

Short Communication: Potential threats to seagrass in the waters of Tanah Bumbu District, South Kalimantan, Indonesia

DAFIUDDIN SALIM^{1,2,♥}, ROHANI AMBO-RAPPE^{3, ♥♥}, SUPRIADI MASHORENG³, NADIARTI NURDIN KADIR⁴

¹Doctoral Program in Fisheries Science, Faculty of Marine Science and Fisheries, Universitas Hasanuddin. Jl. Perintis Kemerdekaan Km. 10, Tamalanrea, Makassar 90245, South Sulawesi, Indonesia

²Department of Marine Science, Faculty of Fishery and Marine, Universitas Lambung Mangkurat. Jl. A Yani Km. 35.8, Banjarbaru 70714, South Kalimantan, Indonesia. ♥email: dsalim@ulm.ac.id

³Department of Marine Science, Faculty of Marine Science and Fisheries, Universitas Hasanuddin. Jl. Perintis Kemerdekaan Km. 10, Tamalanrea, Makassar 90245, South Sulawesi, Indonesia. Tel/fax. +62-411-586025, ♥♥email: rohani.amborappe@mar-sci.unhas.ac.id

⁴Department of Fisheries, Faculty of Marine Science and Fisheries, Universitas Hasanuddin. Jl. Perintis Kemerdekaan Km. 10, Tamalanrea, Makassar 90245, South Sulawesi, Indonesia

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Abstract. *Salim D, Ambo-Rappe R, Mashoreng S, Kadir NN. 2024. Short Communication: Potential threats to seagrass in the waters of Tanah Bumbu District, South Kalimantan, Indonesia. Biodiversitas 25: 1882-1889.* Seagrass meadows are one of the most productive coastal communities, but they are easily degraded or lost due to declines in water quality. This study was conducted to analyze the potential threats to seagrass in the waters of Tanah Bumbu District, South Kalimantan, caused by increased turbidity from sedimentation and resuspension, the occurrence of invasive species, macroalgal and epiphytic cover on seagrasses. Field surveys on three coral cays (i.e. Anugrah, Penyulingan and Katoang) and a literature study were conducted to collect data on sedimentation rate, total suspended solids (TSS), climate and precipitation, invasive species, and percentages of seagrass, macroalgae and epiphyte cover. Results showed a sedimentation rate of 46.66 mg/cm²/day and TSS range of 0.83-774.8 mg/l. These parameters were likely influenced by changes in land cover, sediment loads from surrounding rivers, climate, and port activity, especially at coal and palm oil terminals. An invasive species, i.e. zebra mussel (*Dreissena* spp.), was found on seagrass, and this is the first report of such an occurrence on seagrasses. The overall average percentage of seagrass, epiphyte and macroalgae cover on Anugrah, Penyulingan and Katoang coral cays were 33±26.78%; 37.68±29.31%; and 2.43±1.77%, respectively. The results of this study imply that seagrass ecosystems in Tanah Bumbu are threatened by increased turbidity, minimum light penetration, fluctuations in salinity, and the occurrences of competitors (invasive species and macroalgae).

Keywords: Invasive species, seagrass, sedimentation, South Kalimantan, zebra mussel

INTRODUCTION

Seagrasses are higher plants (Anthophyta) that live and grow submerged in marine environments. Seagrass ecosystems are known as one of the most productive ecosystems on Earth (Azcarate-Garcia et al. 2020). Seagrasses evolved from terrestrial plants, which have physiologically adapted to marine waters (Mishra and Deepak 2021). They can form extensive vegetation communities (known as seagrass beds) at almost all latitudes except on polar seas (Mckenzie et al. 2020). Seagrass meadows are one of the most productive coastal vegetation communities and provide important and valuable ecosystem services in marine, lagoonal and estuarine ecosystems (Espel et al. 2019). Seagrass plants release dissolved oxygen, which is used by marine and estuarine biota (Thangaradjou and Bhatt 2017), filter the water column (Ruiz-Frau et al. 2017), and filter pathogens from coastal waters, helping to reduce the contamination of seafood and bacterial diseases of coral reefs (Cullen-Unsworth and Unsworth 2018). These plants can also transfer nutrients and organic matter (carbon) to deeper

waters of the ocean (Duarte and Krause-Jensen 2017) and capture suspended particles (Jiang et al. 2019). However, seagrass is easily degraded or lost due to a decline in water quality (Schrammeyer et al. 2018; Espel et al. 2019), pollution, aquaculture, invasive species, and capture fisheries (Murphy et al. 2019). They can also be affected by climate change phenomena, such as increased water temperature, as well as by sedimentation, erosion and ocean acidification (Wilson and Lotze 2019; Artika et al. 2020; Artika et al. 2021).

