Article

Diversity and abundance of gastropods in the intertidal zone of Muduing Bay, Zamboanga Peninsula, Philippines

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Abstract
The Dumanquillas Bay Protected Landscape and Seascape (DBPLS) of the Zamboanga Peninsula in the Philippines is a leading fishing ground and source of income for thousands of fisherfolks of the different communities residing along the coast of the Peninsula. One of the coastal bays along the DBPLS has been subjected to severe human-induced pressures such as encroachment of the mangrove areas for human habitation, resource utilization, and construction of fish pens. It is perceived that these activities compounded with the effects of global climate change are considered threats to marine life in the area; thus, we investigated one of the groups of marine organisms that are generally considered a good indicator of the health of the marine ecosystem – the gastropods. Their diversity and relative abundance can be used as a useful measure in understanding the status of the bay. Determining the correlation between the diversity and abundance with conditions such as pH, salinity, dissolved oxygen, water temperature, and total suspended solids is also considered a good measure; thus was also done in the study. Only one site was found to have a high diversity index. Three species from two sampling sites were associated with pH, while the low species richness in one location was due to low dissolved oxygen. Other physicochemical parameters have no significant effects on the diversity and abundance of gastropods. These results indicate that the low diversity index observed can be primarily attributed more to anthropogenic activities in the area. While the area is included in the protected landscape, is still a need to study further the dynamics of the populations of the different species focusing on other possible environmental and anthropogenic factors affecting their biodiversity. The information that will be generated will be valuable in the proper establishment and management of fishponds in the bay, including appropriate practices for their conservation and sustainable utilization.

Keywords diversity; gastropods; relative abundance; Dumanquillas Bay.

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1 Introduction

Anthropogenic activities and other sources of problems in marine ecosystems such as pollution are serious but familiar problems that were not given any significant attention until it reached some threshold levels with adverse consequences on the ecosystems and organisms (Islam and Tanaka, 2004; Suratissa and Rathnayake, 2017). The Dumanquillas Bay Protected Landscape and Seascape (DBPLS) is a leading fishing ground and source of income for thousands of fisherfolk inhabiting the surrounding six municipalities in the two provinces of Zamboanga del Sur and Zamboanga Sibugay. However, over the past decades, the DBPLS has been subjected to severe human-induced pressures, such as encroachment, overexploitation of resources, and destructive activities (DBPLS, General Management Plan, 2016-2020). It is argued that the compounded effects of global climate change and local human activities pose severe threats to the existing marine life that caused the increase of biodiversity extinction rates to 1,000 – 10,000 times to their natural rates (Lovejoy, 1997). For example, one of the major causes that are being pointed out for the degradation of Dumanquillas Bay is the presence and continuous construction of fishponds to maintain demand and to keep overfishing under control. However, many current fishpond operations negatively impact the environment being installed in sheltered mangrove areas in shallow waters. The conversion of mangrove forests into fishponds has resulted in the loss of essential ecosystem services, including the provision of fish/crustacean nurseries, wildlife habitat, coastal protection, flood control, sediment trapping, and water treatment (Primavera, 2006; Wu, 1995). The discharge of effluents from fishponds with a high level of nutrients and suspended solids into adjacent waters has resulted in eutrophication, oxygen depletion, and siltation of the bay (Herbeck et al., 2013). In effect, water degradation has influenced red tide events andlocalized and substantial changes on macro-invertebrate community structure resulting to a reduction of species diversity and increase in the abundance of pollution-tolerant species such as the gastropods (Nabirye et al., 2016; Yahiya et al., 2016; Temporetti et al., 2001; Pitta et al., 1999). Since many of these species inhabit intertidal pools and in diverse habitats like sandy beaches, rocky coasts, mangroves, and muddy areas (Pawar and Al-Tawaha, 2017; Suratissa et al., 2017), they are regularly used as bioindicators of aquatic health (Pawar and Al-Tawaha, 2017). Because many of these species are also used for human consumption, and ornamental, medicinal, and commercial purposes (Tabugo et al., 2013; Pawar and Al-Tawaha, 2017), they also have become a natural resource of economic importance that are collected extensively resulting in overexploitation and loss of biodiversity (Pawar and Al-Tawaha, 2017). This study was therefore conducted to assess the status of gastropod diversity in Muduing Bay, where coastal communities have been dependent on the ecosystem services provided by the bay.

