Seagrass bed status: Case study of Panjang Island, Banten Bay

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Abstract. Seagrass community status was measured using a vegetation analysis method at three observation stations in Panjang Island, Banten Bay. Each station was transected by three lines that divided these stations into plots measuring 50 × 50 cm to record the seagrasses species found, number of seagrass shoots, and coverage. In addition, measurements of water quality parameters, including temperature, salinity, pH, brightness, and sediment grains at each station, sediment grain. A Pearson’s correlation test was conducted to determine the correlation between sediment and seagrass density. The measurement of water quality in Panjang Island indicates optimal conditions for seagrass growth, with sediment mixed with clay and sand rubble. The seagrasses found were Enhalus acoroides, Cymodocea serrulata, Syringodium isoetifolium, Halodule uninervis, and Halophila ovalis. The seagrass community in Panjang Island has good coverage (60.16 %) and high density levels (235.03 ind/m²). S. isoetifolium was the dominant seagrass with an importance value (IV) of 119.90. The correlation test showed that mud and clay sediments correlated with the density of E. acoroides.

Keywords: Community, correlation, Cymodocea, Enhalus, Syringodium

1. Introduction

Indonesian scientists have been monitoring the seagrass ecosystem in Banten Bay since 1989. Most of this work was originally conducted by the Indonesian Institute of Sciences (LIPI) and based on a research collaboration with Indonesia–Netherland from 1997 to 2001. Banten Bay has a large seagrass bed area. It has good coverage, high density, and rich species of seagrass. However, seagrass in Banten Bay has been threatened due to large-scale coastal developments, inland pollution, erosion, over exploitation of marine resources, and use of destructive fishing methods [1]. Research monitoring programs, reports, and some seagrass management work has been conducted to protect the seagrass in Banten Bay, but threats are on-going and seagrass declines year by year.

Seagrass provides valuable ecosystem services, such as a habitat for commercial fish and the dugong (Dugong dugon), a protected marine mammal [2]. There are 85 commercial fish species that are closely linked with the economic activity in Panjang Island [3]. Ecologically, seagrass beds serve as a habitat and food source for dugong. The last dugong found in Banten Bay was in October 1999 when it was accidentally caught by fishermen and then transferred to Jaya Ancol Oceanarium in Jakarta.

The declining seagrass bed caused not only undermines the valuable ecosystem services that seagrass provides, but also affects the local economy. Fortes [4] and Douven et al. [1] suggested that
measuring changes in the seagrass bed was sufficient to determine the risks posed to seagrass and the impact of any threats. The study site was located at Panjang Island, the largest inhabited island in Banten Bay, and is surrounded by 17.2 ha of seagrass beds [5]. However, the island’s extensive seagrass beds have decreased due to the same factors that have affected Banten Bay’s seagrass beds since 1989. This paper presents the seagrass community’s status at Panjang Island and investigates its correlations with factors that affect this community, specifically sediment density and composition.

2. Methodology

2.1. Study site
Panjang Island is located at 5°55′–6°5′ S and 106°5′–106°15′ E. The boundaries of Panjang Island are the Java Sea in the north, the port of Merak in the west, the village of Bojonegara in the south, and some small islands in the east. There is a village called Pulo Panjang on Panjang Island, and the inhabitants’ main livelihood is fishing. There is mangrove vegetation on the south of the island, and seagrass is found immediately beyond the mangrove ecosystem. Seagrass beds are also found in some coral reefs around the island. This study was conducted at three observation stations in the south of Panjang Island, Banten Bay (figure 1). Stations 1 and 2 were adjacent to mangrove ecosystems, while station 3 was located on a reef flat.

2.2. Water quality
Water quality measurements aimed to identify factors that influenced seagrass growth. The parameters measured included water temperature (measured using a thermometer), salinity (measured using a hand refractometer), pH (measured using a pH meter), and brightness (measured using a Secchi disk).

2.3. Sediments
Sediment samples were taken at each station at a depth of ~10 cm. Next, the sediment sample was dried (60 °C; 48 h). Dried samples were then sieved with mesh sizes of 2, 1, 0.5, 0.25, 0.125 and < 0.063 mm. The remaining sediments at subsequent levels were weighed and classified as follows: sediment > 2 mm is gravel, sediment in the range 2–0.5 mm is sand, sediment in the range 0.5–0.063 mm is mud, and sediment < 0.063 mm is clay [6].

