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Status of seaweeds in San Miguel Island, Lagonoy Gulf, Philippines: a review related to the effects of changing environment and local issues

[1]Alex P. Camaya, [1]Victor S. Soliman, [1]Antonino B. Mendoza Jr., [2]Kazuo Okuda

[1] Coastal Resources Management Unit, Bicol University Tabaco Campus, Tabaco City 4511, Albay, Philippines; [2] Graduate School of Kuroshio Science, Kochi University, 2-5-1, Akebono, Kochi 780-8520, Japan. Corresponding author: A. P. Camaya, lhex3479@gmail.com

Abstract. This contribution is a review on the results of three comprehensive studies previously done in 1994, 2004 and 2010 on the seaweed community in San Miguel Island, Lagonoy Gulf, Philippines. The status was evaluated with the aim of providing basis to sustain the resource along with local issues and the changing environmental factors. In 1994, twenty three (23) species were found and recorded mean biomass (B) of 112.72 g/m^2. Only five (5) species had been found in 2004 with 35.22 g/m^2 while eleven (11) species were determined in 2010 that registered to 159.45 g/m^2. As depicted in the relative frequency (F) and cover (C) values, seaweeds in 1994 were diverse but have limited density compared in 2010 where most species have significant abundance rate. An implication of the decline in species composition was in fact altered by the individual productivity in the past 16 year. The predominant algae such as *Sargassum* spp. and *Halimeda* spp. have shared substantially to the standing crop. From the revealing status, several attributions were determined. The varying seaweed community structure has significant response with the seasonal variations in the environmental factors. The correlation indicator showed that the seaweed abundance was due to the gradual increase in sea surface temperature (SST) and the intensifying conditions of precipitation, wind speed and alternating wind direction. The effect of phenology was evident as the NE monsoon was pronounced more influential than SW monsoon. In the event of tremendous loss of seaweeds in 2004, severe climatic disturbances were depicted. The seaweed resource was indeed important to ecosystem and socio-economic aspect. The deposition of the calcareous *Halimeda* spp. to coral reef formation was reported in 1994. The seaweed involvement to fish and invertebrate aggregation influence local fisheries production. Assessment in 1994 has revealed 76 mollusk species, 30 echinoderms and 7 crustaceans associated with algal beds. Test fishing in 2004 recorded 54 finfishes and some invertebrates from various fishing gears used. The local *Caulerpa* sp. was highly utilized as food source, although species loss was noted in the recent survey. In the past studies cited herein mentioned that the production of siganids and commercially-important macro invertebrates were attributed to benefits from seaweeds association. The issues and problems in the resource involved anthropogenic and natural stressors. Human interventions i.e. through fishing and transportation apparently contributed to resource depletion. Whereas seaweeds pose a critical role to local economy and ecosystem though subjected to adverse natural and anthropogenic impacts, resilient conservation effort should be made. Management perspective must consider dual-pronged approaches, vis-à-vis seaweed stock protection and habitat interventions reduction.

Key words: seaweeds, community structure, environmental factors, anthropogenic and natural stressors.

Introduction. Seaweeds were one of the highly diverse marine resources along with the Kuroshio Current that runs northerly from Philippines to Taiwan then eventually Japan region. Called as 'Kurose river' by the Japanese during Edo period (1603-1867), this current runs northward off Kochi comparable to a river where Philippines serve as upstream to Taiwan as midstream then Japan as downstream (Morooka et al 2008). Warm temperate and subtropical algal florae extend, along the Kuroshio and its branch currents (Okuda 2008). However, seaweed issues and trends varied from coast to coast in these countries involved. In the Philippines, Lagonoy Gulf in Bicol Region hosts a diverse assemblage of thallophyte to 55 species (Bonga et al 1995). Algal prevalence was noted mostly along Albay coast.

Distinctly, San Miguel Island is one of the notable sites covering about 3.6 km^2 intermixing seaweed and seagrass community. They were found both in the adjacent Rawis and Sagurong coastal barangays. Coasts of Barangay Rawis (13°24.88'N - 123°45.75'E) and Sagurong (13°24.43'N - 123°41.70'E) were both shallow, with sandy-muddy substrates. The establishment of the latter site as marine protected area (MPA) in 1997 was then known as San Miguel Island Marine Fishery Reserve and Sanctuary (SMI-MFR/S). Several typical coenocytic green algae (CGA) such as *Caulerpa* spp. and *Acetabularia* sp. were found. The local *Valonia* spp. that was first reported on its reproduction at cellular level (Camaya & Okuda 2009) was found with significant attributions to several ecological conditions including substrate and wave inferred to species seasonal occurrence (Camaya 2010). Along with the basic findings were rate of salinity (mean 35‰) and pH (mean 8.5) that have showed consistencies and remained within permissible level of the Class SC standard seawater limit. At this level, the water condition implied to be suitable for aquatic life propagation and maintenance of biological integrity (Philippine DENR AO 34, 1990 Series as cited in Camaya 2010). No adjacent river run off or any freshwater intrusion was present in the site while structural build up was fairly less.

For many years the island and the entire gulf became prominent study sites due to prevalence of interesting diverse species such as finfishes i.e. siganids and tuna, invertebrates, coastal habitats i.e. corals and many others (Soliman et al 2008a; Soliman et al 2008b; Nieves et al 2010). Studies have shown that local seaweed beds were home with associated diverse finfishes and macrofauna. Further they were critical determinants in the commercial fisheries production. Of the 480 fish species 131 or 27% are seaweed-associated or these fishes have utilized the seaweed habitat for juvenile settlement, refuge, breeding and feeding sites (Soliman et al 2008b). They added that, siganids as seaweed-bed thriving fish contributing 560 $mt\text{-}yr^{-1}$ to the total fishery production including 60 mt. juvenile catch. Likewise in 22 species of macroinvertebrates that were noted in the gulf, the highest was in Albay with biomass of 42.44 g/m^2 and density of 0.42 $individual/m^2$ (Nieves et al 2010).

However declining seaweeds ecosystem was evident due to several attributions which may have direct or indirect effect to the resource. Natural disturbances in macroalgal beds in the gulf include pollution and high siltation (Soliman et al 1997 and Bongga et al 1995 as cited by Mendoza & Soliman 2013). San Miguel Island's location on the eastern Pacific seaboard (Figure 1) originating from the Pacific makes it vulnerable to tropical storms, heavy rainfall and storm surge that eventually devastate coastal habitats (Nieves & Bradecina 2011). Likewise human perturbation within tidal flats such as gleaning activities (Nieves et al 2012 as cited by Mendoza & Soliman 2013), 'banca' or boat navigation, intrusions, illegal fishing activities and many others contributed further to seaweeds devastations and other benthic communities. Despite the successful MPA establishment in the island the incidence of poaching by illegal fishers from neighbouring communities had increased (Morooka et al 2008). With the increasing 79% poverty incidence, fishing is a way of life for the total of 5,932 inhabitants of the island (Nieves et al 2009).

Material and Method. This report analyzed the data on the community structure such as the species composition, frequency, cover, and biomass (B) of seaweeds in San Miguel Island based from the two (2) national comprehensive surveys in 1994 and 2004 and the main author's in-depth study in 2010. These studies in the past 16 years involved the Resource and Ecological Assessment (REA) project in 1994 done by the collaboration between the Bicol University College of Fisheries (former name of Bicol University Tabaco Campus) and International Centre for Living Aquatic Resources and Management (ICLARM), Post-Lagonoy Gulf Resource and Socio-Economic Assessment (Post-LG RSA) conducted in 2004 by the BUTC in partnership with Bicol Small Business Institute (BSBI) under the national program 'Fishery Resource Management Program' (FRMP) of the Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR), Philippines and the recent study adopted from the master's thesis of the first author in 2010. Further in this study the local issues on the resource were evaluated together with the changing trends in the environmental factors. The environmental factors with potential effect to algal productivity such as sea surface temperature (SST), precipitation and the wind were determined. Using database from National Oceanic & Atmospheric Administration (NOAA) (Earth System Research Laboratory - Physical Science Division) of the United States of America, the monthly mean values of these parameters were obtained (http://www.esrl.noaa.gov). Using the positional plots (10°N 15°N latitude; 120°E 128°E longitude), the data were obtained from NOAA Optimum Interpolation (OI) SST V2 (for SST), NCEP/NCAR Reanalysis I: Surface (for precipitation) and CDC Derived NCEP Reanalysis Products Surface Level (for wind). The data encompass the northern portion of island with proximity to the site. Further to compute for correlation with the established seaweed community structure, the Pearson's correlation coefficient was used.

