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Influence of Monsoon Seasons on Seagrass Ecosystems on the Coast of Kota Kinabalu (Sabah, Malaysia)

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ABSTRACT

Seagrass beds in Kampung Kebagu, Kota Kinabalu, Sabah, are notably affected by natural events and human activities. Seasonal monsoons particularly the Northeast Monsoon (NEM) and the Southwest Monsoon (SWM), intensify these effects, causing significant changes to the seagrass beds in a short period. This study aimed to determine seagrass coverage and leaf length during the NEM and SWM at Kampung Kebagu. The leaf length was focusing on the dominant species; *Enhalus acoroides* along the transect line. This study was conducted within a year from February 2023 until January 2024 to cover both monsoon periods. Seagrass coverage was estimated using 50 cm × 50 cm (0.25 m^2) quadrat with every 5 m interval along the transect line. Field measurements and data collection were done in February 2023, March 2023, May 2023, July 2023, September 2023, November 2023, and January 2024. The NEM was divided into two phases: February to March 2023 (T1) and November 2023 to January 2024 (T3). The SWM, identified as T2, spanned from May to September 2023. Further analysis of seagrass coverage and leaf length using Two-Way ANOVA was done to find significant effects of month between the parameters. There were significant different between seagrass coverage and months ($p < 0.05$). Seagrass coverage declined significantly to 38 ± 23% during the NEM but rebounded to 80 ± 11% in July 2023 during the SWM. The average leaf length of *E. acoroides* reached 29 ± 8 cm in May 2023 but was reduced to just 7 ± 2 cm by January 2024. Although this study was limited to a single year, it effectively captured fluctuations in seagrass coverage and leaf length across different seasonal monsoons. These results provide baseline data on how monsoon-related environmental changes affect seagrass ecosystems in this region.

Keywords: Kota Kinabalu, leaf length, northeast monsoon, seagrass coverage, southwest monsoon

INTRODUCTION

Seagrass is a unique marine angiosperm that can live up to a certain meter depth in the intertidal or subtidal zone. Malaysia is home to 17 different species of seagrass, which belong to three distinct families and these seagrass species are categorized into the genera *Enhalus, Halophila*, *Cymodocea, Halodule, Syringodium* and *Thalassia* (Kamal *et al*., 2023; Md-Nor, 2023).

Each genus contributes to the rich biodiversity of Malaysia's coastal and marine ecosystems. *Enhalus acoroides* is known as tape seagrass or tropical eelgrass and it is a large-sized seagrass found throughout the coastal waters of Southeast Asia and it can reach up to 1 meter or more in height (Bujang *et al*., 2018; Syed *et al*., 2019). The above-ground parts of the plant consist of long, strap-like leaves and flowers, while the below-ground parts include cord-like roots and thick rhizomes with black bristles. Seagrass provides numerous ecosystem services, and it may vary from biological importance such as being the nursery and feeding ground for marine species, and physical processes where seagrass assists in increasing the clarity of water by acting as a biological filter (Honda *et al*., 2013). Seagrass also provides habitat to marine life where coastal communities around the globe catch and collect their protein in seagrass areas thus becoming their livelihood (Green & Short, 2003).

The seasonal monsoon orients the climate in Malaysia; Northeast Monsoon (NEM) (November to March), the first inter-monsoon period (April), the Southwest Monsoon (SWM) (May to September), and the second intermonsoonal period (October) (Lolli *et al*., 2019). The extreme wave and storm events mainly occur during the peak of NEM. The changes of beach morphology in seagrass-dominated environments are influenced mainly by extreme wave events that lead to excessive erosion and deposition (Risandi *et al*., 2023). Coastal erosion may also occur when waves, longshore currents, and wind transport the sediment from shore and deposit it somewhere else (Prasad & Kumar, 2014). Monsoon rains can result in increased runoff from the land, carrying large amounts of sediment from rivers and streams into the coastal areas (Sadhwani *et al*., 2022). This soil erosion and sediment movement may result in sediment deposition in coastal regions, changing the dynamics and morphology of the shoreline and these processes affect the coastal ecosystems such as seagrass and mangrove ecosystems (Fitri *et al*., 2019; Figlus, 2022).

