IRJIEST 10 (1) 2024 01 - 05
Available online at https://ojs.batstate-u.edu.ph
International Research Journal on Innovations in Engineering, Science and Technology

Bioindicator potential of marine macrophytes: Assessing seaweed communities in an urbanized coastal system

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ABSTRACT
Seaweeds are one of the known bioindicators for determining the possible effects of anthropogenic inputs on the marine environment. With the presence of power plants, resorts, and households, the coastal areas of Brgy. Ilijan in Batangas City is changing due to industrialization and urbanization. Thus, this study was conducted to determine the composition, abundance, dominance, and species diversity of the seaweeds community in Brgy. Ilijan, Batangas City, using the line transect-quadrat method. There were seven species identified in the area, namely, *Dictyota dichotoma*, *Tricleocarpa fragilis*, *Amphiroa foliacea*, *Padina* sp., *Neomeris vanbosseae*, *Halimeda opuntia*, and *Caulerpa lentillifera*. Two species are possible bioindicators, such as *D. dichotoma* and *Padina* sp. The line transect near the powerplant and resorts recorded 64.88% cover for *D. dichotoma,* while the line transect near the residential area had a 35.63% cover of *D. dichotoma.* Lastly, the line transect near the run-offs, *Padina* sp. recorded a cover of 52.88%. *D. dichotoma* and *Padina* sp. were the dominant species in the area, having a total distribution of 60.6%. In addition, the area had a moderate marine macrophyte diversity. The potentiality of these species to be bioindicators in the area should be further explored, and thus, the need for continuous monitoring of these species in the area.

Keywords: *abundance, bioindicator, diversity, dominant species, seaweeds*

Received: June 11, 2024 **Revised:** September 9, 2024 **Accepted:** September 17, 2024

1. Introduction

Industrialization has become one of the stepping stones for the development of society. It has a great impact on people since it gives them a source of income that will help with their daily necessities. The Philippines is home to some of the world's most unique marine ecosystems, unfortunately, it is increasingly threatened due to various human activities such as overfishing, pollution, and other economic activities as a result of the country's progressive industrialization. In addition, rapid population growth, specifically in coastal regions of the country, has put pressure on the marine economy [1].

Industrialization and urbanization are very evident on the different coasts of Batangas. Brgy. Ilijan is one of the coastal areas of Batangas City with high tourism activities and the location of a power plant in the province. Industrialization has become significant for society, providing livelihood and economic benefits, but it may cause drastic changes to the marine environment. These changes include destruction of the shoreline, mangroves, and other biological ecosystems resulting from community pressures on these habitats. Industrialization can also lead to the misuse of foreshore leasing agreements and illegal coastline tilting, which can limit access to marine resources.

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Organisms are greatly affected by changes in their ecosystems [2]. Changes in the environment, such as in their community structure, can be a key basis for understanding how different external factors, like industrialization, affect the environment. Seaweed communities are sensitive to nitrogen concentration changes in the coastal environments and thus serve as a bioindicator [3]. When effluent from agriculture, industry, aquaculture, and households is dumped in the ocean, it creates a nutrient imbalance, which leads to algal blooms, an indication of marine chemical harm. Seaweeds are being utilized as a bioindicator for anthropogenic pollution in the marine environment (both organic and inorganic), since they offer a method for examining the indirect impacts of pollutants on the entire food chain in addition to biomonitoring [4].

Human activities have greatly contributed to marine pollution (e.g., untreated sewage, agricultural runoffs, oil, and heavy metals from industries). Since coastal areas are very sensitive to changes in the environment [5], and with the presence of anthropogenic activities in the area, a study that assesses the community structure of organisms in the area is proposed. It is very significant since it may help in identifying changes in the ecosystem, especially in areas with increasing human activity and industrialization. The results of the assessment of the seaweed community may help in monitoring the quality of the marine life in the area. Also, by checking the physicochemical characteristics of the water, researchers may be able to identify how abiotic parameters affect the seaweed community in the area. This study is considered to be the first attempt at the assessment of seaweed communities in Brgy. Ilijan, Batangas City.

2. Material and methods

2.1. Study site

The study was conducted in Brgy. Ilijan, Batangas City (13.63° N 121.07° E) at locations beginning close to the power plant towards the runoff (Figure 1). It has a sandy and rocky substrate located inside a lagoon.

Figure 1. The Philippine map showing the location of Brgy. Ilijan, Batangas City, wherein the three (3) locations were determined from its distance to the runoff and power plant.