Figure 1. Research area: Panjang Island, Banten Bay.
2.4. Seagrass community
The seagrass community structure was measured at three observation stations (figure 1) using the vegetation analysis method established by English, Wilkinson, and Baker [7]. Each station was transected by three lines perpendicular to the boundary edge of the beach, with a 25 m distance between each transect. The length of the transected line at station 1 was 60 m, that of the transected line at station 2 was 105 m, and that of the transected line at station 3 was 150 m. Next, each transect was divided into several observation plots (dimensions: 50 cm × 50 cm). There were 15 plots at station 1, 21 plots at station 2, and 30 plots at station 3. Seagrass species, the number of shoots, and the percentage of coverage were recorded at each plot. The seagrass measurement results were then calculated using the formulation proposed by English, Wilkinson and Baker’s [7] to obtain the importance value (IV).

The results were then classified using the Braun-Blanquet scale (1965) to determine density levels and coverage conditions (table 1). The health and condition of seagrass was assessed using a quantitative scoring method to yield a specific value to each component [8]. Components were assessed and the scores presented in table 2 [8] Assessment results were then classified based on the criteria listed in table 3.

2.5. Density and sediment correlation
To determine the correlation between sediment and seagrass density, a Pearson’s correlation test was conducted using SPSS 1.6 with a 95% confidence level (α = 0.05) for all types of sediment and seagrass species.

| Table 1. Range of values for seagrass ecosystems using the Braun-Blanquet scale (1965) [9]. |
| Scale | Density (ind/m²) | Condition | Coverage (%) | Condition |
| 5     | > 175           | Very high | > 75         | Very good |
| 4     | 125–175         | High      | 50–75        | Good      |
| 3     | 75–125          | Medium    | 25–50        | Medium    |
| 2     | 25–75           | Rare      | 5–25         | Small     |
| 1     | < 25            | Very rare | < 5          | Very small |

| Table 2. Scoring method proposed by Supriyadi [8] to assess the condition of seagrass. |
| No | Component           | Range of species number | Score |
|----|---------------------|--------------------------|-------|
| 1  | Number of seagrass species | ≤ 2                      | 1     |
|    |                     | 3–4                      | 3     |
|    |                     | 5–6                      | 5     |
|    |                     | ≥ 7                      | 7     |
| 2  | Number of algae species | 1–6                     | 1     |
|    |                     | 7–12                     | 3     |
|    |                     | 13–18                    | 5     |
|    |                     | 19–24                    | 7     |
| 3  | Seagrass coverage   | 5–25                     | 1     |
|    |                     | 26–50                    | 3     |
|    |                     | 51–75                    | 5     |
|    |                     | 76–100                   | 7     |
3. Results and discussion

3.1. Water quality
The results of water quality measurements performed at Panjang Island showed that the water conditions were optimal for the growth of seagrass (table 4).

3.2. Sediments
The order of dominance of the sediments at Panjang Island is as follows: clay (46.94 %), sand (23.21 %), mud (16.68 %), and gravel (13.15 %). Clay was mainly found at stations 1 and 2, while the sediment composition at station 3 was more diverse (figure 2).

3.2.1. Seagrass diversity and species composition. There were five seagrass species identified at Panjang Island: *Enhalus acoroides*, *Cymodocea serrulata*, *Syringodium isoetifolium*, *Halodule uninervis* and *Halophila ovalis*. Not all seagrass species were found at each observation station. The presence of each seagrass species at each observation station is given in table 5.

In general, Panjang Island hosts a mixture of seagrass species: a combination of *S. isoetifolium*, *C. serrulata*, and *E. acoroides* or *S. isoetifolium*, *C. serrulata*, and *H. ovalis*. Monospecific seagrass species, e.g., *H. ovalis*, *S. isoetifolium*, *E. acoroides*, and *H. uninervis*, were also found, along with some seagrass species associated with algae species, e.g., *Sargassum*, *Padina*, and *Halimeda*.

