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Species composition of benthic macroalgae in the coastal areas of Surigao City, Philippines

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Abstract

This study aimed to determine the species composition of the benthic macroalgae in relation to the environmental parameters in one of the coastal areas in Surigao City, Philippines. It is conducted along the coasts of Barangay Day-asan with established three stations. The macroalgae species were observed and collected using line transect method. The water quality parameters were obtained in situ using water quality apparatus and the species composition were determined through diversity indices such as Shannon H, dominance and evenness and abundance. There were six (6) species observed in the study site. *Sargassum polycystum* is the most abundant and is present in three stations. As to diversity indices, the benthic macroalgae has a moderate category in terms of Shannon H, low dominance and almost a uniform distribution of species in all three stations. The coastal water parameters of Barangay Day-asan passed the DAO standards and still within the limits and ranges based on the diversity indices of Shannon H, dominance and evenness. Depth has a strong correlation to Codium fragile and pH to *Amphiroa fragillissima* and *Halimeda opuntia*. As indicated by the diversity indices of the benthic macroalgae species composition, the coastal water of Barangay Day-asan has still a suitable environmental condition for their growth. Hence, it is recommended to have strong information, education and communication environmental campaign and policies for locals and tourists as ecotourism starts to kick off in the locality to ensure sustainable conservation and protection of the natural environment with benthic macroalgae as good bioindicators.

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Introduction

In coastal waters around the world, the dominant primary producers are benthic macrophytes, including seagrasses and macroalgae (Melsasail *et al.*, 2018). Macroalgae are photosynthetic organisms which play vital roles in ecology and in human life. Ecologically, they act as primary producers of energy, provide food to non-photosynthetic organisms and are basis of food cycle in marine life (Al-ashwad *et al.*, 2020). They also provide habitat and nursery area for commercially and recreationally important fish species, protect against erosion and act as buffering mechanisms for excessive loading thereby making them as biological indicators of heavy metal pollution in marine environment (Chakraborty *et al.*, 2014). Several types of macroalgae have economic values and significant advantages to humans (Srimariana *et al.*, 2020) such as being sources of medicines, food, feedstock and industrial basic materials (Radulovich *et al.*, 2015).

As photosynthetic sessile organisms, benthic macroalgae respond directly to abiotic and biotic environmental factors making them as sensitive bioindicators of natural and anthropogenic changes (Borja *et al.,* 2013). The aquatic environment conditions strongly affect their distribution in nature (Bruno *et al.*, 2014). The diversity of macroalgae species in waters can be an indicator of water quality. According to Fachrul (2007) and Namakule *et al.* (2017), if the diversity of macroalgae species in waters is high, the quality of the waters will be good, whereas if the diversity of macroalgae species in waters is low, the quality of the waters will decrease. In the Philippines, there were a number of studies on diversity and distribution of macroalgae carried out by several authors. To name are the works of Trono (1972, 1986) and Meñez (1961) in Hundred Islands, Hurtado-Ponce *et al.* (1992) in Panay, Liao & Sotto (1980) in Cebu, Mendoza and Soliman (2013) in Bicol region, Jumawan *et al.* (2014) in Sarangani Province, Del Rosario *et al.* (2016) in La Union and Clemente *et al.* (2017) in Romblon Island Group. Most of these studies focused only on the major islands and coastlines within the country or to areas that are readily accessible for macroalgal studies. There were still places with ecotourism potentials where economic developments are surging and yet there is scanty information on the status of their natural resources and environmental condition. Hence, more scientific investigations may be strengthened. Barangay Day-asan is one of the coastal barangays of Surigao City. It is a village of stilts and residences on the water and shoreline for livelihood. It is rich in mangrove and marine resources hence, well known for farming lobsters and milkfish. As observed currently, there have been changes in aquatic and environmental quality due to increasing human activities in the area brought by eco-tourism and coastal development like beaches and resorts. These scenarios would certainly give impacts on biodiversity conditions including benthic macroalgae composition. Hence, this study on species composition of benthic macroalgae in relation to environmental parameters is conducted. Results of this study can be used as baseline information of the benthic macroalgae species found in Barangay Day-asan, Surigao City and may be reference for policy brief of the local government unit.