2.2. Line transect-quadrat method

The collection of data took place in October 2022 and followed that of [6]. To identify the composition of the seaweed community in the area, all of the seaweed species in the area were identified using the "Field Guide and Atlas of the Seaweed Resources of the Philippines" by [7] and through AlgaeBase [8].

Three (3) replicates of a 100-meter line transect with a 50-m interval were placed parallel to the shore. A 25 cm x 25 cm metal quadrat was laid to the right of the line transect. Each transect line had twenty-one (21) quadrats placed on it at a 5-m interval. The surface covered by a species inside one small square was categorized into six (6) indices, each represented by an index with a corresponding 'multiplier' for conversion into percentage cover (Table 1).

Table 1. Indices describing the cover of the seagrass observed on each grid of the quadrat [6]

Index, n	Degree of seaweed cover on a small square, q_n, of the quadrat	Multiplier
6	Fully covering 95-100% of substratum surface	4.0
5	Covering ½ -1/1 or 50-100% of substratum surface	3.0
4	Covering ¼-½ or 25-50% of substratum surface	1.5
3	Covering ⅛-¼ or 12.5-25% of substratum surface	0.75
2	Covering 1/16-⅛ or 6.25-12.5% of substratum surface	0.375
1	Covering less than 1/16 or <6.25% of substratum surface	0.1875

Abundance was expressed as a summation of the percent cover of the species following the formula below:

$$C(\%) = (qn_6 \times 3) + (qn_5 \times 3) + (qn_4 \times 1.75) + (qn_3 \times 0.75) + (qn_2 \times 0.375) + (qn_1 \times 0.1875) \quad (1)$$

To determine which seaweed species were dominant, the formula for the percent contribution of a species was used to determine the percent contribution of each species to the tidal macrophyte cover obtained in a specific area. A species was dominant if it covered 50% or more of the total macrophyte cover in the sampling area.

Shannon-Weiner Diversity Index (H') was used to determine the diversity of seaweed species in the study site.

$$H' = -\sum_{i=1}^{R} p_i \; ln\, p_i \quad (2)$$

where Pi is the proportion of individuals in the sample belonging to the ith species and is calculated using this equation:

$$p_i = \frac{\text{number of individuals of species } i}{\text{total number of individuals of all species}} \quad (3)$$

2.3. Measurement of physicochemical characteristics of the water

To measure the physicochemical characteristics of the water at the site, a YSI multi-probe (YSI, Yellow Spring, Ohio, USA) was used. For the phosphate and nitrate, 1 Liter of the water sample was taken to the nearest Provincial Government Environment and Natural Resources Office.

2.4. Statistical treatment of data

Principal component analysis (PCA) was used to determine the possible relationship between physicochemical parameters and seaweed abundance. The statistical test was conducted using R Foundation for Statistical Computing version 4.2.2.

3. Results and discussion

3.1. Community structure of seaweeds in Brgy. Ilijan, Batangas City

There are a total of seven (7) marine macrophyte species that were identified during the study period, namely, *Dictyota dichotoma*, *Tricleocarpa fragilis*, *Amphiroa foliacea*, *Padina* sp., *Neomeris vanbosseae*, *Halimeda opuntia*, and *Caulerpa lentillifera*. The researchers identified species suitable for farming, such as *Caulerpa lentillifera*, and two (2) species that are good bioindicators, *Dictyota dichotoma,* which can be used to monitor organic UV filter pollutants [4], and *Padina* sp. [9].

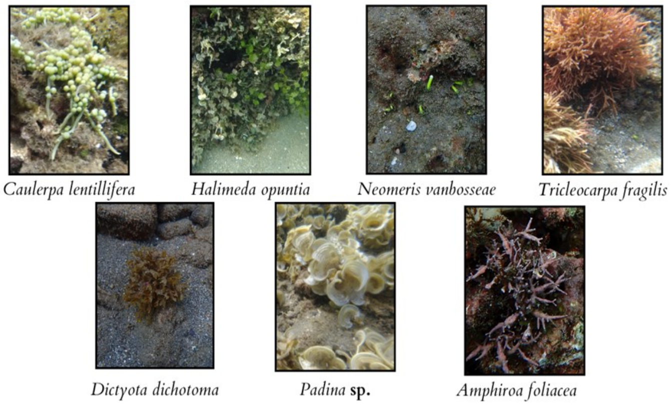

Figure 2. Seaweed species in Brgy. Ilijan, Batangas City.

Figure 3 presents the percent cover (%C) of each species in each transect line, and Figure 4 presents the total cover of each species in the study site.

