Evaluating the seagrass ecological condition and habitat extent in Karimunjawa National Park, Jepara Indonesia

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Abstract

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In the coastal ecosystem, seagrass meadows play a vital role in delivering ecosystem services such as provision, control, and support. However, this ecosystem is one of the most threatened in the coastal environment, and it has been degraded as a result of anthropogenic disturbance and rapid environmental changes. Furthermore, the extent of the seagrass meadows is unknown, and the health of the meadows is unmonitored and unrecorded. There is little information on the current state of the seagrass extent and health conditions in Karimunjawa National Park. We evaluate the abundance, states, and health conditions of the seagrass meadows based on the ecological quality index in Karimunjawa National Park, Jepara, Indonesia. This district has a vast extent of seagrass meadows but has been affected by the expansion of the industrial/tourism area within the region. This study aimed to assess the seagrass current condition based on the ecological quality index. The result showed that the total seagrass extent area in Karimunjawa National Park was 969,15 ha where seven species were found in this area, including Enhalus acoroides, Thalassia hemprichii, Cymodocea rotundata, Cymodocea serrulate, Halodule pinifolia, Halophila ovalis and Halodule uninervis. Seagrass meadow coverages were moderate and categorized as less healthy. The seagrass ecological quality index value was 0.66 which indicated that the seagrass condition in Karimunjawa National Park was moderate. Ecological factors that affect the seagrass state are epiphyte cover and macroalgal cover.

Keywords: *Seagrass, states, Karimunjawa, ecological quality index, habitat extent*

INTRODUCTION

The Seagrass ecosystem plays an important role as a provider of ecosystem services to the coastal environment (Duarte *et al*., 2013; Nordlund *et al*., 2018). Consequently, the decline of the seagrass ecosystem could lead to various effects on the surrounding ecosystem, including loss of nursery ground for pelagic species (fish), depletion of detritus producers, increased the possibilities of coastal erosion, reduced water clarity, changes in nutrient regulation and carbon sequestration (Costanza *et al*., 2014; Nordlund *et al*., 2016; Unsworth *et al*., 2019). However, in some cases, the seagrass beds are abandoned by the coastal community, government and even forgotten compared to others nearshore ecosystems such as coral reefs and mangroves (Potouroglou *et al*., 2020). whereas, the seagrass ecosystem is one of the most threatened in comparison to corals and mangroves as the seagrass areas worldwide are decreasing significantly (Xu *et al*., 2016).

Given the importance of seagrass beds, multiple efforts are required to ensure their sustainability. One of the efforts that can be made is to assess the current state of the seagrass beds, So that it can be determined whether the seagrass status is still in excellent condition, what activities are required, and whether immediate intervention is required since the condition is already alarming. Furthermore, understanding the health of the seagrass is crucial for boosting government attention and community conservation knowledge to preserve the long-term viability of this ecosystem. In addition, monitoring the seagrass condition is critical to the management and sustainability of the

Diterima/Received : 24-10-2023, Disetujui/Accepted : 03-01-2024
DOI: https://doi.org/10.14710/jkt.v27i1.20637

coastal environment (Rustam, 2019), because it can be used to guide suitable management and conservation (Supriadi *et al*., 2012)

The Karimunjawa National Park was established in 1986 based on the decree of the Minister of Forestry no. 123/Kpts–II/1986 (BTNKJ, 2016). The park is divided into eight designated zones including the core zone, protection zone, tourism zone, aquaculture zone, rehabilitation zone, religious and historical zone, residential zone, and utilization of traditional fisheries zone. The Study of seagrass ecosystems in the Karimunjawa National Park and its surrounding has been done previously such as seagrass community structure at Kumbang Island (Hartati *et al*., 2012), Menjangan Besar Island (Iftinaan *et al*., 2017), and Karimunjawa archipelago (Rustam *et al*., 2019; S. G. Wicaksono *et al*., 2012). However, such studies only look at seagrass conditions, whereas information on ecological conditions and seagrass extent in this area is still scarce. The lack of data could lead to underestimating seagrass resource role in certain locations (Brodie & N'Yeurt, 2018) and mitigation for improvement cannot be informed. Therefore, this study aimed to assess the seagrass ecological status and its habitat extent in The Karimunjawa National Park based on the ecological quality index to provide the current state of seagrass health in the Karimunjawa National Park.