The existence of seagrass is strongly influenced by several environmental factors, including depth, substrate grain size, organic material, water temperature and light (Jahnke et al. 2019; Meysick et al. 2019), nutrient availability (Bulmer et al. 2018; Murphy et al. 2021), wave energy (Uhrin and Turner 2018), salinity (Ontoria 2020) and turbidity (Bulmer et al. 2018; Li et al. 2020). Declining water quality, often indicated by high turbidity, can be a driver of seagrass meadow and coral reef degradation (Yamamoto et al. 2019). Pollution in the form of coal dust in the water can have a direct impact on the growth of seagrasses due to reduced light penetration, limiting the photosynthetic

activity of the seagrasses (Berry et al. 2016; Tretyakova et al. 2021). Some other phenomena can also increase the turbidity of coastal waters, including floods, erosion, rain run-off and atmospheric events due to climate change and periodical dredging operations (Zhou et al. 2017; Li et al. 2020).

Coastal turbidity is influenced by terrestrial sediment loads originating from several adjacent river basins (Yamamoto and Nadaoka 2018). Sediment loads on land are increasing due to human activities, such as the intensification of agriculture and forestry, which makes the land surface more vulnerable to soil erosion (Yamamoto et al. 2019). The conversion of mangrove forests into brackish-water aquaculture ponds also contributes to increasing turbidity in coastal areas since these ponds might serve as a source of organic material and nutrient inputs, triggering massive phytoplankton growth (so-called algal bloom) and increasing turbidity in the surrounding waters (Yamamoto et al. 2019).

Tanah Bumbu District, South Kalimantan Province, is among the regions in Indonesia which is increasingly pressured by land-use changes, including the expansion of palm oil plantations, coal mining, and port operations. Such activities cause sedimentation of soil and other land-based materials carried by run-off into the rivers and ending in the sea, leading to the decline of marine water quality characterized by turbidity of the waters (Jamal et al. 2020; Pratama et al. 2021). In the long run, such pollution and sedimentation can degrade marine habitats, including seagrass beds and coral reefs (Unsworth et al. 2018; Jamal et al. 2020). Therefore, the aim of this study was to analyze the potential threats to seagrasses in the waters of Tanah Bumbu District. We expected the results of this study might provide an overview of the potential degradation of seagrass in the research area due to massive land changes.

MATERIALS AND METHODS

Study area

This study was conducted at three sites in the coastal waters of Tanah Bumbu District in South Kalimantan (3.756067°S, 115.717878°E; -3.760667°S, 115.741917°E;

and 3.760833°S, 115.723611°E) in April 2019 (Figure 1). The three study sites were situated on coral cay (*gosong karang* or GK in Indonesian). Katoang, Penyulingan, and Anugrah cays were selected for their extensive seagrass meadows and also had patch reefs. Seagrasses were present in the sub-tidal and intertidal zones of each cay, as well as around the coral outcrops and reefs. At the time of the study, people living in the region's coastal area mainly worked in transportation, mining, agriculture, plantations, port-associated activities, and fisheries. These activities can have negative impacts on seagrass, threatening the sustainability of seagrass meadows and their functions.

Seagrass cover and health condition measurement

Data on seagrass parameters were collected using 50×50 cm² quadrats (n=6) placed at 10 m intervals along 50 m transect lines that were laid perpendicular to the shore in a seaward direction (Rahmawati et al. 2017). In total, 18 quadrats were established across the study sites. Data collected included line transect coordinates, percentage cover of seagrass, epiphytes and macroalgae (McKenzie and Yoshida 2009). In addition, invasive species were identified based on morphology (Sugianti et al. 2014). The seagrass percentage cover was classified into four categories: rare (0-25%), moderate (26-50%), dense (51-75%) and very dense (76-100%) (Rahmawati et al. 2017). Seagrass condition or health category was based on the national regulation Minister of the Environment Decree No. 200/2004 (Good >60%; fair 30-59.9%; poor 0-29.9%). Environmental factors that may influence the health condition of the seagrass were also measured.