Figure 1. Geographic location of San Miguel Island in Lagonoy Gulf, Eastern Philippines with the prevailing monsoon (modified from www.google.maps): (inlet) mean wind directions during SW monsoon in 1994 (yellow), 2004 (blue) and 2010 (red).

Results

Status of seaweeds. In Albay, the prominent seaweed ground was found in San Miguel Island (Figure 2). In Table 1, there were 31 algal species found from seven (7) orders of the three (3) major algal divisions. Mostly belong to Division Chlorophyta with 18 species while Division Rhodophyta has 7 species then the least was Division Phaeophyta with 6 species, respectively. During REA period, there were 23 species identified while only five (5) species were found in RSA. But in Camaya (2010) there were eleven (11) species that were known. Likewise around 17 species from the three divisions were conspicuously not found in the two succeeding periods where most of them were chlorophytes. No phaeophytes in 1994 which can be found in 2004 and rhodophytes as well in 2010. Over time, the green algae - *Halimeda* spp*.* dominated foremost the site where five (5) species were recognized. *H. opuntia* and *H. macroloba* were frequently noted in every period. Likewise, *Sargassum* spp*.* and *Neomeris* spp*.* were also commonly found in the site except in 2004. On the other hand, *Hormophysa trequetra* was the only alga in 2004 that was absent in 1994 as well as in 2010. While in the recent survey there were six (6) species that emerged. Most were chlorophytes by which one of them was *Valonia* spp*.,* a rare alga that was distinctly emphasized in the report of Camaya & Okuda (2009).

Figure 2. (R) Rocky algal substrate exposed during extreme low tide at the eastern 'reserve' area of SMI-MFRS.

Table 1

Summary of seaweed species composition found *in situ* from three (3) survey periods

Algal division	*Seaweeds species*	*Assessment periods*		
		1994	*2004*	*2010*
Chlorophyta	(Order Siphonocladales)			
	Caulerpa lentillifera	√	-	-
	Caulerpa peltata	√	-	-
	Caulerpa racemosa	√	-	-
	Chlorodesmis comosa	√	-	-
	Chlorodesmis sp.	-	-	√
	Codium sp.	-	-	√
	Dictyospheria cavernosa	-	-	√
	Dictyospheria sp.	√	-	-
	Halimeda incrassata		√	√
	Halimeda opuntia	√	√	√
	Halimeda macroloba	√	√	√
	Halimeda tuna	√	√	-
	Halimeda sp.	√	-	-
	Neomeris sp.	√	-	√
	Udotea sp.	√	-	-
	Valonia aegagropila	√	-	-
	Valonia ventricosa (Ventricaria ventricosa)*	√	-	-
	Valonia sp.	-	-	√
Phaeophyta	(Order Dictyotales)			
	Padina sp.	-	-	√
	(Order Fucales)			
	Hormophysa triquetra	-	√	-
	Hormophysa sp.	√	-	-
	Sargassum sp. 1	√	-	√
	Sargassum sp. 2	√	-	-
	Turbinaria sp.	√	-	-
Rhodophyta	(Order Ceramiales)			
	Acanthophora sp.	-	-	√
	(Order Cryptonemiales)			
	Amphiroa foliacea	√	-	-
	Amphiroa fragilissima	√	-	-
	Mastophora rosea	√	-	-
	Halymenia sp.	√	-	-
	(Order Gelidiales)			
	Gelidiella acerosa	√	-	-
	(Order Nemaliales)			
	Actinotrichia fragilis	√	-	-

* new genus for *V. utricularis* (Olsen & West 1988), "√" = present, "-" = absent.

In Figure 3, the successive graphs for the relative frequency (F) and cover (C) values of every algal genera were presented. The relative frequency is closely related index to density that may be interpreted as the actual count or number a certain species occurred in a plot. While the relative cover according to English et al (1994) as cited by Camaya (2010) was the estimate of the algal substratum covered in a plot with reference to frequency. However here F has no direct influence in C as in the subsequent data have shown. In the graphs from Figure 3, the F and C values among present seaweeds in 2010 were certainly outstanding than in 1994 and 2004. In both variables, large discrepancies by the latter survey over the two other previous periods had revealed. Apparently, majority of the species that previously occurred in the preliminary survey were of minimal rates. In terms of ranges, in REA the F-values (0.2-7.3) and C-values (0.1-7.0); RSA F-values (1.0-1.7) and C-values (1.0-2.0) while in 2010 the F-values (1.9-17.5) and C-values (3.1–13.5), respectively.

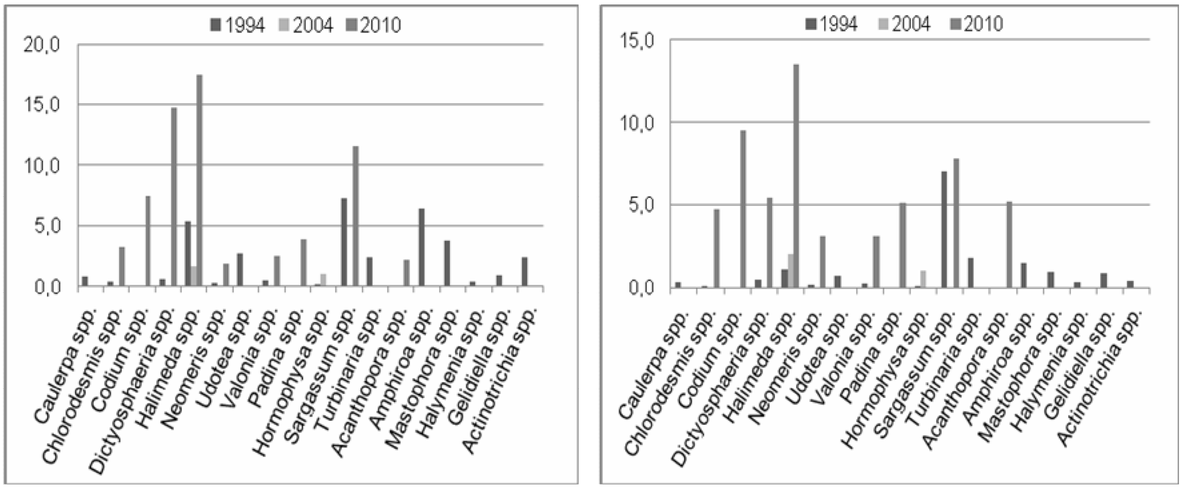

Figure 3. Mean relative frequency (left) and cover (right) of seaweeds resources in San Miguel Island.

Among seaweeds, *Halimeda* spp. was the most occurring yet the densest species having significant values in 1994 (F = 5.4; C = 1.1); 2004 (F = 1.7; C = 2.0); and 2010 (F = 17.5; C = 13.5). With its abrupt increment in the latter period, the species remain the dominant algal lifeform in the entire San Miguel Island. Likewise several chlorophytes such as *Chlorodesmis* spp., *Dictyosphaeria* spp., *Neomeris* spp. and *Valonia* spp. boosted in the latter period except in 2004. They were known as coenocytic green algae (CGA) which the latter species at cellular level was discussed briefly in Camaya & Okuda (2009). However *Sargassum* spp. which has similar condition was noted to be the most abundant alga in 1994 had just shown slight F and C increment recently compared with the other species. The alga appeared to obtain fair disparity within inter survey periods re: F = 7.3 (1994) vs. 11.6 (2010) and C = 7.0 (1994) vs. 7.8 (2010). On the other hand, somehow the F and C values of *Hormophysa* spp. in 2004 had also shown minor increase despite the condition of the site that time. Whereas newly recognized species such as *Codium* spp., *Padina* spp. and *Acanthopora* spp. were evident in significant values.

In terms of biomass or the standing crop unit measured by g/m^{-2} (Figure 4), this is commonly expressed as the dry weight of species that occurred in the given area at any one time (English et al 1994 as cited by Camaya 2010). Macroalgal biomass may vary depending on its bulkiness and biochemical composition likewise others are succulent species that may have lower biomass value than massive one. During 1994 assessment, the mean biomass obtained was 112.72 g/m^2. The first degree (1°) standing crop relative to the algal bed recorded was *Sargassum* spp. having 28.23% of the total algal population. This was followed by *Halimeda* spp. with 15.26%. Then in 2004, from the least species found the mean biomass rate was 35.22 g/m^2. This was shared mainly by *Halimeda* spp. with 64.91% plus *Hormophysa* spp. with 35.09%. Further in 2010, mean biomass had registered to 159.45 g/m^2. Certainly *Halimeda* spp. has significantly contributed much of 28.96% while *Sargassum* spp. with 3.28%. In the other hand, CGA`s such as *Dictyosphaeria* spp. slightly obtained 0.57%, *Codium* spp. with 0.35% as well as *Valonia* spp. with 0.47%, respectively.