MATERIAL AND METHODS

Fieldwork was done on October 2021 at nine stations in The Karimunjawa National Park, Central Java, Indonesia (Fig. 1) Line transects of 100m perpendicular to the coastal line were laid to collect seagrass data, with three transects in each location. The data was collected using a 50cm × 50cm quadrate spaced at 10 m intervals along the transect (McKenzie *et al*., 2001; Rahmawati *et al*., 2017). The following data is collected: seagrass species, seagrass percentage cover, seagrass species percentage cover, and substrate type. We also measured macroalgae percentage cover, epiphyte percentage cover, and water transparency. Macroalga and epiphyte cover were estimated in the same quadrate with seagrass cover, while qualitative data of water transparency was determined using three categories, which are 0 = turbid water; 1=moderate: 2=clear. These data were used to assess the *Seagrass Ecological Quality Index* (SEQI) (Hernawan *et al*., 2021).

Seagrass covered and health condition measurement

Measuring the seagrass percentage cover was used scientific literature based on Rahmawati *et al*. (2017), with the percentage covered of seagrass was categorized as rare (0-25%), moderate (25-50%), dense (51-75%) and very dense (76-100%). The health condition of seagrass was categorized based on the national regulation of the Minister of Environment Decree No. 200/2004 (Table. 1).

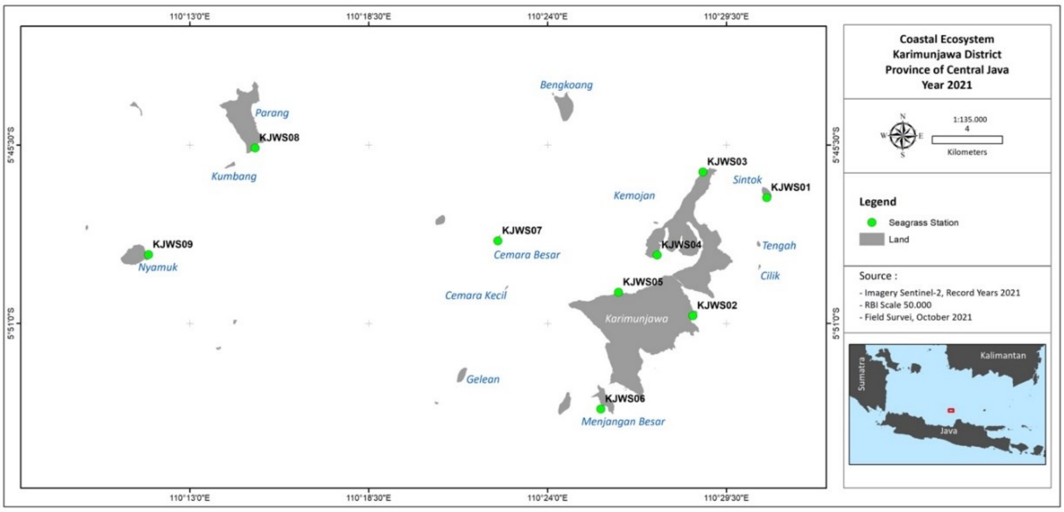

Figure 1. Survey site at Karimunjawa National Park, Central Java

Table 1. The status of Seagrass condition based on The Decree of the Ministry of Environment (KepMenLH no. 200/2004)

Status		Coverage (%)
Good	Dense/Health	≥ 60
	Less healthy	30 – 59.9
	Poor	≤ 29

Seagrass Ecological Quality Index (SEQI)

Besides the measurement of seagrass status based on biophysical, we also assessed the ecological quality of seagrass by applying SEQI (Seagrass ecological quality index) developed by Hernawan *et al.,* (2021). The SEQI value was calculated using the formula as follows:

$$SEQI = (St/Sref)*0,2 + (Ct/Cref)*0.2 + (Wt/Wref)*0.2 + (1-(Mt/Mmax))*0.2 + (1-(Et/Emax))*0.2)$$

Where, **St** represented as seagrass species richness observed; **Sref** as maximum value of seagrass species richness (9); **Ct** represented as seagrass percent cover observed and **Cref** as maximum value of seagrass percent cover (100%); **Wt** indicated as water transparency observed, with three categories i.e clear (2), moderate (1), and turbid (0); **Wref** represented as maximum value of water transparency (2); **Mt** as macroalga percent cover observed; **Mmax** as maximum values of macroalgae percent cover (100%); **Et** as epiphyte percent cover observed, and **Emax** as maximum value of epiphyte percent cover (100%) respectively.

