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REVIEW

Seaweed Biodiversity and Temperature Fluctuations of Calatagan Bay, Verde Island Passage

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ABSTRACT

Changes in seaweed biodiversity reflect ecological changes and management of coastal communities. Calatagan Bay is a tourism, agriculture and aquaculture hotspot fronting the Verde Island Passage, touted to be the global center of marine biodiversity. Detection of stressors through monitoring is the key in the proper management of the area. This study surveyed existing seaweed species of the coast, and contrasted it with reported species in the area together with fluctuations in sea surface temperatures for the past two decades, contrasted with the local knowledge and perspectives of local coast-dwellers. Seaweed along the coast were collected from a representative area of 50 km2 with species identification based on morphology and pigment. Ten species that were previously unreported were found while fourteen previously reported species were no longer observed. *Caulerpa*, *Kappaphycus* and *Sargassum*, all with known market demands, were the dominant genera. Sea surface temperature data from local weather stations and the NOMADs database indicate significant warming events from June 1998 to present, with peak sea surface temperature at 31.9oC. Focused group discussions with local communities indicate increased incidences of ice-ice disease, and issues with the uncontrolled use of fertilizers of neighboring farms contaminating their coastal fronts.

1. Introduction

Seaweeds are macro benthic marine algae that contribute in the marine primary production on the shallow portion of seas and oceans while providing habitats for benthic communities[1]. Seaweeds are named after the dominant photosynthetic pigment, which could be red, brown, green and blue-green algae[1]. Underwater, it is distributed from the lower intertidal to the shallow subtidal zones of the marine environment. Their ability to adapt to the condition of the habitat results to the differences in their vertical and horizontal distribution. Thus, some species are only seen in the sheltered bays and coves while some are limited to the rocky exposed along the shore or margins of the reef.

Several species are found in a variety of intergrading environments. The presence or absence of species in a habitat is therefore the result of the combined and synergistic effects of various physico-chemical factors[1]. A major contributor to the species success and abundance is sea surface temperature[2]. Changes in subtidal vegetation, including increase in morphologically simple warm water

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varieties as well as expansion of non-indigenous species have been noted in waters that have experienced at least 1^{o}C of warming[2-4].

Due to its strong market potential and high market importance, seaweed farming in the Philippines accounted for 69% of the total aquaculture production[5], making it an important economic activity to lessen poverty in the rural areas. In 2016, the Department of Environment and Natural Resources identified Calatagan, Batangas as one of the potential farming sites for seaweeds with its existing biodiversity in macroalgae (Table 1). In the almost three decades of studies documenting the biodiversity in the area, recorded threats included substratum loss[6], low irradiance and low salinity in certain sites where farming was being considered[7], fungal contamination and disease[7-9], and increase in sea surface temperature due to climate change[7-11]. Records of existing species are also limited by the scope of the studies performed and the most recent assessment of biodiversity in the area was done in 2012[12]. It was noted in this study that research on seaweeds has transitioned to applied and commercial applications. It has also resulted to alterations in biodiversity brought about by efforts to contribute to the seaweed trade and industry.

Table 1. Published reports on found seaweed species in Calatagan, Batangas, Philippines

Species	Reports of incidence
Caulerpa lentillifera [10,13]	1999; 2014
Ceramium mazatlanense [9]	2017
Eucheuma denticulatum [13]	1999
Gayliella flacida [9]	2017
Gelidiella acerosa [13]	1999
Kappaphycus spp.	
K. alvarezii [9,11,13]	1999; 2016; 2017
K. striatum [7,11]	2010; 2016
Sargassum spp.	
S. siliquosum [8,10,14]	1985, 2006, 2014
S. paniculatum [8,10,14]	1985, 2006, 2014
S. abbottiae [8]	2006
S. baccularia [8]	2006
S. cinctum [8]	2006
S. crassifolium [8]	2006
S. cristaefolium [8]	2006
S. feldmanii [8]	2006
S. gracillimum [8]	2006
S. hemiphylum [8]	2006
S. ilicifolium [8]	2006
S. kushimotense [8]	2006
S. oligocystum [8]	2006
S. polycystum [8]	2006
S. turbinaroides [8]	2006

In this study, sea surface temperatures from 1985 to present were mapped and compared with rapid biodiversity assessment of seaweed species in towns along the Calatagan coast facing the Verde Island passage to test if observable warming in the coastal waters of the area has occurred and if this has affected the species present in the region. The data collected were supplemented by focused group discussions with local experts, seaweed farmers and occupants of households fronting the coast to assess other perceived factors that affect the growth and trade of seaweed in Calatagan, Batangas.