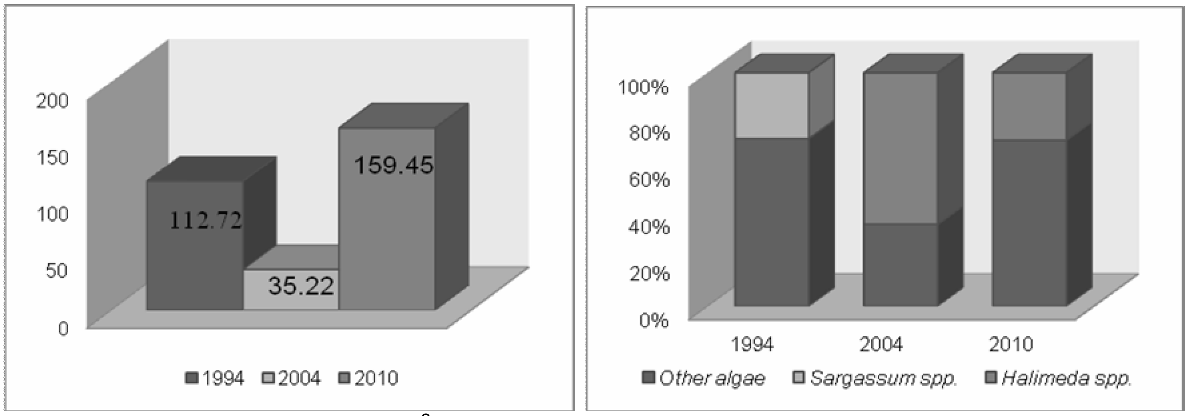

Figure 4. Mean biomass (g/m^2) (left) and ratio (1°) standing crop (right) of seaweed resources.

In Camaya (2010), the aspects of algal ecology and distribution in the SMI-MFR/S were discussed. The ecological examinations revealed that the water quality of the site remained within permissible level of the Class SC standard seawater limit. As per standard indication implied, the water was suitable for aquatic life propagation and maintenance of biological integrity. With regards to distribution, seaweed intermixed organization was noted where most of them were observed sporadically dispersed. Species like *Halimeda* spp., CGA`s and other algae preferred no specific zone where they can be observed within sandy to coralline substrates. Patchy areas in the reef portions had noted with monospecific occurrences of *Halimeda* spp. as well as *Padina* spp. However the *Valonia* spp. and *Sargassum* spp. were observed mostly at the subtidal area bordering down the floral bed within wave-swept reef front. The *Valonia* spp. population was commonly found attached in the crevices or on smooth surfaces of massive rocky and dead corals, living collectively with other macrophytes (Figure 2). However no such species was found within the sandy substrata which indicate its substrate preference.

Correlation of seaweeds and environmental factors. The seasonal condition of the environmental parameters such as the sea surface temperature (SST), precipitation rates as well the wind speed and direction encompassing gulf wide observation in the past 16 years was presented in this study (Figure 5). Addressing the prevailing monsoons, such factors provide insights of the past phenomenon useful in understanding its effect to algal productivity. The association of seaweeds abundance indicators to environmental factors detailed during northeast monsoon (NE) and southwest monsoon (SW) (Figure 1) were presented (Figures 6-8) while their correlation indicators were also determined. In most surveys, NE monsoon data collections were commonly done in February to April while during SW monsoon between August to October. Annually, both seasons have usual occurrence that may last to about 4 months.

a. Sea Surface Temperature (SST). The highest SST in the three surveys that recorded to 30.3°C had occurred within the SW monsoon. In contrast, the least happened in the NE monsoon of 2004 with 26.5°C. As noted, the mid-year months *i.e.* June to July obtained the warmest SST ranging from 29.5 to 30.4°C while January remains the coldest month having 26.5-27.1°C. The gulf had registered the highest mean SST in May (30°C) and the least in February (28°C) (Valmonte-Santos et al 1995). Normally the SST in the early semesters was relatively higher as the results of the past warm atmosphere in summer from April and May. Further, the SST semestral trend in the span of 16 years specifically in the NE monsoon had shown increment of approximately 0.2°C. This was shown in the graph where the trend line was slightly inclined in time (Figure 5).

As to seasonal pattern, the graphs indicated that SST in all surveys have shown direct associations with the seaweed frequency, cover and biomass values (Figures 6 to 8). Apparently as the SST increases, the rates in these variables tends also to increase. With this parallel response, apparently the fate of algal abundance rates may lie upon the revealing SST condition of the site. As depicted (Figure 6), where the relatively low F values during NE monsoon in 2004 was simultaneous to slight decline in SST. Whereas shortly in SW monsoon the increment corresponded with the gradual ascend in the SST rates. Likewise, the C values had portrayed related outcome from seasonal SST variation except for minor inconsistency in the NE season of 1994. In terms of biomass, the condition was also comparable with the cover with a discrepancy in later SW monsoon of 2004. In view of their empirical linkages, these three variables were perfectly correlated (Figure 9) to SST in all surveys with the coefficient values of r_{xy} = 1.0 (F); r_{xy} = 1.0 (C) and r_{xy} = 0.9 (B), respectively. This implied that seaweed seasonal productivity has robust relationships with the prevailing SST in the site by which the recent change was extremely evident. This report however does not indicate that all species involved may tolerate the current warming sea considering the loss of several species in the recent survey.

b. <u>Precipitation</u>. The representation of the over-all precipitation status has showed that some of the extreme incidences had occurred within the survey periods. The heaviest rainfall to a mean rate of 15.4 mm day^{-1} happened in the SW monsoon of 1994, while the least with mean of 8.0 mm day^{-1} took in the similar season of 2004. Likewise in the latter period, severe rainfall as well (ave. 5.1 mm day^{-1}) was noted. These were rather pertinent as compared from the reports done from the previous REA 1995 and RSA 2005 surveys. On the other hand, the recent precipitations status in 2010 was relatively low to moderate i.e. 1.6 mm day^{-1} (NE) 10.2 mm day^{-1} (SW). Based on the trend, both seasons have revealed unstable curves which indicated high fluctuation incidences of rainfall in the past. But in the event of projected cross-oriented pattern, such will likely to occur where gradual rainfall increase will be observed on NE monsoon while declining during SW monsoon.

Evaluating the attributions of precipitation to seaweeds abundance was pronounced as entirely contradicting event against the SST. As the graphs revealed (Figures 7-9), the community structure indicators have shown reverse outcome from the seasonal rainfall status in the past. Such as in NE monsoon of 2004 having the least seaweed production obtained in all surveys was associated with extreme rainfall incidences. In contrast, in 2010 survey which acquired the significant F and C values was then noted with the least precipitation rate. This was comparable to 1994 when the biomass stands out along with the rational precipitation rate. Nevertheless in the same year, the drawback in SW monsoon might be attributed to tremendous rainfall incidence. As depicted by their correlation indicators (Figure 8), most coefficients were perfectly negative values i.e. r_{xy} = -1.0 (F); r_{xy} = -1.0 (C); and r_{xy} = -0.9 (B) that have accounted for highly deviating inclination. Likewise the result directly implied that severe rainfall has contributed a dwindling impact to seaweeds productivity. The algal die off (Bonga et al 1995; Mendoza & Soliman 2013) was an evident response towards the seasonal occurrence of rainfall especially during SW monsoon.

c. <u>Wind speed</u>. As to wind speed, the year 1994 was noted with the highest rate of 4.7 m s^{-1} that happened in NE monsoon, while the least was in 2004 with 2.7 m s^{-1}. But the later period was then observed with relatively stronger wind during the succeeding season. In fact, the SW monsoon wind that is characteristically stronger had showed more fluctuation than the more stable NE monsoon. However the trend had showed the exchanging condition of these prevailing winds. The SW monsoon gradually slows while NE monsoon intensifies in time. In the site, August to December was typically windy months of the year. This may entailed to the influence of weather disturbances lying upon the typhoon season. The typhoon Durian's (locally known as 'Reming') destructive wind in the island was reflected as the monthly value had reached 8.2 m s^{-1}in December 2006. The graph showed that the site had usually experienced stronger wind in the early season while it became progressive on the succeeding term. Frequent strong wind condition had occurred in December 1998 up to January 1996 when they struck from 10.4 m s^{-1} up to 10.9 m s^{-1} as peak level. In contrast, the mid-year winds were also fluctuating compared in early summer and rainy seasons. The trend have shown opposing direction where the NE monsoon was observed gradually incline while SW monsoon bearing to waning pattern.

