Kuroshio Science **7**-1, 49-57, 2013

Community Structure of Macroalgae of Lagonoy Gulf, Bicol Region, Philippines

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Abstract
Algal community structure in Lagonoy Gulf, the eastern Philippines, was examined to reveal the influence of monsoon and ecological factors. Twelve sampling sites included 10 intertidal and 2 subtidal sites. Fifty-five species (29 chlorophytes, 10 phaeophytes and 16 rhodophytes) were identified. The number of species collected was high near the mouth of the gulf and low along the coast within the gulf. The presence of species and their abundance as well as their biomass were significantly different between sampling periods that covered northeast (NE) and southwest (SW) monsoons (p 0.04, $\alpha = 0.05$). Biomass decline could be attributed to senescence of the large phaeophytes that contributed more than 30% to total biomass. Clustering of the intertidal sites using the frequency data showed that they are separated into northern and southern groups with a few exceptions, which are under the influence of SW and NE monsoons, respectively. The Shannon diversity index was high in the sites exposed to strong waves and currents and low in embayment.

Key words: macroalgae, community structure, biomass, species richness

Introduction

Community structure is a significant aspect in assessing the condition and functionality of a community's ecosystem (Caswell, 1976; Hoe *et al.,* 2011; Wells *et al.,* 2007; Littler and Littler, 1994). It is a key basis for understanding environmental changes as organisms respond to changes in external factors (Hoe *et al.,* 2011; Wells *et al.,* 2007). In the marine environment, seaweeds are used as indicators of pollution (Vieria and Volesky, 2000), productivity (Littler and Murray, 1974) and climate change (Hughes *et al.,* 2007).

Macroalgae are the centrum of aquatic primary productivity and they are important habitats for diverse fish species (Christie *et al.,* 2009; Norderhaug *et al.,* 2005; Coppejans *et al.,* 1992). They provide a substrate for the attachment of epiphytes which serve as food for small fish and invertebrates (Christie *et al.,* 2009; Norderhaug *et al.,* 2005; Coppejans *et al.,* 1992). As aquatic plants, they are used as an indicator of coastal productivity and therefore are very crucial in fishery production (Fortes, 1990) and their diversity is indicative of environmental (ecological) conditions (Wells *et al.,* 2007; Odum, 1993). They efficiently absorb nutrients from water and surface sediment which means that they are vital in the control of water quality in shallow areas (Patriquin, 1972 as cited by Coppejans *et al.,* 1992).

Lagonoy Gulf is a regular pathway of some 6-8 typhoons a year from the Pacific Ocean. The Kuroshio Current that bifurcates from the north equatorial current and the exposure to monsoons are key natural factors that could influence the diversity and community structure of macroalgae in the gulf. These factors can regulate the distribution and survival of macrophytes by affecting the supply of seeds and nutrients (Wells *et al.,* 2007; Lobban and Harrison, 1994; Botin *et al.,* 2010; Velimirov and Griffiths, 1979).

Macroalgae in the gulf were observed to have degenerated due to boat navigation, construction of fish corrals, establishment of mariculture facilities and high siltation (Mendoza *et al.,* 2003; Mendoza *et al.,* 2000; Bonga *et al.,* 1995). Fortes (1990) cautioned on the loss of biodiversity due to the subsequent high degree loss of seagrass habitat, a loss that may bring danger to human lives due to the reduction of protective functions of the ecosystem.

The main objective of this paper is to examine the community structure of macroalgae in Lagonoy Gulf by determining species richness, abundance, biomass and distribution as influenced by monsoon and vital ecological factors.

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Materials and Methods

Lagonoy Gulf (Fig. 1) is situated on the northeastern side of the Philippines. It is where the north equatorial current bifurcates into the Mindanao Current and the Kuroshio Current. The gulf is usually affected by typhoons and by the northeast (NE) and southwest (SW) monsoon systems. Eight stations (1-8) face the prevailing wind of the NE monsoon and four stations (9-12) face the SW monsoon wind (Table 1). Most of the stations are seagrass-dominated and macroalgae are associated flora.