| Table 3. Classification of seagrass ecosystem conditions. |
|----------------------------------------------------------|
| Value range     | Seagrass bed condition |
| ≥ 16            | Very good              |
| 12–15           | Good                   |
| 8–11            | Medium                 |
| ≤ 7             | Worse                  |

| Table 4. Results of water quality measurements performed at Panjang Island, Banten Bay. |
| Parameter     | Unit | Station 1 | Station 2 | Station 3 |
|---------------|------|-----------|-----------|-----------|
| Temperature   | °C   | 30.5      | 30.5      | 30.5      |
| Salinity      | %    | 30        | 30        | 30        |
| pH            |      | 7         | 7         | 7         |
| Brightness    | %    | 100       | 100       | 100       |

Figure 2. Sediment composition at the study sites.
3.2.2. Seagrass community structure. The seagrass community at Panjang Island was dominated by *S. isoetifolium* with an IV of 119.90 (table 6). *S. isoetifolium* was also the most widespread species in terms of density and coverage across the entire Panjang Island, while the most frequently observed seagrass species was *E. acoroides*. The vegetation analysis at each observation station summarized in table 7 showed that the highest density and frequency occurred at station 3 and the highest coverage was at station 2.

3.2.3. Seagrass conditions. The classification of seagrass ecosystem conditions according to Supriyadi [8] shown in table 8 indicates that the seagrass bed condition at each station in Panjang Island was medium (11 points). Density and coverage measurements using the Braun-Blanquet scale [9] indicated that the seagrass at Panjang Island has considerably high density and good coverage (table 9).

3.2.4. Correlation between density and sediment. The results of a bivariate Pearson’s correlation test between seagrass species and sediment types are summarized in table 10. The positive sign (+) indicates a correlation between *E. acoroides* and mud (Sig. 0.00 < 0.05) and clay (Sig. 0.38 < 0.05), but no correlation was found between any other sediment or seagrass types.

The seagrass community structure in each region varied depending on the parameters affecting seagrass growth, such as sediment characteristics, constituent seagrass species [10] and level of anthropogenic activity [11]. Temperature, salinity, and turbidity can affect a range of processes.

### Table 5. Seagrass species found at Panjang Island.

| No. | Seagrass species       | Station 1 | Station 2 | Station 3 |
|-----|------------------------|-----------|-----------|-----------|
| 1   | *Enhalus acoroides*    | +         | +         | +         |
| 2   | *Cymodocea serrulata*  | +         | +         | +         |
| 3   | *Syringodium isoetifolium* | +       | +         | +         |
| 4   | *Halodule uninervis*   | -         | -         | +         |
| 5   | *Halophila ovalis*      | -         | -         | +         |

(+) means present; (-) means not present.

### Table 6. Seagrass community structure at Panjang Island.

| Seagrass species | D\(^a\) | RD\(^b\) | F\(^c\) | RF\(^d\) | C\(^e\) | RC\(^f\) | IV\(^g\) |
|------------------|---------|----------|---------|----------|---------|---------|---------|
| *E. acoroides*   | 20.21   | 8.60     | 0.70    | 39.52    | 7.09    | 10.49   | 58.60   |
| *S. isoetifolium*| 154.23  | 65.62    | 0.22    | 12.13    | 28.50   | 42.15   | 119.90  |
| *C. serrulata*   | 30.19   | 12.85    | 0.33    | 18.38    | 16.12   | 23.84   | 55.07   |
| *H. ovalis*      | 26.84   | 11.42    | 0.47    | 26.23    | 6.98    | 10.32   | 47.97   |
| *H. uninervis*   | 3.56    | 1.51     | 0.07    | 3.75     | 8.93    | 13.20   | 18.46   |
| Total            | 235.03  | 100.00   | 1.78    | 100.00   | 67.62   | 100.00  | 300.00  |

\(^{a}\) D = density (ind/m\(^2\))

\(^{b}\) RD = relative density (%)

\(^{c}\) F = frequency

\(^{d}\) RF = relative frequency (%)

\(^{e}\) C = coverage (%)

\(^{f}\) RC = relative coverage (%)

\(^{g}\) IV = importance value
Table 7. Seagrass community structure at three observation stations around Panjang Island.