The monsoonal wind speed has shown deviating attributions against the abundance indicators as shown (Figures 6-8). During NE monsoon, the F and C as well as the biomass values were noted to be slightly inclined as the wind speed increases. The progress in these indicators may apparently link with the gradually intensifying wind in time. While during SW monsoon, these indicators were noted to be inversely proportional with this environmental factor. Such as when this monsoon wind eventually tends to weaken, the algal production was observed to become significant despite the worst incident in 2004 due to typhoon. Successive extreme winds were also perceived in December, 2003 that recorded with 8.9 m s^{-1} and February with 7.7 m s^{-1}. The revealing data from 2004 may only showed the repercussion of the past events. To prove the revealing link, in Figure 9 showed that the correlation coefficients of r_{xy} = -0.6 (F), r_{xy} = -0.8 (C) and r_{xy} = -0.4 (B) were mainly negative accounts which depicted contrasting response. However considering the deviating monsoonal attributes, the wind may pose both favorable and threatening impacts against seaweeds production. Since water movement and current are highly dependent on the prevailing wind, it should be considered that the geographical location of MPA is definitely exposed from NE monsoon and merely protected during SW monsoon. Abundance is therefore reversible depending upon the force from wind and associated wave it may produce.

d. Wind direction. Monsoons though literally refer to as the wind where they normally originate, characterize also their seasonality, nature and directions. In the site these two major monsoons that showed distinctive directions were described emphasizing its contribution to seaweed productivity. In Figure 5, SW monsoon was remarkably observed with highly descending fluctuation while the NE monsoon with relatively stable wind at ±60°. With the widest variation from SW monsoon that exhibited well disoriented tracks, may be attributed to the intervening intertropical convergence zone (ITCZ) due by the merging northeast and southeast (trade winds). Among survey periods, the wind direction in 1994 was extremely diverted at mean 277° lat. as compared lately in 2004 at mean 151° lat. and 2010 at mean 143° lat. This demonstrated an alternating westerly to southeasterly wind course in time (Figure 1). However with the northeasterly wind, the past trend has relatively low shifts ranging between 63°-60° latitudes. This rather corresponds with the typical NE monsoon path.

The established involvement of the wind direction towards the seaweeds abundance were indeed different from the wind speed. In NE monsoon, both F and C values were consistently inclined with the roughly stable wind direction except the biomass with the extreme descend in 2004. While in the SW monsoon, these three indicators exhibited similar responses against the wind flow. With the remarkable shift in 2010, recent abrupt algal production were noted with the dominant wind track along 143° lat. With the later position of wind track, the location of the MPA was somehow less protected than the typical southwesterly wind. On the other hand, although 2004 had almost congruent wind track, severe loss had occurred. In this case, such outcome may not be attributed to the direction hence to its intensity. Further as revealed in these opposing monsoon, seaweeds were apparently favorable with the northeasterly as well the as southeasterly winds.

Its correlation to biomass was determined approximately comparable with wind speed in this report. With the negative coefficients of r_{xy} = -0.6 (F), r_{xy} = -0.8 (C) and r_{xy} = -0.6 (B), they were mainly accounted with contrasting response. Associated with the speed, wind direction somehow may pose similar two-way impacts against seaweeds population. Seaweed definitely preferred exposed areas *i.e.* *Valonia* spp. which is known to thrived best within wave-swept zones (Børgessen 1913) for their proliferation rather than cove areas with extreme calm water. However such water movement must be optimal enough for them to tolerate considering their physiological susceptibility to natural disturbances such as strong waves due to typhoon. Seaweed production was indeed responsive to wind through exposure to water movement it produces by which the fate of their subsistence is inclined to seasonal circumstances.

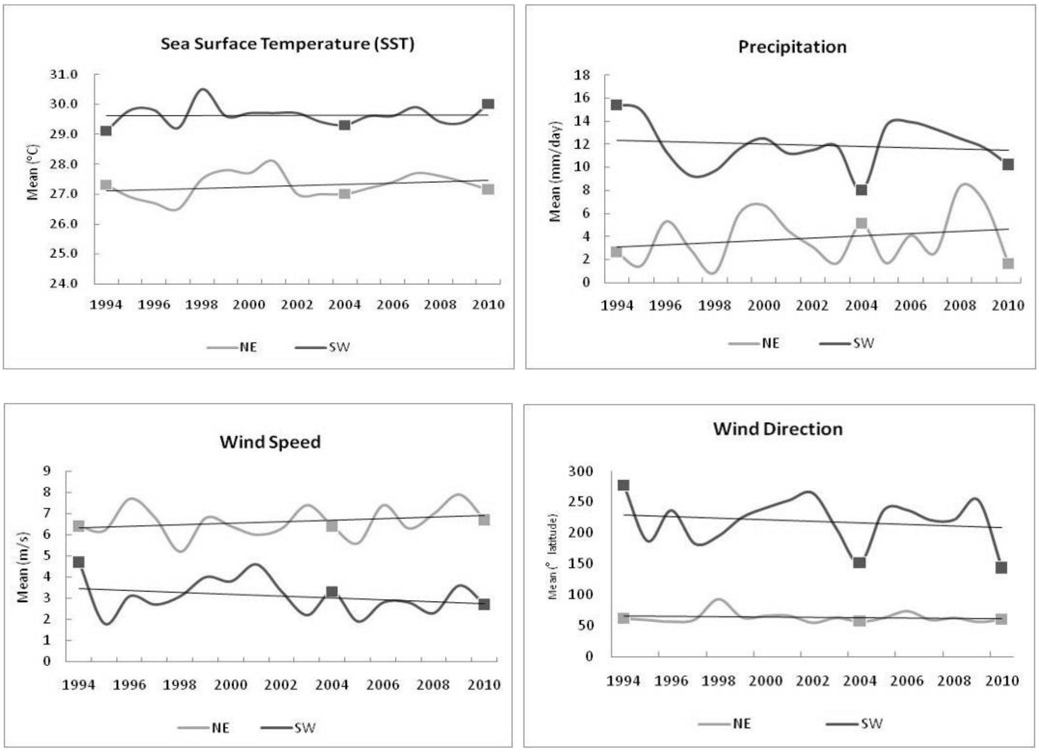

Figure 5. Monsoonal trend of environmental factors in the past 16 years emphasizing the 3 survey periods (dotted).

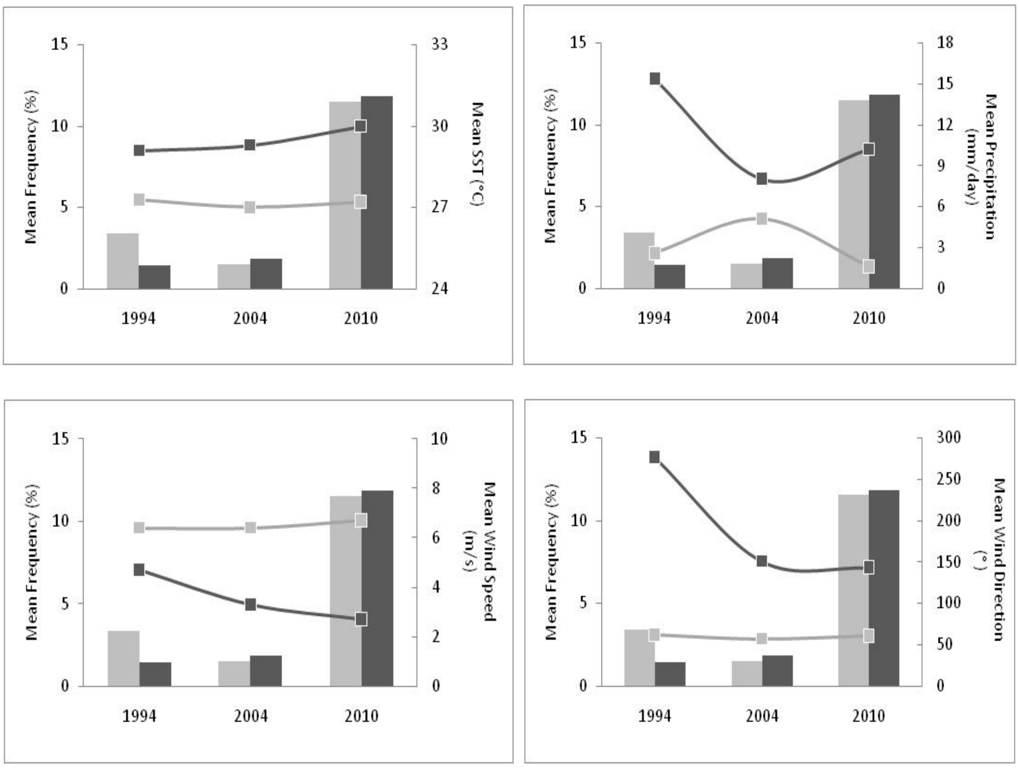

Figure 6. Monsoonal (NE and SW) seaweeds frequency (bars) associated to major environmental factors (marked lines).