Materials and methods

Study Site

This study was conducted at the coastal areas of Barangay Day-asan, Surigao City which is geographically located at 9°46'21'N, 125°32'07'E (Surigao City Planning and Development Office [CPDO], 2016) (Fig.1). It is 15 km away from the Surigao City Hall and can be reached either by motorboat or land vehicle. It is part of Arellano District with a total land area of 3, 040.447 hectares in which 554 hectares is dominated by mangrove forest. According to barangay statistical data, as of May 2020, it has a total of 1, 949 population with 451 households of which majority are considered coastal settlers.

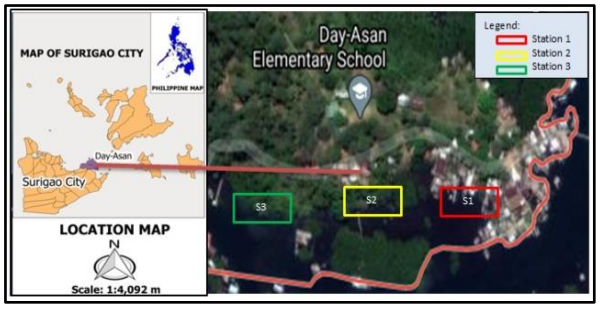

Fig. 1. Map of the Study Site showing the three stations. (Inset: Philippine and Surigao City maps).

Three study stations were established in the study site which was designated as Station 1 (S1), Station 2 (S2) and Station 3 (S3). The exact positions of these locations were determined using the Global Positioning System (GPS) apparatus. Station 1 is established in an area where a number of coastal household settlers are located. It has a rocky shoreline and a mixed sandy and coralline with some rocks in the substratum. Station 2 has almost the same substrate with Station 1 but closer to mangrove area. Station 3 is far from household settlers, has some corals and rocks with mixed sandy-muddy substrate.

Establishment of Sampling Plots

There were three stations established in the study site considering varied environmental conditions. In each station, three transects were laid having a length of 100 meters. A 50 – meter distance between transect was established. In each transect, 10 quadrats were laid with a dimension of 1m x 1m. Benthic macroalgae were then identified and counted. Data collected were used to analyze values for biodiversity indices.

Assessment of Physico-chemical Characteristics of Coastal Water and Nature of Substrates

The water pH, salinity, turbidity, DO, TDS and TSS were determined *in situ* using a water quality checker (Hana HI9829). The nature of substrates was determined through on its color and texture while the depth of sea level was obtained using a meter stick.

Collection and Identification of Species

All observed benthic macroalgae found within the sampling plots were identified, counted and recorded within the conduct of the study from March – May 2020. Sample specimens were collected through handpicking and were placed in pre – labeled plastic containers for further taxonomic identification and herbarium purposes. The collected sample specimens were identified using Dr. Hilconada Paalan Calumpong's book entitled Field Guide to the Common Mangroves, Seagrasses and Algae of the Philippines and some literatures (e.g., Jumawan, J, 2014; Del Rosario *et al.*, 2016; Liao, L., 2018). Identification was made from class to species level.

Data Analysis

The data collected were used to compute for biodiversity values such as species richness, abundance, dominance and evenness using the PAST software (Hummer *et al*, 2001). To determine the correlation between species composition and the measured water physico – chemical parameters, a canonical correspondence analysis (CCA) was performed using PAST software (Hummer *et al.*, 2001).

Results and discussion

Physico-chemical Characteristics of Coastal Water and Nature of Substrates

The coastal water of Barangay Day-asan is classified as Class SC based on the Department of Environment and Natural Resources (DENR) Administrative Order 2016-08. Class SC is characterized based on its intended beneficial use such as for propagation and growth of fish and other aquatic resources intended for commercial and sustenance fishing; for boating and other recreational activities and with marshy and/or mangrove areas declared as fish sanctuaries.

As shown in Table 1, the coastal water quality parameters of the study site passed the DAO Standards (2016-08). This means that the seawater condition of Barangay Day-asan is still suitable for the growth of marine organisms in the area. Melsasail *et al.* (2018) highlighted that the distribution of macroalgae species is influenced by environmental condition of its habitat, both physical and chemical conditions, or the combination of both. Substrate characteristics also allow a wide range of macroalgae to be found in an area.

Species Identification and Composition

There were six (6) species observed and taxonomically identified in the study area (Table 2). These were *Codium fragile, Ulva reticulata, Halimeda discoidea, Padina pavonica, Sargassum polycystum and Amphiroa fragillisima* (Fig. 2). Among the six (6) species, three (3) species belonged to class Ulvophyceae, two (2) from Phaeophyceae and only one (1) from Florideophyceae. All the six (6) species were found in Station 3 (S3) while only three (3) species found in the Station 1 (S1).