Environmental data collection

Environmental data, namely temperature, salinity, pH and light penetration, were measured of 3 replicates at the sea surface (McKenzie and Yoshida 2009). Secondary data on sedimentation, TSS, climate and rainfall were obtained through a literature study. No statistical analyses were conducted in this study. The values of environmental factors values were calculated and presented as mean±standard deviation (SD).

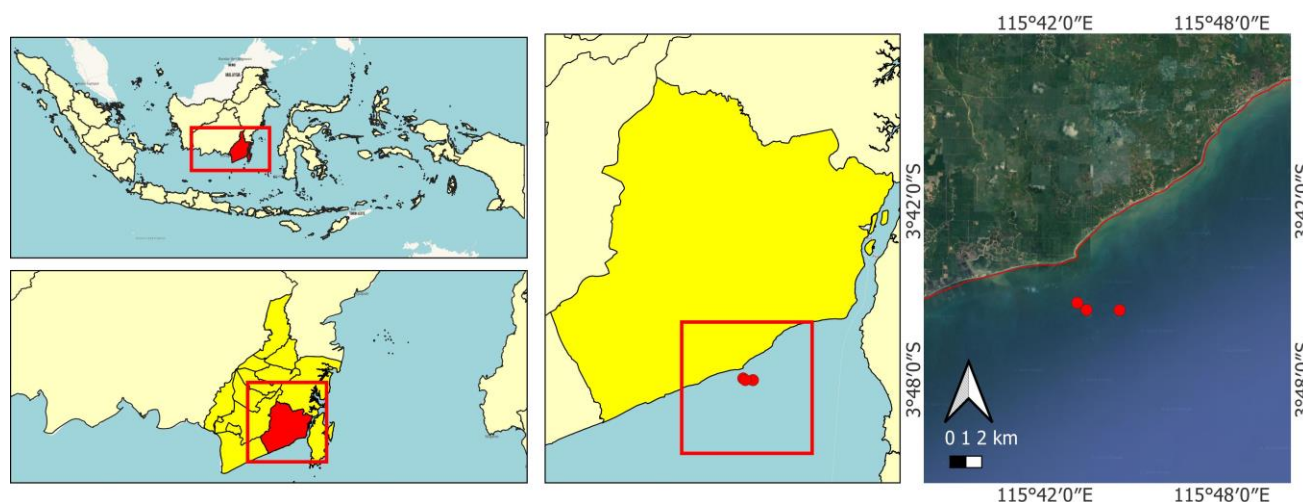


Figure 1. Map of the sampling sites in Tanah Bumbu District, South Kalimantan, Indonesia

Changes in land cover

Land cover changes were estimated by analyzing images downloaded from the Google Earth application covering the last 10 years (2012-2022). This uses a quantitative spatial-temporal method, namely the process of mapping and calculating land area based on space and multi-time (Daswin and Kumar 2023). The data used comes from Google Earth, taking into account data availability, good resolution and easy of accessing the data.

RESULTS AND DISCUSSION

Seagrass cover and health

Seagrass percentage cover varied among sites, ranging from $2.13 \pm 1.73\%$ to $50.00 \pm 5.59\%$ (Table 1). GK Anugrah had the highest percentage cover with $50.00 \pm 5.59\%$, and GK Katoang had the lowest with only $2.13 \pm 1.73\%$, while at GK Penyulingan, the cover was $46.88 \pm 10.27\%$. Two seagrass meadow sites (Anugrah and Penyulingan) had moderate cover and fair condition, while the seagrass meadows in Katoang had rare cover and poor condition. The associated organisms observed were epiphytes and macroalgae (Table 1).

The environmental parameters also varied among sites (Table 2). Seawater temperatures ranged from 29.10 to 30.00°C, salinity ranged from 25.30 to 29.80 ppt, pH ranged from 8.00 to 8.50, and visibility ranged from 2.30 to 2.50 m.

Land-cover changes and human activities

The analysis of Google Earth images showed massive land changes within a period of ± 10 years, especially in several areas in the Tanah Bumbu District watershed. Intensive land use categories that expanded in the hinterland included coal mining, oil palm plantations, industry, aquaculture, agriculture, and settlements (Table 3 and Figure 2). The changes in land use in plantations, mining and coastal infrastructures could be strongly related to increased sedimentation and turbidity in coastal waters (Pratama et al. 2021). At least 20 ports and harbors were identified along the coast of Tanah Bumbu District. These include ferry and national inter-island transport (PELNI) ports, fishing ports, passenger terminals (with speed boat services) and so-called special ports owned and operated by private companies (palm oil, cement and coal terminals) (Jamal et al. 2020).