2 Study area and Methodology

The Muduing Bay is part of the Dumanquillas Bay Protected Landscape and Seascape (DBPLS) that constitutes parts of the three municipalities of Zamboanga del Sur and Zamboanga Sibugay. Sampling was conducted in the five coastal barangay of the Municipality of Kumalarang, Zamboanga del Sur with coordinates of 7.7703° N, 123.1464° E, namely Barangay Buyugan West, Bualan, Cabug Island, Gusom, and Picanan. One coastal barangay of the Municipality of Lapuyan with coordinates of 7.6916° N, 123.1914° E namely Barangay Latas and one coastal barangay of Municipality of Buug, Zamboanga Sibugay with coordinates of 7.7407° N, 123.0564° E namely Barangay Pamintayan (Fig. 1).

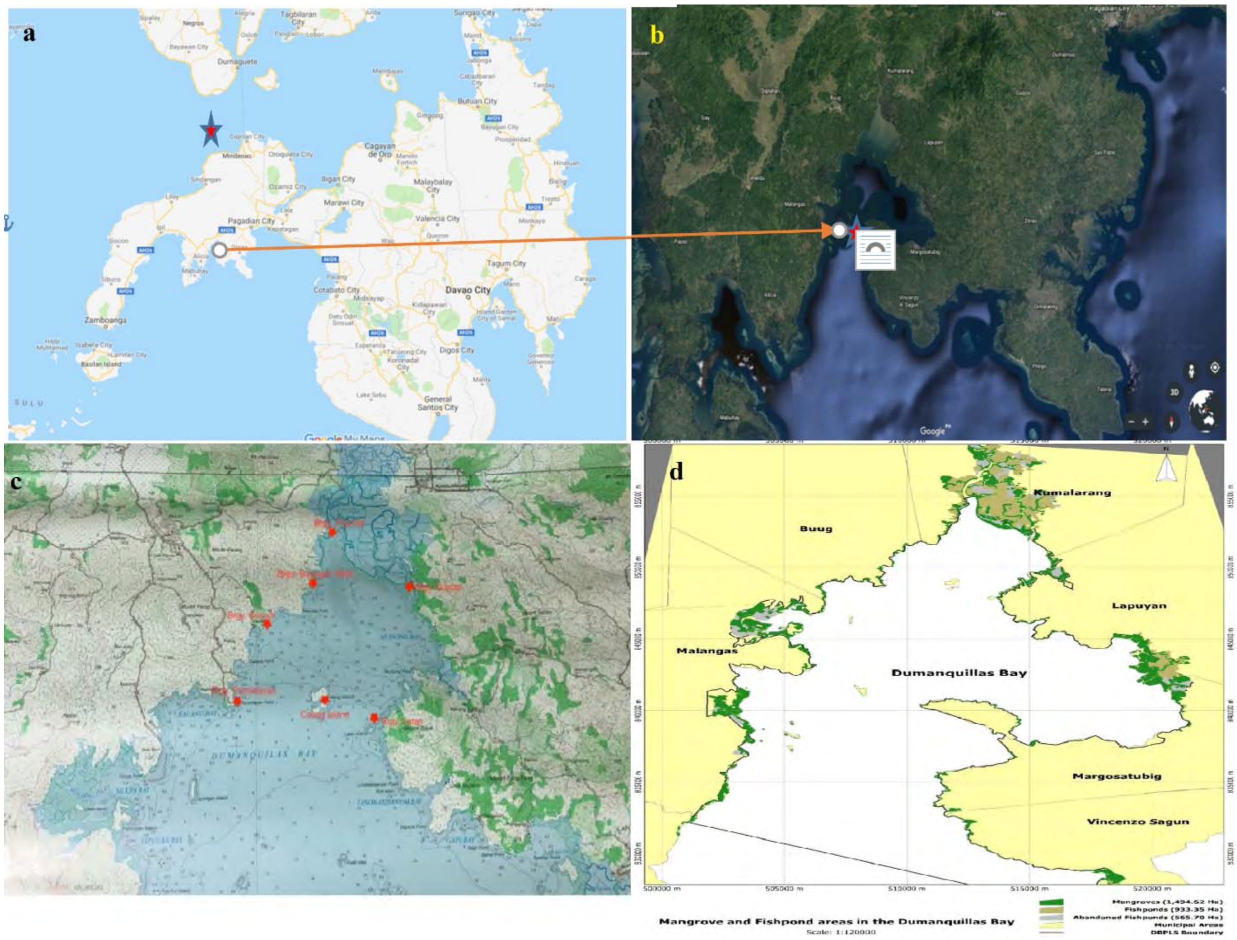

Fig. 1 Map of Mindanao (a) and satellite image (b) of the Muduing Bay showing the study areas (c) [Brgy. Picanan, Brgy. Buyogan West, Brgy. Gusom, Brgy. Bualan, Brgy. Pamintayan, Brgy. Latas and Cabug Island]; (d) Mangrove and Fishpond areas (green) in the Dumanquillas Bay

The collection was done by handpicking methods (live specimens only) during low tide to ensure the visibility of the gastropod species. To delineate the zone of sampling collections, 50 meters from the highest flow was assumed to cover the intertidal zone. Three stations were established in every site. The collection of species was done 30 minutes in every location. After collecting, samples were cleaned, sorted, identified, and photographed using a high-resolution digital camera. Water temperature, salinity, pH, dissolved oxygen, and total suspended solids (TSS) were measured. Identification of the species using several taxonomic guides (Nichols and Bartsch, 1945; Springsteen and Leobrera, 1986; Abbott and Morris, 1995; Dance, 1992; De Bruyne, 2003; Esqueda et al., 2000).