Patches of seagrass can be found near the coastal area and islands in Sabah. Record of seagrass species and its distribution in Kudat, Sabah were reported by Bujang *et al*. (2006) and Rajamani and Marsh (2015). Seagrass monitoring activities were also conducted on Pulau Gaya, Sabah (Short *et al*., 2014). There were two study sites (Kuari Bay & Police Beach) in Pulau Gaya that were reported to decline in seagrass total coverage due to excess sedimentation (Freeman *et al*., 2008). One of the remaining seagrass beds in the coastal area of Kota Kinabalu is located at Kampung Kebagu (Figure 1). However, it is prone to encounter seagrass beds degradation from both natural and anthropogenic activities. The natural cause primarily arises from seasonal monsoons, which bring changes in rainfall, wind, waves, and currents, thereby impacting seagrass coverage, leaf length and seabed sediment (Thomas, 2023; Yanalagaran *et al*., 2019; Govindasamy *et al*., 2013). During low tide, the seagrass is exposed to air and the nearby coastal communities glean on the seagrass bed for shellfish, sea cucumber, and small fish. This activity might affect the growth and coverage of the seagrass. Currently, no study on seagrass coverage and leaf length related to seasonal monsoons has been conducted in this area. More research is needed to understand the ecology and its response of seagrass on the seasonal variation. The objective of this study was to determine the seagrass coverage and leaf length between NEM and SWM at Kampung Kebagu. The findings of this study provide baseline data that will be important for the long-term monitoring of seagrass ecosystems in this area. This information is essential for documenting and understanding the changes and dynamics in seagrass beds in this area over time.

MATERIALS AND METHODS

Study Area

The study area is located in Kampung Kebagu, Kota Kinabalu (6º03'11.86" N, 116º06'35.62" E), Sabah. There were about 12 seagrass species identified in Sabah, and seven of the seagrass species are found in Kampung Kebagu (Thomas, 2023; Bujang *et al*., 2006; Phang, 2000). The study area is located about 2 km from the river mouth of the Sungai Menggatal (Figure 1). The river plays an important role as a source of terrestrial sediment. Thomas (2023) reported that the salinity, dissolved oxygen, and temperature near the seagrass meadow were about 25.74 ppt, 8 mg/L, and 34.7ºC, respectively. These environmental parameters are suitable for seagrass growth. The field trips for data collection and measurement were done during the NEM (February, March, November 2023 and January 2024) and SWM (May, July and September 2023). The tidal elevation was less than 0.5 m (Royal Malaysian Navy, 2023; Royal Malaysian Navy 2024).

Field Data Collection and Measurement

Seagrass coverage was estimated following the guidelines set by seagrass watch (McKenzie *et al*., 2009). Three transect lines were strategically established across the seagrass beds to ensure comprehensive data collection throughout the study area. These transects were positioned perpendicular to the shoreline to capture variations in seagrass coverage and leaf length of the dominant species at various distances from the coast. The layout of these transects lines illustrated in Figure 2, providing a clear visual representation of the study design. Each transect extended 50 meters from the shoreline on seagrass beds (Figure 3), with adjacent lines spaced 25 meters apart horizontally to facilitate effective assessment of seagrass coverage (%). To estimate the seagrass coverage, a 50 cm × 50 cm (0.25 m²) (Figure 4) quadrat was placed at 5-meter intervals along each transect, starting from the zero-meter mark and continuing to the 50-meter endpoint.

The seagrass leaf length was measured using a 40-cm ruler (Figure 5). The ruler was placed from the base to the tip of the leaf of the dominant seagrass species along the transect lines. Measurements were taken within a quadrat placed at 5-meter intervals, starting from the 0-meter point and extending to the 50-meter endpoint. For each measurement, the leaf length was recorded from the sediment to the tip of the leaf for three different shoots, with three replicates taken to calculate the average value (McKenzie *et al*., 2009).