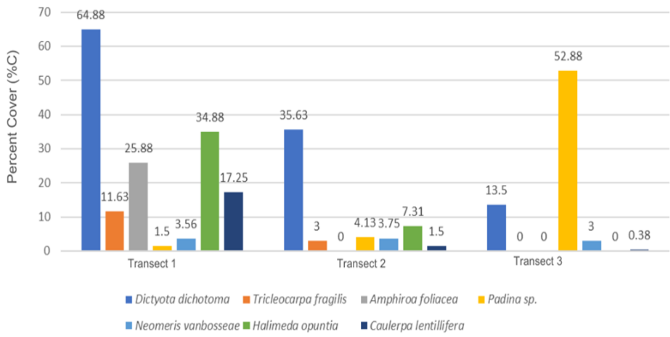

Figure 3. Percent cover (%C) of seaweed species in Brgy. Ilijan, Batangas City.

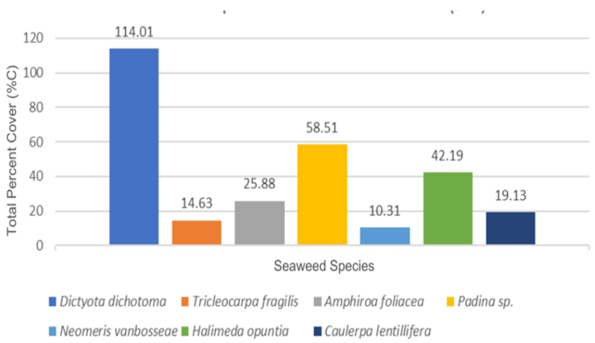

Figure 4. Total percent cover of seaweed species in Brgy. Ilijan, Batangas City.

In the first transect, which was in a nearby power plant and resorts, the *Dictyota dichotoma* was the most abundant, with a percent cover of 64.88%. In the second transect, which had the presence of a nearby residential area, *Dictyota dichotoma* was also the most abundant seaweed species, with a cover of 35.63%. Lastly, in the third transect, which had a nearby runoff, *Padina* sp. was the most abundant seaweed species with a percent cover of 52.88%.

D. dichotoma had the highest abundance among species in two transect locations (near a residential area and a power plant). This may be because of its morphology; *D. dichotoma* has a thin thallus, which helps in absorbing nutrients and other means of development much faster than other species. *Padina* sp. tends to develop much faster in areas near runoffs where they can absorb huge concentrations of nutrients [3].

Among the seaweed species in the area, the most abundant species was the *Dictyota dichotoma* with 114.01% cover. *Padina* sp. was the second highest abundance with 58.51% cover. *Neomeris vanbosseae* was the least abundant, with 10.31% % cover. The following seaweed species may be abundant due to the substrate of the study site. It has a sandy-rocky substrate, which may influence abundance by giving good anchorage to the seaweeds, thus, greatly increases its survivability-especially during seasons with great wave action [3].

Table 2 presents the community structure of the seaweed community in terms of dominance.

Table 2. Distribution of seaweed species in Brgy. Ilijan, Batangas City

Species	% Contribution of Species
Dictyota dichotoma	40.05
Padina sp.	20.55
Halimeda opuntia	14.82
Amphiroa foliacea	9.09
Caulerpa lentillifera	6.72
Tricleocarpa fragilis	5.14
Neomeris vanbosseae	3.62

Dictyota dichotoma had a distribution of 40.05%, and *Padina* sp. had 20.55%. These two species, having the highest distribution, were the dominant species in the area, with a total distribution of 60.6%. Since these seaweed species were dominant in the area and were good bioaccumulators of heavy metals, they were valued as biomonitoring agents for heavy metal contamination [10]. Similar to the findings of [11], who reported a 40.36% distribution of *P. minor* in Sinisian East, the study also shows a significant contribution of this species in the area. The primary difference, however, is that *P. minor* exhibits a more localized dominance in Sinisian East, whereas *Dictyota dichotoma* and *Padina* sp. display broader distributions that are less area-specific.

Brgy. Ilijan, Batangas City, and Verde Island both had moderate marine macrophyte diversity with H = 1.64 and H = 1.67, respectively [9]. In comparison, in Surigao Del Norte, the macrophyte diversity index ranged from H = 1.07 - 2.4 and indicated high diversity [12]. This moderate marine macrophyte diversity of the study site may indicate that it could be capable of sustaining food and habitat for marine organisms.