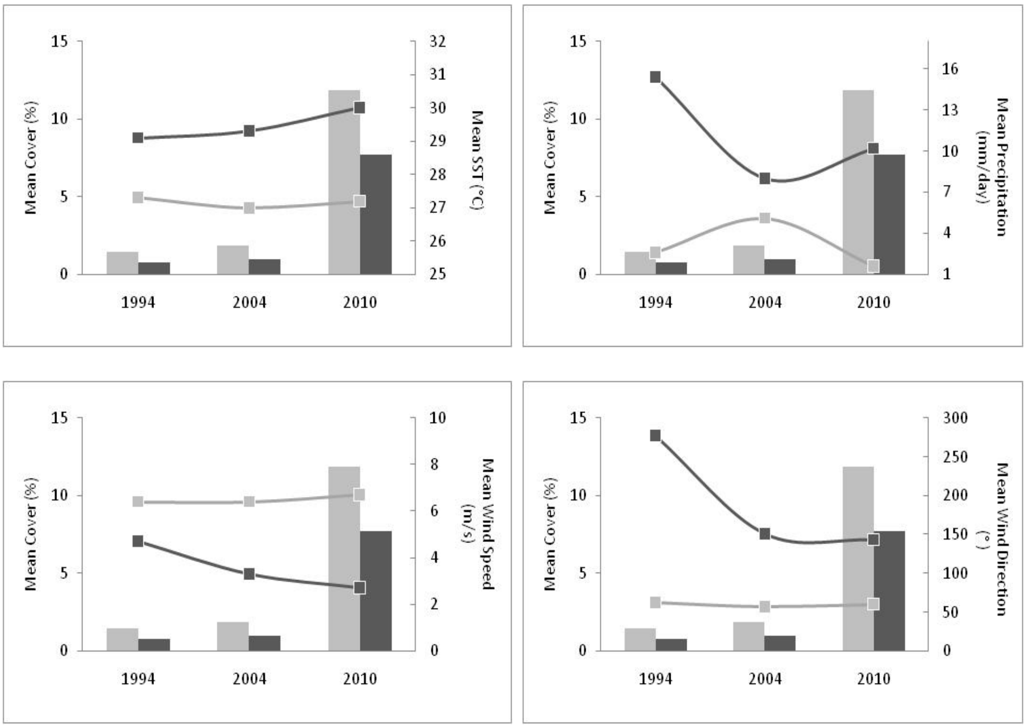

Figure 7. Monsoonal (NE and SW) seaweeds cover (bars) associated to major environmental factors (marked lines).

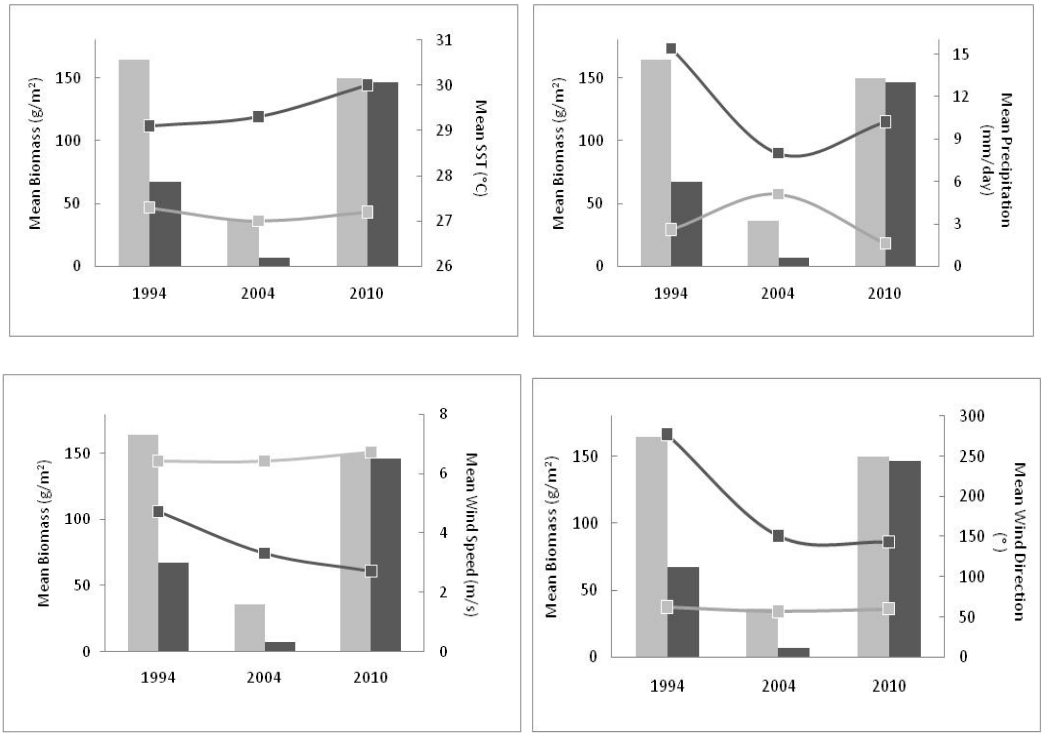

Figure 8. Monsoonal (NE and SW) seaweeds biomass (bars) associated to major environmental factors (marked lines).

Discussion. Revealing the seaweed status, its community structure has changed in the extent of less than two decades. In 1994, algal composition showed that 56.3% of the total number of species in the entire gulf can be found in the said area. Except the distribution which is pronounced heterogeneous in nature since then, the species composition had extremely declined so far to about 83.8% in 2004 then 61.3% in 2010. However 19.3% new seaweeds had emerged in the recent period. But to the extent of having such condition comparing in 1994, most recently found species were structurally massive relative to the bed space occupied. With the prevailing trend in species composition, the abundance of the present dominating seaweeds tends to increase which then ultimately altered the pre-existing species. This corresponded with the mean algal biomass that merely states the yield per unit area which recorded the highest value 159.45 g/m^2. This implied that simultaneous to recent seaweed productivity were the shifting species composition with the subsistence of some new species.

So far, the seaweed seasonal variation was noted. In the case of *Valonia* spp., its occurrence was observed to be affected by the prevailing NE monsoon in the early semesters i.e. in March (Camaya 2010). Most seaweeds exhibit seasonal differences in growth which are responses to environmental changes hence phenological difference may be expressed (South & Whittick 1987). Concomitant to this is the "die off season" which in Bonga et al (1995) and Mendoza & Soliman (2013) contributing to phaeophyte biomass decline in the gulf.

The condition of the dominant species in the bed remains over time and will likely to expand its distribution due to adaptation to changing environmental condition as discussed later. The *Halimeda* spp. solely endured with significant productivity in all survey periods. Attributed to its massive calcareous composition that obtained remarkable weight value, the species can resist the ever changing climatic condition of the site. The calcium component of *Halimeda* spp. comprises up to 90% of dry weight (Drew & Abel 1983 as cited by Bonga et al 1995). Likewise together with the *Sargassum* spp. they both contributed substantially to the standing crop. They almost shared equal proportion as 1° standing crops relative to the bed of their respective period covered in 1994 and 2004. The latter species was highly noted in 1994 compared in the 2010 but completely missing in 2004. Although it possessed bulky structure, the total mass of the living matter of this species was relatively low. Some associated macrophytes had showed also similar characteristics. Some coenocytic green algae such as *Valonia* spp. and *Caulerpa* spp. for instance, in spite of their succulent properties they obtain very low standing crop when extremely dehydrated.