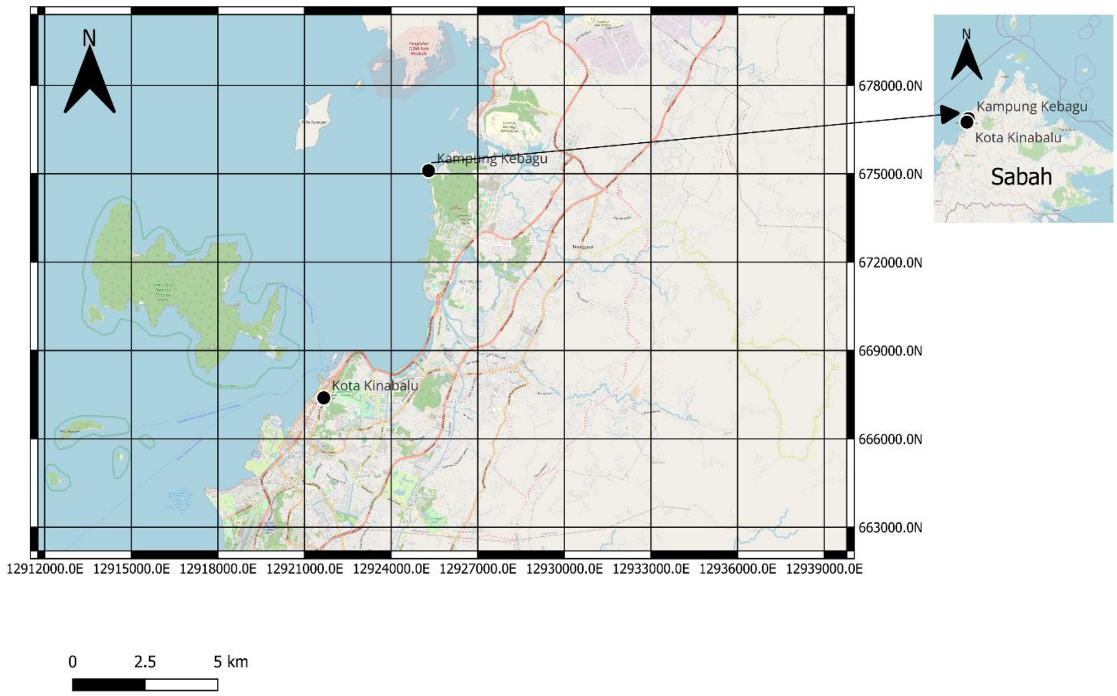

Figure 1. Location of the study area and sampling station

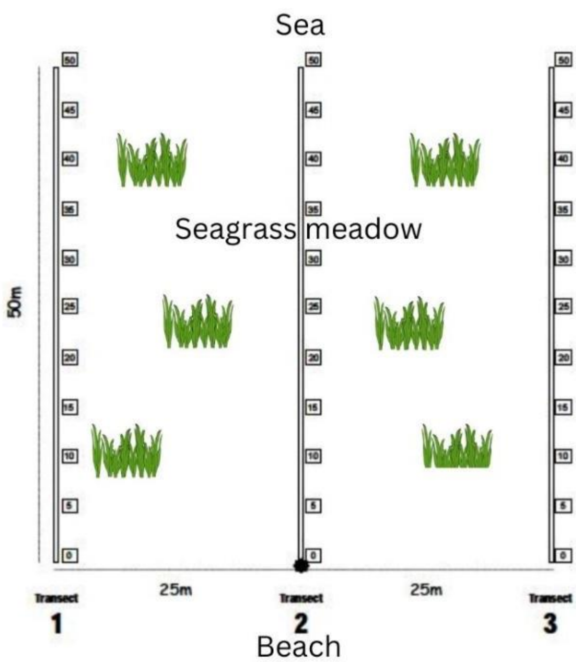

Figure 2. Illustration of the transect lines layout

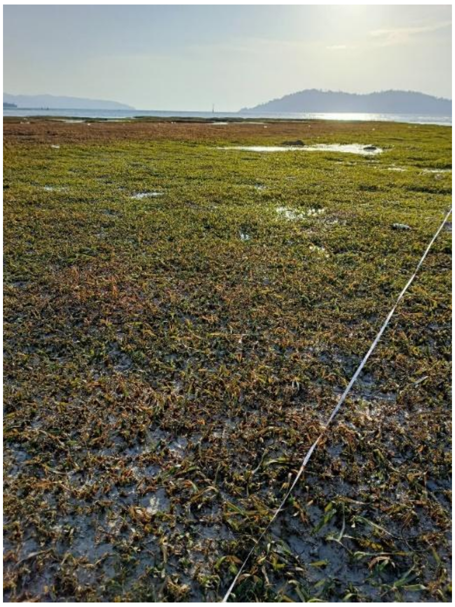

Figure 3. Transect lines on seagrass beds in Kampung Kebagu

Figure 4. Quadrat used for estimation of seagrass coverage

Figure 5. Measurement of leaf length using ruler

Data Analysis

The data collected and measured during the field trips were divided into three phases (T1, T2 and T3). The NEM, divided in two phases: February to March 2023 (T1) and November 2023 to January 2024 (T3). The SWM, marked as T2, occurred from May 2023 to September 2023. The mean and standard deviation for seagrass coverage and leaf length data were calculated using Microsoft Excel 2016. Two-Way ANOVA analysis was conducted to examine the effects of seasonal monsoon on the month and their interaction with both seagrass coverage and leaf length, with a significance level set at 0.05.

RESULTS AND DISCUSSION

Seagrass Coverage

The seagrass beds in Kampung Kebagu consist of mixed species within the beds (*Halophila ovalis*, *Enhalus acoroides*, *Oceana serulata, Halodule uninervis* and *Cymodocea rotundata)*. The seagrass beds were located about 100 m from the shoreline. No seagrass survived near the shoreline where the active longshore transport and resuspension of sediment occurred.

During the field trips, the most common seagrass species identified inside the quadrat was *E. acoroides*. This species was selected to serve as a reliable indicator of the seagrass ecosystem's health and dynamics during different seasonal monsoons. The pattern of seagrass coverage exhibited a notable rise starting from the initial phase of NEM in February-March 2023 (T1), culminating in its maximum extent in July 2023 during SWM (T2) (Figure 6). Following this peak, the seagrass coverage began to decrease from September 2023 until the onset of the second phase of NEM (T3).

During the NEM (T1) period, average seagrass coverage was approximately 38 ± 23% in February 2023 and increased to 53 ± 22% in March 2023 (Figure 6). Coverage continued to rise, reaching a peak of 80 ± 11% in July 2023 during the (SWM) (T2). However, the seagrass coverage was dropping to about 40 ± 15% by September 2023 (marked at the end of the SWM). The coverage declines persisted to 31 ± 14% and 31 ± 15% in November 2023 and January 2024 (T3), respectively. There were significant different between seagrass coverage and months ($p < 0.05$). These findings were aligned with the seagrass's study done by Saleh *et al*. (2020) in Pulau Gaya, Sabah where wave actions could reduce seagrass coverage to 41% during the NEM. However, the coverage has recovered up to 66% during the SWM period.