3.2. Physicochemical characteristics of water

The study site had a salinity of 33.174 ppt. The level of salinity at the study site is up to standard, which was in the range of not less than 15 ppt and more than 35 ppt [13]. The pH level of water in the study site was 8.433. The pH level must be within the range of 6 to 9 [14]. With this, the pH level of the water, Brgy. Ilijan was up to the standard of DENR for seaweeds to be able to thrive within the area. The dissolved oxygen content in the study area was 96.383 mg/L.

The dissolved oxygen level required for seaweed growth is at least 5 mg/L [14].

The phosphate level that was measured in the water was 0.0182 mg/L, which is good for seaweed growth. The growth rate of aquatic biota will not be hindered in salt water with a minimum phosphate level of 0.01 mg/L; nevertheless, if the phosphate level decreases below 0.01 mg/L, the cell growth rate will continue to decline [15]. For aquatic species, nitrate is a vital nutrient. For primary production in marine environments, nitrogen is a limiting element [16]. During the assessment, the nitrate content of the water that was obtained was 1.7333 mg/L.

3.3. Possible relationship between seaweed species abundance and physicochemical parameters of water in Brgy. Ilijan, Batangas City

Figure 5 shows how the abundance relates to the physicochemical parameters. The salinity, pH, and dissolved oxygen (DO) showed wide angles away from the abundance. This wide-angle shows that the following physicochemical parameters are not correlated with the abundance of seaweed species at the study site. On the other hand, nitrate and phosphate showed a smaller angle, indicating a closer correlation with the seaweed species' abundance; nitrate, however, displayed a much closer correlation than phosphate. The closer the plot of the variables and the smaller the angle shown in the biplot, the greater the possibility of a relationship between the variables [17].

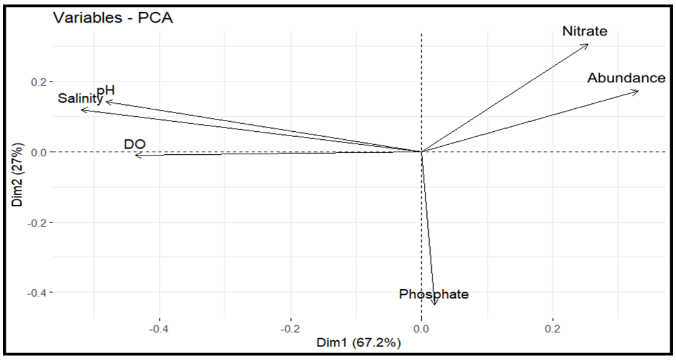

Figure 5. Biplot of abundance and physicochemical parameters of the water in Brgy. Ilijan, Batangas City.

Physicochemical parameters such as salinity, pH, and dissolved oxygen do not affect the abundance of seaweeds in the area, but nutrients, specifically nitrate, have an impact on the abundance of seaweed species in the area. There is a possible relationship between the nutrients nitrate and phosphate, specifically, and the seaweed species found in their study area [17]. The substrate may have affected the abundance of the seaweed species in the study site since it has a sandy and rocky substrate that greatly assists in the seaweed's anchorage, which helps the species thrive in the area.

Figure 5's biplot displays that nitrate and phosphate are the dependent variables, as they exhibit a smaller angle, reflecting a stronger correlation with seaweed species' abundance. In contrast, the physicochemical parameters appear to have no impact on seaweed abundance and are therefore regarded as independent variables.

4. Conclusion

There are seven (7) different species of seaweed in the area. Some of which can be cultivated, such as *Caulerpa lentillifera.* Some can serve as bioindicators for the surveillance of Brgy. Ilijan's coastal area, such as *Padina* sp. and *Dictyota dichotoma,* which are the dominant species in the area. Additionally, the seaweed community in the area was moderately diverse, which possibly supports the marine ecosystem.

The physicochemical properties of the water obtained in Brgy. Ilijan, Batangas City, was suitable for the growth and development of the seaweed species. Furthermore, the physicochemical properties and nutrients of the water measured matched with the ideal standard of the Department of Environment and Natural Resources in terms of salinity, pH, dissolved oxygen, phosphate, and nitrate. Lastly, most of the physicochemical parameters of the water do not have a relationship or effect on the abundance of seaweed species in Brgy. Ilijan, Batangas City.

5. Recommendations

A study may be done on the same site to see the difference in the seaweed community over the years for possible community changes in seasons and their physicochemical parameters. Seminars and workshops about the seaweed community assessment may be conducted in the barangay, which may help the Local Government Unit (LGU) in monitoring their coastal area and learn about the importance of marine macrophytes in their area. The study may be used by the LGUs of Brgy. Ilijan as a baseline for coastal monitoring and management.

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