As to distribution, most seaweeds were found to dwell most within shallow tidal and reef flat. The growth of seaweeds in the sublittoral is far richer in the intertidal areas (Mann 1973). Algal population were pronounced unevenly distributed due to anthophyte co-existence thus heterogeneously intermixed. Algal zonation was largely determined by space competition and that interactions between macrophytes were more important than predation in delimiting zones (South & Whittick 1987). Dominant species like *Halimeda* spp. thrived in the broad range of substratum types within no specific zone. However algal infringement in the deeper bed to reef area forming rockweeds was noted. In Soliman et al (2008a) recently there was relatively high algal cover in the reef areas of the MPA's in Albay that may have impact to coral recruitment and growth. Likewise this was noted by occurrences of macroalgae assemblages over dead corals and rocky substrate. In Camaya (2010) the *Valonia* spp. and *Sargassum* spp. on the other hand were evident in distinct portion of the site where they exhibited well-defined zonation pattern. Most seaweeds are restricted to the fringes where the substrate is sufficiently stable to permit their attachment (South & Whittick 1987)

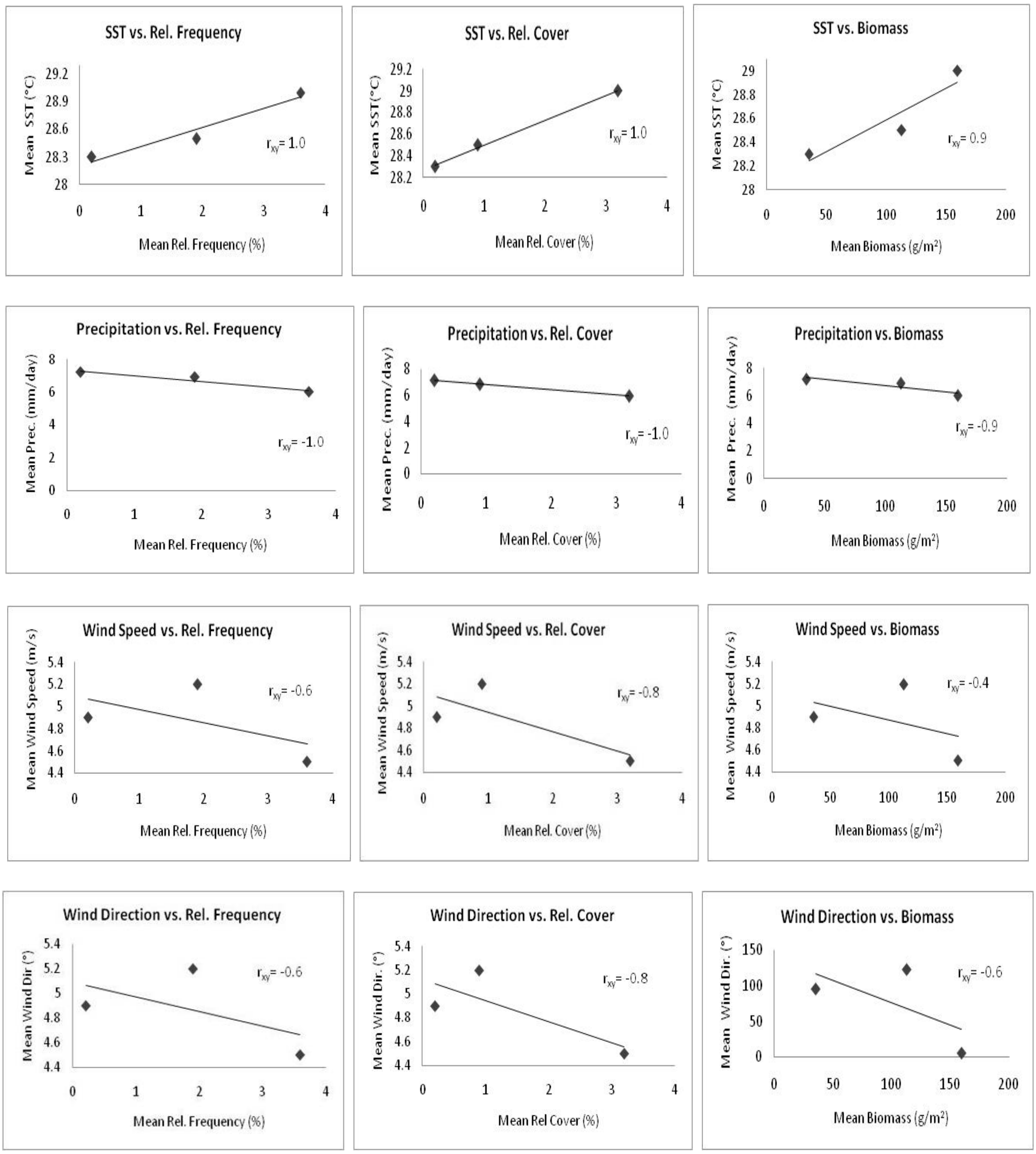

Figure 9. Correlation (Pearson's coefficient values) of seaweeds community structures (x-axis) against the major environmental factors (y-axis).

Effect of environmental factors in the seaweed community. Recently there are numerous studies on the issues in the seaweeds composition and abundance due to changes in the environmental condition related to changing climate. In this report the four important environmental factors were emphasized to prove their involvement to seaweeds community in the island in the past 16 years. In all surveys our findings showed that the prevailing weather conditions during NE monsoon were more influential to these organisms than in SW monsoon. Seaweed production is highly dependent on the growth of the species which in turn is highly influenced by monsoons (Trono 1990). The low abundance rate of *Sargassum* spp. was attributed to senescence and die-back stage in August while its peak came in May (Bonga et al 1995; Mendoza & Soliman 2013). Here, our query otherwise relate, if monsoons are recurrent why does seaweed productivity changes from time to time? How far do changing environmental factors affect them?

Evaluating the SST factor, in the span of 16 years an increment of approximately 0.2°C in the SST was pronounced in this study. This was comparative in southwestern

Japan where a large increase of 0.3°C/decade was determined in the annual mean SST in the past 40 years (1970 to 2010) (Tanaka et al 2012). However the gradual sea warming has ecological effect to thallophytes species. In Haraguchi & Sekida (2008) and Tanaka et al (2012) the decline of the species composition among common temperate *Sargassum* spp*.* then subsequent takeover of dominant tropical species in Tosa Bay was due to recent increasing water temperature along with flow from 'Kuroshio current'. Similar condition occurred also with *Ecklonia* sp. where its population fluctuation in response to changing SST was noted while lowering distribution was attributable to same phenomenon (Tanaka et al 2012). Likewise in Ugarte et al (2009), the changes in the composition of *Ascophyllum nodosum* bed by the increase in biomass of *Fucus vesiculosus* from 2004 to 2008 in Canada was also attributed to warming seawater.

In the present study, findings had showed that the progress in the seaweed community structure has parallel response to the gradual sea warming of the gulf. Corroborating these algal abundance indicators showed that the recent survey in 2010 were indeed significant than in 1994 and 2004 associated with this incidence. In fact, the minor seaweed production from the earlier surveys such as in 2004 was concomitant to relatively low SST rates. Entirely this assumption was established with the revealing highly positive correlation coefficients between these defining aspects.

On the other, the inclination as well of seaweeds towards the seasonal trend in SST was evident with the substantial effect by the NE monsoon. In spite of this leaning means, the thermal preference of these organisms was apparently observed. This was established in seagrass *Enhalus acoroides* with an increase of 1.8 mm day^{-1} on leaf growth with an increase of 1°C in water temperature (Brouns & Heijs 1986 as cited in Bonga et al 1995). In this study, the abundance indicators were relatively higher with the extremely low SST increment during NE monsoon rather than in SW monsoon with the fairly advanced rise in SST. The SST increment in NE monsoon was approximately 0.4°C while in SW monsoon was 0.3°C. In fact the seaweeds production in the site was significant with the SST rates noted from 27.2 to 27.3°C.

In terms of precipitation, high fluctuations were observed in the two prevailing monsoons but had changed dramatically. The SW monsoon that is commonly characterized with severe precipitations than NE monsoon was noted with gradual decline as the later intensify. Addressing the continuous seasonal SST rise with such rainfall condition poses a disproportionate manner in time. However considering their correlation distinctive from SST, seaweeds respond conversely against the rainfall with the high negative coefficients. The fact that the seaweeds during SW monsoon were relatively poor compared in NE monsoon, this essentially revealed the direct effect of rainfall to the organism. Further the prevalence of most storms in this season associated with heavy rainfall was largely considered (Buella et al 2005). Extensive precipitation rate in the gulf may affect basic properties of seawater that may limit seaweed productivity. Likewise incidental to rainfall is the increase in volume of land and river runoff (Bonga et al 1995). In Martins et al (1999), the growth rate of the estuarine *Enteromorpha intestinalis* was mainly affected by the seasonal precipitation. High precipitation cause low growth rate in the species which the event was mainly attributed to low salinity level hence this factor was pronounced important parameter to control the growth of the alga.