Across the three (3) stations, *S. polycystum* was the most abundant species with a total of 58 individuals while *C. fragile* was the least abundant having 12 individuals and present only in Station 3. *U. reticulata, P. pavonica and S. polycystum* were the species present across stations with 40, 36 and 58 total number of individuals respectively.

The abundance of Sargassum in this study conforms to the study of Del Rosario *et al.* (2016). Many Sargassum species are renowned in their adaptability to strong current of sea water and can withstand in strong waves. As brown algae, they are not affected by the conditions of the water due to their toughness compared to other nature of algae such as red algae.

Table 1. *Physico – chemical Characteristics of Coastal Water and* Nature of Substrate of the Coastal Area of Barangay Day-asan.

Parameters	Stations			Mean Value	DAO Standard (Class SC)	Remarks
	S1	S2	S3			
Water pH	7.20	7.72	7.21	7.38	6.5-8.5	Passed
Salinity	6.42	6.73	5.77	6.31	n/a	n/a
Turbidity	2.00	0.50	1.00	1.17	n/a	n/a
DO mg/L	23.50	16.70	15.00	18.40	min of 5	Passed
TDS	30.10	28.10	19.92	26.04	n/a	n/a
TSS(g/mL)	49.00	35.35	31.50	38.62	max of 80	Passed
Depth (cm)	80.00	83.00	88.00	83.67	n/a	n/a
Nature of Substrate	rocky shoreline with mixed sandy & coralline substratum	rocky shoreline with mixed sandy & coralline substratum closer to mangrove area	with corals and rocks mixed sandy -muddy substrates in the mangrove area	n/a		

Table 2. Species Composition of Benthic Macroalgae in Coastal Areas of Day-asan, Surigao City.

Class	Order	Family	Species	Stations			Total
				S1	S2	S3	
Ulvophyceae	Cordiales	Cordiaceae	*Codium fragile*	0	0	12	12
	Ulvaves	Ulvaceae	*Ulva reticulata*	13	12	15	40
	Bryopsidales	Halimedaeceae	*Halimeda discoidea*	0	11	11	22
Phaeophyceae	Dictyotales	Dictyotaceae	*Padina pavonica*	10	12	14	36
	Fucales	Sargassaceae	*Sargassum polycystum*	16	14	28	58
Florideophyceae	Corallinales	Corallinaceae	*Amphiroa fragillissima*	0	11	12	23
Total # of Species per Station				3	5	6	
Total # of Individuals				39	60	92	191

The presence of macroalgae species in coastal waters of Barangay Day-asan is very few, only six species. This is in contrast to Clemente *et al.* (2017) who observed 129 species in Romblon Island Group. Del Rosario, *et al.* (2016) found 103 macroalgae species in San Fernando, La Union. Jumawan, *et al.* (2014) found 19 species in the intertidal zone of Sarangani province while Mendoza and Soliman (2013) spotted 55 species in Lagunoy Gulf, Bicol region. These differences in the number of species are brought by different natural conditions which certainly have different environmental factors affecting the presence of macroalgae (Melsasail *et al.,* 2018). Furthermore, Diaz-Pulido and mc Cook (2008) explain that the increase in the number of individuals and species of an organism occurring in an area is due to its varying substrate. Other than substrate, it is also influenced by environmental factors, such as temperature, salinity, light intensity (brightness) and current velocity (Dawes, 1981).

Benthic Macroalgae Species

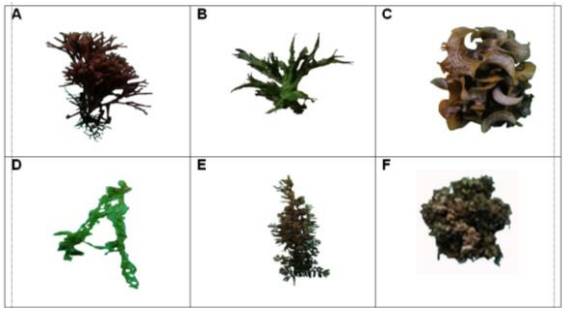

Fig. 2. Benthic Macroalgae Species (A)*Amphiroa fragillissima* (B) *Codium fragile* (C) *Padina pavonica* (D) *Ulva reticulata* (E) *Sargassum polycystum* (F) *Halimeda opuntia.*

Diversity Indices of Benthic Macroalgae Species in Coastal Waters of Barangay Day-asan

