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Diversity, distribution, and habitat association of seagrass in Calatagan, Batangas, Philippines

Felimon P. Brazas Jr[*, 1], and Ronaldo D. Lagat[2]*

[1]Department of Liberal Arts, Education, and Sciences, San Pedro College of Business Administration, San Pedro City, Laguna, 4023, Philippines

[2]College of Science and Computer Studies, Graduate Studies, De La Salle University- Dasmariňas, Cavite, 4114, Philippines

*Corresponding Author
*Email: mhon.brazas0108@gmail.com
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A B S T R A C T

Seagrass is an important component of coastal ecosystems. It contributes nutrients to coastal water productivity due to its high biodiversity as it provides food and shelter to marine organisms and supports local economies. This study measured the diversity and determined the environmental factors affecting seagrass distribution in five selected barangays in Calatagan, Batangas: Balibago, Gulod, Bagong Silang, Barangay Tres, and Sta. Ana. Ten 50cm x 50cm quadrats were placed on both sides of the 50m transect line at 5m intervals. Eight seagrass species have been documented: *Cymodocea rotundata, Halodule uninerves, H. pinifolia, Syringodium isoetifolium, Enhalus acoroides, Thalassia hemprichii, Halophila minor,* and *H. ovalis.* The Shannon diversity index was calculated using *Estimate S* software to measure the species diversity. Results showed a diversity index of 1.82, implying a moderate to high seagrass species in the area with a maximum diversity index of 2.08. The barangays with the most seagrass species documented are Balibago and Bagong Silang with both seven species. Principal Component Analysis and Canonical Correspondence Analysis were utilized to relate the abundance of seagrass species to temperature, salinity, pH, dissolved oxygen, and total suspended solids (TSS). Our preliminary results showed that *E. acoroides, H. pinifolia, H. uninerves, H. minor,* and *H. ovalis* were found to be associated with higher temperatures. *Thalassia hemprichii* and *S. isoetifolium* prefer lower temperatures and showed a negative correlation to TSS. *Cymodocea rotundata* can thrive in a wide variety of environmental conditions. However, further studies are needed to identify the most important factors that determine the abundance and distribution of seagrasses in Calatagan, Batangas. The high seagrass diversity in Calatagan, Batangas needs to be protected to improve its cover and enhance its many ecological functions and services.

Keywords: *Diversity index, canonical correspondence analysis, principal component analysis, seagrass distribution*

1 Introduction

Seagrasses are highly specialized flowering plants that inhabit marine and brackish waters in temperate and tropical regions (Jumawan et al. 2015). Seagrass meadows support a rich diversity of species and provide shelter for both commercially and ecologically important marine organisms (Fortes and Santos 2003). Seagrass evolved around 100 million years ago with approximately 72 species as of today and covers a large geographic area (Ahmad-Kamil et al. 2013). The tropical waters of the Indian and Western Pacific oceans recorded 14 species of 7 genera from 2 families (Reynolds 2018). In the Indo-Pacific region, from southeast Asia to the southern part of Japan which is regarded as the center of seagrass diversity in the world (Short et al. 2011 and Fortes 2013), has 24 species belonging to 9 genera and 4 families, which make up 29% of the world's seagrass species (Reynolds 2018). In the Philippines alone,13 species were reported (Yaakub et al. 2018).

Seagrass is a prominent component of the Philippine coastal ecosystem and mapping of seagrass areas for coastal management purposes has been undertaken successfully in some parts of the Philippines. At present, eighteen species of seagrasses have been identified under three families: Cymodoceaceae, Hydrocharitaceae, and Ruppiaceae (Fortes 2013). Several different seagrass species were documented in different parts of the Philippines. For example, seven species belonging to Cymodoceaceae, and Hydrocharitaceae families were recorded in Paligue, Hagonoy, Davao del Sur (Jumawan et al. 2015). Six species (*Syringodium, Cymodocea, Thallasia, Enhalus, Halodule,* and *Halophila*) were recorded in Claveria, Cagayan (Fortes 1990). Eight species (*C. serrulata, C. rotundata, E. acoroides, H. ovalis, H. pinifolia, H. uninerves, S. isoetifolium*, and *T. hemprichii*) were recorded in Lubang and Looc Islands of Occidental Mindoro (Genito et al. 2009). Nine species were documented in Igang Bay, Guimaras (Alimen et al. 2010). Seven species (*E. acoroides, H. minor,* and *H. ovalis* of family Hydrocharitaceae and *C. rotundata, C. serrulata, H. pinifolia,* and *H. uninervis* of family Cymodoceaceae) were documented in Bontoc, Southern Leyte (Meode et al. 2014). Five species (*C. rotundata, H. pinifolia, H. decipiens, H. ovalis,* and *T. hemprichii*) were documented in Verde Island, Batangas City (Saco et al. 2020).