The wind speed had also shown obvious divergent trends in the both seasons in the past. The wind speed tends to rose during NE monsoon while it weakened during SW monsoon. The wind speed may indirectly influence seaweed, but roughly influence the condition of wave it may produce. With that monsoonal wind speed condition, related influence in the seaweed status was noted in the site. The seasonal variation in seaweed production means an adaptation of pre-dominating species to shifting wind speed causing high exposure to water motion during NE monsoon while heavily protected due to calm water on SW monsoon. The wave motion supports seaweed growth rather than extreme calm or cove water which allows superficial suspended materials. Wave action is generally considered an important factor in distribution and abundance of intertidal organisms (Vadas et al 1990 as cited by Coelho et al 2000) but limited to optimum water force. In Engelen et al (2005) wave exposure exhibited considerable effects on biomass and density of *Sargassum polyceratium* which thallus size was bigger and population structure was higher in more exposed bays than calmer water. However he added that in most macroalgae the size and biomass had reduced with the increasing wave exposure.

The later was likewise congruent with the species in the present study such as those correlation coefficients that have depicted negative attributes in most surveys. The wind speed has no direct effect against seaweeds but it was the extent of wave that may indicate further impact to the organisms. Seaweeds are one of the highly vulnerable species to wave which some has relatively tough physiological properties. It has to be considered that in 2010 though more productive than in 1994, was noted with lesser species while the later was highly dense by some dominating algae such as *Halimeda* spp*.* This was similar with the extremely poor structure of 2004 while this calcareous species chiefly stands the seaweed bed.

Pertinent to wind direction is the monsoon prevalence to a certain site. As discussed earlier, the deviation in the courses between monsoonal winds was evident in the entire duration of seaweed surveys particularly in the NE monsoon. In this condition, such change was associated to seaweed abundance. Merely the stable northeasterly wind was noted more conducive to seaweeds than deviating westerly or southeasterly winds of SW monsoon as revealed in the seasonal productivity indicators. On the whole, their negative correlation coefficients presumably imply for the indefinite inclination of seaweeds towards highly shifting wind directions. However, seasonal correlation may reveal the major discrepancy between monsoons as evident in the data incurred.

Upon the location, normally the island experienced rough seas during exposure to NE monsoon while calm in the opposite SW monsoon. Incidental to this wind direction is the gradual increase in the wind speed in the earlier season which along with the increasing wind speed is the increasing exposure to wave. Pertinent to this event has significant effect to the subsistence of the pre-dominating algal species in the island. Likewise this was associated for the higher algal frequency, cover and biomass rates in NE monsoon than the calm water during SW monsoon. This corresponds as well with findings of Engelen et al (2005) as mentioned earlier. In Oliver & Babcock (1992), Petersen et al (1992) and Pearson et al (1998) as cited by Coehlo et al (2000) seaweeds reduce the success in fertilization with the change in current direction and water velocities. The later seem to be relevant in the present study mainly on our findings with SW monsoon.

This study proposed that the changing seasonal intensities of the environmental factors such as SST, precipitation and wind poses significant effect to the community structure of the seaweed. We further assumed that species in the recent period may have greater tolerance to impact from these factors that evolve in time. Comparing the early surveys, the decline in the recent species composition by which either some remain or may have been altered by the newly emerging species were comparatively dense and productive. The present findings considerably in agreement with that of Rice & Chapman (1982) as cited in South & Whittick (1987) which changes in biomass and survivorship of brown seaweed *Chordaria flagelliformis* was characterized with the decrease in number of individuals that were correlated with an increase in biomass of individual plants.

On the broader sense, this study considers the fact that the seaweeds demonstrated seasonal variation in occurrence and abundance, this event is highly address to the influence of phenology by which the extent of its associated factors varies eventually. As seaweeds exhibited phenologic differences as response to environmental changes, this differentiation may be expressed morphologically or in reproductive status (South & Whittick 1987).

Local issues of seaweed resource*.* The seaweed association with macrofauna i.e. fishes and invertebrate communities certainly influence local fisheries production. In Bonga et al (1995) reported that in San Miguel Island there were 76 mollusk species, 30 echinoderms and 7 crustaceans found associated with algal beds. Besides, most of them are commonly used as food and as raw materials for the shellcraft industry. There was slight increase in the population of fishes inhabiting seaweed beds of the island (Soliman 1999 as cited by Morooka et al 2008). Likewise in 2004, test fishing within the bed area has been employed to survey the faunal associates. The catch composition revealed at least 54 finfishes and some invertebrates from various fishing gears used. One of commonly found fishes was the highly commercialized Siganids spp. by which the site is notable for diverse and vast production that were homed by juveniles in certain period during summer (Soliman et al 2008b). There were 14 (fourteen) species of siganids in the entire gulf, which 90% of its juveniles them can be found in the island. Seine net (locally known as 'sapo-sapo' or 'bitana') fishers in the gulf can catch about 66-175 mt/yr of siganid juveniles in one season. In a particular incidence called as 'dinagsaan' (may refer as 'flocking'), the thalli of dominant seaweeds were characterized with structural defenses to herbivory, which suggested that the area is regularly subjected to herbivory because the seaweed community reflects on it.

In the assessment of the macro-invertebrate gleaning practices in the island, there were twelve (12) species of which five (5) were regularly found that constituted mainly of mollusks, crustacean, sea urchins and sea cucumbers and few edible sea anemones (Nieves et al 2010). About 37.2% of these organisms can be found in the seagrass-seaweed beds. To most fishers, gleaning contribute largely to their livelihood as source of income and food for the family.

On the other hand, some of those seaweeds found in 1994 were commercially utilized species like *Caulerpa lentillifera*, *C. racemosa* and *Gelidiella acerosa.* These species were reported as three of the most commonly utilized food in the Philippines (Trono 1999). Locally consumed as raw food, *Caulerpa* spp. was sold daily in the wet market. Recently, the price of this had increased due to supply and demand issue (Figure 10). Apparently the loss of *Caulerpa* spp. as highly consumed food demand for the local community perhaps because of over harvesting in the site. The excessive extraction of these species may affect growth recovery. Harvesting from natural stocks, usually the practice in most developing countries is unreliable, hence efforts thus be directed towards actual farming of seaweeds (Trono 1990). In addition, the absence of a management program for the naturally produced species often results in the depletion and/or destruction of natural stock due to over harvesting. At present no *Caulerpa* culture projects yet was being established in the enter province. In Batan Island, Rapu-rapu, Albay (Figure 1), the seaweed farming were mostly on *Eucheuma* spp. and *Kappaphycus* spp. (Nieves et al 2008). However, introduction to inland seaweeds farming particularly for *C. lentillifera* may require financial as well as capability building for the community as adaptive sustainable livelihood. Seaweed farming is not only reliable but is also a very efficient way of conserving local stocks (Trono 1990).

Figure 10. Fresh *Caulerpa* spp. harvested from the adjacent island sold at the local market (Photo taken by A. P. Camaya).

Moreover, the seaweed-based dynamics influencing adjacent coral reef communities in the site was reported in Bonga et al (1995). The indication of their significance in the reef ecosystem of the site particularly the *Halimeda* spp. was likewise discussed due to evident deposition of calcareous substrate. In Bonga et al. (1995), the latter species was indicated with substantial contribution to standing crop hence highly incorporated to coral reef community of the island. As been individually observed during the course of reef surveys in 2004 as well as in 2008, most reef sites established as MPA's in the entire Lagonoy Gulf were commonly noted with significant prevalence of the said species. In 1994 study, island reef areas such as San Miguel Island, Agojo, Bitaogan and San Pablo described as coral-seaweed associated sites were highly endured with *Halimeda* spp. Carbonate sediments from calcareous algae contribute in growth and productivity of the reef ecosystem and that of formation of low islands (Doty 1971 as cited in Bonga et al 1995).

There were several factors that influenced seaweed bed of the island. These were implications of natural and socio-economic elements which transformed it to its current condition. On the brighter side, the establishment of MPA seaweed beds and other benthic organisms were potentially protected. In fact the continued investigation of the latter local academe suggested that this resource management scheme resulted to fair improvement of seaweed bed cover and fish biomass, likewise a dynamic method for protecting the coastal environment (Morooka et al 2008). However despite the existing regulatory measures, human intervention had been never eased totally. Open transport accessibility, illegal fishing incidences and other extractive activities were common issues.