Canonical Correspondence Analysis (CCA) and biodiversity indices using the software Paleontological Statistical Tool (PAST)(Hammer et al., 2001) were used to determine the relationship of the different physicochemical parameters with the abundance of species.

3 Results and Discussion

A total of 2347 individuals from nineteen (19) species from 11 families of gastropods were collected in the seven sampling sites (Table 1, Fig. 2). The number of individuals per species varies per collection site. The highest number of individuals was recorded in Site 6 (Brgy. Pamintayan). The highest species richness (12) was both documented in two sites (Sites 1 and 6) while the lowest was recorded in Site 5 (Table 1). Among sites, the species *T. sulcata* was most abundant in 6 sampling sites while two species *C. thalassiarchus* and *H. sulzyckii* were found only in sites 1 and 5, respectively (Table 1, Fig. 3).

Fig. 2 Gastropods identified in Muduing Bay (a)- *C. charbonnie,* (b)- *F. ater,* (c)- *N. undata,* (d)- *A. travassosi,* (e)- *L. angulifera,* (f)- *T. telescopium,* (g)- *H. sulzyckii,* (h)- *C. capucinus,* (i)- *T. palustris,* (j)- *T. sulcata,* (k)- *P. undosa,* (l)- *C. lampasrubincunda (var),* (m)- *C. omaria sindon,* (n)- *B. rugosa,* (o)- *N. caffra,* (p)- *N. parallelavittina (var),* (q)- *V. patulum,* (r)- *C. thalassiarchus,* and (s)- *N. violaceum*.

Table 1 Species composition, number of individuals, and relative abundance (in parenthesis) of gastropods species in seven different sampling sites.