The seagrass distribution is affected by physicochemical factors. The survival and growth of seagrass are affected by nutrients (Burkholder et al. 1992). For example, nutrients affected the shoot density (Burkholder et al. 1992,1994), reproduction, morphology (Short et al. 1995 and Van Katwijk et al. 1997), and physiology of seagrasses (Udy and Dennison 1997; Greve, and Binzer 2004). The response of photosynthesis to increasing pH was observed in some seagrass species; *Posidonia oceanica* and *Oceanica nodosa* showed a linear decrease in photosynthetic efficiency and *Zostera noltii* was much less sensitive to pH increase and maintains high photosynthetic efficiency (Invers et al. 1997). The abundance and distribution of seagrass may be influenced by salinity (Lirman and Cropper 2003). Different species react to salinity levels in terms of growth. *Thallasia testudinum* and *S.filiforme* stop growing at 45 – 60% salinity level while Halodule wrightii continue to grow at 72 – 80% salinity level (McMillan 1976) and *H. wrightii* have a high tolerance for low salinity (Lirman and Cropper 2003). The distribution of seagrass is also affected by dissolved oxygen. *Thalassia testudinum* is present in a low percentage of oxygen demand and may indeed dominate in areas of stress and low oxygen and may be unable to colonize high salinity regions (Cuddy 2015). Another factor that may influence the seagrass distribution is the total suspended solids (TSS). *Syringodium filiforme* is present in low TSS (Cuddy 2015). Higher TSS indicates that there are more suspended particles in the water, thus increasing turbidity and reducing light availability to seagrass (Cuddy 2015).

Seagrass is one of the significantly diverse and geographically multi-specified components of coastal marine ecosystem (Reynolds 2018) that can enhance the diversity and abundance of animals (Salita et al. 2003; McKenzie et al. 2003) and is sensitive to environmental deterioration threatened by human activities because of its submerged state (Romero et al. 2015). Seagrass also has been regarded as a biological indicator used by marine biologists to detect changes in ecosystems, particularly caused by anthropogenic activities (Heink and Kowarik 2010; Roca 2015) and are being exploited not only for fishing but also for developmental purposes (Calumpong and Meñez 1994), land reclamation, or changes in land use (Bach et al. 1998). The instability of the seagrass ecosystem has great effects on the marine organisms depending on it (Jumawan et al. 2015; Roca 2015).

The growth of the Philippine coastal tourism market is one of the most rapid in the Asia Pacific region (Fortes 2011) and Calatagan, Batangas is one of them having a progressive tourism-related activity. The municipality is continuously becoming one of the areas for reclamations and tourism ventures being known as having one of the best beaches in our country. The influx of tourists in the municipality increased from 2016 to 2019. There were 88,446 tourists in 2016 and it reaches up to 356,076 tourists in 2019 according to the

Calatagan tourism office. The different activities in the coastal water of Calatagan may pose threat to the seagrass community. The objective of this study is to identify the seagrass species and the physicochemical factors affecting their distributions in Calatagan, Batangas.

2 Materials and Methods

Study Area

The study was carried out at the municipality of Calatagan, Batangas, Philippines (13° 50´ latitude and 120° 38´ longitude). Within Calatagan, Batangas five barangay sites with sandy sediments were selected (Figure 1) – Balibago, Gulod, Bagong Silang, Sta. Ana and Tres. The three barangays, Balibago, Gulod, and Bagong Silang are facing the Verde Island Passage and the two remaining barangays Sta. Ana and Tres are facing Pagapas Bay and located on the other side of Calatagan, Batangas.

Sampling design and strategy

The modified field sampling design (Figure 2) was based on the intertidal fixed transect sites of McKenzie et al. (2003) and the sampling scheme of English et al. (1997). For the determination of seagrass diversity, three 50m transect lines were laid perpendicular to the shore and each transect line was 50m apart. In each transect line, ten 50cm x 50cm quadrats were placed on both sides and each quadrat has a 5m interval. Individual seagrass species found from quadrat 1 to quadrat 20 for each transect were counted and recorded using the seagrass recording sheet in the three replicate transect lines.

