

Original Research

Community structure and condition of seagrass meadows in Ayau Islands, Raja Ampat Regency

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ABSTRACT

Seagrass meadows are an important component of coastal ecosystems, providing many ecosystem services beneficial for human well-being. Basic information about seagrass meadows in Indonesia is relatively limited, particularly in the eastern part of Indonesia, such as the remote Ayau Islands in Raja Ampat. In this paper, we reported the community structure and condition of seagrass meadows in Ayau Islands surveyed during Nusa Manggala Expedition in November 2018. We conducted the seagrass survey using quadrat transect method at five locations, i.e. Reni, Rutum, Abidon, Kanober, and Dorehkar. In the survey, we assessed parameters of community structure, including habitat extent, species composition, seagrass cover, seagrass density, macroalgae and epiphyte cover. We also recorded environmental parameters, i.e. substrate types, water clarity, salinity, water temperature, and nutrient (phosphate and nitrate). Our study showed that seagrass meadows in Ayau Islands are multispecies meadows, composed of two to five species. In overall, five species recorded in Ayau Islands are *Cymodocea rotundata*, *Enhalus acoroides*, *Halodule pinifolia*, *Halophila ovalis*, and *Thalassia hemprichii*. The most common species is *T. hemprichii* as it can be found in all locations. Meadows in Reni, Rutum, and Dorehkar are in a healthy condition, while in Abidon and Kanober are in less healthy condition. This information is of significance as baseline information needed for seagrass conservation planning.

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1. Introduction

Seagrasses are flowering plant adapted to live underwater in the marine environment. These plants grow covering extensive areas of the seafloor, called as seagrass meadows. Their morphology resembles common terrestrial grasses with true leaves, rhizomes, roots, flowers and fruits (Brazier, 1975; Susetiono, 2004), which distinguished them with seaweeds, as seaweeds do not have those organs. Seagrass meadows play important ecological roles in the shallow waters of tropical and temperate coasts (Dawes, 1981). Seagrass canopy structure and root system have a large influence on sedimentation and ecology of shallow habitats (Brazier, 1975). The meadows support a great variety of marine animals. They provide habitat for sea mammals, benthic organisms, and fishes, some of which are commercially

important species. Some species use seagrass meadows for spawning and nursery ground, and shelter/protection from predators. Seagrasses are primary producers, which serve as the foundation of the food web (de Boer, 2007). Furthermore, seagrass meadows help mitigate climate change because they absorb carbon dioxide dissolved in seawater (Fourqurean, *et al.*, 2012)

As an archipelagic country, Indonesia's coastline is one of the longest in the world. Consequently, Indonesia is blessed with vast coastal areas, and these areas are rich with diverse coastal ecosystems, such as seagrass meadows. Although seagrass habitat in Indonesia is potentially the largest in the world, our knowledge on seagrasses in Indonesia is relatively limited, compared to mangroves and coral reefs that have received more scientific attention. Furthermore, for many remote locations in the eastern parts of Indonesia, such as Ayau Islands, Raja Ampat, basic information on seagrasses is even absent. Species composition, habitat extent, community structure, and condition of the seagrass

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meadows area still unknown in such locations (Supriyadi, et al., 2018), despite the fact that this area is part the Coral Triangle (Fortes, et al., 2018). Furthermore, in remote locations such as Ayau Island, accessibility and logistic problems might hamper a study to be held there (Fortes, et al., 2018). Most of the information about seagrass in this regency came from neighbouring bigger islands closer to the mainland, such as Waisai (Ausal, et al., 2017) and Salawati (Hoek, et al., 2016).

Thus, an expedition to reach this area was carried out in November 2018 using the Research Vessel Baruna Jaya VIII, which called Nusa Manggala Expedition 2018. In particular, this study assessed meadow's characteristics, species composition and their distribution, and the status of the seagrass meadows in the islands.

2. Materials and Methods

The field study was conducted in November 2018 at five locations (Reni, Rutum, Abidon, Kanober, and Dorehkar (Figure 1). These locations were selected based on seagrass habitat representation interpreted from remote sensing of Google Earth imageries. At each location, data was collected using the quadrat transect method. Due to the limited time in the field and the main objective of the expedition was on diversity aspect, therefore a single line transect was laid perpendicular to the shore, started from the point where seagrasses were found to the final point seaward where seagrasses were no longer present. This transect length data also serve as ground truth data for satellite image analysis. For this purpose, the geographical position of each transect was determined and recorded by a GPS receiver. The

additional transect was planned to laid if there was still time to do it. However, in practice the allocated time already consumed by the journey to find a save passage to reach the island by rubber boat from the vessel and also the traditional permission process to the local people.

On the transect, a 50x50cm-quadrat frame was placed at every 10 m intervals, and data on species composition, seagrass cover (total and per species), seagrass density, macroalgae and epiphyte cover inside the frame was determined and recorded. The seagrass, macroalgae and epiphyte cover refers to the seagrass cover standard from Seagrass-Watch (McKenzie, et al., 2003). Data of seagrass composition, cover and density were combined to calculate Important Value Index (IVI) for determining the dominant seagrass species in the seagrass meadows (Gopal & Bhardwaj, 1979).

Additionally, we also measured environmental parameters directly in the location, i.e. substrate type, water clarity, salinity, water temperature, and nutrient (phosphate and nitrate). Dominant substrate type was determined by hand-touch as mud, sand, rubble, or a combination of two or three types. Water clarity was planned to be measured by a Secchi disk, however, the disk had already hit the bottom before can be unseen from the surface as the water clarity was quite clear. Therefore, quantitative data for water clarity is not available.

Due to limited personnel to handle physiochemical parameters and the lack of equipment, the measurement was done by simple equipment and test kit. Salinity was measured by using a refractometer. Water temperature was measured by using a thermometer. Phosphate and nitrate concentration was determined by using Sera® Phosphate-Test and Sera® Nitrat-Test kit, that usually used



Figure 1. Research sites in Ayau Island which located at Kanober, Reni, Rutum, Abidon, and Dorehkar

for aquarium testing. The phosphate test kit have a reading range from 0.1 – 10.0 mg/l, meanwhile the nitrate test kit have a reading range from 0 to >100 mg/l. However, as both are simple test kit, detailed reading could not be gained because these kits show a group of value range than unit value. For example, for nitrate analysis, the result will appear as a colour of solution that corresponds to the value of 0, 25, 50, or >100 mg/l.

