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Seagrass in Sulaman Lake, Tuaran, Sabah, Malaysia: Distribution and Threats

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ABSTRACT

Seagrass is a vital component of marine ecosystems, providing food, habitat, and nursery areas for numerous marine organisms. It is mainly found in intertidal zones and coastal lagoons. Healthy seagrass supports ecological functions that sustain fisheries productivity, thereby enhancing the livelihoods and food security of coastal communities. However, recent coastal development has increased suspended sediment in the water column and reduced seagrass coverage. Information on seagrass coverage and distribution is therefore crucial for management planning and protection. This study aimed to identify seagrass coverage, distribution, and associated threats at Sulaman Lake, Tuaran, Sabah, Malaysia. The lagoon, located on the west coast of Sabah, connects to about 5 km of shoreline. A seagrass survey, guided by the local community, was conducted between 28–29 January 2025 during spring low tide. Coordinates of seagrass patches were marked using a Global Positioning System and synchronized with Google Earth. Field surveys for data collection and species identification were repeated on 8 August 2025. Seagrass distribution was also assessed using a DJI Mavic Air 2S drone. Only one seagrass species, *Enhalus acoroides*, was detected in Sulaman Lake, with patches located approximately 30 m from mangrove edges. The present study estimated the seagrass coverage in Sulaman Lake is ~140 ha. The main threats to seagrass include sedimentation, suspended sediments, fishing and human settlements. Strengthening environmental management measures related to water quality and human activities is recommended to ensure the survival of seagrass ecosystems and associated marine organisms. Continued monitoring and conservation are also essential to sustain the ecological and socio-economic functions of seagrass in the lagoon.

1. Introduction

Seagrasses are vital to marine ecosystems, providing food and shelter for many marine species, including fish, mollusks, bivalves, and crustaceans [1,2]. Seagrass beds are especially important for juvenile marine life, offering both protection and nursery ground [1]. They also serve as a “blue carbon” ecosystem, trapping and storing carbon while protecting coastal communities from natural

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disasters [3]. Seagrass habitats have long provided coastal communities with food resources while supporting local economies through recreational fishing and tourism [1,4].

One of the remaining seagrass areas in the west coast of Sabah is located in the lagoon of Sulaman Lake, Tuaran, Sabah. The water parameters inside the lagoon are influenced by tidal condition and its surrounding runoff. Extreme freshwater influx stresses seagrass by transporting large amounts of suspended sediments from terrestrial sources. Jafferysin, [5] reported that the mean salinity and dissolved oxygen were relatively low at 26.85 ± 1.88 PSU and 5.05 ± 0.58 mg/L, respectively. The salinity level suggests freshwater influence while the dissolved oxygen concentration indicates marginal water quality, where values near the lower range may impose stress on sensitive aquatic organisms. During high tide, salinity could reach up to 32 PSU (Patrick, [6]). The water temperature ranged from 28–31 °C [5] reflects typical tropical conditions that support high primary productivity in seagrass ecosystems.

Information on seagrass in Sulaman Lake is limited. Mukai [7], highlighted the seagrass coverage. According to coastal communities, coastal development (e.g., road construction) and land clearing for agricultural activities within the catchment area have increased suspended sediment loads in the water column. Elevated suspended sediments reduce light penetration, which is critical for seagrass photosynthesis, and may lead to the degradation of seagrass cover. However, few studies have been carried out to understand the current status of seagrass in this area. Such information is essential for informing future management strategies and protecting marine ecosystems in Sulaman Lake. The present study aimed to assess seagrass cover, document species composition, and identify key anthropogenic threats affecting the persistence of seagrass meadows within the lagoon.

2. Methodology

2.1 Study Area

Sulaman Lake generally refers to a mangrove area located in Tuaran, Sabah, Malaysia. Within this region lies a large water body that forms a lagoon covering approximately 1,312 hectares, separated from the surrounding mangroves. This water body is a shallow lagoon connected to the sea about 5 km away towards inland through a narrow channel (Figure 1). Several studies have named this area as Sulaman Lagoon [8,9] or Sulaman Bay [4-7]. Locally, it is also referred to as Sulaman Lake, as it is surrounded by mangroves and, in certain areas, supports seagrass ecosystems. Generally, the area is extensively utilised by local communities from nearby villages for fishing and aquaculture activities. Although the surrounding villages (Kg. Penimbawan, Kg. Sambah, Kg. Serusop, and Kg. Betotai) (Figure 1) are accessible by road, the primary users of Sulaman Lake are fishermen and boats transporting the communities across the lagoon between Kg. Penimbawan and Kg. Serusop.