The SEQI values were categorized into five categorical statuses i.e.: 0-0.36 categorized as "Bad", 0.37-0.52 as "Poor", 0.53-0.68 as "Moderate", 0.69-0.84 and 0.85-1 as "Good" and "Excellent" respectively.

Benthic habitat distribution

In addition to ecological parameters, we estimated seagrass areas in temporal and spatial scales by applying remote sensing approaches. The primary data used in this study are the Sentinel 2A level 1C satellite imagery that was acquired on July 30, 2021, and August 26, 2021. The satellite imagery has been corrected at Top-of-Atmosphere reflectance in cartography geometry (Vinluan & De Alban, 2001). The study utilized satellite imagery of 10-meter spatial resolution that consists of three visible bands (B2: blue band, B3: green band, B4: red band) as well as one near-infrared band (B8: NIR band) which are needed for image corrections. Image processing consists of image correction, modeling, and classification. the image correction itself consists of atmosphere and water column corrections. Selecting dark objects for creating offset values to atmospheric correction using Dark Object Correction (P. Wicaksono & Hafizt, 2013)

The result of atmosphere correction then becomes input data for the water column correction step. This correction aims to reduce water column attenuation effects causing misclassification in the image classification process and would decrease the accuracy level of benthic habitat maps. The water column correction is performed using the Depth Invariant Index (DII) model (Green *et al*., 2000) modified from Lyzenga, (1981). The method used pixel values of sand samples on different depths to calculate several parameters required to create the DII equation, namely variance of each visible band, covariance between visible bands, attenuation coefficient (a), and attenuation ratio (ki/kj).

Image modeling is performed to generate depth information from the image which is used to develop a benthic habitat map. We use the Relative Water Depth Index (RWDI) model developed by Stumpf *et al*., 2003. The model is available in image processing software and applied to Sentinel 2A images. The model output is an image showing depth information in indexed values for each pixel. The depth image is then classified as shallow and deep areas based on index value and is used as input data for the classification process. The corrected images (atmosphere and DII images) were used as input data in the classification process using the ISO-DATA method. The method is categorized as an unsupervised classification approach meaning that spectral classes are generated automatically by computer. Our role is only determining minimum and maximum classes and a number of iterations. for the classification step, we classified all pixels of the entire reef area using the DII image as input data. The accuracy level of the used model like a confusion matrix table for its overall, producer and user accuracies (Danoedoro, 2012). Ground truth for validating the result of the benthic habitat map is conducted using the photo transect method developed by Roelfsema & Phinn, (2009). The samples are photos of the bottom cover and the georeferenced information on each photo. All objects in the photos were then classified into benthic habitat classes.

RESULT AND DISCUSSION

The seagrass ecosystem in the Karimunjawa National Park and its surroundings was composed of mixed vegetation that includes at least three species and forms a continuous habitat at each observation site. There were a total of seven seagrass species recorded in the study areas, namely *Enhalus acoroides, Thalassia hemprichii, Cymodocea rotundata, Cymodocea serrulata, Halodule pinifolia, Halodule uninervis,* dan *Halophila ovalis* (Table. 2). The current discovery was verified by a prior discovery in which 6-10 species were discovered within and near the Karimunjawa National Park (Hartati *et al*., 2012; Iftinaan *et al*., 2017; Rustam *et al*., 2019; S. G. Wicaksono *et al*., 2012), two species in Leuweung sancang, Garut (Zulfadillah *et al*., 2021), eight species from Bali Island (Mahesswara *et al*., 2021; Martha *et al*., 2018; Widagti *et al*., 2021), (Mahesswara *et al*., 2021; Martha *et al*., 2018)five - seven species in Seribu island (Adharini *et al*., 2022; Handayani *et al*., 2022; Rustam, 2019), six species in Lampung Bay (Isnaini *et al*., 2021) and 15 species were recorded in Indonesia (Sjafrie *et al.,* 2018). The persistent species *T. hemprichii* was the most frequent among the species discovered. This finding supports the claim that *T. hemprichii* and *E. acoroides* species are the most prevalent species in Indonesian waters, where this species was discovered in 371 of 423 survey locations (Hernawan *et al*., 2017; Sjafrie *et al.,* 2018)