Measuring the water quality

The salinity (ppt), temperature (°C), dissolved oxygen (DO) mg/L, pH, and total suspended solids (TSS) mg/L were measured in situ at 0m, 25m, and 50m of each transect line. Salinity and pH were measured with a salinity and pH meter (RC Yago, Shenzhen, China) by dipping the instrument to the surface of the water. Dissolved oxygen was measured with a dissolved oxygen meter. The total suspended solid was measured with a TSS meter and the water temperature was measured with a marine thermometer with three replicate readings.

Collection of water samples for nitrate, phosphate, and marine sediments

The water sample was collected at 0m, 25m, and 50m of each transect line and was placed on a vial for phosphate and nitrate level. To measure the nitrate level, the AquaCheck water quality strips (HACH, Hach Company, Colorado, USA) were

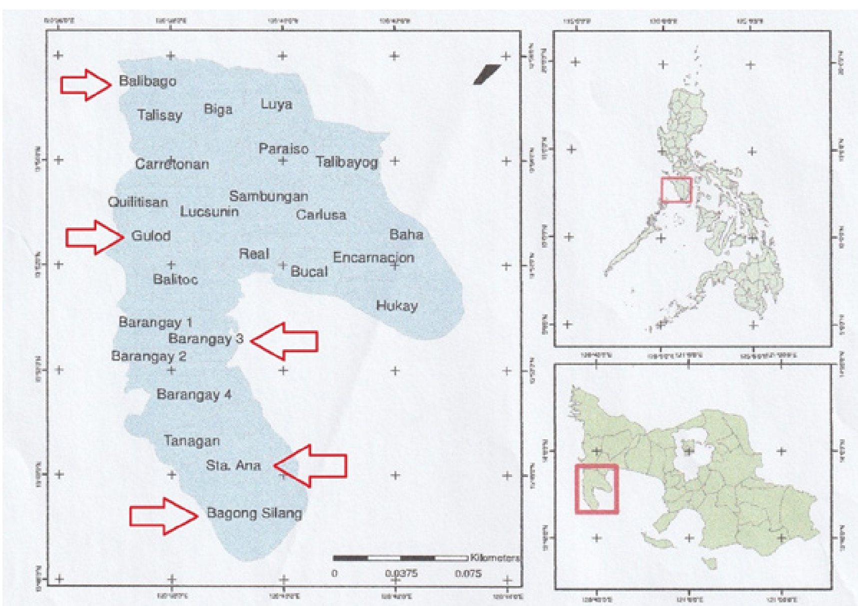

Figure 1. Map of Calatagan, Batangas visualizing the study sites (in red arrow). Adopted from Quicoy and Briones 2009.

used. A strip was dipped into the collected water for 1 second and was compared to the color chart. For the phosphate level, the strip was dipped for 5 seconds and was then compared to the phosphate test pad color chart. All water samples for nitrate and phosphate levels were collected and measured from 10:00 am to 12:00 pm based on the Water Quality Guidelines (WQG) of DENR Administrative Order – 2016-08 (DENR 2016).

The marine sediment composition was assessed by digging the fingers at a depth of 1cm at 0m, 25m, and 50m of each transect line to feel the texture. Marine sediment was described by noting the grain size in the order of dominance (e.g., sand, fine sand, coarse sand, mud, and gravel). The manual for describing marine sediment composition by McKenzie et al. (2007) for seagrass watch was used. Mud if it has a smooth and sticky texture; fine sand if it has a fairly smooth texture and with some detectable roughness; sand, if it has a rough grainy texture and particles, that are distinguishable; gravel if it has a very coarse texture with some small stones (McKenzie 2007).

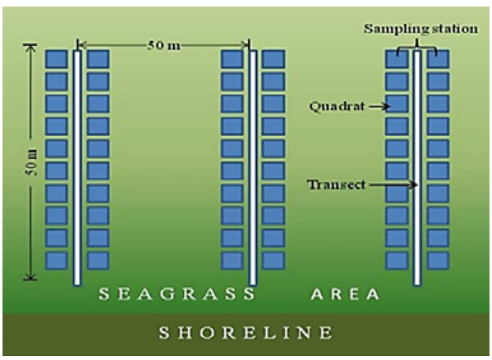

Figure 2. The field sampling design based on the model of McKenzie et al. (2003), aided by the sampling scheme by English et al. (1997), and cited by Meode et al. (2014).