Acal Point (Rapu-rapu Island) is in the southeastern portion of the mouth of the gulf where the substrate is extensively sandy; in the rapidly shifting sand there the seagrasses and seaweeds have little opportunity to grow and develop.

In Gaba (Batan Island), the substratum is sandy-muddy due to its proximity to rivermouths and the high sedimentation rate in the bay. The bay is also a major navigational route of fishing boats and passenger craft. It is dominated by seagrasses and associated seaweed species.

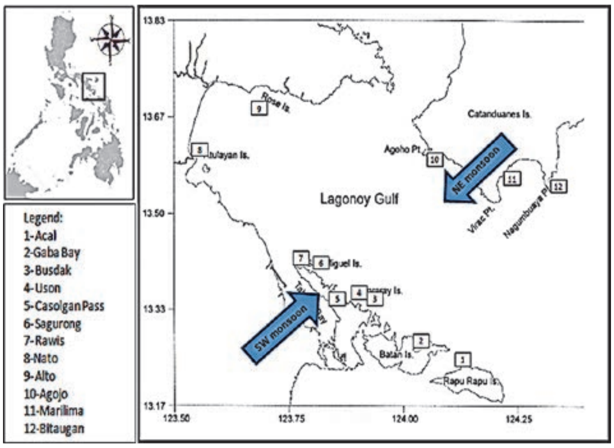

Fig. 1. Location of sampling stations; arrows indicate the prevailing monsoon.

Busdak is generally sandy-muddy and is dominated by seagrasses. The area is shallow and it is exposed during low tides.

The sampling station in Uson, Cagraray Island is in a marine protected area. It has a sandy substratum, regularly experiences a moderate to strong current and is wave-exposed during the SW monsoon (November to March).

Casolgan is located in a short channel between San Miguel Island and Cagraray Island. It is both shallow and sandy-muddy, dominated by seagrasses, and experiences a moderate to strong current during the onset of high and low tides. The channel connects the gulf to Tabaco Bay.

Sagurong and Rawis, both in San Miguel Island, are mainly sandy-muddy dominated by seagrasses. Both areas are shallow and exposed during lowtide but they are used as a navigational lane during high tide.

Nato (Camarines Sur) is located at the western portion of the gulf. The area is shallow and has a rocky substratum. It is a pure seaweed station and experiences moderate waves and currents throughout the year. It is influenced by high freshwater run-off and sediment during the rainy season (June to February).

Alto is the deepest station. It is surrounded by coral reefs at 30-40 feet down. It has a sand-rocky substrate dominated by seagrasses.

Agojo, Maralima and Bitaugan (all in Catanduanes Island) are in the northeastern part of the gulf and have a rocky-sandy substratum. The site is shallow and is exposed during low tide. The site is dominated by seagrasses.

The Line Quadrat Method (English *et al.,* 1994) was used to assess the macroalgal community. In each station, one to two 100 m transects were laid perpendicular to the shoreline. From these transects, 0.5 m x 0.5 m quadrats with 25 subquadrats measuring 10 cm

Table 1. Coordinates of sampling stations and the influential monsoon.

Station	Coordinates	Prevailing Monsoon
Acal	13°14.07'N -124º07.45'E	Northeast (NE) monsoon
Gaba	13°17.04'N -123º03.17'E	NE monsoon
Busdak	13°20.04'N -123º55.23'E	NE monsoon
Uson	13°20.15'N -123º54.61'E	NE monsoon
Casolgan	13°21.60'N -123º50.90'E	NE monsoon
Sagurong	13°24.43'N -123°41.70' E	NE monsoon
Rawis	13°24.88'N -123º45.75'E	NE monsoon
Nato	13°36.15'N -123°32.27' E	NE monsoon
Alto	13°41.83'N -124º40.25'E	Southwest (SW) monsoon
Agojo	13°36'1. N - 124° 2.57'E	SW monsoon
Marilima	13°32.18'N -124º09.96'E	SW monsoon
Bitaugan	13°33.41'N -124°19.02'E	SW monsoon

x 10 cm were placed at 10 m intervals. All macroalgae found inside the quadrats were identified, counted and harvested to determine frequency and biomass. The frequency of macroalgae was determined by counting in how many subquadrats the macroalgae appeared; while biomass was determined by oven drying after removing soil, silt and epiphytes. Two sampling periods were conducted - one in March representing the NE monsoon and another in August representing the SW monsoon of 2004.

