Seagrass rehabilitation in Thousand Islands, Jakarta: step to restore

R F Darus¹,², S B Agus¹, F Kurniawan³,⁴, Juraj⁵ and T Subarno⁶

¹Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, IPB University (Bogor Agricultural University), Jl. Agatis, Darmaga Bogor, Bogor 16680, Indonesia
²Biology Education, Faculty of Mathematics and Natural Sciences Education, IKIP PGRI Jember, Jl. Jawa Sumber Sari, Jember 68121, Indonesia
³Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University (Bogor Agricultural University), Jl. Agatis, Darmaga Bogor, Bogor 16680, Indonesia
⁴Center for Coastal and Marine Resources Studies, Bogor Agricultural University, Jl. Pajajaran No. 1, Tegallega, Bogor Tengah, Kota Bogor, Jawa Barat 16129, Indonesia
⁵Indonesian Seagrass Foundation, Jl. Amonia F–10, Beji Timur, Depok 16422, Indonesia
⁶Rare Kendari-Indonesia, Jl. Sao-Sao, BTN 1 blok H6, Bende Kadia, Kendari 93117, Southeast Sulawesi, Indonesia

*Corresponding author: robbadarus@apps.ipb.ac.id

Abstract. Seagrass plays an essential role in coastal areas with ecological functions as a marine habitat, sediment trap, sediment stabilizer, nutrients filter, and dampen current. Fisheries and tourism are the seagrass ecosystem services that are the primary community livelihood in Thousand Islands. However, seagrass condition has decreased in the last decade, influenced by coastal development, mass tourism, and climate change. This study aims to assess the seagrass status and identify the threat in the last decade. Seagrass coverage was assessed in 2007 and 2018 using plot transect, and then seagrass threats were documented and collected from research articles, manuscripts, proceedings, and unpublished reports. Seagrass coverage has significantly decreased on Thousand Islands. Seagrass threats include pollution, reclamation, vessel activities, mass tourism, coastal development, climate change, and biotic factors (macroalgae and epiphyte coverage). The threats impact seagrass conditions, such as species diversity, area, and ecosystem services. Rehabilitation is needed to recover seagrass conditions using a direct or indirect approach. These findings recommend that managers should arrange the seagrass rehabilitation action plan to minimize seagrass degradation.

Keywords: coastal development; climate changes; rehabilitation; seagrass; Thousand Islands

1. Introduction

Seagrasses are marine plants with a wide distribution from topical to subtropic region [1-3]. Indonesia had a seagrass area of about 293,464 hectares in 2018 and reported 16 species [4]. Seagrass plays an essential role in a coastal area such as marine habitat [5], sediment trap, sediment stabilizer, nutrients filter, and dampen current [6, 7]. Furthermore, seagrasses provide ecosystem services such as provisioning (nursery and feeding grounds for fish, food), regulating (coastal protection), cultural (recreation, aesthetic, and spiritual), and supporting services (biodiversity, primary production) [8-10].

Waycott, Duarte, Carruthers, Orth, Dennison, Olyarnik, Calladine, Fourqurean, Kenneth L. Heck, Hughes, Kendrick, Kenworthy, Short and Williams [11] reported that seagrass declined 1% per year from 1940 and 7% per year since 1990. The seagrass decline is caused by diseases, anthropogenic and natural disturbances [12, 13]. Erosion is an example of a natural disturbance that can lead to reduced seagrass growth, reducing light availability, and burial for young plants [14-16]. In addition, seagrass
exposed to anthropogenic impacts such as coastal development, land reclamation, destructive fishing practice (anchor damage), fish farming, excess nutrient, land run-off, solid waste disposal, lack of awareness of the importance of seagrass, and lack of tools and information for enforcing seagrass conservation [10].

Thousand Islands are one of the seagrass distribution areas in Indonesia. Fisheries and tourism are the primary community livelihood influenced by population growth [17, 18]. Land-use becomes driven based on the coastal community livelihood [19]. Accordingly, tourism is the alternative income. These activities can threaten the seagrass’s existence, including the condition and area. The impact of disturbances is the loss of seagrass ecosystem services [10]. This study will assess seagrass condition, identify and evaluate the seagrass condition decline, and describe the mitigation.

2. Material and methods

This study was conducted in 2018 in Thousand Islands, including Pari Island, Tidung Island, Payung Island, Pramuka Island, Panggang Island, Harapan Island, Kelapa Island, and Panjang Island (figure 1). Seagrass coverage assessment used the plot transect method (50x50 cm) from the beach to slope with an interval of 10% each plot by snorkelling. Seagrass coverage of 2007 was used to compare the seagrass condition between 2018 collected from E Estradivari, E Setyawan and Yusri [20]. Seagrass threats that affected seagrass conditions were documented directly in the field and identified from scientific articles and unpublished reports. Threat mitigation will be evaluated using the DAPSIR framework, a tool to
manage an ecosystem locally [21]. Seagrass threats are divided into drivers and activities [22]. The driver is a trigger; the disturbance and activities are the threat that arises by the driver. Pressure is affected by the activities (threats), the state represents environmental change by the stressor, whereas impacts are consequences of environmental changes. Responses mitigate socio-economic problems and manage, detect, prevent, and restore the seagrass meadow.