Family	Genus	Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Potamididae	*Cerithidae*	*Cerithidae charbonnie*	31(7.95)	23 (9.02)	2 (0.5)	5 (2.48)	0	0	0
Pachychilidae	*Faunus*	*Faunus ater*	20 (5.13)	1 (0.39)	7 (1.75)	0	0	42 (8.02)	0
Neritidae	*Nerita*	*Nerita undata*	209 (53.59)	101 (39.61)	42 (10.47)	8 (3.96)	0	56 (10.69)	85 (26.4)
Olividae	*Agaronia*	*Agaronia travassosi*	2 (0.51)	2 (0.78)	1 (0.25)	8 (3.96)	0	0	0

Littorinidae	*Littoraria*	*Littorinopsis angulifera*	8 (2.05)	0	0	5 (2.48)	0	11 (2.1)	0
Potamididae	*Telescopium*	*Telescopium telescopium*	27 (6.92)	38 (14.9)	7 (1.75)	74 (36.63)	0	0	0
Pisaniidae	*Hesperisternia*	*Hesperisternia sulzyckii*	1 (0.26)	0	0	0	0	0	0
Muricidae	*Chicoreus*	*Chicoreus capucinus*	0	0	1 (0.25)	0	0	25 (4.77)	6 (1.86)
Potamididae	*Terebralia*	*Terebralia palustris*	18 (4.62)	2 (0.78)	2 (0.50)	9 (4.46)	0	0	0
Potamididae	*Terebralia*	*Terebralia sulcate*	20 (5.13)	62 (24.31)	233 (58.1)	64 (31.68)	0	67 (12.79)	124 (38.51)
Pisaniidae	*Pollia*	*Pollia undosa*	0	8 (3.14)	0	0	183 (72.33)	101 (19.27)	12 (3.73)
Ranellidae	*Charonia*	*Charonia lampasrubincunda* (var)	0	0	0	0	43 (17)	54 (10.31)	0
Conidae	*Conus*	*Conus omaria sindon* (var)	0	0	0	0	1 (0.4)	1 (0.19)	0
Turbinidae	*Bolma*	*Bolma rugosa*	0	0	0	0	1 (0.4)	39 (7.44)	28 (8.7)
Neritidae	*Neritina*	*Neritina caffra*	13 (3.33)	0	72 (17.96)	3 (1.49)	25 (9.88)	0	0
Neritidae	*Neritina*	*Neritina parallelavittina*(var)	10 (2.56)	17 (6.67)	0	0	0	0	0
Costellariidae	*Vexillum*	*Vexillum patulum*	0	0	0	0	0	126 (24.05)	67 (20.81)
Conidae	*Conus*	*Conus thalassiarchus*	0	0	0	0	0	1	0
Neritidae	*Neripteron*	*Neripteron violaceum*	31 (7.95)	1 (0.39)	34 (8.48)	26 (12.87)	0	1 (0.19)	0
TOTAL Number of Individuals			**390**	**255**	**401**	**202**	**253**	**524**	**322**

Site 1 (Brgy. Picanan), Site 2 (Brgy. Boyugan West), Site 3 (Brgy. Gusom), Site 4 (Brgy. Bualan), Site 5 (Cabug Island), Site 6 (Brgy. Pamintayan) and Site 7 (Brgy. Latas).