Diversity indices and clustering analysis were calculated using the frequency data of each species using the PAST ver 2.17 (Hammer *et al.,* 2001) and Multivariate Statistical Package Software (MVSP ver 3.22, Kovach Computing Services 1985-2013 www.kovcomp.com), respectively. Clustering analysis of the frequency data using the Bray-Curtis measures and nearest neighbour was used to group the sites. These analyses were done to examine the community structure of macroalgae from determination of a general pattern of species richness alongside ecological characteristics of the sites. Analysis of Variance was done to determine differences in species number, frequency and biomass of macroalgae among stations and between sampling periods representing the NE and SW monsoons.

Results

Species numbers

Fifty-five species were identified including 29 chlorophytes, 10 phaeophytes and 16 rhodophytes (Table 2, see also Table 2a for the list of species). The numbers of species were greatest in Bitaugan (33) and there were also a large number in Rawis (20), Agojo (20), Nato (18) and Acal (18). The other seven stations showed 15 species or less. Chlorophyte species were greater than other phyla in most stations and they were generally found in rubble and sandy areas dominated by seagrass. Rhodophyte species were relatively high in areas characterized by rocky-coral substratum with a moderate to strong current as in Acal and Nato. *Halimeda* spp. were the most common macroalgae (Table 5). The number of species was significantly different for each sampling period ($p = 0.004$) and among stations ($p = 1.45255E-10$).

Biomass

Stations with the highest macroalgae biomass were Rawis, Bitaugan and Nato with 399.32-326.8 g dry wt/m^2 (Table 4). Biomasses in the rest of the stations were low with 97.5-256 g dry wt/m^2. Chlorophytes contributed more than half of the total biomass in seven sampling stations (Sagurong, Agojo, Gaba, Budak, Uson, Bitaugan and Acal) whereas phaeophytes recorded the greatest biomass in Alto (98%) Casolgan (64%), Marilima (61%) Rawis (56%) and Nato (53%) (Table 3). Rhodophytes had the lowest biomass in most of the sites except Acal and Nato. Phaeophytes, though represented by only a few species, have a higher biomass compared to other phyla with higher species numbers (Fig. 2). Most representative species of phaeophytes have a huge plant body as in *Sargassum, Turbinaria* and *Hormophysa*. Biomass was significantly different between sampling periods ($p = 0.00126$) and among stations ($p = 0.00108$).

Groups based on frequency data

Two major groups were observed namely in Alto and Acal. Alto is a deep site that differed from all the other stations. Acal, a sandy-coral site characterized by moderate to strong currents, was also separated from other sites. Further finer groupings were observed and the data showed that the southern sites along San Miguel and Cagraray Islands (Rawis, Sagurong, Uson, Casolgan,

Table 2. Species distribution (by phylum) of macroalgae in Lagonoy Gulf.

Stations	Chlorophyta		Rhodophyta		Phaeophyta		Total
	1st sampling	2nd sampling	1st sampling	2nd sampling	1st sampling	2nd sampling	
Acal	8	7	2	2	8	7	18
Gaba	6	5	2	2	1	0	9
Busdak	5	3	1	1	0	0	6
Uson	2	2	0	1	2	2	4
Casolgan	4	3	4	3	1	1	9
Sagurong	3	3	0	0	0	0	3
Rawis	10	8	4	4	6	5	20
Nato	7	6	3	3	8	7	7
Alto	1	1	5	5	1	1	18
Agojo	18	16	1	1	1	1	20
Marilima	10	11	4	4	1	1	15
Bitaugan	21	18	3	3	9	9	33

Table 2a. List of species found in Lagonoy Gulf. (* denotes presence in the station)