Sediment loads

Sedimentation rates of $46.66 \text{ mg/cm}^2/\text{day}$ have been reported in the waters around the coral cays of Tanah Bumbu District (approximately 3 km offshore) (DKP 2020). A study on the spatial distribution of TSS due to sedimentation in the waters of Tanah Bumbu showed TSS values in the range 0.83-774.80 mg/L with an area of 0.17 ha in the low threat category, 212.11 ha in the moderate threat category and 128.14 ha in the high threat category (Jamal et al. 2020).

Table 1. Percentage cover of seagrasses, epiphytes and macroalgae at each site (mean \pm SD)

Site	Seagrasses (%)	Epiphytes (%)	Macroalgae (%)
Anugrah	50.00 ± 5.59	49.58 ± 9.95	3.13 ± 3.42
Penyulingan	46.88 ± 10.27	4.29 ± 3.48	4.17 ± 5.10
Katoang	2.13 ± 1.73	59.16 ± 16.87	0

Table 2. Environmental parameters measured at the three study sites (mean \pm SD)

Site	Temperature (°C)	Salinity (ppt)	pH	Visibility (m)
Anugrah	30.00 ± 0	29.60 ± 0.5	8.00 ± 0	2.50 ± 0
Penyulingan	29.80 ± 0.2	29.80 ± 0.2	8.40 ± 0.05	2.50 ± 0
Katoang	29.10 ± 0.2	25.30 ± 0.5	8.50 ± 0	2.30 ± 0.5

Table 3. Land-cover change within a period of ± 10 years

Land-cover	Area (ha) 2010	Area (ha) 2022	Information
Forest cover	886.39	267.52	Decrease
Shrubs	705.9	1420.04	Increase
Aquaculture (fishpond)	620.49	509.99	Decrease
Settlements	96.17	111.46	Increase
Oil palm plantations	4464.77	2265.12	Decrease
Mangrove	217.88	150.04	Decrease
Coal mining/open ground	116.53	2225.88	Increase
Rivers	86.76	86.76	Stable
Rubber plantation	59.12	217.17	Increase

Climate and precipitation

The climate in the study area is included in the monsoon type, which is strongly influenced by the monsoon winds which change according to the season (DKP 2020). From October to March, monsoon winds blow from northwest to southeast. Meanwhile, from April to September, the winds blow from the southeast to the northwest. This climate type has a short dry season (<60 mm precipitation) with 1 to 2 dry months per year. Air temperature is high throughout the year with a minimum monthly average temperature greater than 18°C, high rainfall throughout the year, and annual precipitation greater than 1,500 mm. Furthermore, data on the monthly average rainfall during the period 2001-2017 in the western part of Tanah Bumbu shows that the rainfall is highest in January and December (393 and 419 mm, respectively) and lowest in September (21 mm). Meanwhile, in the eastern part, the rainfall is highest in January (277 mm) and lowest in August (104 mm). Thus, the annual rainfall data for the last 10 years show annual precipitation ranging from >1000 to >3000 mm with 70 to 200 rainy days per year (DKP 2020).

Invasive species

The presence of invasive bivalves is reported for the first time in this study in April 2019 (Figure 3). However, the origin and impact of the invasive species on the seagrasses are not known with certainty, although this invasive species had covered most of the seagrasses in GK Katoang. The

specimens observed were identified as *Dreissena* spp., a group of mollusks belonging to the family Dreissenidae, the class Bivalvia and the order Myida. Typical morphological traits of these mussels include a “D” shaped shell. The specimens observed had zebra-like stripes, varying zigzag patterns of black or brown with white and yellow stripes, a smooth thin shell, and the average length of 1 to 2.5 cm. Most individuals were attached to the leaves and rhizomes of *Halodule uninervis* (Forssk.) Boiss. by their byssus (Figure 3). This species does not seem to have been seen in the area prior to the report, and to our knowledge, this alien species has not been monitored since that first report.