2. Methods

2.1 Collection of Materials and Species Identification

Initial collection of macro algae was coordinated with the local community via the Seaweed Farm of ELFARCO. Sampling took place from September to November, where the southwest monsoon is affecting the coast. This study was unable to survey existing species during the northeast monsoon. Preliminary collection was performed with the assistance of a local diver at 13.81667 N and 120.60357 E. Additional sampling was performed at 13.83991 N and 120.59661 E, 13.84748 N and 120.58719 E, and at 13.85542 N and 120.59405 E. A 2-km radius from the deployment point was done to search for isolates. All samples encountered within 360^{o} of a circle with a 2-km radius were recorded and three to five representative samples were collected per putative species. In the absence of a clear reference to set expectations for existing algal typologies in the area, different morphologies were used as basis for collection but no quantitative method for abundance was performed. Additional samples were taken to verify the preliminary species identification, especially for samples with highly similar morphologies, to accommodate for histological analysis in the laboratory. The isolates were gathered for local identification and compared in the standard collections archive of seaweeds by the farm (Figure 1). qGIS software was used to map the species of seaweed collected along the coast per genus[15].

Figure 1. Sampling sites along the Calatagan beach fronting the Verde Island passage

2.2 Morphological Analysis for Species Identification

The collected samples, upon return to the laboratory, were analysed based on morphological characters. The analysis utilized discrete and continuous characters of the sampled organisms. Species identification was done based on morphological traits. The morphological traits included the characters of the frond, gas bladder, stipe, blade, & holdfast[16]. Verification of species identification was performed by experts from ELFARCO and the Philippine National Museum of Natural History.

2.3 Collection of Temperature Data and Tracking of Temperature Changes

Sea surface temperatures (SST) of the area from 1985 to present were collected from the NOMAD database[17]. Ground-truthing of data was based on data collected by local weather stations and temperature collections during dates of sampling. Averages and standard deviations were computed using R software and transmuted to a monthly basis [18].

2.4 Determination of Local Knowledge and Perceptions

Focused group discussions (FGDs) and one-on-one interviews were performed with an expert from the ELFARCO Seaweed farm, five local farmers in the area, and seven locals who have lived along the coast of Calatagan Bay for 15 years or more. Prior informed consent was acquired from all participants prior to the execution of the discussions and interviews.

The points of inquiry for the discussions involved the participant's familiarity with the different species of seaweed in Calatagan bay, the changes they have observed along the coast in terms of water quality, environmental factors and changes in the taxa of seaweed found in the coast, their knowledge of the economic importance of the seaweeds, and their familiarity with efforts being done to maintain sustainability of local seaweed industries as well as environmental programs to protect the coast. Responses were processed in a qualitative manner and compared to the results of the biodiversity assessment and the generated SST maps.

3. Results and Discussion

3.1 Identified Species of Macroalgae and Comparison with Historical Records

Eighteen distinct species were identified from a total collection of 286 individual samples (Table 2). Ten species have been reported before and includes the commonly known genera of *Caulerpa*, *Kappaphycus* and *Sargassum* with known market demands. Of the previously reported species, however, representatives from the *Ceramium*, *Gayliella*, and *Gelidiella* genera were not found.

3.2 Greater Relative Biodiversity in Preliminary Sampling Site

Site 1 is distinguished by having three unique species. Anthropogenic factors that could be related to this observation include the presence of established seaweed farms in the area that cultivate the indicated species. The area covered by sites 1 and 2 play host to the bigger seaweed farms operated by ELFARCO, FARMC and PBMA. These organizations and cooperatives have access to trainings and grants that allow for a wider diversity of cultured species, including those that may have been introduced to improve the local seaweed industries. All the newly reported species are known as high sources of carageenan and agar and are widely cultivated across different coastal communities in the country[13]. Despite the wider scale of operations in sites 1 and 2, they only account for 1% of the total production of the region[19]. Greater contributions are acquired from smaller backyard operations that dominate sites 3 and 4 take advantage of predominant species in the area. This makes the stakeholders in sites 3 and 4 more vulnerable to uncontrollable challenges of climate, and also the proximity to major drainage points of nearby sugarcane farms[20].