Seagrass area was obtained from satellite image analysis of Planet Dove imagery (3-meter spatial resolution and visible-NIR bands) (Marshall, *et al.*, 2017), which suitable to map detailed information in a large area like Ayau Islands. In addition, the visible bands are essential to identify seagrass cover under the waters (Green, *et al.*, 2000). The analysis was conducted by following the guideline to map benthic habitat, which included seagrass cover in it (Green, *et al.*, 2000; Rahmawati, *et al.*, 2019). Regarding the guideline, image correction and image classification was applied before calculating the seagrass area. Image correction consisting of sun glint correction (Kay, *et al.*, 2009) and water column correction using Depth Invariant Index Model (Hafizt, *et al.*, 2017a; Hafizt, *et al.*, 2017b), while image classification used ISO-DATA algorithm (Green, *et al.*, 2000). The next step is converting raster to vector in order geometry calculation can be proceeded.

Meadow's characteristics of each location are based on the length of seagrass meadows from the beach to the sea, and also the area size. Other parameters for the characteristics consist of the depth, seagrass and macroalgae cover along the transect, water clarity, substrate type, seagrass composition, and dominant seagrass in each location.

Seagrass species composition and their distribution are determined by the result of on-field observation inside the quadrat. The identification to species level was strengthened by further examination of the samples in laboratory facility of RV Baruna Jaya VIII using several references (Azkab, 1999; Menez, *et al.*, 1983; den Hartog, 1970; den Hartog & Kuo, 2006).

Status of the seagrass meadows in the islands determined mainly by their canopy cover average in each location, which refers to the standard value from the Indonesian Ministry of Environment to determine seagrass meadows condition. In this ministerial decree (KMNLHRI, 2004), there are three categories of seagrass meadows condition based on their canopy cover, which are: rich/healthy (cover \geq 60%), less rich/less healthy (cover 30 – 59.9%) and poor (cover \leq 29.9%). Although there is a lot of criticism about this standard and there is an effort to propose a new standard which covers more parameters, at the moment this decree is the legal standard which applied in Indonesia.

3. Results

3.1 Characteristic of each location

3.1.1 Reni Island

Reni Island is located in the northeast part of Ayau Islands. The length of the island is approximately 2 km from north to south and 650 m from west to east. The settlements are concentrated in the southern part of this island, occupying a third area of the island. According to the satellite image, the seagrass meadows are mostly located on the southern side of this island, so the observation transect was located there (Figure 2).

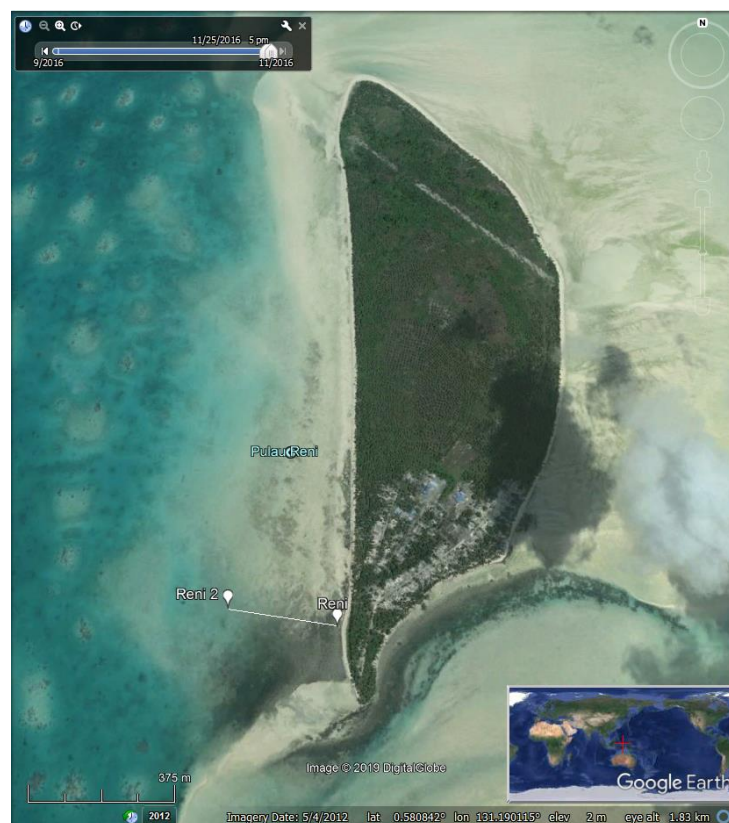


Figure 2. Transect placement (white line) in Reni Island, with a length of 310 m. The line started at N 0.57551 E 131.18916 and finished at N 0.57595 T 131.18643

The seagrass meadow extends around 310 m from the shore to the sea, with depth varied from 10 to 120 cm (Table 1). In the first and last 80m of the transect, the seagrass cover fluctuates between 50 to 90% accompanied by seaweed vegetation with maximum cover 30%. In contrast, in the middle of the transect, the seagrass cover remains steady at 70%, with a small peak on the 150 meters at 90%. In this part of the transect, the macroalgae cover is ranged from 0 to 25% (Figure 3). Overall, the seagrass meadows in Reni Island is considered as healthy because the average canopy cover is 71% (Table 1).

The meadow on this island has a clear water condition and the substrate mostly in the form of sand (Table 1). Analysis of satellite imagery and ground truth data shows that the seagrass meadow occupies 163,944 m² of the coastal area of this island, which composed of *Cymodocea*

rotundata and *Thalassia hemprichii* (Table 1). Based on Important Value Index calculation, *T. hemprichii* value is the largest than the other, which make this species as the dominant species in this location.