	Acal	Gaba	Busdak	Uson	Casolgan	Sagurong	Rawis	Nato	Alto	Agojo	Marilima	Bitaugan
CHLOROPHYTA												
Ulva sp.	*											*
Ulva clathrata	*											*
Chaetomorpha sp.	*											*
Avrainvillea lacerata										*		
Boergesenia forbesii												*
Caulerpa dentata								*				
Caulerpa lentilifera							*					*
Caulerpa peltata							*					
Caulerpa racemosa										*		
Caulerpa serrulata										*		*
Caulerpa sertularoides								*		*	*	*
Chlorodesmis comosa												*
Codium sp.										*		*
Dictyosphaeria sp.							*			*		*
Halimeda incrassata		*	*	*	*	*	*			*		
Halimeda macroloba	*	*		*		*	*			*	*	*
Halimeda opuntia	*	*		*	*	*	*			*	*	*
Halimeda taenicola			*							*		*
Halimeda tuna	*						*	*		*		*
Halimeda sp.							*	*		*		*
Udotea occidentalis				*			*	*		*	*	
Valonia aegagropila										*		*
Valonia ventricosa										*		*
Acetabularia major								*		*	*	*
Bornetella oligospora	*	*									*	
Bornetella sphaerica				*						*	*	*
Chlorocladus philippinensis		*			*						*	*
Halicoryne wrightii											*	
Neomeris vanbosseae	*	*			*		*	*	*	*	*	*
PHAEOPHYTA												
Dictyota cervicornis											*	
Dictyota dichotoma	*				*				*			
Dictyota linearis									*		*	*
Padina sp.	*	*			*			*		*	*	
Padina japonicum									*			*
Padina minor		*			*							
Hormophysa trequetra							*	*				
Sargassum sp. 1				*	*		*	*	*		*	
Sargassum sp. 2							*					
Turbinaria sp.							*		*			*
RHODOPHYTA												
Actinotrichia fragilis	*		*		*		*	*		*		*
Galaxuara oblongata								*	*			*
Liagora sp.	*											*
Gelidiella sp.	*		*				*					*
Amphiroa sp.							*	*				
Amphiroa foliacea							*	*				
Mastophora rosea								*				
Halymenia sp.							*	*				*
Lithothamnium sp.							*					
Jania sp.												*
Eucheuma sp.								*				*
Garcilaria arcuata	*											
Gracilaria sp.	*	*										*
Hypnea boergesenii	*							*			*	*
Acanthopora muscoides	*											
Laurencia papillosa	*											

Table 3. Average biomass (g dry wt/m^2) of macroalgae in Lagonoy Gulf; values in parentheses indicate relative percentage by station.

Stations	Chlorophyta		Rhodophyta		Phaeophyta		Total
Acal	133.66	(52.33)	103.00	(40.48)	17.79	(6.99)	254.45
Gaba	147.97	(95.48)	5.00	(3.23)	2.00	(1.29)	154.97
Busdak	127.50	(84.72)	23.00	(15.28)	0.00		150.50
Uson	178.65	(78.13)	0.00		50.00	(21.87)	228.65
Casolgan	78.90	(33.50)	12.00	(5.10)	144.60	(61.40)	235.50
Sagurong	97.50	(100.00)	0.00		0.00		97.50
Rawis	114.90	(29.82)	69.96	(18.15)	200.50	(52.03)	385.36
Nato	35.30	(10.80)	122.00	(37.33)	169.50	(51.87)	326.80
Alto	4.45	(2.32)	0.78	(0.40)	186.97	(97.28)	192.20
Agojo	223.94	(96.30)	4.50	(1.94)	4.10	(1.76)	232.54
Marilima	111.55	(43.48)	2.00	(0.78)	143.00	(55.74)	256.55
Bitaugan	255.17	(63.90)	118.65	(29.71)	25.50	(6.39)	399.32

Table 4. Biomass (g dry wt/m^2) of macroalgae in Lagonoy Gulf by sampling period.