3. Result and discussion
3.1. Seagrass status
A total of nine species were found in Thousand Islands in 2018, namely *Enhalus acoroides* (Ea), *Cymodocea rotundata* (Cr) or *Cymodocea rotundata* (Cr) (new name), *Cymodocea serrulata* (Cs), *Syringodium isoetifolium* (Si), *Halophila ovalis* (Ho), *Halophila minor* (Hm), *Thalassia hemprichii* (Th), *Halodule uninervis* (Hu), and *Halophila decipiens* (Hd) (figure 2). *Thalassia hemprichii* is found in all study areas, while *Cymodocea serrulata* is only found in Panggang Island.

In 2018, the highest coverage was Panggang Island, while the lowest was Kelapa Island. In 2007, the highest coverage was Panggang Island, and the lowest was Tidung and Payung Island. Seagrass coverage has decreased from 2007 to 2018 for Pari Island, Pramuka Island, Panggang Island, Harapan Island, Kelapa Island, and Panjang Island.

![Figure 2. Seagrass species diversity of Thousand Islands](image2)

Figure 2. Seagrass species diversity of Thousand Islands

![Figure 3. Seagrass status in Thousand Islands from 2007 to 2008.](image3)

Figure 3. Seagrass status in Thousand Islands from 2007 to 2008.
Island, Kelapa Island, Panjang Island. However, it increased for Tidung Island and Payung Island (figure 3). Seagrass coverage variation was caused by island geomorphology, water quality, coastal activities, and seagrass species composition [23]. Community residence influenced the nutrient enrichment in sediment [15, 24]. Furthermore, the type of substrate and sediment characteristics trigger the seagrass species composition and coverage. Sediment size can decrease the biomass, while sediment characteristics only influence leaf morphology [25]. Lamit and Tanaka [26] reported that seagrass with silt and clay sediment had the highest biomass and leaf length. In some cases, seagrass grew longer on the sandy than rocky substrate [27]. Kaewsrikhaw and Prathep [28] showed that leaf length, width and petiole length were more significant on the sand substrate.

3.2. DAPSIR analysis for seagrass rehabilitation
Three main drivers had been identified with local activities, namely population growth, coastal development, and climate change. The Pressure, state, and impact are represented in figure 6. The activities and pressures harm the seagrass meadow. Coastal development that is disposed of human activities is related to population growth. For the last decade, population growth increased in Thousand Island, changing the land use and income needed (figure 4). Mass tourism occurred in Thousand Island

![Figure 4](image-url)  
**Figure 4.** The number of populations in Thousand Islands Regency period 2006-2019.

![Figure 5](image-url)  
**Figure 5.** The number of tourists in Thousand Islands Regency period 2006-2019.
from 2006 to 2014, negatively impacting the seagrass ecosystem (figure 5). Increasing population will enhance human activities in the coastal area. The anthropological activities increase side-by-side with population enhancement: seaweed culture, mariculture, fishing, boat fishing, and boat anchoring. Activities of coastal development are reclamation, sand dredging, mass tourism (Figure 5), conversion into the residence, and domestic sewage. Climate change impacts sea-level rise, so it constructs breakwater to mitigate this problem in the small island. These disturbances involve multiple stressors for seagrass meadows. For example, mass tourism, residence, and domestic sewage led to nutrient enrichment, and reclamation cause land-use changes. Nutrient enrichment cause increasing algal growth, decreasing seagrass productivity, and change ecosystem functioning. Furthermore, the activities and pressure will impact water quality change, habitat loss, and loss of ecosystem services.

Based on the DAPSIR framework, rehabilitation is a possible response to reduce and minimize the seagrass meadow disturbance. Direct and indirect approaches separate to conduct rehabilitation action. Direct rehabilitation would be done by replanting or preserving seagrass such as transplantation, environmental clean-ups, water quality monitoring, and increasing research monitoring. Managers could lead indirect rehabilitation to minimize the disturbance by arranging the protected area, education and awareness, regulatory and policy, and community capacity development. The DAPSIR framework recommends monitoring water quality after the pandemic. Education, awareness, and capacity development for the community is necessary action to manage the disturbance. A regulatory and policy is needed to manage the mass tourism in Thousand Island.

