discrepancy between these 2 areas is presumed to be influenced by some important environmental variables as pinpointed by Canonical Correspondence Analysis or CCA (Fig. 4). The result of CCA showed that total organic matter (TOM) and calcium carbonate may be responsible for the high abundance of mollusk community observed in station 2. It has been pointed out that deposit and suspension feeding organisms obtained their food from organic matter contained in the sediment (Snelgrove and Butman, 1994). Generally, station 2 displayed high total organic matter contents of the sediment and it is most likely that the mollusk population in this area may be herbivores-deposit feeders which feed not only on plant epiphytes but took advantage of the abundant supply of total organic matter to increase their numbers. Moreover, peak concentration of calcium carbonate noted in the sediment in station 2 is expected because this mineral is an indication of the presence of shell debris from mollusks. It is noteworthy that empty shells of *C. stercusmuscarum* were frequently encountered during our sampling suggesting its contribution of calcium carbonate to the sediment. Shells of mollusk are primarily made of calcium carbonate because this mineral is considered a key component in shell formation (Addadi *et al.*, 2006).

Table 3. Diversity profile of the two sampling stations for intertidal mollusk in Lugait, Misamis Oriental.

Diversity Index	Station 1	Station 2
Taxa (S)	35	31
Individuals	178	367
Dominance (D)	0.0685	0.1644
Shannon (H)	2.995	2.403
Equitability (J)	0.8424	0.6999

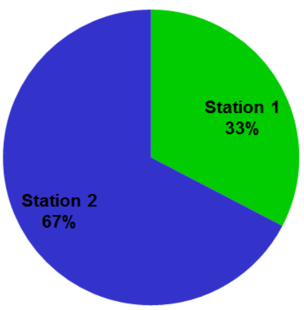

Fig. 3. Overall relative abundance of intertidal mollusks in the two sampling stations.

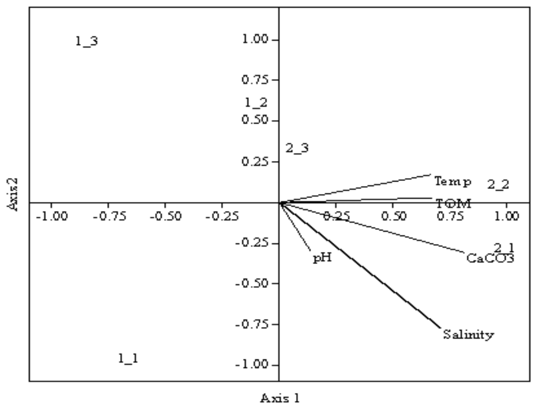

Fig. 4. Canonical Correspondence Analysis (CCA) biplot of the distance among the sampling stations and the physico-chemical factors that influence the distribution and abundance of intertidal mollusk.

Conclusion

The mollusk community in the study area exhibits high diversity and uniformity in distribution, thereby showing that the organisms cover a broad geographical area. Further, differences in the abundance of mollusk assemblage between stations suggested the important role of some variables in shaping the community. In particular, total organic matter and calcium carbonate contents in the sediment were the most crucial factors in influencing the abundance of mollusk population in the rocky intertidal areas in Lugait, Misamis Oriental, Northern Mindanao. Considering the functions of benthic mollusks in the marine food webs and to the world economy, the present results are valuable knowledge in comprehending the organization and dynamics of rocky intertidal communities of the Philippine coast, particularly in Northern Mindanao. Moreover, this study provide data that are useful in formulating monitoring strategies and management plans in Lugait, Misamis Oriental since a marine sanctuary is already in existence. It is recommended that further studies examining the effect of other environmental factors, such as desiccation, migration behavior and wave action must be carried out which would add to the knowledge on the distribution and abundance of mollusk species in this shoreline. Monthly monitoring must also be carried out in order to observe the trend and compare their distribution in different seasons (wet and dry months).

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