Data Gathering and Statistical Analysis

The *Estimate S* software version 9.1 (Colwell 2019) was used to calculate the Shannon-Diversity Index. A maximum diversity (Hmax) was generated and compared to the computed Shannon-Weiner's (H) diversity index (Nolan and Callahan 2006).

The data gathered from salinity, pH, temperature, dissolved oxygen, and TSS were analyzed using the principal component analysis (PCA). The principal component analysis trims down all the physicochemical factors into significant components based on their eigenvalue and canonical correspondence analysis (CCA) determines which among the physicochemical factors the seagrass is associated with (Braak and Verdonschot 1995).

3 Results and Discussion

Seagrass documented

A total of eight species of seagrass from two families in six genera were observed in the sampling areas (Table 1). The species are *Cymodocea rotundata, Halodule uninerves, Halodule pinifolia, Syringodium isoetifolium, Enhalus Acoroides, Halophila minor, Halophila ovalis,* and *Thalassia hemprichii*.

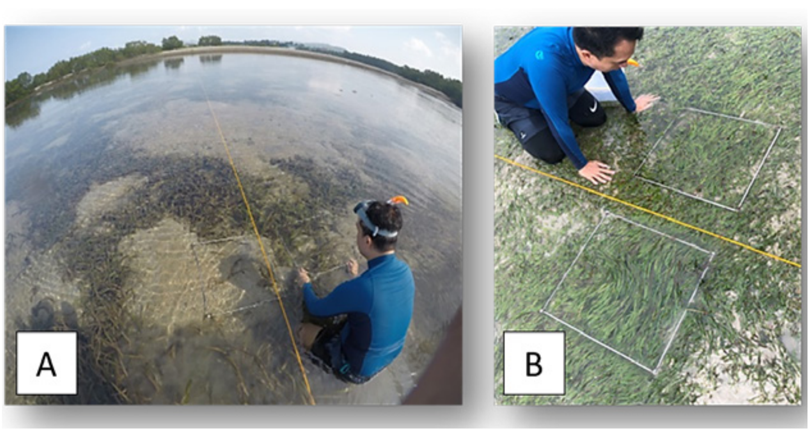

Figure 3. A. The establishment of a 50m transect line perpendicular to the shore. B. Placement of a 50cm x 50cm quadrat on both sides of the transect.

Table 1. Seagrass species documented at Calatagan, Batangas, Philippines.

Family Cymodoceaceae	Family Hydrocharitaceae
Cymodocea rotundata Asch. & Schwein	*Enhalus acoroides* (L.f.) Royle
Halodule uninerves Boiss	*Halophila minor* (Zoll.) Hartog
Halodule pinifolia Hartog	*Halophila ovalis* Tasman
Syringodium isoetifolium Aschers	*Thalassia hemprichii* (Ehrenb.) Asch.

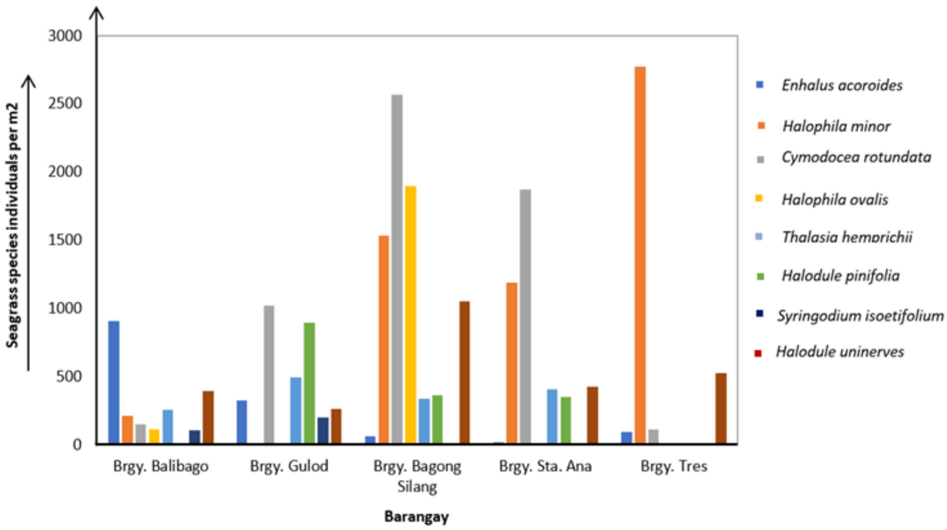

Figure 4. Seagrass species and the mean number of individuals documented at the selected barangays at Calatagan, Batangas; Balibago, Gulod, Bagong Silang, Sta. Ana, and Tres.