Sulaman Lake is an important aquaculture site, with more than ten small-scale oyster farms owned by local communities in the northeastern part of the lagoon, and approximately five floating fish cages located in front of Kg. Penimbawan. The lagoon is also occasionally used for tourist activities. For example, by the recently established Borneo Beach and Mangrove Resort (Figure 1) and Tembara River Cruise cruising the lagoon as part of its ecotourism activities.



Fig. 1. Sulaman Lake and location of the sampling stations

2.2 Fieldtrip Verification and Data Collection

Seagrass surveys guided by the local community were conducted between 28–29 January 2025. A small boat hired from the local community was used to access seagrass areas within the Sulaman Lake. The distribution of seagrass was detected using a DJI Mavic Air 2S drone (Figure 2) on 8 August 2025 during low tide. The aerial surveys provided large-scale mapping of seagrass distribution within the lagoon. The locations of seagrass beds were subsequently plotted in Google Earth. Ten random stations were selected to estimate seagrass percentage cover (Figure 1). Seagrass cover (%) was quantified using quadrat sampling, and the coordinates of each site were recorded with a handheld GPS device (Garmin 62s).



Fig. 2. DJI Mavic Air 2S drone used for seagrass mapping

The identified seagrass areas were compared with secondary data from previous studies [7]. Informal interviews with local community members were conducted during fieldwork to document the importance of seagrass and the challenges associated with natural and anthropogenic impacts. Potential threats to seagrass were observed and assessed for possible correlations with human activities surrounding the lagoon. A smartphone camera (iPhone 13) and binoculars (Bushnell Powerview 20×50) were used to record threats and environmental conditions around the study sites. The binoculars were also used to magnify seagrass areas and to observe human activities that may contribute to seagrass degradation. The assessment of seagrass was compared between studies conducted in the Riau Islands, Indonesia [10,11] and Sulaman Lake, both of which utilised field data on seagrass coverage and species identification. However, the study in the Riau Islands employed Sentinel-2 spectral imagery, whereas the study in Sulaman Lake used drone-based surveys due to

turbid water conditions. 3. Results 3.1 Seagrass distribution The seagrass in Sulaman Lake was identified as *Enhalus acoroides*, the only seagrass species recorded in the area during the fieldtrips. It is primarily distributed adjacent to the mangrove zone (Figure 3), extending approximately 10–30 m from the fringing mangroves. The seagrass beds are fully or partially exposed during spring low tides. A previous study [7] estimated the seagrass coverage in Sulaman Lake to be 1,089,835 m² (~109 ha), whereas the present study estimated an increase to approximately 1,400,000 m² (140 ha) (Figure 3). This estimation was based on dense seagrass meadows (coverage > 70%) detected by drone surveys conducted during low tide. Seagrass distribution ranged from patchy assemblages (Figure 4a) to dense and continuous meadows (Figure 4b). Dense seagrass meadows were mainly concentrated in the northern and eastern parts of the lagoon. The patchy assemblages were mostly not mapped during the survey, as the seagrass leaves were covered by sediment and difficult to detect using a drone. However, the leaves of *Enhalus acoroides* in dense seagrass meadows were visible from the water surface during low tide. At high tide, the meadows became submerged and were obscured by turbid water. The inner lagoon has a water depth ranging between 2–3 m during high tide [4]. Decade ago, *Thalassia hemprichii* was a dominant seagrass species in certain areas of Sulaman Lake but very limited distribution [7]. This species was not detected during this study.



Fig. 3. Distribution of seagrass in coastal area of Sulaman Lake

3.2 Seagrass Coverage

According to local community reports, seagrass coverage was extensive in the 1970s, consisting of multiple species and forming a large area of continuous meadows throughout the lagoon. In those days, the area was considered to support a healthy and stable seagrass ecosystem. However, destructive fishing practices and catchment area clearing for agriculture, such as rubber plantations has increased sediment and nutrient runoff, contributing to the degradation of seagrass meadows. Intervention by the Sabah Department of Fisheries has since halted destructive fishing activities within seagrass areas. During this study, the local community reported signs of recovery with seagrass coverage increasing. The seagrass coverage has increased by approximately 31 ha since 2012 [7]. However, this estimate may be influenced by the methods used to assess coverage, as this recent study has employed drone technology for more accurate mapping. Although there has been an increase in coverage, seagrass remains sparse in certain areas, indicating low density. A patchy distribution such as in Station 1 (Figure 4a) was also observed in certain parts of the lagoon. These areas may require human intervention to enhance seagrass coverage in Sulaman Lake.