| Station | Seagrass species | D<sup>a</sup> | RD<sup>b</sup> | F<sup>c</sup> | RF<sup>d</sup> | C<sup>e</sup> | RC<sup>f</sup> | IV<sup>g</sup> |
|---------|------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 1       | E. acoroides     | 21.60       | 38.39       | 0.47        | 77.78       | 14.39       | 25.52       | 141.68      |
|         | S. isoetifolium  | 22.67       | 40.28       | 0.07        | 11.11       | 15.75       | 27.93       | 79.33       |
|         | C. serrulata     | 12.00       | 21.33       | 0.07        | 11.11       | 26.25       | 46.55       | 78.99       |
|         | Total            | 56.27       | 100.00      | 0.60        | 100.00      | 56.39       | 100.00      | 300.00      |
| 2       | E. acoroides     | 19.43       | 32.59       | 0.81        | 89.47       | 4.53        | 6.71        | 128.77      |
|         | S. isoetifolium  | 34.29       | 57.51       | 0.05        | 5.26        | 47.25       | 69.97       | 132.74      |
|         | C. serrulata     | 5.90        | 9.90        | 0.05        | 5.26        | 15.75       | 23.32       | 38.49       |
|         | Total            | 59.62       | 100.00      | 0.90        | 100.00      | 67.53       | 100.00      | 300.00      |
| 3       | E. acoroides     | 19.60       | 3.33        | 0.83        | 30.12       | 2.35        | 4.99        | 38.43       |
|         | S. isoetifolium  | 405.73      | 68.86       | 0.53        | 19.28       | 22.50       | 47.74       | 135.88      |
|         | C. serrulata     | 72.67       | 12.33       | 0.87        | 31.33       | 6.37        | 13.52       | 57.18       |
|         | H. ovalis        | 80.53       | 13.67       | 0.47        | 16.87       | 6.98        | 14.81       | 45.35       |
|         | H. uninervis     | 10.67       | 1.81        | 0.07        | 2.41        | 8.93        | 18.94       | 23.16       |
|         | Total            | 589.20      | 100.00      | 2.77        | 100.00      | 47.13       | 100.00      | 300.00      |

<sup>a</sup> D = density (ind/m<sup>2</sup>)
<sup>b</sup> RD = relative density (%)
<sup>c</sup> F = frequency
<sup>d</sup> RF = relative frequency (%)
<sup>e</sup> C = coverage (%)
<sup>f</sup> RC = relative coverage (%)
<sup>g</sup> IV = importance value

Table 8. Seagrass conditions at Panjang Island based on Supriyadi’s criteria [8].

| No | Component                        | Station 1 Amount | Score | Station 2 Amount | Score | Station 3 Amount | Score | Panjang Island Amount | Score |
|----|----------------------------------|------------------|-------|------------------|-------|------------------|-------|-----------------------|-------|
| 1  | Number of seagrass species       | 3                | 3     | 3                | 3     | 5                | 5     | 5                     | 5     |
| 2  | Number of algae species          | 3                | 1     | 1                | 1     | 1                | 1     | 3                     | 1     |
| 3  | Coverage                         | 56.39            | 5     | 67.53            | 5     | 47.13            | 3     | 67.62                 | 5     |
|    | Total                            | 9                | 9     | 9                | 9     | 11               |       |                       |       |

Category: Medium

including photosynthesis, respiration, and productivity causing stress and disturbed seagrass growth [12]. Different sediment types host different species of seagrass. *E. acoroides* and *S. isoetifolium* grow in mud sediments, whereas *T. hemprichii*, *H. uninervis*, *C. Serrulata*, and *H. ovalis* grow in sandy sediments [2]. The level of anthropogenic activity both on land and in sea can damage seagrass communities [12].

*S. isoetifolium* was the highest density seagrass at Panjang Island with the widest coverage. The seagrass morphology influenced seagrass density and coverage. *S. isoetifolium* has a high density due to the size of the slender leafy needles, and the coverage was the highest due to the good quality of seawater and suitable sediments. *S. isoetifolium* was the dominant seagrass species across
Table 9. Seagrass density (D) and coverage (C) conditions at Panjang Island using the Braun-Blanquet scale [9].

| Location       | D (ind/m²) | Category  | C (%)  | Category |
|----------------|------------|-----------|--------|----------|
| Station 1      | 56.27      | Rare      | 56.39  | Good     |
| Station 2      | 59.62      | Rare      | 67.53  | Good     |
| Station 3      | 589.20     | Very high | 47.13  | Medium   |
| Pulau Panjang  | 235.03     | Very high | 67.62  | Good     |

Table 10. Correlation between seagrass and sediment silt and clay.

| No. | Seagrass species | Gravel | Sand | Mud | Clay |
|-----|------------------|--------|------|-----|------|
| 1   | E. acoroides     | -      | -    | +   | +    |
| 2   | C. serrulata     | -      | -    | -   | -    |
| 3   | S. isoetifolium  | -      | -    | -   | -    |
| 4   | H. uninervis     | -      | -    | -   | -    |
| 5   | H. ovalis        | -      | -    | -   | -    |

Panjang Island with an IV of 119.90. The IV indicates the role of a particular species or a species’ space control in a given ecosystem.