4. Conclusion
In conclusion, seagrass meadow decreased in Thousand Island and will continue now and in the future if there is no action to mitigate the disturbance. Population growth, coastal development, and climate changes are identified as a driver of seagrass decline. Coastal development cannot ignore because it relates to human livelihood and income. This result recommends that managers should arrange the seagrass rehabilitation action plan to minimize seagrass degradation. A transdisciplinary approach is needed to make a policy for seagrass conservation.
References
[1] Short F T, Coles R G and Pergent-Martini C 2003 *Globar Seagrass Research Methods*, ed F T Short and R G Coles (Amsterdam (NL): Elsevier Science B V).
[2] Hemminga M A and Duarte C M 2001 *Seagrass Ecology* (Cambridge (UK): Cambridge University Press).
[3] Phillips R C and Menez E G 1988 *Seagrasses* (Washington D C (UN): Smithsonian Institution Press).
[4] Sjafrie N D M, Hernawan U E, Prayudha B, Supriyadi I H, Iswari M Y, Rahmat, Anggraini K, Rahmat, Anggraini K, Supriyadi I H and McMahon K 2021 The first nation-wide assessment identifies valuable blue-carbon seagrass habitat in Indonesia is in moderate condition *Science of The Total Environment* 782.
[5] Madi Moussa R, Bertucci F, Jorissen H, Gache C, Waqalevu V P, Parravicini V, Lecchini D and Galzin R 2020 Importance of intertidal seagrass beds as nursery area for coral reef fish juveniles (Mayotte, Indian Ocean) *Regional Studies in Marine Science* 33 100965.
[6] Manca E, Cáceres I, Alsina J M, Stratigaki V, Townend I and Amos C L 2012 Wave energy and wave-induced flow reduction by full-scale model Posidonia oceanica seagrass *Continental Shelf Research* 50-51 100-16.
[7] Lapointe B E, Herren L W, Brewton R A and Alderman P K 2020 Nutrient over-enrichment and light limitation of seagrass communities in the Indian River Lagoon, an urbanized subtropical estuary *The Science of the total environment* 699 134068.
[8] Cabaço S, Santos R and Duarte C M 2008 The impact of sediment burial and erosion on seagrasses: A review *Estuarine, Coastal and Shelf Science* 79 354-66.
[9] Lasso A and Dahles H 2018 Are tourism livelihoods sustainable? Tourism development and economic transformation on Komodo Island, Indonesia *Asia Pacific Journal of Tourism Research* 23 473-85.
[18] Lange G-M 2015 Tourism in Zanzibar: Incentives for sustainable management of the coastal environment *Ecosystem Services* 11 5-11.

[19] Zhang X, Song W, Lang Y, Feng X, Yuan Q and Wang J 2020 Land use changes in the coastal zone of China's Hebei Province and the corresponding impacts on habitat quality *Land Use Policy* 99.

[20] E Estradivari, E Setyawan and Yusri S 2009 *Terumbu karang Jakarta: Pengamatan jangka panjang terumbu karang Kepulauan Seribu* (2003-2007) (Jakarta: Yayasan TERANGI)

[21] Griffiths L L, Connolly R M and Brown C J 2020 Critical gaps in seagrass protection reveal the need to address multiple pressures and cumulative impacts *Ocean & Coastal Management* 183.

[22] Mishra A K and Apte D 2021 The current status of Halophila becchari: An ecologically significant, yet vulnerable seagrass of India *Ocean & Coastal Management* 200.

[23] Kawaroe M, Nugraha A H, Juraij and Tasabaramo I A 2016 Seagrass biodiversity at three marine ecoregions of Indonesia: Sunda Shelf, Sulawesi Sea, and Banda Sea *Biodiversitas, Journal of Biological Diversity* 17 585-91.

[24] Ambo-Rappe R 2014 Developing a methodology of bioindication of human-induced effects using seagrass morphological variation in Spermonde Archipelago, South Sulawesi, Indonesia *Marine pollution bulletin* 86 298-303.

[25] Vivanco Bercovich M, Schubert N, Almeida Saá A C, Silva J and Horta P A 2019 Multi-level phenotypic plasticity and the persistence of seagrasses along environmental gradients in a subtropical lagoon *Aquatic Botany* 157 24-32.

[26] Lamit N and Tanaka Y 2019 Species-specific distribution of intertidal seagrasses along environmental gradients in a tropical estuary (Brunei Bay, Borneo) *Regional Studies in Marine Science* 29 100671.

[27] Balestri E, de Battisti D, Vallerini F and Lardicci C 2015 First evidence of root morphological and architectural variations in young *Posidonia oceanica* plants colonizing different substrate typologies *Estuarine, Coastal and Shelf Science* 154 205-13.

[28] Kaewsrikhaw R and Prathep A 2014 The effect of habitats, densities and seasons on morphology, anatomy and pigment content of the seagrass *Halophila ovalis* (R.Br.) Hook.f. at Haad Chao Mai National Park, Southern Thailand *Aquatic Botany* 116 69-75.