Stations	Chlorophyta		Rhodophyta		Phaeophyta	
	1st sampling	2nd sampling	1st sampling	2nd sampling	1st sampling	2nd sampling
Acal	135.00	132.32	91.00	115.00	17.79	17.79
Gaba	147.74	148.19	5.00	5.00	2.00	2.00
Busdak	157.00	98.00	23.00	23.00	0.00	0.00
Uson	240.30	117.00	0.00	0.00	80.00	20.00
Casolgan	101.40	56.40	12.00	12.00	204.10	85.10
Sagurong	118.00	77.00	0.00	0.00	0.00	0.00
Rawis	123.40	106.41	64.44	75.48	266.00	135.00
Nato	51.80	18.80	122.00	122.00	217.00	122.00
Alto	4.45	4.45	0.78	0.78	263.95	110.00
Agojo	259.96	187.93	4.50	4.50	4.10	4.10
Marilima	106.50	116.60	4.00	0.00	189.00	97.00
Bitaugan	263.72	246.63	122.60	114.70	25.50	25.50

Table 5. Average frequency of macroalgae in Lagonoy Gulf by sampling period.

Stations	Chlorophyta		Rhodophyta		Phaeophyta	
	1st sampling	2nd sampling	1st sampling	2nd sampling	1st sampling	2nd sampling
Acal	18.29	14.17	12.00	5.00	20.75	15.00
Gaba	27.00	15.33	22.50	9.50	30.00	15.00
Busdak	20.25	16.25	0.00	0.00	15.50	11.50
Uson	42.20	20.20	29.00	11.00	0.00	0.00
Casolgan	10.00	7.75	32.73	10.28	18.00	12.00
Sagurong	2.00	1.33	0.00	0.00	0.00	0.00
Rawis	14.49	7.11	48.75	14.25	16.39	8.91
Nato	26.77	9.37	40.33	22.33	32.38	14.75
Alto	51.00	33.00	24.65	14.55	19.23	0.78
Agojo	19.70	7.41	16.00	10.00	15.50	4.50
Marilima	38.29	17.21	36.75	11.25	12.60	4.00
Bitaugan	19.49	7.94	18.50	10.83	10.72	4.17

Table 6. *p* values among sampling stations and between sampling periods for species number, frequency of species and biomass.

	Species number	Frequency of species	Biomass
Among stations	1.453E-10	0.0464	0.00126
Between sampling period	0.0046	0.0039	0.00108

Gaba), except for Busdak and the stations in Catanduanes Island (Agojo, Bitaugan and Marilima), were separated into a distinct group (Fig. 3).

Diversity indices

In terms of index of dominance which suggests abundance, Alto and Busdak had the highest with 0.38. Sagurong had 0.36 and Uson with 0.30 while the rest had less than 0.30 (Table 7). Simpson's and Shannon's diversity indices of the stations had relatively close values to indicate comparable diversity. The sequence of ranking of the stations in the index of dominance was the reverse of Simpson's and Shannon's index. Nato, Acal, Bitaugan, Rawis, Marilima and Agojo were highly diverse sites wheras Gaba, Casolgan Uson, Alto Busdak, Sagurong had low diversity. The Evenness index, which indicates equal distribution of abundance, showed that Sagurong, Marilima, Nato, Busdak and Acal have a relatively even distribution of species in relation to their abundance (0.96-0.80). Gaba, Uson, Rawis Casolgan and Agojo have a less even distribution of number of individuals per species (0.77-0.59). Alto and Bitaugan have a low even distribution (0.49-0.42).