3.1.2 Rutum Island

Rutum Island is located in the northeast part of the Ayau Islands. The length of the island is approximately 900 m from north to south and 350 m from west to east. The settlements are situated in several areas of this island in north to south direction with an area of half of the island. Based on the satellite image, the seagrass bed is larger on the west side of the island (Figure 4), so the observation transect was placed in this area.

The length of the seagrass bed from the beach to the sea was approximately 90 m, with depth varied from 50

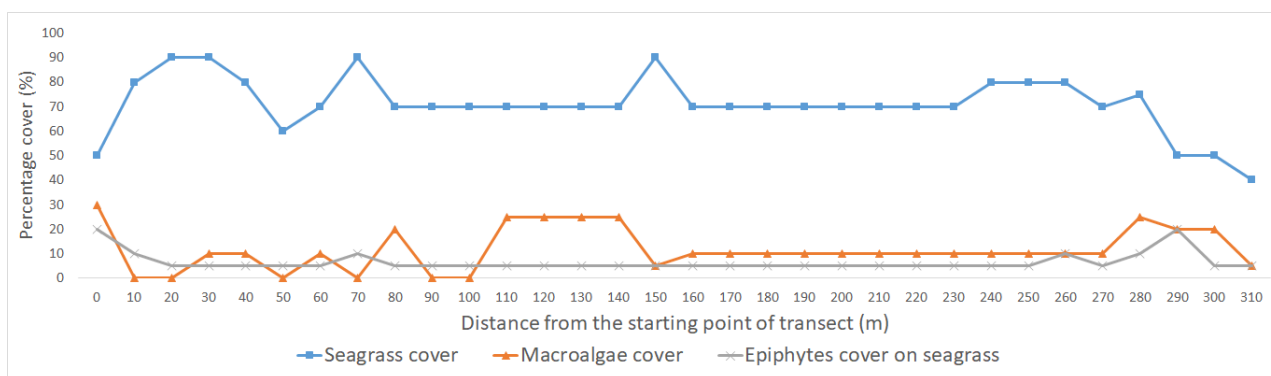


Figure 3. Dominant vegetation composition along the transect in Reni Island.

Table 1. Seagrass species distribution and seagrass meadow environmental and vegetation parameter of five locations in Ayau Islands

	Reni	Rutum	Abidon	Kanober	Dorehkar
Species					
<i>Halodule pinifolia</i>		x	x		
<i>Cymodocea rotundata</i>	x	x	x		x
<i>Enhalus acoroides</i>				x	x
<i>Thalassia hemprichii</i>	x	x	x	x	x
<i>Halophila ovalis</i>			x		x
Environmental parameters					
Dominant substrate	sand	sand	sand + rubble	sand	sand
Water clarity	clear	clear	clear	clear	clear
Water temperature (°C)	36	31	33	30	33
Salinity (‰)	35	34.5	34.5	33.5	35
Phosphate concentration (mg/L)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Nitrate concentration (mg/L)	undetected	undetected	undetected	undetected	undetected
Vegetation parameters					
Meadows length (m)	310	90	160	60	> 600
Meadows area (m ²)	163944	139518	37593	4815	1367694
Meadows depth range (cm)	10 - 120	50 - 255	30 - 155	120 - 270	50 - 95
Seagrass density (mean ± SD) shoots/m ²	716.00 ± 201.03	914.80 ± 166.74	495.06 ± 71.24	108.00 ± 21.71	596.26 ± 152.16
Seagrass cover (mean ± SD) (%)	71.09 ± 11.57	64.00 ± 15.45	30.00 ± 17.90	44.29 ± 15.91	67.21 ± 21.28
Macroalgae cover (mean ± SD) (%)	11.72 ± 8.62	5.50 ± 7.23	23.82 ± 21.18	0.00 ± 0.00	5 ± 9.36
Epiphyte cover (mean ± SD) (%)	6.56 ± 3.84	6.50 ± 2.29	15.88 ± 23.21	11.43 ± 11.86	12.62 ± 14.27
Meadows statuses	Healthy	Healthy	Less healthy	Less healthy	Healthy
Dominant seagrass (IVI)	Th	Th	Th	Ea	Th

Notes: x = present, IVI = Important value index

to 255 cm (Table 1). The seagrass cover is gradually decreasing along the transect from 70% to 40% with a moderate fluctuation from 0 to the 60th meter (Figure 5). Meanwhile, macroalgae coverage is mostly less than 10%, except at the 30th meter of the transect. Overall, the seagrass meadows could be considered as healthy because the canopy cover has the average at 64% (Table 1).

The meadow on this island has a clear water condition and the substrate mostly in the form of sand (Table 1). Analysis of satellite imagery and ground truth data shows that the seagrass meadow occupies 139,518 m² of the coastal area in this island, which composed of *Halodule pinifolia*, *Cymodocea rotundata* and *Thalassia hemprichii* (Table 1). Based on IVI calculation, the largest value belongs to *T. hemprichii*, making this species as the dominant seagrass in this location.

3.1.3 Abidon

Abidon is located at the centre of Ayau Island. The length of the island is approximately 2 km from northwest to southeast and 600 m from southwest to northeast. Local settlements are concentrated only in the southeast part of the island with an area of approximately 10 – 15% of the island. There are two long piers stretching out from the settlement to the deeper waters.

Based on the satellite image, seagrasses grow surrounding the island but covering a narrow band in the intertidal areas. The longest length of seagrass located in the southern part of the island (Figure 6), so the observation transect was placed there. There are no rivers nor mangroves in this location. In addition, there was a lot of boat traffic in the seagrass area when the observations was taking place.