Diversity is a very important parameter to compare various communities of marine biota, especially to determine the effect of water quality (Melsasail *et al.*, 2018). As shown in Table 3, it appears that the value of diversity is directly proportional to evenness and inversely proportional to the value of dominance. The highest dominant index is at Station 1 (0.3452) while the lowest is at Station 3 (0.1907). The average dominant index value of the three stations is 0.2459. According to Odum (1994), if the D value < 0.5, it indicates a low dominance and if D reaches 1, then the dominance is highest. With this, the benthic macroalgae species in the coasts of Barangay Day-asan having low dominance can grow optimally and have high adaptation rate making them able to live on diverse substrate conditions (Jorgensen *et al.,* 2005).

Table 3. Diversity Indices of Benthic Macroalgae Species in the Coastal Areas of Barangay Day-asan.

Diversity Indices	Station		
	1	2	3
Taxa _S	3	5	6
Individuals	39	60	92
Dominance_D	0.3452	0.2017	0.1907
Simpson_1-D	0.6548	0.7983	0.8093
Shannon_H	1.0810	1.6050	1.7300
Evenness_e^H/S	0.9822	0.9959	0.9397

In this study, the highest diversity index is in Station 3 (1.7300) while the lowest is in Station 1 (1.081). The average diversity index of the three stations is 1.472. According to Shannon and Weaver (1963) as cited by Romimohtarto and Juwana (2001) and Melsasail *et al.,* (2018), if the index value of H' = 1.0-3.0 then the diversity of species in a territorial water is included in the moderate category. This diversity index is often associated with water conditions which can be used as an indicator of water cleanliness. Since the diversity of macroalgae in coastal water of Day-asan is within the moderate category, its water condition is moderately contaminated although most of its water quality parameters passed the DAO Standards (2016-08). According to Fachrul (2007), if the value of H' = 1.0-3.0, it indicates a moderately polluted water quality; if H' < 1, it means a heavily polluted water quality, otherwise, if H' > 4, it indicates clean water.

In terms of evenness index, the highest evenness value is Station 2 (0.9959) while the lowest is Station 3 (0.9397). The average evenness index value on the observed stations is 0.9726 which indicates that there is not much difference on the evenness among the three stations. The uniformity of macroalgae species in the coasts of Barangay Day-asan is also evident in its low dominance indicating that species can grow optimally due to its stable water conditions and environmental factors. According to Hukom (1998), the limit of the uniformity index value (E) indicating a stable environmental condition ranges from 0.75 to 1.00. The results of this study on the diversity indices conforms to Namakule *et al.* (2017) that the diversity of organisms in the waters is strongly influenced by environmental factors.

Canonical Correlation Analysis Between Benthic Macroalgae Species Composition and the Physico-Chemical Parameters of the Coast of Barangay Day-Asan

The results of the canonical correspondence analysis of benthic macroalgae in the coast of Barangay Day-asan show that *A. fragillisima* and *H. opuntia* are moderately and positively correlated with depth and pH but negatively correlated with turbidity, DO, and TSS and weakly correlated with TDS and salinity. *C fragile* is strongly and positively correlated with depth; strongly negatively correlated with TDS; moderately and negatively correlated with salinity,

DO, and TSS and weakly correlated with turbidity ad pH. Moreover, *P. pavonica*, *U. reticulata* and *S. polycystum* are close to the origin, so they are weakly correlated with physic-chemical parameters. As can be gleaned from Fig. 3, among the six (6) species, *P. pavonica*, *U. reticulata* and *S. polycystum* are not strongly correlated to the measured physico-chemical parameters. This can be accounted to their presence in all three stations (Table 2). Among the seven (7) measured physico-chemical parameters, depth is strongly correlated to *C. fragile* which is only present in Station 3 with a depth of 88cm. Depth is a factor to consider in investigating macroalgae distribution which together with substratum type determines the macroalgal community suitable in an area (Littler and Littler 1988, Lobban and Harrisson, 1994). Deep areas would have reduced light for photosynthetic activity while sand and rubble as substrate in addition to the strong currents would prevent macroalgae from colonization. The pH parameter is strongly correlated to *A. fragillissima* and *H. opuntia*. This results suggest that high pH may be an important, but so far overlooked factor in regulating coastal primary production of macroalgae (Middelboe and Hansen, 2007). The pH of seawater which is suitable for the growth of macrolgae is between 7-9. Low pH will suppress the growth rate of macroalgae, and even the acidity level can be deadly, and which may hinder any reproduction rate in macroalgae (Melsasail *et al.,* 2018).