Discussion

The low percentage of seagrass cover at GK Katoang was strongly influenced by the presence of other associated organisms that dominated substrate cover in the area. Additionally, the epifauna consisted mainly of bivalve mollusks, most of which were firmly attached to the seagrass stems or rhizomes in GK Katoang and might have contributed to reducing the space available for the seagrasses to grow. While epiphytes were also the most dominant substrate cover at GK Anugrah (49.58±9.95%), the seagrass cover at this site remained high at around 50%, higher than at the other sites. In contrast, there were relatively few epiphytic organisms at GK Penyulingan with low cover just about 4.29±3.48%, while the seagrass cover was relatively high (46.88±10.27%).

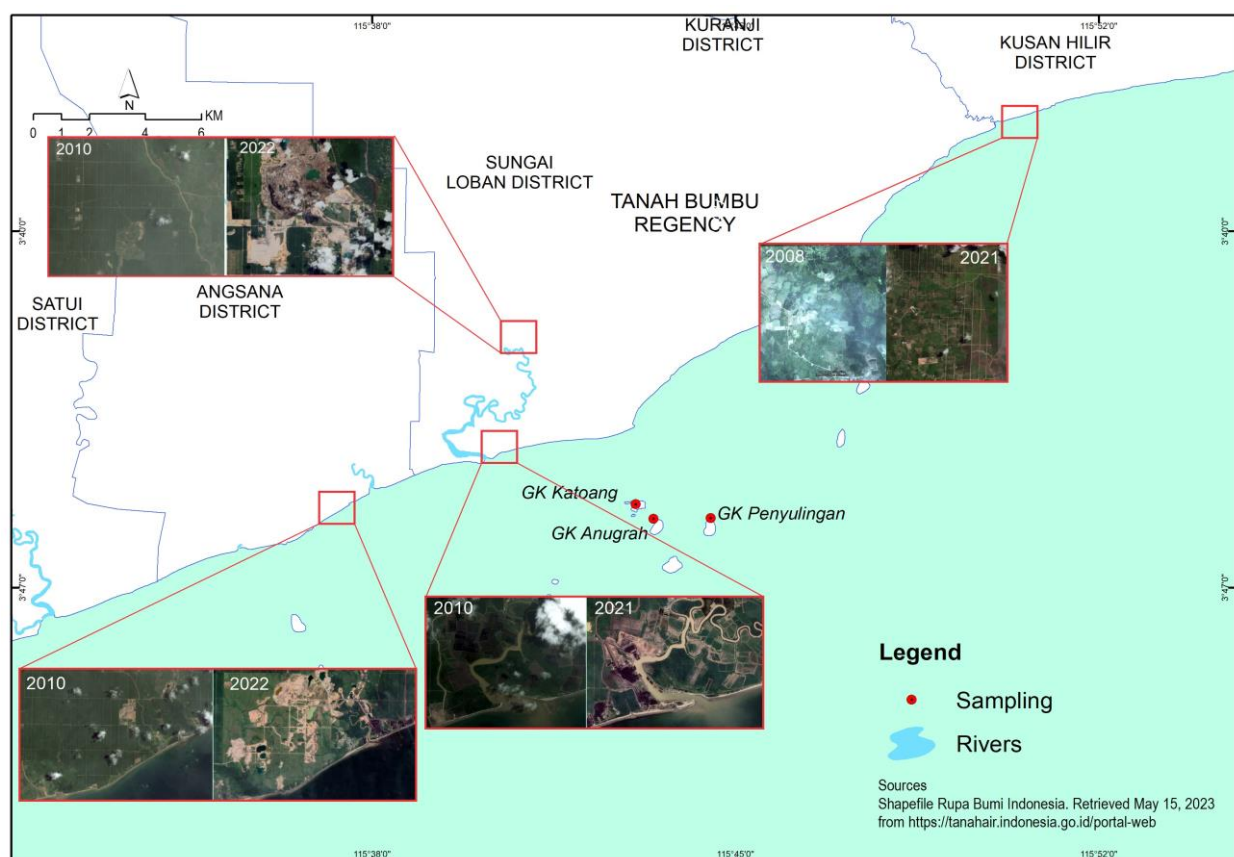


Figure 2. Changes in land cover in Tanah Bumbu District, South Kalimantan, Indonesia, between 2012 and 2022



Figure 3. A. Zebra mussel *Dreissena* spp.; B. Mussels attached to seagrass leaves and rhizomes