Seagrass species diversity

There are eight species of seagrass found in five selected barangays in the municipality of Calatagan. These species are *E. acoroides, C. rotundata, T. hemprichii, S. isoetifolium, H. minor, H. ovalis, H. pinifolia* and *H. uninerves* (Figure 4). *Enhalus acoroides* is found in barangay Balibago with 907 individuals per m², Gulod with 320 individuals per m², Bagong Silang with 58 individuals per m², Sta. Ana with 3 individuals per m2 and Tres with 89 individuals per m² (Figure 4). *Cymodocea rotundata* is found in barangay Balibago with 212 individuals per m², Bagong Silang with 1,530 individuals per m², Sta. Ana with 1,186 individuals per m² and barangay Tres with 2,774 individuals per m² while it is absent in barangay Gulod (Figure 4). *Thalassia hemprichii* is found in barangay Balibago with 150 individuals per m², Gulod with 1,018 individuals per m², Bagong Silang with 2,564 individuals per m², Sta. Ana with 1,867 individuals per m² and barangay Tres with 110 individuals per m² (Figure 4). *Syringodium isoetifolium* is found in barangay Balibago with 107 individuals per m² and Bagong Silang with 1,892 individuals per m² while it is absent in barangay Gulod, Sta. Ana and barangay Tres (Figure 4). *Halophila minor* is found in barangay Balibago with 253 individuals per m², Gulod with 493 individuals per m², Bagong Silang with 338 individuals per m², and Sta. Ana with 401 individuals per m² while it is absent in barangay Tres (Figure 4). *Halophila ovalis* is found in barangay Gulod with 890 individuals per m², Bagong Silang with 361 individuals per m², and Sta. Ana with 349 individuals per m² while it is absent in barangay Balibago and barangay Tres (Figure 4). *Halodule pinifolia* is found in barangay Balibago with 102 individual species per m² and Gulod with 200 individual species per m² while it is absent to barangay Bagong Silang, Sta. Ana and barangay Tres and *Halodule uninerves* is found in barangay Balibago with 394 individuals per m², Gulod with 257 individual species per m², Bagong Silang with 1,050 individuals per m², Sta. Ana with 421 individuals per m² and barangay Tres with

524 individuals per m² (Figure 4). The barangays with the most seagrass species documented are barangays Balibago and Bagong Silang (Figure 4).

By utilizing *Estimate S* software employing Shannon-Diversity Index it generated a maximum diversity (H_{max}) of 2.08 for the seagrass communities in Calatagan, Batangas, and Shannon (H) diversity of 1.82. The computed Shannon (H) diversity is near to the generated maximum diversity which means that there is a moderate to wide variety of seagrass species in the area and biodiversity contributes to the ecosystem's sustainability. The seagrass community of Calatagan, Batangas has moderately high seagrass species diversity.

Canonical Correspondence Analysis

Halophila minor and *H. pinifolia* are the documented seagrass species from barangay Balibago and barangay Gulod that might be associated with higher temperatures (Figure 5). They are found numerous in the barangays with the highest recorded temperatures. High temperatures can result from high total suspended solids and make gases less available as these are rendered less soluble in water (Fondriest Environmental 2014). This means that *E. acoroides, H. pinifolia, H. uninerves, H. minor,* and *H. ovalis* are species that can be designated as indicators of warmer waters (Menez et al. 1983). *Thalasia hemprichii* and *S. isoetifolium* is associated with low temperatures (Menez et al. 1983). Barangays Bagong Silang, Sta. Ana and barangay Tres have the lowest temperature recorded. *Syringodium isoetifolium* has a negative correlation to total suspended solids (Bach et al. 1998). *Cymodocea rotundata* is a non-specialist seagrass dwelling in any type of environment (Meode et al. 2014; Arriesgado et al. 2016; Kawaore et al. 2016; Dedel et al. 2018). It was also found that dissolved oxygen has no species association.