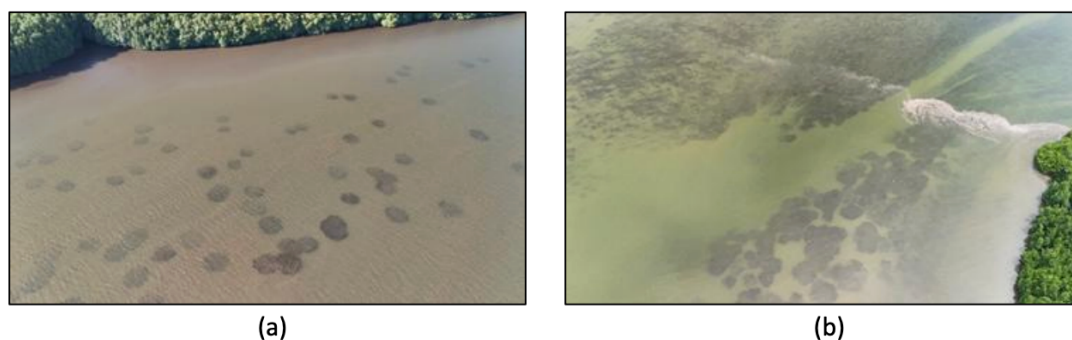


Fig. 4. Seagrass taken using drone showing the patchy (a) and meadow (b) seagrass area

The coverage of *Enhalus acoroides* in Sulaman Lake varied by location. Dense seagrass coverage (>70%) was observed (Figure 3; Table 1), while moderate (40–70%) and sparse (10–40%) coverage occurred near the shoreline, and very sparse coverage (<10%) was recorded along the channel. Random seagrass surveys showed that all sampled stations had seagrass coverage exceeding 70%. Seagrass was absent in the central part of the lagoon and along the channel, which is directly exposed to strong waves from the open sea. No seagrass was also observed in the areas where floating cages and oyster farms were located. Human intervention and waste discharge from these activities may affect the presence of seagrass beds.

Table 1

Seagrass coverage and turbidity in Sulaman Lake

Station	Coordinates (N/E)	Seagrass Coverage (%)	Turbidity (NTU)
1	6.256067°, 116.249444°	75	0.22
2	6.267653°, 116.278374°	70	0.32
3	6.266215°, 116.290574°	76	0.30
4	6.260198°, 116.283097°	80	0.31
5	6.253576°, 116.275638°	85	0.31
6	6.243006°, 116.271660°	90	0.35
7	6.232938°, 116.283969°	70	0.33
8	6.230791°, 116.272701°	70	0.20

3.3 Fisheries and Aquaculture Activities

Coastal lagoons are important fishing grounds for local communities. In Sulaman Lake, most fishing activities (e.g., gill nets and fish traps) were carried out near or within the seagrass areas. Fish bait was placed in the seagrass meadows during high tide, while nets and traps were set before low tide. According to the local community, seagrass plays a crucial role in supporting their fishing activities. Ong [9] reported that a total of 38 fish species and 9 macroinvertebrate species were caught in the seagrass areas. Fishes associated with seagrass habitat amount to 51 species from 24 identified families with the Gobiidae family being the most common [6]. Oyster farming is concentrated at the east side of Kg. Penimbawan in Sulaman Lake, using longline culture systems with oyster strings suspended from the lines in accordance with guidelines stated by [12]. Oyster farming addresses the issues of food security and protection to the environment [13]. Aquaculture activities in the area include floating cage culture within the lake and pond culture around its periphery. Although farming areas are located outside the seagrass meadows, increased turbidity from uneaten fish feed and metabolic waste reduces water clarity and limits light availability for seagrass photosynthesis [14]. Furthermore, excess nutrient loading and sedimentation from fish cages can disrupt ecosystem balance by elevating organic input rates. Seagrass mortality has been reported to increase up to 20-fold compared to control sites within the first 100 m of fish farms [15].

3.4 Issue and Challenges

Development in the catchment area, aquaculture and, water pollution represents the main threats and challenges to seagrass in Sulaman Lake (Table 2). Road construction and forest clearance for agriculture, has adversely affected the seagrass in Sulaman Lake. These activities contribute to increased sedimentation and nutrient runoff, which reduce water clarity, limit light penetration, and ultimately impair seagrass growth and survival. The turbidity level recorded during the field survey ranged from 0.20 to 0.35 NTU (Table 1), indicating clear water conditions with excellent light penetration suitable for seagrass growth. However, turbidity levels are likely to increase during heavy rainfall and storm events due to sediment resuspension.

The seagrass in Sulaman Lake is exposed to destructive fishing practice such as push nets, physical damage to seagrass meadows, uproot shoots, and resuspend sediments, compounding turbidity issues [16,17]. Seagrass located nearby villagers are exposed to boat anchoring and propeller scarring that contribute to the mechanical stressors to seagrass rhizomes and reduce meadow resilience.