Leaf Length Variations

The pattern of seagrass leaf length exhibited a gradual decline from the early phase of the NEM (T1) to its later phase (T3) (Figure 7). During the T1 period, the average leaf length exhibited a steady increase, starting at approximately 20 ± 2 cm in February 2023 and growing to around 23 ± 5 cm in March 2023. This phase marked the initial stage of growth, with leaves gradually elongating. As the SWM (T2) phase commenced, the average leaf length continued to rise at approximately 29 ± 8 cm in May 2023. This growth trend stabilized during July 2023, indicating that the SWM provided optimal conditions for leaf development. However, with the onset of the second phase of NEM (T3), a gradual decline in leaf length became apparent. By September 2023 (as shown in Figure 6), the length had decreased to about 19 ± 4 cm, marking the start of a consistent reduction. This downward trend persisted, with leaf length shrinking further to approximately 12 ± 3 cm in November 2023 and reaching its lowest point of 7 ± 2 cm by January 2024.

This finding identified that the longest leaf length was measured in May 2023 during SWM (T2). This study aligned with study carried out in Indonesia at different monsoons. Rustam *et al*. (2013) reported the leaf length of *E. acoroides* were high during SWM. The growth rate of *E. acoroides* leaves can reach up to 5.6 cm/day and this period is characterized by optimal conditions for seagrass growth that, leading to increased productivity.

Analysis using Two-Way ANOVA showed that there was a statistically significant effect of month on leaf length where ($p < 0.05$). Seagrass was exposed in January 2024 (T3) as the low tide occurred in the morning. The burned and rotten seagrass leaves prone to become severely short during this period (Figure 8). The interaction between distance and month ($p < 0.05$)

suggested that these impacts are more pronounced closer to the shoreline as this part of the intertidal areas exposed to the sunlight compared to the seagrass beds located further offshore. This reflected exposure to daylight significantly reduced above-ground plant biomass due to desiccation and the scorching effect on leaves (Erftemeijer & Herman, 1994).