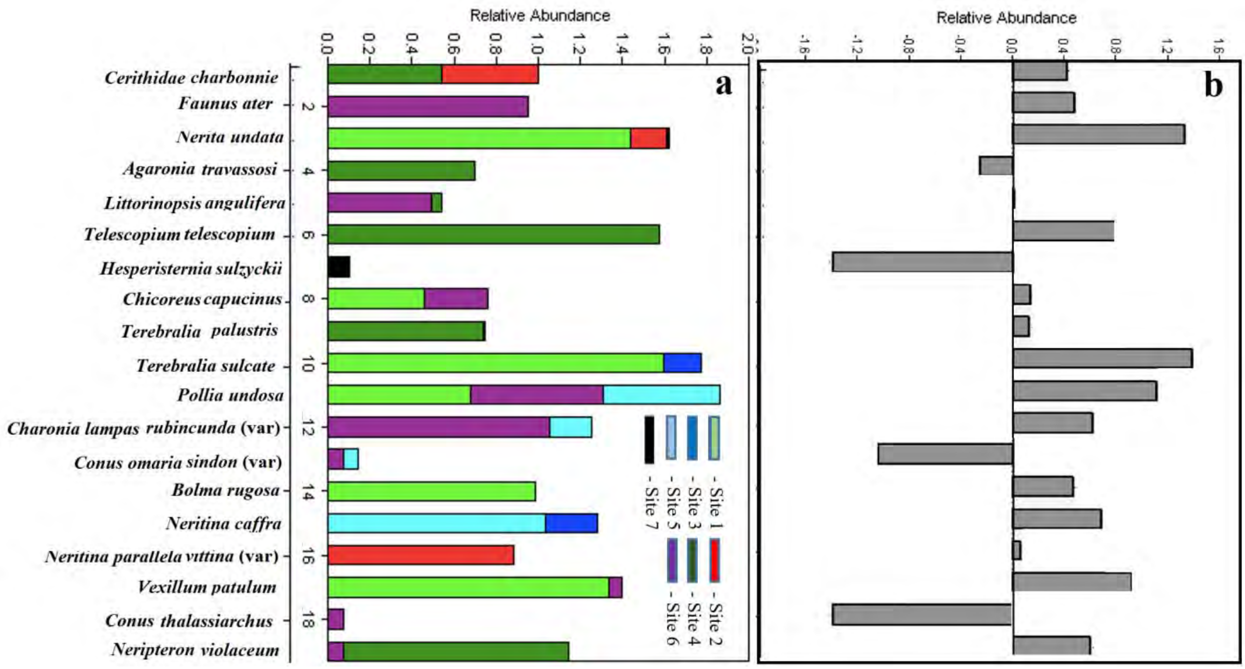

Fig. 3 Relative Abundance Bar Chart Plot (a) and the Relative Abundance (LogY) (b) of gastropods species in 7 different sampling sites. Site 1 (Brgy. Picanan), Site 2 (Brgy. Boyugan West), Site 3 (Brgy. Gusom), Site 4 (Brgy. Bualan), Site 5 (Cabug Island), Site 6 (Brgy. Pamintayan) and Site 7 (Brgy. Latas).

High diversity was observed in site 6, while site 5 was low. All other sites were moderate (Table 2). Site 7 had the evenest distribution. Since evenness indicate the area may be influenced by the competition of species for food and territory within an area, it can be argued that the competition of species in this site is less compared to other sites. The high dominance value of (D = 0.5619) in site 5 was due to the high abundance of *P. undosa*. That total dominance of one species probably indicates an unfriendly environment in this site (Macintosh et al., 2002; Imakulata and Tokan, 2018; Legendre and Legendre, 1983).

Table 2 Biodiversity indices in 7 sampling sites.

Biodiversity Indices	Sampling Sites in Muduing Bay						
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Species Richness	12	10	10	9	5	12	6
Shannon's Diversity (H')	1.698	1.62	1.293	1.636	0.8079	2.054	1.455
Dominance (D)	0.3142	0.2519	0.3887	0.2577	0.5619	0.1481	0.2706
Evenness (E)	0.4551	0.5053	0.3645	0.5705	0.4487	0.6499	0.714

Site 1 (Brgy. Picanan), Site 2 (Brgy. Boyugan West), Site 3 (Brgy. Gusom), Site 4 (Brgy. Bualan), Site 5 (Cabug Island), Site 6 (Brgy. Pamintayan) and Site 7 (Brgy. Latas).

Abiotic factors such as temperature, pH, salinity, dissolved oxygen, and total suspended solids (TSS) may also affect the diversity, distribution, and abundance of the gastropods. In this study, however, it can be seen that the abundance of species *P. undosa*, *C. lampasrubincunda* (var), and *C. omaria sindon* in site five and site six are positively affected by the pH and the low species richness in site 5 (Cabug Island) may be due to low value of dissolved oxygen (1.5 mg L^{-1}). The maximum DO for the life of benthic mollusks ranges from 4.5 to 6.6 mg L^{-1}. If the DO value is below 2.0 mg L^{-1}, it can cause the death of organisms. Dissolved oxygen is an essential requirement for the life of aquatic biota (Effendi, 2003; Imakulata and Tokan, 2018). Other physicochemical parameters such as salinity, temperature, and total suspended solids do not affect the diversity, abundance, and species richness of the gastropods in Muduing Bay, Zamboanga Peninsula.