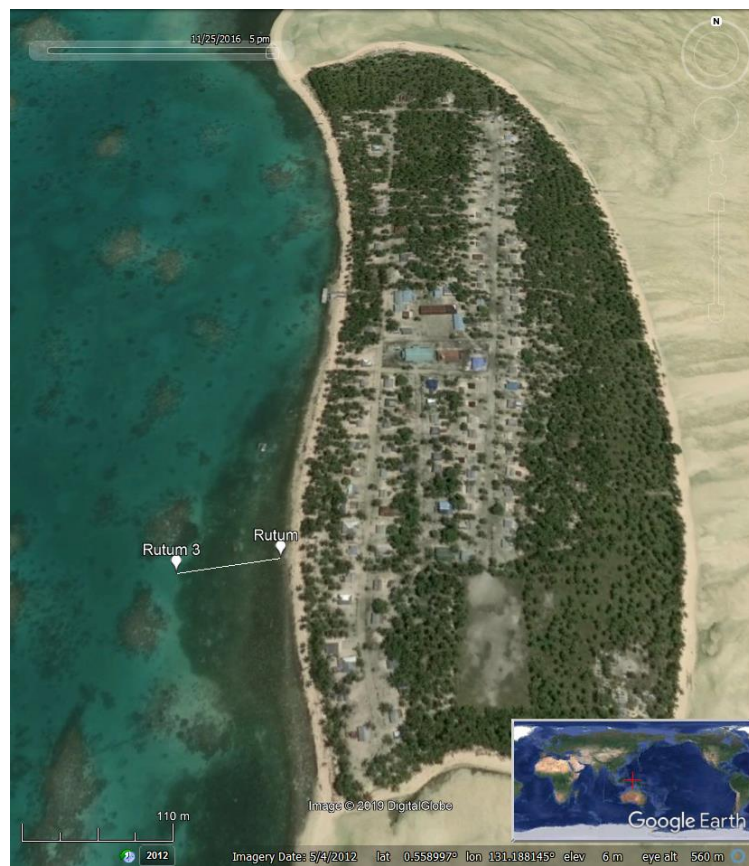


Figure 4. Transect placement location (white line) in Rutum Island. The length of the transect was 90 m, started from the beach at N 0.55794 E 131.18736 and finished in the sea at N 0.55783 E 131.18655

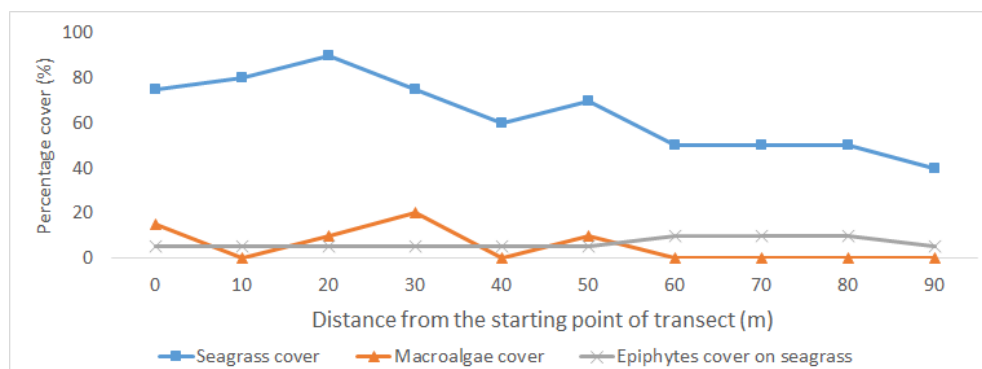


Figure 5. Dominant vegetation composition along the transect in Rutum Island

The seagrass bed in the south of the island stretched 160 m from the coast to the sea, with depth varied from 30 to 155 cm (Figure 7, Table 1). In the first 70 meters, the seagrass cover increases gradually from 20 to 70% with some fluctuations. Seagrass in this area is accompanied by seaweed vegetation up to 50%. For the next 70 meters, the seagrass cover drop to less than 10%, which started by a dramatic decline in 70th to 80th meter and levelling off until the 120 meters at around 20% with a dip around the 100m at 15%. From this point, the seagrass cover drops to less than 15% towards the end of the transect, with a peak of 30% on the last 10 meters. On the contrary, the seaweed cover is increasing dramatically from 0 to 50% in the second 70-meter area before drops again to around 10% in the last 40 meters. Overall, the seagrass meadows in Abidon could be considered as less healthy because the canopy cover has an average of 30% (Table 1).

The meadow on this island has a clear water condition and the substrate mostly in the form of mix sand and rubble (Table 1). Analysis of satellite imagery and ground

truth data shows that the seagrass meadow occupies 37,593 m² of the coastal area in this island, which consisted of *Halodule pinifolia*, *Cymodocea rotundata*, *Thalassia hemprichii*, and *Halophila ovalis*. According to the IVI calculation, *T. hemprichii* is the most dominant species in this location (Table 1).

3.1.4 Kanober

Kanober is located in the north part of the Ayau Islands. The length of the island is approximately 1.7 km from west to east and almost 1 km from north to south. There is no settlement on this island. According to the satellite images, seagrass is growing along the coast, and the vast meadow located in several bays of this island (Figure 8), so the observation transect was placed in one of the bay.

The seagrass bed in Kanober stretched about 60 m from the beach to the sea (Figure 9), with depth varied from 120 to 270 cm (Table 1). The seagrass cover increases sharply from 25 to 50% in the first 10 meters and continued with a slight increase to 60% for the next 40



Figure 6. Transect placement location (white line) in Abidon. The length of the transect is 160 m, started at N 0.49505 E 131.13127 and finished at N 0.49361 E 131.13124

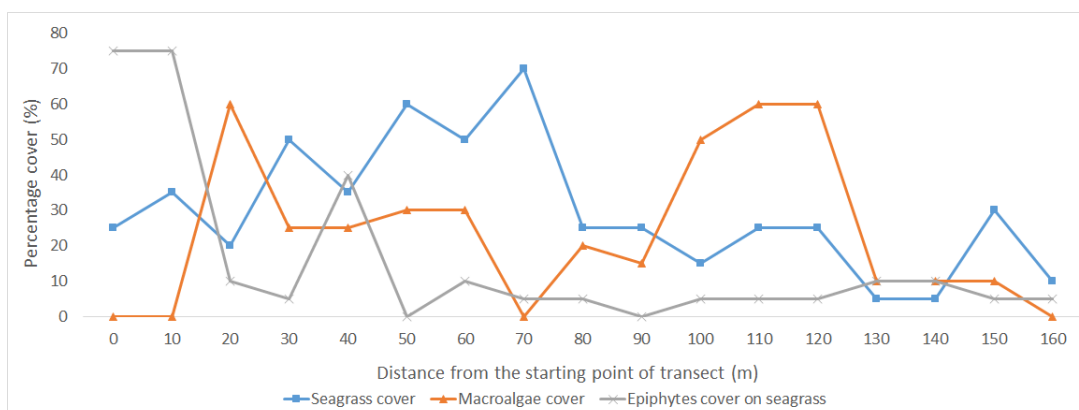


Figure 7. Dominant vegetation composition along the transect in Abidon

meters to the sea. From this point, the seagrass cover is decreasing dramatically to around 15% in the last 10 meters. Overall, the seagrass condition in Kanober could be considered as moderate (less healthy) status because the average of canopy cover is 44% (Table 1).