Overall, this study supports the idea that monsoonal disturbances have significant impact on the macroalgae community (Zainee & Rozaimi, 2020). Coverage and leaf lengths were varied across different seasonal monsoon where the observed seasonal and spatial variability underscores the sensitivity of seagrass ecosystems to environmental changes, particularly monsoonal influences. The peak productivity during SWM suggests that favourable light and nutrient conditions outweigh the potential stress from hydrodynamic forces like waves (Rustam *et al*., 2013). However, the decline during second phase of NEM (T3) associated with increased strong wind and heavy rainfall that leads to lower salinity and dissolved oxygen levels. Waves exposure and resuspended of sediment that led to turbidity peaks and finally negatively impacting seagrass (Peralta & Yusoff, 2014).

Seagrasses influence local hydrodynamics by minimizing sediment resuspension, enhancing light penetration, and supporting their growth. These variables may independently affect seagrass coverage and leaf length at different distances and across different monsoon. Bujang *et al*. (2006) mentioned one of the threats faced by intertidal seagrass in Sepangar Bay was waves driven by wind, sand movement, and erosion during the monsoon. Seagrass beds in Kampung Kebagu faced the same threats during the seasonal monsoon as the geographic location of this area in proximity with Sepangar Bay. This shown through the fluctuations of seagrass coverage and leaf length throughout the study.

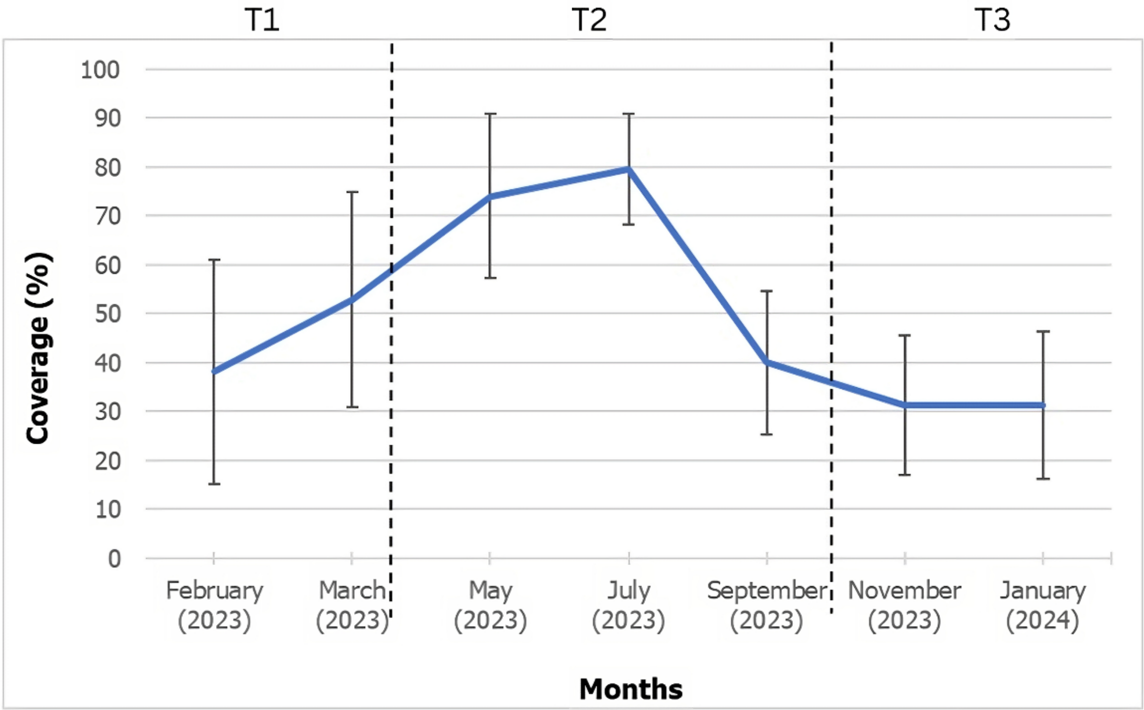

Figure 6. Changes in seagrass coverage (%) over three periods: First phase Northeast monsoon (T1), Southwest monsoon (T2), and Second phase Northeast monsoon (T3)