Looking at the physicochemical properties of the different sampling sites (Table 3, Fig. 4), it can be seen that the abundance of species *P. undosa*, *C. lampasrubincunda* (var), and *C. omaria sindon* in sitesfive and six are positively affected by the pH. All other species were not affected by environmental conditions.

Table 3 Physico-chemical condition in the seven different sampling sites.

Sites	Community Village	Water Temp.	Salinity	pH	Dissolved Oxygen	Total Suspended Solids (TSS)
1	Brgy. Picanan	30.50	1.010	7.66	5.49	32.77
2	Brgy. Buyogan West	30.60	1.009	7.65	5.3	41.73
3	Brgy. Gusom	31.63	1.013	7.76	5.66	68.07
4	Brgy. Bualan	31.47	1.015	7.55	5.04	64.27
5	Cabug Island	34.77	1.020	8.27	1.5	81.7
6	Brgy. Pamintayan	31.61	1.016	7.80	4.92	52.87
7	Brgy. Latas	31.50	1.015	7.83	4.31	55.98

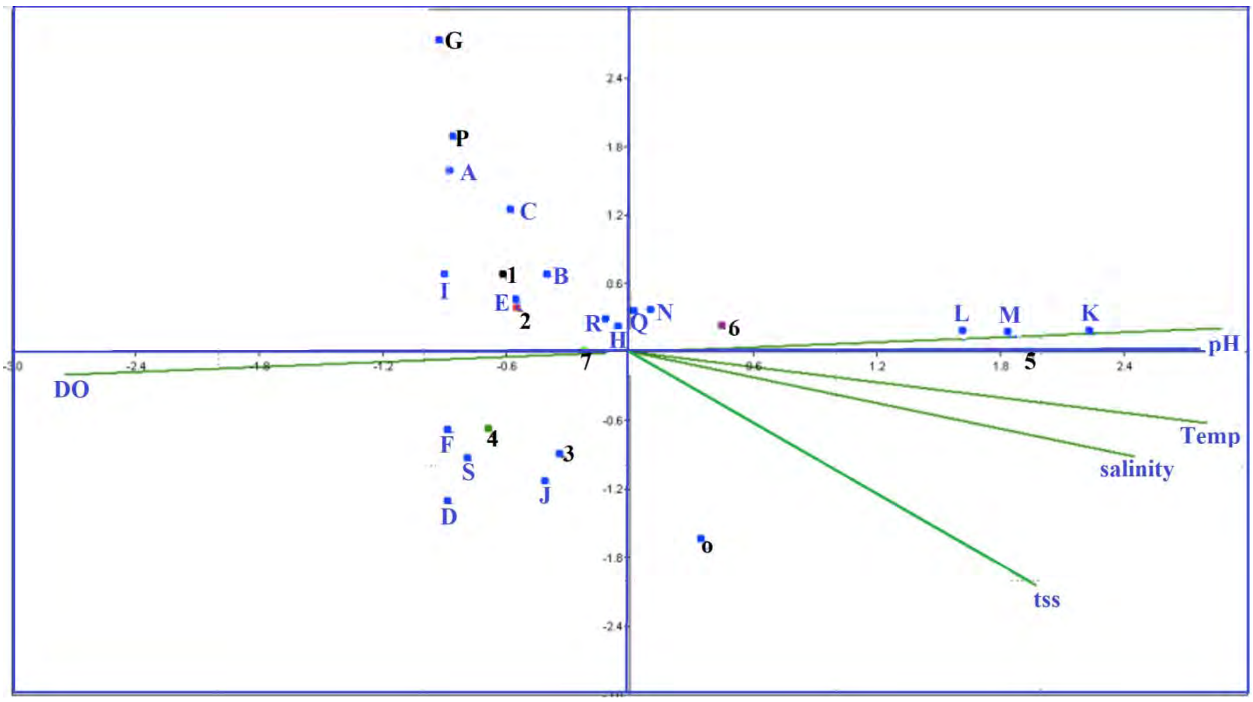

Fig. 4 Ordination diagram showing five environmental factors: temperature, salinity, pH, dissolved oxygen and total suspended solids (TSS). Numbers 1-7 [1 (Brgy. Picanan), 2 (Brgy. Boyugan West), 3 (Brgy. Gusom), 4 (Brgy. Bualan), 5 (Cabug Island), 6 (Brgy. Pamintayan) and 7 (Brgy. Latas). A- *C. charbonnie,* B- *F. ater,* C- *N. undata,* D- *A. travassosi,* E- *L. angulifera,* F- *T. telescopium,* G- *H. sulzyckii,* H- *C. capucinus,* I- *T. palustris,* J- *T. sulcata,* K- *P. undosa,* L- *C. lampasrubincunda (var),* M- *C. omaria sindon,* N- *B. rugosa,* O- *N. caffra,* P- *N. parallelavittina (var),* Q- *V. patulum,* R- *C. thalassiarchus,* and S- *N. violaceum.*

Results in this study revealed that the diversity and abundance of the marine gastropods in Muduing Bay might have been affected by environmental factors such as different kinds of habitat, habitat degradation, and unregulated harvesting for food and marketing (Underwood and Denley, 1984; Keough and Black, 1996; (Underwood and Fairweather, 1989; Denny and Paine, 1998). Disturbance regimes (Thrush et al., 1994; Frouin, 2000; Giovaset al., 2010; Suratissa and Rutnayake, 2017) and other factors such as tidal regime, temperature, red tides, changes in sea level, storms, wave action, and fisheries (Underwood and Fairweather, 1989; Denny and Paine, 1998) may also have influenced the heterogeneity of the environment (Barry and Dayton, 1991; Peterson, 1992). Differences in the kind and richness of species in various sites can also be attributed to the nature of the biology of gastropods. Some species inhabit both in the mud and trunks of mangroves and are therefore more adapted to the ever-changing and harsh mangrove environment (Dolorosa, 2014).