The meadow on this island has a clear water condition and the substrate mostly in the form of sand (Table 1). Analysis of satellite imagery and ground truth data shows that the seagrass meadow occupies 4,815 m² of the coastal area on this island, which composed of *Enhalus acoroides* and *Thalassia hemprichii*. The first species is the dominant species due to the larger IVI value than the other one (Table 1).

3.1.5 Dorehkar

Dorehkar is located in the south part of Ayau Island and being the largest island of this area. The length of the island is approximately 4 km from northwest to southeast and 2 km from southwest to northeast. There are several groups of settlements on the west and south coast of the island, with the largest one located in the south part of the island near the lagoon. Based on the satellite image, the seagrass bed is situated in the western and southern parts of the island. Because the southern part has a larger size, so the transect was placed there (Figure 10).

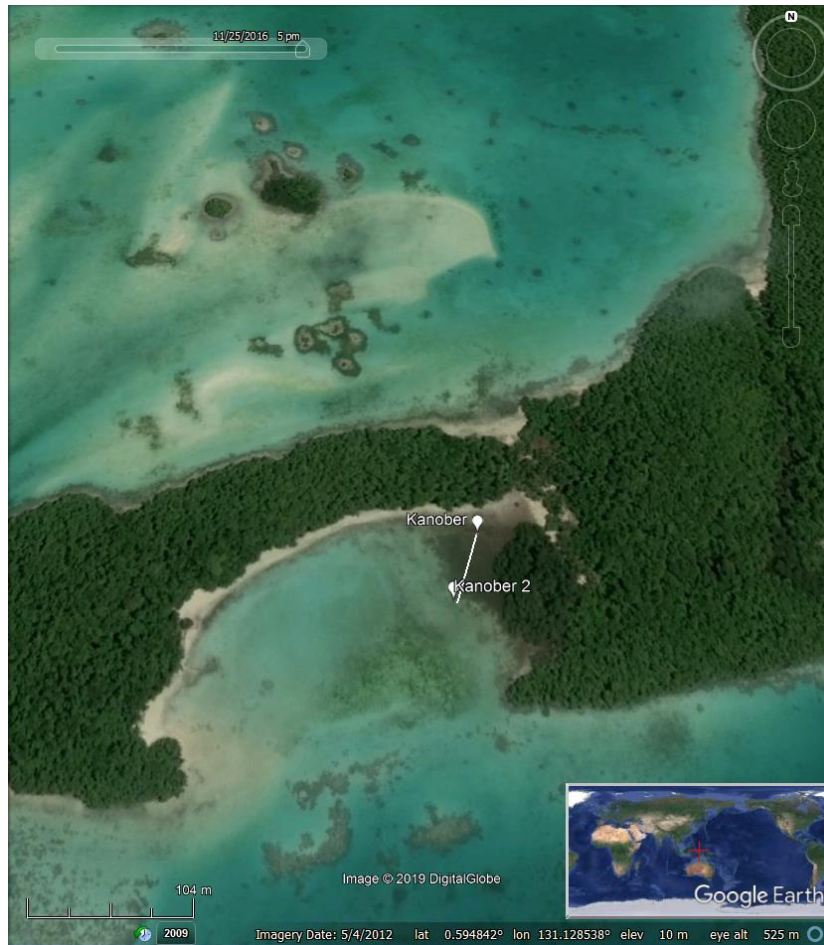


Figure 8. Transect placement location (white line) in Kanober. The length of the transect is 60 m, which started at N 0.59438 TE131.12892 and finished at N 0.59392 E 131.12875

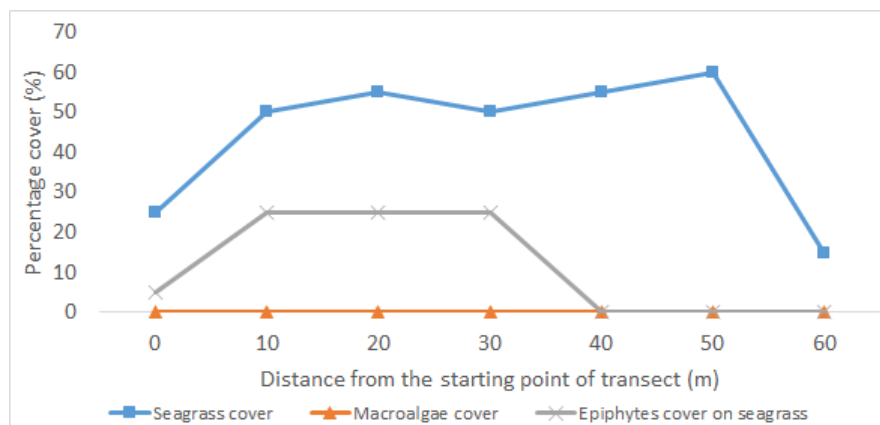


Figure 9. Dominant vegetation composition along the observation transect in Kanober

Seagrass bed in Dorehkar stretch more than 600 m from the coastline to the sea; however, due to the time allocation in the field, we just finished the survey at 600m of the transect (Figure 11). In the first half of the transect, the seagrass cover fluctuates wildly, with the range from 50 to 95%. There were some seaweed patches in this area, with the cover around 10%. For the next half of the transect, the seagrass cover is gradually decreasing from 80 to 15% at the end of the transect. In the last 100 meters, seaweed vegetation is more dominant to seagrass, with the cover ranges from 10 to 40%. Overall, the seagrass meadow status in Dorehkar is considered as healthy because the average canopy cover is 67% (Table 1).