Table 2

Threats and challenges to seagrass in Sulaman Lake

Threats and challenges	Description
Development at catchment area	Contributions to high sedimentation from deforestation, land clearing, and poor watershed management increase sediment loads. Ongoing road construction (e.g., Pan Borneo) may destroy or fragment seagrass habitats. High suspended sediments input from surrounding rivers alter sediment conditions in the lagoon. The accumulation of organic matter can make sediments anoxic and unsuitable for seagrass rhizomes.
Water pollution	Agricultural runoff from the catchment area and sewage discharge from nearby villages, Kg. Penimbawan and Sambah, directly enter the seagrass areas. These pollutions lead to increased nutrient loading and reduced water clarity.
Aquaculture	Increased turbidity from uneaten fish feed and waste reduces water clarity. Excess nutrient input and sedimentation from floating fish cages and oyster farms alter the ecosystem balance. Lack of water circulation and elevated nutrient levels lead to organic enrichment and eutrophication, potentially causing algal blooms and oxygen depletion that place stress on seagrass habitats.
Fisheries activities	Anchoring, mooring ropes, and boat propeller activity cause mechanical disturbances that uproot seagrass shoots and create propeller scars across seagrass beds. Similarly, the deployment of fishing gears such as, crab/fish traps and gill nets, within seagrass meadows results in physical damage of seagrass habitats.

The increasing number of communities around the lagoon, particularly in Kg. Penimbawan, has a direct impact on the seagrass beds in Sulaman Lake. Small boats are commonly used for transportation between villages and for fishing activities. Some fishing practices, such as shell digging and raking, disturb seagrass habitats by cutting leaves, damaging root systems, and loosening bottom sediments. Speeding boats generate wake waves that resuspend sediments, which later settle and smother seagrass leaves. In Sulaman Lake, small-scale trawling carried out by the local community in the past has caused serious damage, including cutting of leaves and uprooting of seagrass shoots. High suspended sediment loads from human development and construction near the study sites exacerbate the burial of seagrass and degradation of the lagoon seabed. Comparative seagrass studies between Indonesia [11,12] and Malaysia revealed that seagrass in the Riau Islands comprised mixed species (*Halophila ovalis*, *Halophila minor*, *Thalassia hemprichii*) with *Enhalus acoroides* as the dominant species, and showed evidence of temporal degradation. In contrast, Sulaman Lake was dominated by a single species, *Enhalus acoroides*, with coverage increasing over the past few years. This recovery is attributed to heightened community awareness and restrictions on destructive fishing practices that threaten seagrass habitats. Both studies highlight the importance of continued monitoring and conservation to sustain seagrass ecosystems.

4. Conclusions

The present study highlights that seagrass ecosystems in Sulaman Lake remain ecologically significant yet highly susceptible to anthropogenic disturbances. The lagoon is dominated by *Enhalus acoroides*, forming meadows that range from dense to patchy, particularly in the northern and eastern part of the lagoon. Dense meadows with >70% coverage were estimated to occupy approximately 140 ha. Historical accounts indicate that Sulaman Lake once supported multiple seagrass species and extensive continuous meadows. However, destructive fishing practices and catchment development have contributed to degradation through direct mechanical damage and sedimentation, respectively, thereby reducing overall coverage and resilience. Encouragingly, field observations and community reports suggest signs of recovery, with recent estimates showing an increase in seagrass coverage compared to the previous decade. This trend is attributed to community engagement and interventions by the Sabah Department of Fisheries, notably the enforcement of restrictions on destructive fishing practices. Nevertheless, persistent threats from aquaculture effluents, boat anchoring, and shoreline development continue to challenge the sustainability of the meadows, particularly as human activities intensify around the lagoon. In comparison with regional studies, Sulaman Lake is distinct in exhibiting recovery dominated by a single species. Continued monitoring, community participation, and targeted conservation measures are therefore essential to safeguard seagrass ecosystems, support fisheries productivity, and sustain the livelihoods of coastal communities. The findings will contribute to the 17 national biodiversity targets listed in the National Biodiversity Policy 2016-2025, in particular target 7: By 2025, "vulnerable ecosystems such as seagrass beds are adequately protected and restored. Acknowledgements This research was funded by a grant from Yayasan PETRONAS entitled "Seagrass Mapping and Community-Based Management in Sabah and the Federal Territory of Labuan (LKS2508)." We thank the community of Kg. Penimbawan for their assistance, interviews, and for sharing information about the seagrass in the Sulaman Lake lagoon.

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