Overall, the percentage cover of seagrass meadows in the Karimunjawa National Park was measured at 30.99±10.15% which indicated moderate coverage (Table 4). This condition also reflected that the health status of seagrass meadows in each location was categorized as unhealthy. Furthermore, according to the Seagrass Ecological Quality Index (SEQI), the seagrass ecosystem in Karimunjawa National Park and its surroundings was in a "Moderate" state with SEQI value=0.66±0.06. This value means seagrass had a moderate coverage (mean±SD=30.99±10%), low macroalgae cover, high water transparency, yet high epiphyte cover (Table 3). Eight out of nine study sites have a moderate and good ecological quality index with various SEQI values (range=0.64-0.71), except for the site at Merican, which was in “Poor” condition (SEQI = 0.43). The seagrass ecosystems with the highest ecological quality were in Anora Island, Nyamplungan, and Parang Island (SEQI = 0.71). In

Table 2. The seagrass species found in Karimunjawa National Park

Seagrass species	Stations								
	1	2	3	4	5	6	7	8	9
Enhalus acoroides	-	-	+	+	+	+	-	+	+
Thalassia hemprichii	+	+	+	+	+	+	+	+	+
Cyomodocea rotundata	+	+	+	-	+	+	+	+	-
Cymodocea serrulate	-	-	+	+	+	-	+	+	-
Halodule pinifolia	-	+	-	-	-	-	-	-	-
Halodule uninervis	+	+	-	-	+	+	+	+	-
Halophila ovalis	+	+	+	-	+	+	+	+	+

Note: + = present; - = absence

addition to a high diversity and coverage of seagrass species, seagrass ecosystems in Karimunjawa National Park feature good water quality, as evidenced by high water transparency and low macroalga coverage. High water transparency may suggest that there is no pressure causing water quality depletion, such as sedimentation, and it reflects a favorable light environment for seagrass growth. Simultaneously, low macroalgae abundance may imply that there is no pressure promoting excessive macroalgae growth and shifting community structure from seagrass to macroalgae beds (Hernawan *et al*., 2021).

Besides seagrass species, the macroalgal community also found in all stations with the dominant species was *Padina Autsralis* which grew well on a flat bottom substrate of mixed sand and coral fragments. Other macroalgae species identified were *Sargassum sp, Caulerpa racemaosa, C. sertularoides, Halimeda sp, Dyctiota dichotoma, Hypnea sp,* and *Hormopysa sp*. The two stations with the highest macroalgae cover were station KJWS04 (Merican) and KJWS05 (Nyamplungan) with an average of 28,23±23,13 % and 21,12±21,19 %, respectively. According to Rustam *et al*. (2019), the presence of macroalgae beds suggested that nutrients from residential sewage pollution were enriched. The enrichment of nutrients in a water column caused a reduction in water quality, which stimulated the growth of seaweed/macroalgae. Furthermore, this study discovered that the majority of seagrass beds in Karimunjawa National Park have a reasonably high epiphyte cover, particularly near mangrove environments with calm water currents. The presence of epiphytes is an indicator of nutrient enrichment, which harms seagrasses. Excessive epiphyte cover can inhibit seagrass growth by slowing photosynthesis and decreasing leaf density. If these conditions persist, the seagrass ecosystem at the sites will vanish because the water conditions with large amounts of incoming land waste cause seagrass leaves to be completely covered by epiphytes, which cannot be cleaned by the movement of strong enough currents, resulting in leaves that cannot photosynthesize. Producers will shift from seagrasses to macroalgae and even phytoplankton, which might generate an algae bloom under specific conditions (Rustam *et al*., 2019).