As to natural factors, the coastal habitats vulnerability to severe east-originating calamities such as tropical storms mainly affected it. Particularly, the Typhoon Durian's extreme devastations in 2006 had brought massive destruction in the island. This has triggered strong surge and coastal landslide. Likewise shoreline erosion and sedimentation were evident resulting to lowering algal density and community structure. Sand and sediment associated with water movement are major agents of disturbance as storms overturn boulders and move sand onto and off beaches (Coelho et al 2000). The exposure of San Miguel Island to climate-related disasters like tropical storms and cyclones, coastal habitats are the hardest hit (Nieves & Bradecina 2011). Beside siltation occurred in the area. In Camaya (2010), patchy floral distributions were observed recently in the site where partial sandy substrate onto the front ward portion of the bed was evident. In Nieves & Bradecina (2011), the varying degrees of changes on intertidal zone were due to shoreline erosion and sedimentation. High siltation in the entire gulf contributed to macroalgal degeneration (Mendoza et al 2003, Mendoza et al 2000 and Bonga et al 1995 as cited in Mendoza & Soliman 2013).

On the other hand, deterioration may be attributed to anthropogenic perturbation. During low tide, fishers and commuters used to pass along the tidal flats to ride onboard. There is no definite docking area along the coast stretch. Apparently in has been observed that motorized fishing as well as passenger 'bangka' (fishing boat) abound the site. In the daily operations of estimated 200 fishing boats in Bgy. Sagurong alone (Morooka et al 2008), local inhabitants from 600 households has immediate access rather to use the nearby seashore. On the other hand, increased incidences of illegal fishing such as poaching after MPA establishment and other extractive activities were reported.

Evaluating the condition of seaweed resources in San Miguel Island revealed hint as to how far local fisherfolks valued this resource. In fact it has been observed that many inhabitants seem to be unaware while they may overlook the extent of importance of seaweeds to their daily life. With this contribution, this provide basis to sustain the resource despite the inevitable anthropogenic pressure and natural stressors that seaweeds must deserve to be managed.

Addressing the current status of the San Miguel Island in the global-scale seaweed issues is a considerable mechanism towards dealing with common problems this resource facing within the 'Kuroshio' region. In the midst of ever changing climate and widespread human pressure on seaweed ecosystem, dynamics of co-management from coast to coast must be enhanced towards rational resource sustainability. The Japan`s serious causes of seaweed beds deterioration were attributed from various reasons i.e. recent SST increase affecting *Sargassum* spp. (Haraguchi & Sekida 2008) and fucales and laminarians (Tanaka et al 2012). The loss of tidal flats due to reclamation projects and ‘isoyake’ (also called barren grounds or coralline red algae take over) are also critical events (Okuda 2008). The recovery plans have been carried out however harmonious coexistence between human and nature is foremost solution towards sustainable resource conservation.

As key information revealed, indication of critical decline in the near future may occur hence management effort must be provided as basis to sustain the resource. The perspectives of seaweed management scheme should consider dual-pronged approaches, vis-à-vis seaweed stock protection and habitat interventions reduction. The coastal environment is an open-access resource which can be used by everyone as much as they like, thus prone to destruction by excessive use (Morooka et al 2008).

In the case of MPA policies implementation in San Miguel Island, local protective practices focuses mainly on fishery regulatory aspects *i.e.* prohibited fishing activities. While fishing is being regulated, other intervening factors must also be reduced. The transport system *i.e.* ferrying commuters who used to pass along shallow seagrass and seaweed beds poses destructive effect to seaweeds and its natural habitat that hamper their potentials to grow and develop to full extent. The shallow seashore of Sagurong and Rawis during high tides are used as a navigational lane (Mendoza & Soliman 2013), that have direct effect to benthic organisms. Boat navigation was one of the degenerative contributing factors to macroalgae in Lagonoy Gulf (Mendoza et al 2003; Mendoza et al 2000 and Bonga et al 1995 as cited in Mendoza & Soliman 2013). So as to address, transport system must be placed in order such as that designated wharf must be established to minimize intrusion onto the shallow coast. Likewise other traditional fishing activities occupying the bed zone such as seine net during ‘kuyog’ (juvenile siganids) fishing, gleaning, and other should be sustainably prohibited.

Furthermore, the dwindling seaweeds production was largely attributable to natural stressors occurrences such as tropical storms. Seaweed-based resource scarcity due to increasing threats from catastrophes from the frequency to intensity was at alarming state. In the event of storm surge brought by east-originating tropical storms in the eastern Bicol region as noted in late 2003 to early 2004, seaweed beds in the island were at high risk to damage. These events are disturbances that destroy seaweeds (Camaya 2010; Lobban & Harrison 1994 as cited by Coelho et al 2000). Seaweeds morphological aspects reflect problems of growth and mortality hence these organisms on high energy shores experience high breakage and mortality (Vadas 1979). Water motion is a major cause of seaweed mortality (Coelho et al 2000) most likely during storm surges. Further the latter added that increasing storm frequencies decreases seaweed species to reproduce.

Understanding the impact of the changing environment in the context of research and development, would be significant tool towards resiliency and risk reduction. Engaging various community sectors to enhance awareness and capability-building efforts are necessary. In the socio-economic dimension, fishery management should therefore be directed to climate change adaptation to mitigate further risks from resource depletion. Management strategy would thus require effort rationalization on the one hand complementary to habitat enhancement on the other hand, however livelihood for fisher families should be provided to shock absorb the effect on displacement from fishing (Soliman et al 2008b).

Seaweed extractive methods from the natural stock must be reduced. On the other hand, resilient livelihood technology such as protective or inland seaweed farming for economically-important species adaptive to natural stressors should be promoted to have sustainable utilized raw materials. Evaluating livelihood opportunities in the gulf, the seaweed mariculture is the promising activity owing simplicity, affordability and capacity, thus fits well fisher`s resources and capacity (Nieves et al 2008). As natural field, seaweed farming may potentially be established in the site such as the highly consumed *Caulerpa* spp. and other species. In particular, *C. lentillifera* is one of the highly cultivable species among group of food species in the Philippines (Trono 1999). Likewise he added that gathering from local stocks as seedlings the production of *C. lentillifera* is mainly through pond and open lagoon cultures. Alongside the culture system is the technical know-how to be considered precedent to establishment.

In addition to address from global options, the possibilities on promoting intensive seaweed growth in integrated aquaculture or IMTA as potential solution against global warming had existed (Turan & Neori 2010). This combines the cultivation of fed finfishes with extractive shellfishes and seaweeds for an ecologically balanced aquaculture. IMTA may include the locally found seaweeds species in the gulf such as *Caulerpa, Gracilaria, Eucheuma, Kappaphycus* as well as *Sargassum.* In the past there was increasing trend that integrate seaweed culture with other organisms particularly mollusks (Qian et al 1996 as cited by De Silva 1998). However in Chopin et al (2001) such integrated seaweed aquaculture system should undertake much research and development concerns. This will include transfer and modification of cultivation to local technologies and socioeconomics; development of cultivation of native marketable species that will be fast growing at different times of the year and in diverse habitats; site-specific biological, physical, chemical and socioeconomic modeling to define appropriate proportion between co-cultured species; and development of regulatory and legislative management framework.

The fact that the severe makeover in the seaweeds community structure due to climate change is inevitable in the near future, urgent response must be considered. The move on how and when the mitigating efforts will be made lies upon the local constituents. Management options that will fit into the seaweed ecosystem in the island and along 'Kuroshio' region might be independent from one another hence the success may vary.

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Authors:
Alex P. Camaya, Coastal Resources Management Unit, Bicol University Tabaco Campus, Tabaco City 4511, Albay, Philippines, e-mail: lhex3479@gmail.com
Victor Soliman, Coastal Resources Management Unit, Bicol University Tabaco Campus, Tabaco City 4511, Albay, Philippines, e-mail: vssoliman@gmail.com
Antonio B. Mendoza Jr., Coastal Resources Management Unit, Bicol University Tabaco Campus, Tabaco City 4511, Albay, Philippines, e-mail: antox2002@yahoo.com
Kazuo Okuda, Graduate School of Kuroshio Science, Kochi University, 2-5-1, Akebono, Kochi 780-8520, Japan, e-mail: okuda@kochi-u.ac.jp

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