Epiphytes are organisms that only attach to plant surfaces, such as the leaves and rhizomes of seagrasses. It was reported that the presence of epiphytes on seagrass leaves could prevent nutrients from being absorbed, reducing the productivity of the seagrass. This happens if the main predators of the epiphytes are absent or very few, and there will be a build-up of epiphytes on the seagrass leaves, thereby hindering the process of photosynthesis and growth of the seagrass (Mabrouk et al. 2014). In contrast, some epiphytes on leaves have also been shown to be beneficial to seagrasses by increasing the amount of bioavailable inorganic nitrogen through mineralization of dissolved organic nitrogen deposited by microorganisms on the leaf surface, thereby increasing the productivity and growth rates of seagrass as a host for the epiphytes (Tarquinio et al. 2018). Macroalgal also plays a role in influencing seagrass cover, but the percentage of macroalgal cover at the three study sites (Anugrah, Penyulingan, and Katoang cays) was relatively low (around 3%, 4% and zero, respectively) as seen in Table 1. Despite their limited growth at these sites, benthic macroalgae should be able to grow well because they only require 8-10% light penetration (Choice et al. 2014).

Epiphytes and macroalgal cover are often included in the monitoring of seagrass meadows conditions, and they tend to grow well with seagrasses. They can benefit the seagrasses by providing shading from solar radiation and can be used as an indicator of seagrass ecosystem health (Hernawan et al. 2021). Species richness and epiphytic cover on seagrasses in the subtidal zone are highly dependent on permanent submergence which results in relatively constant temperature, salinity and pH, and on the presence of substrate (i.e., seagrass leaves), all of which are key factors in understanding their development.

Seawater temperature, salinity, pH, and visibility are environmental parameters that can influence seagrass growth and reproduction (Ontoria et al. 2020; Artika et al. 2021; Peralta et al. 2021). In this study, these parameters were within acceptable levels for seagrasses to survive and grow. The temperature range observed from 29.0-30.0°C is within the optimal range for the growth of tropical seagrasses. The average salinity in the study area varied among sites. An experimental study found that the seagrass

(*Halophila ovalis* (R.Br.) Hook.f.) could survive in water with salinity levels of 20 ppt and 30 ppt, but was not able to survive at 10 ppt salinity for many months (Lamit and Tanaka 2021). Research based on a combination of surveys and laboratory work found that a salinity of 20 ppt and turbidity below 50 NTU was suitable for growing the seagrass *Zostera japonica* Asch. & Graebn., while high salinity (>25 ppt) and very turbid conditions (>100 NTU) were not conducive to the growth of seagrass seedlings. However, under conditions of high turbidity, growth is better at low salinity (Hou et al. 2020). Decreasing the pH in the waters will impact seagrass metabolism (Apostolaki et al. 2014) and the physiological activity of seagrasses (Artika et al. 2020). Light penetration at the study site was sufficient with a relatively shallow depth (2-3 m). Seagrasses are sensitive to light availability at various depths and seasons, including their leaf responses, shoot scale responses and changes in seagrass structure (Peralta et al. 2021). The low light received by seagrass plants is responsible for physiological changes and decreased their growth and production (Enriquez et al. 2019).

Increasing turbidity in the waters of Tanah Bumbu District cannot be separated from land-use activities, especially oil palm plantations, coal mining and other coastal activities. Such activities contribute to environmental problems on the coast by causing sedimentation as well as supplying land materials carried by rainwater flowing into rivers and finally to the ocean (Jamal et al. 2020; Pratama et al. 2021). Furthermore, the sea currents from the Java Sea and Makassar Strait that traverse the waters of the study area carry sediment as bedload and suspended load, as well as pollutants, that can accumulate in the coastal waters and lead to the degradation of coral reef and seagrass ecosystems (Unsworth et al. 2018; Jamal et al. 2020).

The sedimentation rates in the waters around the coral cays of Tanah Bumbu District are classified as moderate to heavy. Such rates can have considerable negative impacts on marine biota, including a reduction in species density, growth rates, recruitment rates, and a number of species, and increases in invasion by opportunistic species (Magris and Ban 2019; Zabarte-Maeztu et al. 2020). Erosion and sediment transport reduce light penetration and can

eliminate seagrasses by preventing growth (Browne et al. 2017). Fine sediment particles are especially harmful to seagrasses because they block light most effectively (Zabarte-Maeztu et al. 2020). TSS levels tend to be higher, meaning higher turbidity, in areas with low salinity; in turn, this increases the deposition rate of fine particles, such as silt and clay on seagrass leaves, reducing light penetration to the photosynthesizing cells (Lamit and Tanaka 2021).