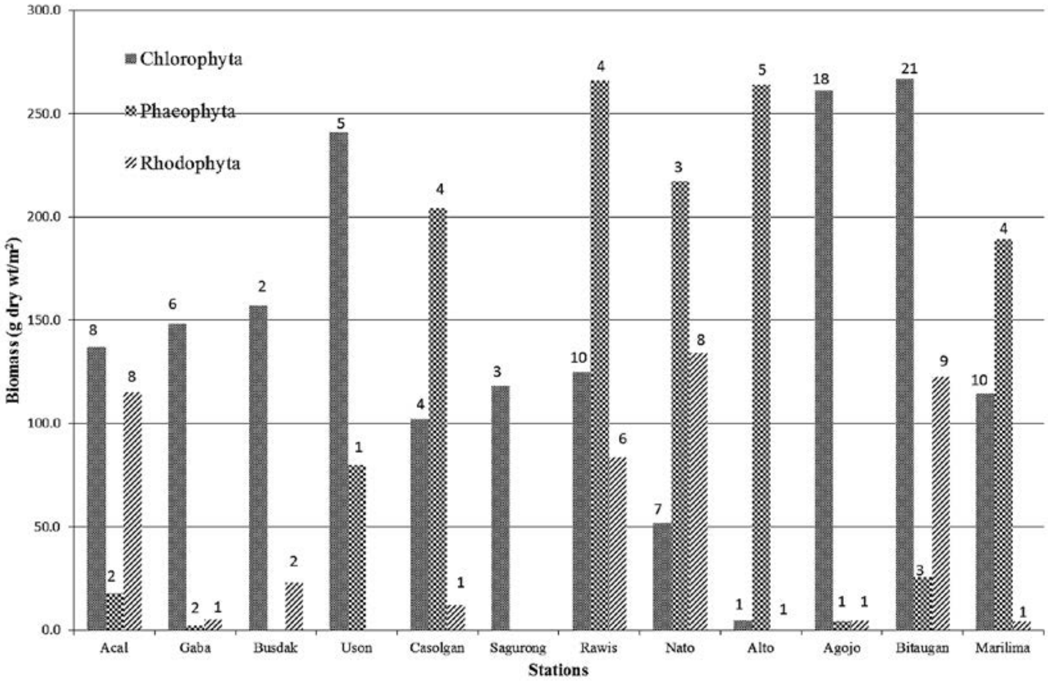

Fig. 2. Biomass (g dry wt/m^2) of macroalgae in Lagonoy Gulf.

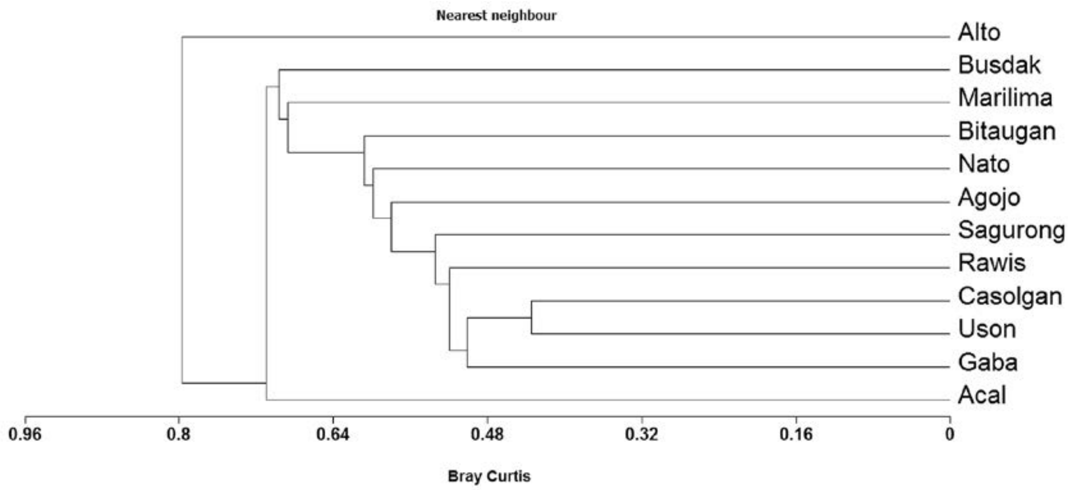

Fig. 3. Clustering analysis (nearest neighbour) using the frequency data of macroalgae found in the selected stations in Lagonoy Gulf.