Anthropogenic activities are believed as the primary factor that causes seagrass ecosystem degradation and seagrass extent reduction (Potouroglou *et al*., 2017; Unsworth *et al*., 2019). Several human activities, such as waste dumping, reclamation, coastal development, and land-use conversion to aquaculture zones, cause seagrass degradation (Unsworth *et al*., 2018). Furthermore, sedimentation and nutrient enrichment, physical disturbances, disease, destructive commercial fishing practices, gleaning, and unsustainable marine aquaculture can all contribute to seagrass degradation on a large scale ranging from square meters to hundreds of square kilometers (Orth *et al*., 2006; Unsworth *et al*., 2018, 2019).

Table 3. Seagrass ecological quality Index (SEQI) in Karimunjawa National Park

No.	Station	Seagrass coverage (%) +SD	Macroalgae Coverage (%)	Epiphytes Coverage (%)	WT	SEQI	
						Value	Category
1	Sintok Island	37,74±19,14	6,68±9,74	24,47±15,15	2	0,70	Good
2	Anora Island	38,07±18,97	8,85±18,63	29,47±21,04	2	0,71	Good
3	Ujung Batu Lawang	25,46±20,38	9,90±13,67	35,47±28,03	2	0,69	Good
4	Merican	13,85±19,85	28,23±23,13	53,50±34,99	1	0,43	Poor
5	Nyamplungan	47,92±22,41	21,12±21,19	39,77±12,28	2	0,71	Good
6	Menjangan besar Island	27,84±19,30	2.51±6,95	40.91±21,95	2	0,67	Moderate
7	Cemara besar Island	32,58±16,73	7,48±14,56	41,67±23,47	2	0,67	Moderate
8	Parang Island	34,19±21,43	4,69±10,21	42,42±15,91	2	0,71	Good
9	Nyamuk Island	21,27±13,63	4,51±7,33	29,81±12,28	2	0,64	Moderate
	Karimunjawa	30,99±10,15	10,44± 8,57	37,50± 8,75	2	0,66	Moderate

The information on the benthic habitat distribution derived from Sentinel-2 satellite image data is verified using ground-truth data derived from 1000-point field observations. The coastal area of Karimunjawa National Park is mostly surrounded by reefs, so the dominating ecosystems are coral reefs and seagrass beds. Corals are found in almost all study areas, but the distribution of seagrass habitat is mostly in coastal areas near to the shoreline, while macroalgae habitat is mostly in coastal areas between seagrass and corals. However, mangrove ecosystems can still be found on the mainland of Karimunjawa Island, Kemojan Island, Nyamuk Island, Parang Island, Bengkoang Island, and Menjangan Besar Island. In general, the distribution of habitats in coastal ecosystems can be seen in Figure 3.

Reefs in the study area are covered by corals, seagrasses, macroalgae, and mixed substrates. However, the distribution of macroalgae could not be detected well through satellite imagery data because its distribution was not wide, only in the form of spots and patchy and mixed with other benthic habitats. However, its distribution could be confirmed during ground checking. Coral habitats are located on the fore reef (reef slope) which has a sloping to gentle surface and has a depth ranging from 2.5 - 7 m at the time of field measurements. In the reef crest area (reef ridge) there is an aggradation of coral fragments (rubble) and several spots of live coral (coral heads). This area is located behind the fore reef and is formed by the accumulation of rubble as a result of coral breaking by the waves. According to the benthic habitat map in Figure 3, seagrasses are more abundant along the southwest coast of Karimunjawa Island, the east coast of Kemojan Island, and the coasts of Menjangan Besar Island and Bengkoang Island.

The area of each habitat situated on the coast of Karimunjawa National Park based on satellite image data analysis is shown in Table 3. Based on the analysis of the area of benthic showed that the Coral habitat is spread over almost the entire study area with a total area of 2702.35 Ha. Seagrass habitat mostly occupies coastal areas close to the coastline with an area of 969.15 Ha in the study area. Most of the macroalgae habitats occupy coastal areas between sea grasses and corals with an area of 772.35 Ha. If seen from the ecosystem map (Figure 3), seagrass is relatively wider along the southwestern coast of Karimunjawa, the east coast of Kemojan, and the coasts of Menjangan Besar and Bengkoang. The area of mangroves in the study area is 457.01 Ha, with the widest distribution in the border areas of the West coast of Karimunjawa and Southwest of Kemojan.