The meadow on this island has a clear water condition and the substrate mostly in the form of sand, with depth

varies from 50 to 95 cm (Table 1). Analysis of satellite imagery and ground truth data shows that the seagrass meadow occupies 1,3 million square meters of the coastal area on this island. Four seagrasses present at the meadows in Dorehkar, which are *Cymodocea rotundata*, *Halophila ovalis*, *Enhalus acoroides*, and *Thalassia hemprichii*. According to the IVI measurement (Table 1), *T. hemprichii* has the highest value, which made this species as the most dominant species in this location.

3.2 Seagrass composition and distribution

There are five seagrass species found from five locations in these islands. The species are *Halodule pinifolia* (Miki) den Hartog, *Cymodocea rotundata* Ehrenberg & Hemprich, ex Ascherson, *Enhalus acoroides*



Figure 10. Transect placement location (white line) in Dorehkar. The length of the transect was 600 m, which started at N 0.36441 E 131.04628 and finished at N 0.36110 E 131.04201

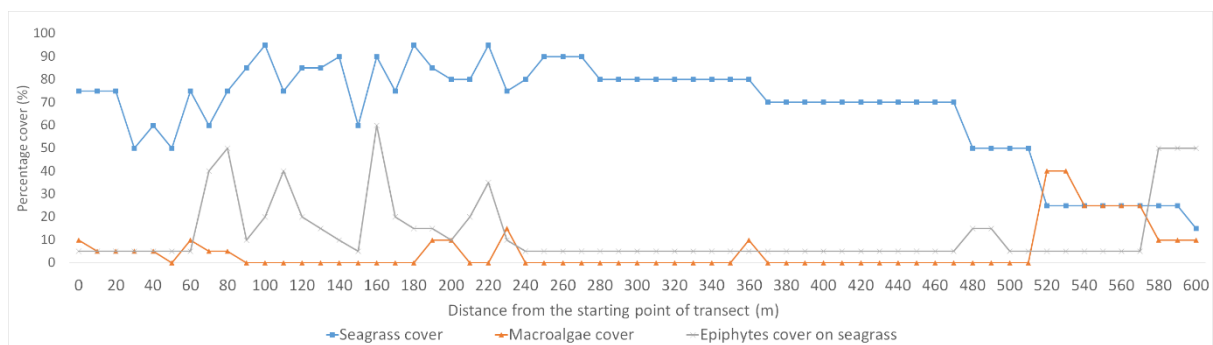


Figure 11. Dominant vegetation composition along the observation transect in Dorehkar

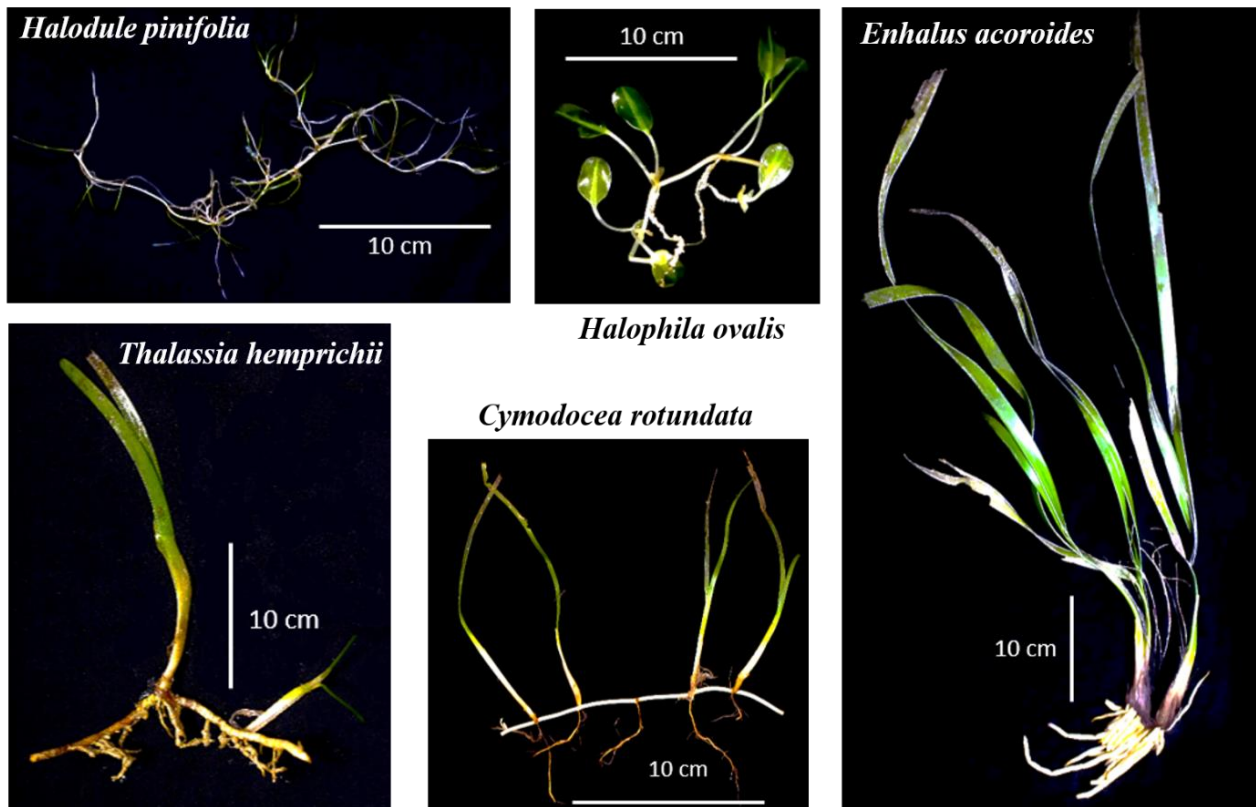


Figure 12. Five seagrasses found in this expedition: *Halodule pinifolia* (Miki) den Hartog, *Cymodocea rotundata* Ehrenberg & Hemprich, ex Ascherson, *Thalassia hemprichii* (Ehrenberg) Ascherson, *Enhalus acoroides* (Linn. f.) Royle, *Halophila ovalis* (R. Brown) Hooker f. Photos taken by Bronto (Media Indonesia).