S. isoetifolium’s presence is important because it is a seagrass species that grows rapidly with a short life span [13, 14] and can survive in fine sediments [2] that are unsuitable for other types of seagrass. S. isoetifolium leaves often break because they are brittle, but the species recovers fast [15]. Fine sediments (terrigenous) have poor nutrients [16] and leaf breakage provides nutrients to the environment. S. isoetifolium has a high density and was found in mixed seagrass that is an important fish habitat. High-density seagrass communities form an important juvenile fish habitat by providing cover against predators. Juvenile groupers (Epinephelus coioides), snappers (Lutjanus russellii) are highly dependent on seagrass and they are an important commercial fish species in Banten Bay [17]. S. isoetifolium is also essential for the dugong diet for both wild dugong and those in captivity in Sea World, Ancol. S. isoetifolium often grows rapidly while other seagrass food sources for the dugong diet (Halophila and Halodule) occur in small quantities or are not available [15].

Anthropogenic activities (industrial, mining, and ports activities) that result in sedimentation mainly caused seagrass loss in Banten Bay [1, 3]. Teluk Banten also has high turbidity, weak tidal and subtidal currents, strong winds and a low depth (12 m) [18]. This combination of factors leads to the accumulation of sediments in the center of the bay [19, 20] where Panjang Island is located. Sediment resuspension usually leads to seagrass death [21]. However, we found that the seagrass community across Panjang Island was in good condition with high density and widespread coverage based on the [9] and [10] criteria. Good seawater quality and the composition of sediment support seagrass growth and did not damage the seagrass.

However, there was a time lag between seagrass measurements and suspended sediment loads. A correlation between clay and silt sediments and the density of seagrass in Panjang Island was only for E. acoroides. The dominance of fine sediments at Panjang Island were not correlated with S. Isoetifolium. Yet, S. isoetifolium density and coverage was high. This may be due to the optimal water quality at Panjang Island and suitable sediments that do not hamper growth. The concentration of heavy metals in the seawater of Panjang Island was below the minimal standart and sediment concentrations were lower than those in Jakarta Bay [22]. In good quality conditions, changes in fine sediment levels did not have a negative impact but provided nutrients required for seagrass growth [20]. S. isoetifolium exhibited increased growth and recovery rates in silt sediments [21].
Each seagrass species tolerates specific sediments differently. \textit{H. ovalis} can resist sedimentation rates up to 2 cm/year. \textit{E. acoroides} can resist sedimentation rates up to 10 cm/year, and \textit{C. serrulata} can resist sedimentation rates up to 13 cm/year [9]. Seagrass has also developed some adaptations to sediment. Experiments conducted by Vermaat et al. [14], who investigated sediment loads and seagrass recovery in the Philippines, showed that \textit{H. uninervis}, \textit{S. isoetifolium}, and \textit{C. serrulate} exhibited an initial decline in shoot density, followed by recovery. Conversely, \textit{E. acoroides} showed initial maintenance of shoot density but had declined by the end of the experiment.

Although the current conditions of seagrass beds around Panjang Island were good, monitoring programs are necessary to (a) quantify the causes of change, (b) examine and assess acceptable ranges of change for each site, and (c) measure the critical levels of impacting agents. Selection of appropriate parameters for research should be prioritized so that the study results and subsequent environmental assessments are ecologically meaningful. Government support is also needed, e.g. protection by legislation, establishment of marine-protected areas and periodic utilization areas, mitigation and restoration measures, effective water planning, and development of effective coastal management [23].

4. Conclusion

\textit{S. isoetifolium} was the dominant seagrass species around Panjang Island. Abiotic factors around Panjang Island provided good conditions for seagrass growth. Around Panjang Island, there exist considerably high-density seagrass beds with good coverage and medium health.

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