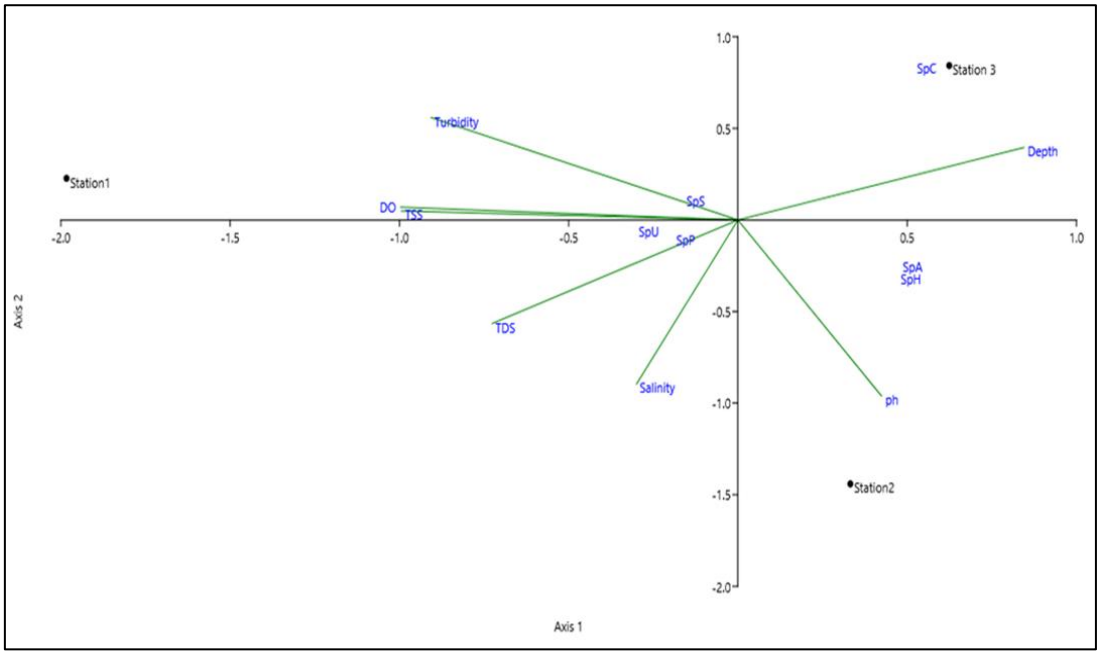

Fig. 3. A canonical correspondence analysis showing the relationship between species composition and measured physic-chemical parameters in the coastal areas of Barangay Day-asan. Environmental variables are represented by arrows. The angle between one arrow and another represents the correlation between them. Species are represented by acronyms while dots represent the stations. SpA - *A. fragillissima*, SpC - *C. fragile*, SpH - *H. opuntia*, Spp - *P. pavonica*, SpS - *S. polycystum*, SpU - *U. reticulata*.

Conclusion and recommendation

The macroalgae observed in the coast of Barangay Day-asan consist only of six species with *Sargassum polycystum* as the most abundant and found in all three stations. As to diversity indices, it has a moderate category in terms of Shannon H, low dominance and almost a uniform distribution of species in all three stations. The coastal water parameters of Barangay Day-asan passed the DAO standards and still within the limits and ranges based on the diversity indices of Shannon H, dominance and evenness. Hence, coastal waters of Barangay Day-asan have still a suitable environmental condition for the growth of benthic macroalgae.

Among the measured physico-chemical parameters, depth has a strong correlation to *C. fragile* and pH to A. *fragillissima* and *H. opuntia*.

The results of this study shows that the coastal waters of Barangay Day-asan is still in stable condition as indicated by the diversity indices of the benthic macroalgae species composition. However, over time, as ecotourism starts to kick off in the locality, it is recommended that: a.) Residents and the tourists in the area may be educated on how to protect the macroalgae habitat as they serve as structural habitat for other marine organisms and help in establishment and maintenance of coral reefs; b.) Barangay local government unit of Day-asan may come up with strong policies for sustainable conservation and protection of the natural environment with benthic macroalgae as good bioindicators; c.) Future researcher may conduct the same considering other areas/islands within Surigao City and in the province of Surigao del Norte for a considerable contribution to phycological diversity map of the Philippines.

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