(Linn. f.) Royle, *Thalassia hemprichii* (Ehrenberg) Ascherson, and *Halophila ovalis* (R. Brown) Hooker f. (Figure 12). Of all these species, only *T. hemprichii* can be found in all locations, whereas other species distributed differently (Table 1). With respect to species richness, Abidon and Dorehkar have the highest number of species (four species) compared to the other locations.

3.3 Condition of the seagrass meadows

3.3.1 Density

The location with the highest seagrass density is in Rutum at 915 shoots/m², and the lowest is in Kanober at 108 shoots/m² (Table 1). Overall, most of the locations have seagrass density of more than 400 shoots/m², which are 716 shoots/m² (Reni), 596 shoots/m² (Dorehkar) and 495 shoots/m² (Rutum). However, due to different morphology of seagrass species, this density value is not suitable as an indicator of seagrass condition. In Indonesia, the status of seagrass meadows is determined by their canopy cover value (KMNLHRI, 2004).

3.3.2 Canopy cover

The highest seagrass canopy cover is observed in Reni, with an average of 71%, and the lowest is in Abidon at 30% (Table 1). The remaining stations have a mean seagrass cover at 67% (Dorehkar), 64% (Rutum) and 44% (Kanober). This canopy cover value have made the seagrass statuses in Reni dan Rutum categorized as healthy due to the cover is larger than 60%, and likely so in Dorehkar. Meanwhile, seagrass meadows in Abidon and Kanober have a status of less health because the seagrass covers are in the range of 30 – 60% (Table 1). In overall, from the average cover value

of the five locations, which is at 55%, it is suggested that the status of the seagrass bed in Ayau Island is less health.

3.3.3 Dominant seagrass

In vegetation study, the dominant species cannot be defined merely from one aspect, such as the highest density, cover, or frequency. All of the aspects should be combined, which form an index of the important value (IVI) of each species (Gopal & Bhardwaj, 1979). Based on the calculation of that index, the dominant seagrass species in Ayau Islands is *Thalassia hemprichii* because its IVI was the highest in four of five locations (Table 1). The only location that this species not dominant was in Kanober because it's IVI is lower than *Enhalus acoroides* value.

3.3.4 Environmental characteristics

Environmental conditions at the field sampling period were relatively similar in all locations. The first parameter is the dominant substrate which mostly in the form of sand, except in Abidon. The second parameter is water clarity which mostly in clear condition. The third parameter is temperature, which ranged at 30 – 36 °C. The fourth parameter is salinity, which ranged at 33.5 – 35 per mille (‰). The fifth parameter is nutrients concentration, which is very low with phosphate less than 0.1 mg/L, and nitrate level is undetected by the test kit that used in this research (Table 1). Almost all nitrate analysis shows a pale yellow colour of the solution, which are brighter than yellow (0 mg/l) as the lowest standard. As the standards are gradually darkened from yellow to brown as nitrate concentration increasing, there is no other explanation on the manual of the kit for pale yellow results.

4. Discussions

The species number of seagrasses in this study (five species) is relatively low compared to several nearby locations (Table 2). In other locations of Raja Ampat Regency, such as in Waisai and North Salawati there are seven seagrasses observed although with different composition in each location (Hoek, *et al.*, 2016; Ausal, *et al.*, 2017), which mean that more than five seagrasses can grow in this regency. If this data compared to further locations such as in Biak, in Papua Province and also Ternate and Weda Bay, in North Maluku Province then the gap becomes wider because there are eight to nine species in those areas (Irawan, 2014; Ramili, *et al.*, 2018). The apparent differences in the Ayau area compared to other locations are on the geographical aspect of the area that is more exposed to the ocean than the other locations and the size of the island that smaller. This condition might reduce the protection of the seagrass from the wave. Another possible factor might because there is a limited dispersal pathway between meadows (Fortes, *et al.*, 2018) in Ayau and the greater Raja Ampat Islands.

Among the five species of seagrasses found on this island, *Thalassia hemprichii* is dominant in four out of five stations (Table 1). The dominance of *T. hemprichii* in a seagrass bed is a common finding in Indonesia as the result of monitoring from 110 locations could confirm that fact, with this species dominate in most of the location (Sjafrie, *et al.*, 2018), also in South East Asia (Fortes, *et al.*, 2018). This dominance could be related to the cosmopolitan feature of this species, which can grow in a wide range of substrate and depth, especially in the intertidal tropical sandy beaches.

Besides seagrass species number, the density of seagrasses is an important property that affecting the condition of the seagrass meadows. The range of the seagrass density in Ayau Island is at 108 - 915 shoots/m². This range is wider than the data from Salawati which is still in the same regency with Ayau at 280 - 391 shoots/m² (Hoek, *et al.*, 2016). Seagrass density in Ayau Island is at a similar range with the seagrass density in Biak at 450 - 898 shoots/m² (Dewi, *et al.*, 2017). Both locations have the same characteristic as an island with more directly expose to the Pacific Ocean than Salawati. However, this relation still needs to be studied further.

Regarding the low seagrass density in Kanober compared to the other locations, it could be related to the type of vegetation that composed by relatively large seagrasses, which are *Enhalus acoroides* and *Thalassia hemprichii*. With their large size, they cannot occupy an area with a large number of shoots compared to the smaller seagrasses such as *Halodule pinifolia* which grows in Rutum. However, this condition does not apply for Abidon, which has a density only at half from Rutum where bigger seagrass grows there. The possible reason could be related to the difference of substrate between both locations. In Abidon, the dominant substrate was a combination of sand and rubble (Table 1) compared to only sand in Rutum. Although more diversification of substrate may lead to more diversity of seagrasses, they usually do not grow well in the rubble type of substrate.