Discussion

Knowledge of the community structure of macroalgae populations is the key to assess the condition and functionality of their ecosystem (Hoe *et al.,* 2011; Wells *et al.,* 2007; Littler and Littler 1994). This is also a basis for understanding environmental changes as macroalgae are sensitive to manifest influences by external factors (Hoe *at al.,* 2011, Wells *et al.,* 2007). In the present study, 55 species of macroalgae were found of which 39 species occurred during the NE monsoon and 53 species appeared during the SW monsoon. Variations in species richness can be linked to the prevailing monsoons which affect the gulf year round. During the SW monsoon the stations 9-12 (see Fig. 1) are mostly affected by waves and currents that peak in August while the NE monsoon affects the rest of the stations from November to March. The strong wind and heavy rain brought by these monsoons can dislodge macroalgae that have fragile and broad thalli such as in the genera *Padina, Acetabularia, Bornetella, Dictyota, Ulva, Liagora, Galaxuara* and *Laurencia*. Heavy rain causes siltation and lower salinity resulting in smothering of macroalage due to their reduced photosynthesis. The wind and rain associated with the NE monsoon (Botin *et al.,* 2010) may cause the disappearance of the small and fragile species that are usually attached to rubble, stones or empty shells (Littler and Littler, 1988; Lobban and Harrisson, 1994). The decrease in biomass during the second sampling could also be attributed to the "die off season" or senescence of large phaeophytes from July to September (Bonga *et al.,* 1995; Hurtado-Ponce *et al.,* 2006) which contributes to high total biomass. Overall, species number, frequency and biomass of macroalgae were significantly different in both sampling periods and between stations (Table 6). The pattern of species richness was observed to be higher near the mouth and head part of the gulf (Bitaugan, Marilima, Agojo, Acal and Nato). The number of species was also high in the sites close to the tip of the island where the current is relatively strong (Rawis and Casolgan). However, the number of species was low in the sites at the middle of the islands (Sagurong, Busdak, Gaba, and Uson) where current and waves were weak.

Clustering of stations can be attributed to the similarity of environmental attributes such as substratum type and wave impact, which are the major factors influencing macroalgal community structure (Littler and Littler, 1988; Lobban and Harrisson, 1994). Similarly, the stations in Alto and Acal were clustered distinctly from other stations due to their unique habitat conditions. Alto is relatively deep and reef-associated while Acal features strong currents and has a sandy substratum. Depth is a factor to consider for 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 photosynthesic activity while sand and rubble as substrate in addition to the strong currents would prevent macroalgae from colonization.

Disturbances in macroalgal beds in the gulf include gleaning activities (Nieves *et al.,* 2012), boat or ship navigation, pollution and high siltation (Soliman *et al.,* 1997; Mendoza *et al.,* 2000; Bonga *et al.,* 1995). Although marine protected areas (MPAs) in the gulf harbour macroalgae, MPAs occupy only a small portion of the total gulf area (<2%); this factor combined with less than satisfactory management of the MPAs may limit their ecological significance.

In summary, the macroalgae found are considered to be low in diversity (55 species) when considering the list by Trono (1999) on the diversity of macroalgae in the Philippines which consists of more than 800 species. Most of the sites were seagrass dominated whereby

Table 7. Diversity indices of the sampling stations in Lagonoy Gulf.

Stations	Dominance	Simpson	Shannon	Evenness
Acal	0.08	0.92	2.66	0.80
Gaba	0.17	0.83	1.94	0.77
Busdak	0.38	0.62	1.16	0.80
Uson	0.30	0.70	1.48	0.73
Casolgan	0.24	0.76	1.73	0.63
Sagurong	0.36	0.64	1.06	0.96
Rawis	0.10	0.90	2.60	0.67
Nato	0.08	0.92	2.68	0.81
Alto	0.38	0.62	1.23	0.49
Agojo	0.11	0.89	2.46	0.59
Marilima	0.09	0.91	2.53	0.84
Bitaugan	0.12	0.88	2.62	0.42

macroalgae were mainly associated flora. Observations near the mouth and head part of the gulf and at the tips of islands revealed that the pattern of richness of species may be enhanced by both stronger water circulation and the type of substratum. Biomass decline could be attributed to the "die off season" of the large phaeophytes that contributed more than 30% to its total biomass. Clustering of stations revealed the effect both of monsoons and of the depth and type of substratum.

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