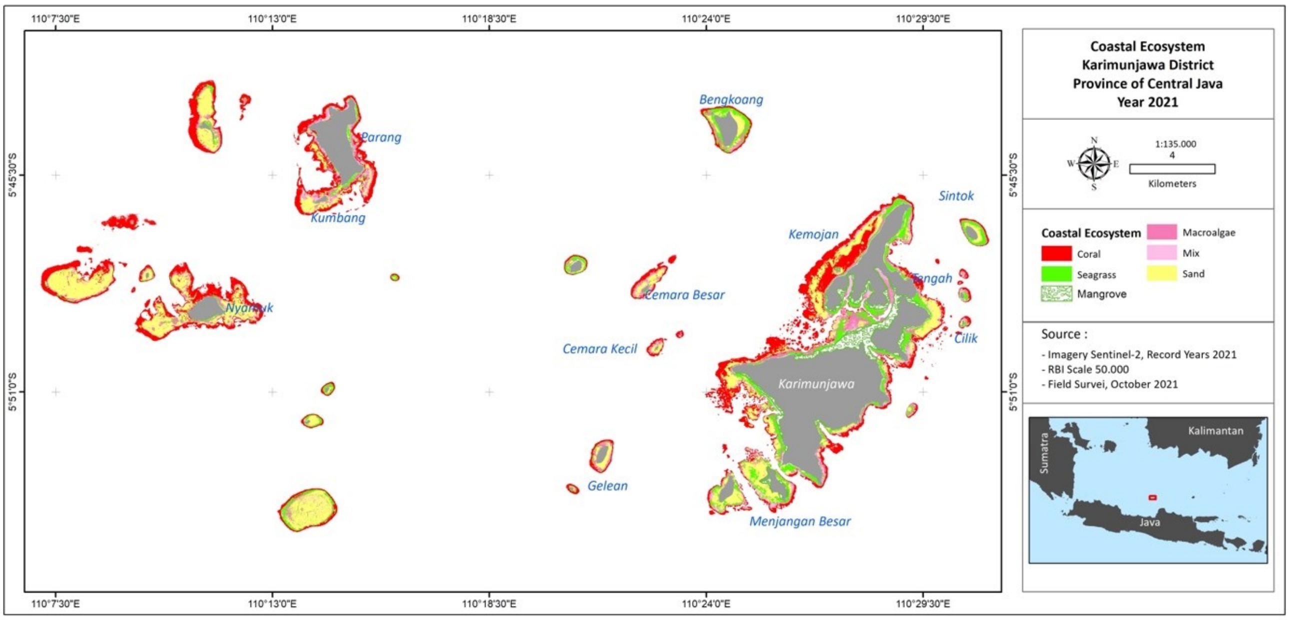

Figure 3. Map of the benthic habitat distribution in Karimunjawa National Park

Table 4. Benthic habitat and mangrove coverage in The karimunjawa National Park

Habitat type	Width (Ha)
Reefs:	
Coral reef	2702.35
Seagrass	969.15
Makroalga	772.35
Mixed substratum	559.04
Mangrove	457.01

CONCLUSION

The seagrass ecosystem in The Karimunjawa National Park was inhabited by six seagrass species and *Thalassia hemprichii* was a dominant species with a percentage of seagrass coverage was 30.99%, categorized as less healthy. In terms of seagrass ecological quality index (SEQI) value, the status of the seagrass ecosystem in The Karimunjawa National Park was categorized “Moderate” which means that seagrass had a moderate coverage (mean±SD=30.99±10%), low macroalgae cover, high water transparency, yet high epiphyte cover.

ACKNOWLEDGMENT

This study was funded by Reef Health Monitoring (RHM) COREMAP CTI, Research Center for Oceanography, Indonesian Institute of Science (LIPI)/National Research and Innovation Agency (BRIN) fiscal year 2021.

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