Geographically, South Kalimantan Province is situated close to the equator. This affects the climatic conditions of this region which experiences relatively small climate fluctuations throughout the year, with no extreme differences between the rainy season and the dry season. Under these conditions, it can be estimated that the study area has a high potential for flooding and an abundance of surface water flowing through rivers, resulting in large river plumes. River plume dynamics in the coastal waters of Tanah Bumbu District are strongly controlled by variations in monsoon weather patterns. Variations in river debit during the year have a limited impact on river plume extent. Biotic communities in the coastal ecosystems are seasonally exposed to episodes of low salinity. The average salinity levels and the period of time for which salinity falls below 25 ppt have a considerable impact on ecosystem health, including seagrass abundance and species richness. In the study area, the dominant seagrass species at the site closest to the shore (about 5.5 km to the Bunati River estuary) were *H. uninervis* and *H. ovalis* (Salim et al. 2016). These seagrass species can grow in waters that are frequently exposed to river plumes (Tarya et al. 2018; Lamit and Tanaka 2021) and are adapted to the relatively high turbidity found in such environments because of their morphometric traits, such as small leaves and their leaf shape. Such conditions can also affect the seagrass population and community structure (Kendrick et al. 2019; Salimi et al. 2021).

Environmental conditions in ports and harbors often cause stress to organisms and coastal marine systems. In particular, maritime traffic and dredging result in increased turbidity, reduced light penetration and changed sedimentation patterns, which have serious consequences for sensitive marine ecosystems, such as seagrasses (Browne et al. 2017). Coal terminals are one of the port types with the greatest impact on seagrasses, as seagrasses can be exposed to high concentrations (e.g., 275 mg/L) of suspended matter, especially coal particles under 63 µm in diameter. Moreover, the particles can be suspended in the water column for up to 28 days before settling on the seabed, affecting light penetration to reach the seagrass and the suspension also can settle on the seagrass leaves and disturb the photosynthetic activity, reducing growth rates and the density of seagrass roots (Berry et al. 2016).

The invasive species found in this study are mostly reported from fresh-water and brackish-water environments, with comparatively few reports from marine waters because the zebra mussel can only survive at salinity <12 ppt (Vanderbush 2021; Riley et al. 2022). In 2002, the presence of this species was reported on the Mississippi coast between Cat Island and Gulfport (15-20 km from Gulfport), but these specimens could not survive

long in marine waters (NAS 2002). In this study, zebra mussel colonies were only found at GK Katoang and none were found at the other sites. It is likely that the invasive species originated from the ballast water and shipping activities (Vanderbush 2021; Riley et al. 2022; Yagci and Yildirim 2022) from the nearby special port (2.3 km away) or the outflow of the Bunati River (5.5 km away). Coastal habitats close to the shore tend to be exposed to a high level of disturbance. Seagrasses provide a high structural complexity habitat, and therefore, a variety of invasive species can be trapped along with large volumes of sediment and various contaminants (Birrner et al. 2021; Byers et al. 2023). Furthermore, shipping lanes, increased maritime traffic, port development, and the use of ballast water by ships on terminals are expected to increase the rate of introduction of invasive species (Murphy et al. 2021; Vanderbush 2021). There is no information on the impact of *Dreissena* spp. on seagrasses, but another invasive species, the Asian mussel (*Arcuatula senhousia* W.H.Benson 1842), has been found to inhibit the spread and growth of the seagrass *Zostera marina* L. in San Diego Bay where the density of *A. senhousia* reached 15,000 ind/m² (Reusch and Williams 1998). A study in El Mellah Lagoon reported that a relatively low density of *A. senhousia* (1321 ind/m²) probably had a limited impact on seagrasses; however, observations of increased density of the mussel were associated with a decrease in the density of *Zostera* spp., indicating a need for monitoring and further research (Hamza et al. 2022).

In conclusion, the varied environmental conditions in the coastal waters of Tanah Bumbu District highlight threats to the high diversity of marine biota and extensive seagrass beds. This area is facing environmental challenges due to coastal development, such as plantations, agriculture, and mining infrastructure. These developments can cause existential threats to seagrass beds. Additional pressure from climate change impacts and the presence of invasive species are likely also drivers of seagrass degradation in Tanah Bumbu District. Monitoring of seagrass beds needs to be carried out by local and central governments and supported by the entire community.

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