Seagrass inhabits all types of substrates, from mud to rock. Seagrass survives in the intertidal zone with the most extensive meadow occurring on soft substrates like sand and mud. From eight species of seagrass documented in the municipality of Calatagan; *C. rotundata, T. hemprichii, S. isoetifolium, H. minor, H. ovalis, H. pinifolia,* and *H. uninerves* are found to be associated with marine sand substrate and *E. acoroides* were found to be associated with muddy - sandy substrate.

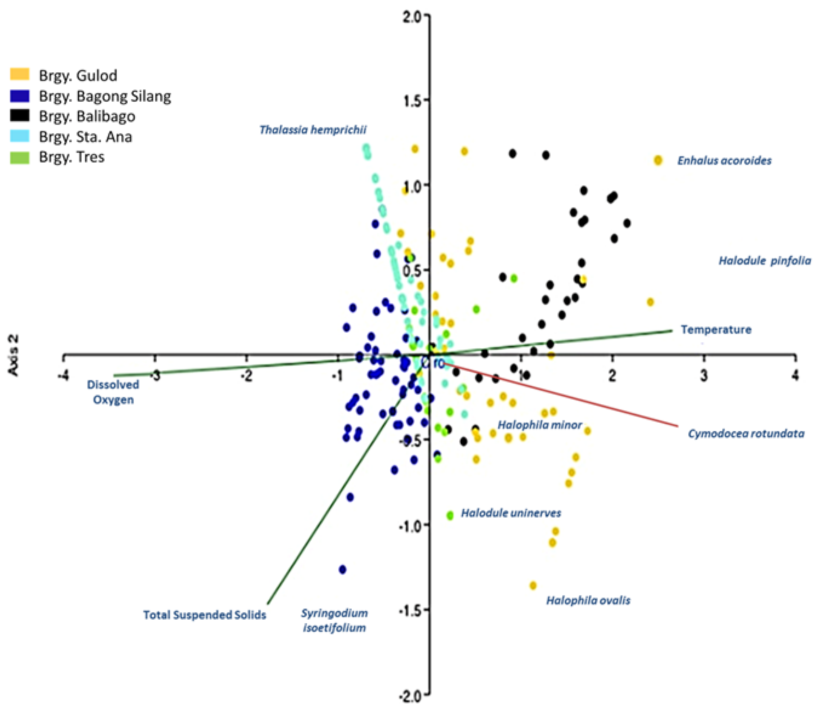

Figure 5. Canonical Correspondence Analysis after Principal Component Analysis shows the association of seagrass species to environmental factors such as temperature, total suspended solids, and dissolved oxygen.

Table 2. Recorded average physicochemical factors from the five Barangays.

Physicochemical factors	Standard as per DAO 2016-08	Barangay Balibago	Barangay Gulod	Barangay Bagong Silang	Barangay Sta. Ana	Barangay Tres
Temperature (°C)	26-30	25.97	26.47*	24.2	24.5	25
pH Level	7.0-8.5	8.3*	7.88*	8.62	8.34*	8.01*
Salinity (ppt)	>30	32.77*	33.7*	31.5*	33.63*	34.17*
DO (mg/L)	>5	7.4*	7.1*	9.2*	9.67*	7.8*
TSS (mg/L)	<50	3.33*	7.4*	38.67*	13.33*	14*
Marine Sediments	-	Sandy	Sandy	Sandy	Muddy	Sandy

(*) Indicates that the measured physicochemical factors per subject area are in compliance and within the range and values prescribed by the Department of Environment and Natural Resources Office Administrative Order 2016-08 (DENR 2016)

The recorded nutrients: nitrate nitrogen, nitrite nitrogen, and phosphate have a zero value. These recorded data are within the prescribed standard as per water quality guidelines and general effluent of DENR Administrative Order 2016 – 08 for marine water class B (DENR 2016), but these recorded data have no statistical effect, therefore it is not included in the PCA and CCA, and since all the recorded data is the same throughout the five (5) Barangays.

4 Conclusion and Recommendations

Eight species of seagrass from the two families have been documented at Calatagan, Batangas, Philippines; *C. rotundata, H. uninerves, H. pinifolia, and S. isoetifolium. E. acoroides, H. minor, H. ovalis,* and *T. hemprichii*. Their distribution may be associated with the temperature and total suspended solids that contribute to the moderately high seagrass diversity of the municipality. The seagrass communities should be protected from the different tourism activities in the area by being one of the tourist destinations in the Southern Tagalog Region and therefore a conservation management plan is a must to prevent the loss of biodiversity of the seagrass communities.

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Statement of Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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