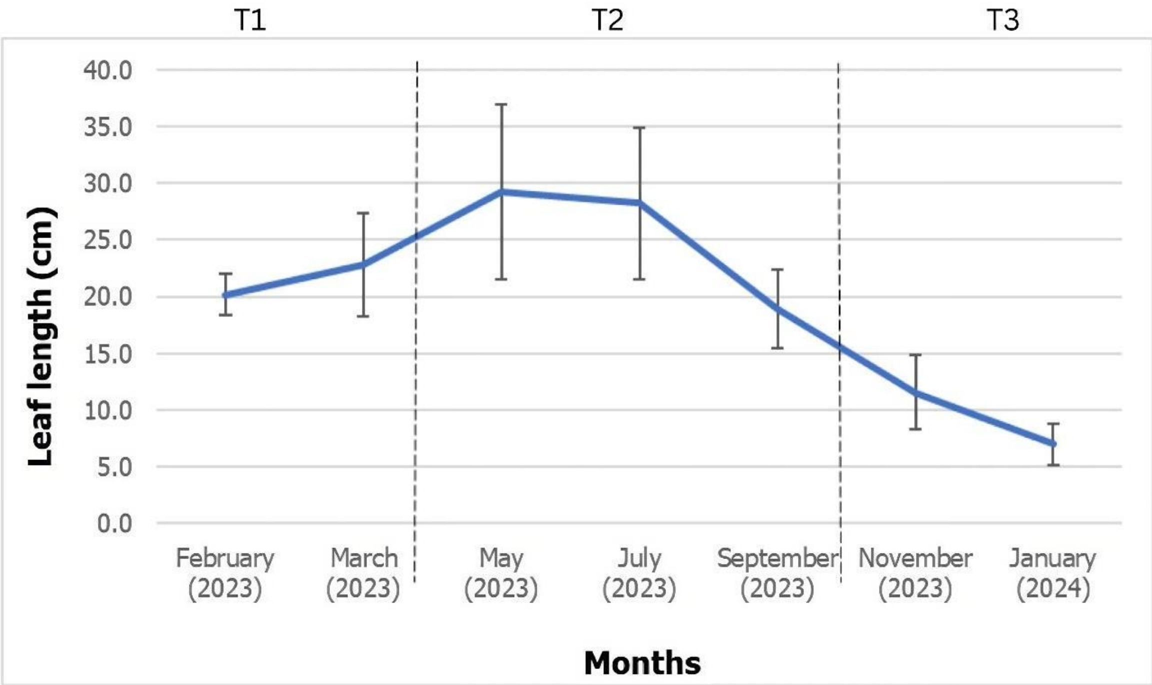

Figure 7. Changes in seagrass leaf length (cm) over three periods: First phase of Northeast monsoon (T1), Southwest monsoon (T2), and Second phase of Northeast monsoon (T3).

Figure 8. Exposure of seagrass to sunlight during low tide causes leaf burning

CONCLUSION

Monsoon seasons influence seagrass ecosystems. This study revealed distinct seasonal differences, with both seagrass coverage and leaf length peaking during the SWM and declining during the NEM. The findings reflect the significant impact of monsoonal dynamics on seagrass ecosystems in the coastal areas of Kota Kinabalu. The dominance of the seagrass species *E. acoroides* highlights its resilience and adaptability to changing environmental conditions, establishing its role as a crucial bioindicator for monitoring seagrass ecosystem health.

Although this study spanned only about a year, it clearly documented a fluctuation of seagrass coverage and leaf length at different seasonal monsoon. During the NEM, the seagrass coverage down to 38 ± 23% but it was recovered to 80 ± 11% in July 2023 during SWM. The average length of *E. acoroides* leaves can be up to 29 ± 8 cm in May 2023 but mostly cut off to 7 ± 2 cm by January 2024.

These findings provide baseline data on the impacts of monsoon-related factors on the seagrass ecosystem at this site. It offers insights into the ecological responses of seagrass beds to seasonal monsoon variations in Sabah. This study emphasizes the importance of conservation measures, particularly during periods of environmental stress. Long-term monitoring and incorporating additional environmental parameter such as water quality, nutrient contain, wave velocity is recommended to improve better understanding on seagrass ecosystem resilience in the face of climate change and anthropogenic pressures.

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