Environmental factors like the muddy habitat, presence/absence of mangroves, and whetherthe areas are rocky/sandyare argued to be affecting the community structures of the gastropods.Overgrazing and conversion of the mangroves area to fishponds also have contributed to the differences in species richness. The absence or the low number of some species can also be attributed to the overcollections since some of the gastropods meat and shells are valuable (Tabugo et al., 2013). The species *N. undata*, *T. Telescopium*, and *T. sulcate* were the commonly exploited species in the area. Still,it was learned from the community that inlate 2017 to the present, only *T. Telescopium* and *T. sulcata* are the only two gastropod species left found sold in the market. There was no harvest regulation on the specific size of gastropods that exclude juveniles to ensure a sustainable supply of harvestable stocks,thus resulting in their depletion (Dolorosa, 2104). Studies have shown that moderate ecological disturbances by humans can alter species composition and enhance diversity and richness in marine environments (Frouin, 2000; Giovas et al., 2010; Suratissa and Rutnayake, 2017; Nabirye et al., 2016; Yahiya and Miranda 2016; Temporetti et al., 2001; Pitta et al., 1999; Ellis 2003; Jumawan et al., 2015; Manzo et al., 2014). Localized and significant changes in macroinvertebrate community structure in Maduing Bay, as manifested in the observed reduction of species diversity and increased abundance of species, are argued to have resulted from the transformation of mangrove forestsin the bay into fishponds. The conversion led to water degradation and deterioration of the habitat of the bay, thus affecting the community structure of gastropods in the area.

4 Conclusion

The results of this study showedvariations in the diversity status of gastropods in Muduing Bay. Populations of the different species may have been affected by the variousenvironmental factors and disturbance regimes such as kinds of habitat, habitat degradation, and unregulated harvests,which vary from site to site. It was also observed that there were variations in the effects of selected factors on species richness and abundance. It was shown that pH affects the population of a species in one site while othersites by total dissolved oxygen. While physicochemical factors such as temperature, salinity, and total suspended solids (TSS) indicated no significant effects on the diversity and abundance of gastropods in the bay, other possible environmental and anthropogenic factors affecting their biodiversity needs to be studied. The information will be valuable in the proper establishment and management of fishponds in the bay, including appropriate practices for their conservation and sustainable utilization.

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