Another feature that forms a seagrass meadow condition is seagrass cover. The range of seagrass cover in Ayau Island is at 30 - 71%. According to the regulation in Indonesia this value can be considered as less healthy to a healthy status of seagrass bed, with three of five stations are at healthy status (Table 1). This condition resembles the general condition of seagrass meadows in the eastern part of Indonesia which half of them are healthy and most of the other half are less healthy (Supriyadi, *et al.*, 2018). Nevertheless, the maximum seagrass cover in this Ayau Island is lower than its neighbours, such as 80% in Biak (Dewi, *et al.*, 2017) and 97% in Salawati (Hoek, *et al.*, 2016). So, regular monitoring is needed to gather more information about the future trend of the seagrass cover.

It is assumed that the higher the density, the higher the canopy cover. However, it might not always be true, particularly for different seagrass beds. In this study, the highest canopy cover was not found in Rutum, which has the highest density, and the lowest was not found in Kanober. In fact, the highest seagrass cover was in Reni, with an average of 71%, and the lowest was in Abidon at 30%. The low seagrass cover in Abidon was possibly related to the rubble content that mixed with sand substrates and the relatively higher macroalgae and epiphyte cover in this location than the other locations. This condition indicates a competition of the three marine plants (seagrasses-seaweeds / macroalgae-epiphytes) in these locations, which may affect to the seagrass cover as the indicator for the health status of the meadows.

Table 2. Comparison of species composition in nearby areas

Species	Location					
	Ayau (This study)	Waisai (Ausal, <i>et al.</i> , 2017)	North Salawati (Hoek, <i>et al.</i> , 2016)	Biak (Dewi, <i>et al.</i> , 2017)	Ternate area (Ramili, <i>et al.</i> , 2018)	Weda Bay (Irawan, 2014)
<i>Halodule uninervis</i>			X	X	X	X
<i>Halodule pinifolia</i>	X	X	X	X		
<i>Cymodocea rotundata</i>	X	X	X	X	X	X
<i>Cymodocea serrulata</i>			X	X	X	X
<i>Syringodium isoetifolium</i>		X	X		X	X
<i>Enhalus acoroides</i>	X	X	X	X	X	X
<i>Thalassia hemprichii</i>	X	X	X	X	X	X
<i>Halophila ovalis</i>	X	X	X	X	X	X
<i>Halophila minor</i>				X	X	X
<i>Halophila spinulosa</i>					X	
<i>Halophila decipiens</i>		X				

Besides it cover, the good/healthy condition of the seagrass bed Reni, Rutum and Dorehkar can be seen from the proportion of seagrass cover to macroalgae cover, that is always bigger along the transect (Figure 3, Figure 5, and Figure 11. In addition, the epiphyte cover on seagrass leaves was mostly below 13%, which might not disturb the seagrass' s leaves to receive sunlight for photosynthesis.

This relationship strengthened by the status of moderate (less healthy) in Abidon that might be related to the competition of source between seagrass and macroalgae. In this location, macroalgae cover was exceeding seagrass cover in some parts of the transect (Figure 7) and has an overall average at 24% (Table 1). In addition, epiphytes cover also reach 40% and 70% in several spots in the transect, indicating the increasing pressure on seagrasses.

However, unlike the other locations, the less healthy status in Kanober unlikely related to the competition with other plants because there were no macroalgae present, and the epiphytes cover did not exceed 30% (Figure 9, Table 1). In this location, the low canopy cover value more likely related to the low density of seagrass. This difference in the factor that may associate with seagrass cover might provide an example that a seagrass meadow is a complex system in the coastal water.

As an ecosystem, its conditions also could be affected by abiotic factors such as salinity and nutrient level. The range of salinity in Ayau Island is between 33.5 and 35‰ (Table 1). The value is still in accordance with the quality standards of salinity for marine biotas in the seagrass ecosystem waters is 33-34‰ (MNLH, 2004). Although the range is one per mile over the upper standard, this plant probably will not encounter any stress because seagrasses are generally euryhaline species. They might become a stress in the hyposaline (<10‰) or hypersaline (>45‰) conditions (Hogarth, 2007).

Nutrient level in seawater in the seagrass beds seems to be in the low-level condition, with phosphate < 0.1 mg/l, and the nitrate is not detected with the kit that used in this study (Table 1). Although the phosphate level in this study could be higher than the quality standards of phosphate in marine water for marine biota, which is 0.015 mg/l for Indonesia and ASEAN standards (MNLH, 2004; ASEAN, 2008), it is still below the level for eutrophication to occur. In fact, it might have fallen to the range of 0.025 – 0.1 mg/l, which stimulated the growth of plants without lead to eutrophication (Fadiran, *et al.*, 2008). This also can explain the low cover percentage of macroalgae and epiphyte in this study (Table 1).

In general, the most extensive meadow was located in Dorehkar with more than 600 meters from the beach toward the sea. The length of the meadows seems to reflect the area of the meadows, with the largest meadows area also located in Dorehkar, supported by the fact that Kanober has the least length and the least area (Table 1). However, the correlation does not apply for Rutum and Abidon because Rutum has least meadow length than Abidon, but their meadows area are inversely ordered (Table 1). Nevertheless, with its relatively high value of seagrass composition, density, canopy cover, and area, seagrass meadow in Dorehkar can be considered having the best condition in this Ayau Islands.

5. Conclusion

Seagrass meadows in Ayau Islands have the characteristic of mixed seagrass meadow with two until five seagrasses forming the vegetation, with a variety of length and area size. In overall, there are five seagrass species from five seagrass bed in Ayau Island, which are *Halodule pinifolia*, *Cymodocea rotundata*, *Enhalus acoroides*, *Thalassia hemprichii*, and *Halophila ovalis*. The dominant species is *T. hemprichii* because this species is dominant in four locations and can be found in all locations. Based on the seagrass cover, the seagrass meadow in Reni, Rutum, and Dorehkar are in healthy status. Meanwhile, the seagrass meadow in Abidon and Kanober are in less health status.

As a baseline study, there are a lot of questions that cannot be answered in this study, such as why the number of species was lower than the neighbouring islands? or are the conditions remain the same from the past? or how are the projected conditions in the future? To answer those questions, further research is needed in this Ayau Islands.

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