Table 2. Identified species of seaweed along Calatagan Bay, relative locations, and local names

Species	Location	Local name	PR*
Caulerpa lentillifera	All sites	Lato	Yes
C. sertularoides	All sites	Pakpak manok	No
C. rasimosa	Preliminary site (Site 1)	Rasimosa	No
Eucheuma spinosum	All sites	Guso	No
Gracilaria arcuata	Sites 1-2	Grasilarya	No
G. firma	All sites	Taliptip	No
G. salicornia	Sites 1-2	Grasilarya	No
Halimeda discoidea	Site 1	Halimeda	No
Halimenia durvillaei	Sites 1-2	Halimenya	No
Kappaphycus striatum	All sites	Sakol	Yes
Laurencia flexilis	Site 1	Lawrensya	No
Padina japonicum	All sites	Abaniko	No
Sargassum cristaefolium	Sites 1-3	Sargasum	Yes
S. oligocystum	Sites 1-3	Sargasum	Yes
S. paniculatum	All sites	Sargasum	Yes
S. polycystum	Sites 1-3	Sargasum	Yes
S. siliquosum	All sites	Sargasum	Yes
S. turbinaroides	Sites 1-3	Sargasum	Yes

Notes: *PR - previously reported

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Limitations in sampling intensity include accessibility of the area due to weather conditions. Sampling was done during a season dominated by trade winds where water turbulence is minimal and farming is expansive. The season lasts from November to May. The southwest monsoon, on the other hand, dominates the area for the rest of the year and the strong winds lead to turbulent waters that disrupt farming practices. The sampling intensity for the study covers approximately 70% of the total Calatagan coast facing the Verde Island Passage. Previously reported species that were not found could be limited by environmental conditions that include higher salinity along the Southern coasts which may be favoured by *Ceramium mazatlanense*[21] and *Gelidiella acerosa*[22].

All three previously reported species that were no longer found during the most recent collection have been reported to prefer cooler waters ranging from 0°C to 25°C, with optimal conditions at 12°C to 15°C[1,2,23].Attributing the distribution or presence of seaweed species to SST would benefit from an overview of the temperature changes in the coast in the past 30 years. It is to be noted, however, that sampling intensity may account for their absence in this survey. Regular thorough monitoring of the coast can provide a more accurate picture of the fluctuations of seaweed species in the area.

3.3 Local Knowledge Highlight Environmental and Anthropogenic Factors Affecting Seaweed Biodiversity

Five similar local names are associated to the species of *Sargassum*, and three to *Gracilaria*. All species of *Caulerpa*, *Eucheuma*, *Kappaphycus*, and Padina have corresponding local names as well. Together with feedback from the participants in the FGD, these species may prove to be the true industrially-valued local species in the area. The other species may have been introduced through workshops and in established farms. Locals are not as familiar with species that are not farmed prior to trainings as they are typically ignored or removed from near-shore areas to make way for the growing of cultivated species, fishing and other local activities.

The most common issue encountered by the locals include the recurring occurrence of ice-ice disease. This disease typically affects the genera of *Kappaphycus* and *Eucheuma*, and results to the whitening and hardening of seaweed tissue due to the over-production of organic substance as a result of stress[24,25]. Ice-ice disease is often attributed to changes in salinity, sea surface temperature, and light intensity. The secretion of organic substances by the seaweeds also attract the growth of pathogens that speed up the development of the morphological abnormalities attributed to ice-ice[24]. The local communities share the concern on the warming of sea surface temperatures and how it would lead to more frequent occurrences of this issue. They believe it is also aggravated by the run off from the local farms that result to eutrophication. Low dissolved oxygen levels and acidification have been attributed to eutrophication[26,27]. This has led to massive fish kills, and though very little to no reports on this in Calatagan, Batangas, this has certainly affected fish ponds and lakes in the region.

4. Conclusion

This study has allowed for the documentation of ten species of seaweed that were previously unreported in the area. Of higher concern is the apparent disappearance of fourteen species. It is suggested that agricultural and environmental groups invest on regular biodiversity monitoring on the area in order to create a more concrete database of species in the area. The information presented in this paper only takes into consideration samples collected during the southwest monsoon during the cooler times of the year. Species that are dominant and prolific during the warmer times of the year and when the currents are affected by the northeast monsoon is also needed.

Data on the fluctuations of the biodiversity in the area is still too little to be correlated with temperature. Considering the information that can be acquired through regular surveys, and the ecological and industrial importance of the site, a closer monitoring of the biodiversity in the area should be considered of prime importance. Local practices that affect the health of the marine ecosystem must be evaluated. Enforcement of environmental laws must be ensured. The local Fertilizer and Pesticide Authority are encouraged to look into the claims of the local community and enforce Presidential Decree 1144 that penalizes the excessive use of fertilizers in coastal communities.

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