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Diversity, coverage, distribution and ecosystem services of seagrass in three small islands of northern Papua, Indonesia: Liki Island, Meossu Island and Befondi Island

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Abstract. *Nugraha AH, Tasabaramo IA, Hernawan UE, Rahmawati S, Putra RD, Darus RF. 2021. Diversity, coverage, distribution and ecosystem services of seagrass in three small islands of northern Papua, Indonesia: Liki Island, Meossu Island and Befondi Island. Biodiversitas 22: 5544-5549.* Papua waters are one of the hot spot areas with high marine biodiversity in the world. Yet, the less accessible location and varying geographical conditions become the significant constraints of biodiversity study in this region, resulting in limited information about the diversity of marine resources, including the seagrass ecosystem. This research aims to investigate the diversity, coverage and distribution of seagrass in three small islands in the northern waters of Papua, namely Liki Island, Befondi Island, and Meossu Island, as well as to study the ecosystem services provided by the seagrass. This research is part of the Nusa Manggala Expedition, which was carried out in November 2018, consisted of seven observation stations. Data collection was conducted using the transect line method combined with plot quadrat. Information regarding seagrass ecosystem services was gathered through observation and direct interviews to the community. The results showed that there were seven species of seagrass in the studied sites, namely *Cymodocea rotundata, Enhalus acoroides, Halodule uninervis, Halodule pinifolia, Halophila ovalis, Thalassia hemprichii,* and *Syringodium isoetifolium.* Liki Island had the highest seagrass cover value of 82.24%, followed by Meossu Island and Befondi Island with seagrass cover of 63.23% and 31.25%, respectively. There were 13 seagrass ecosystem services identified in this research. The people of Liki Island and Meossu Island get the benefits of the existence of the seagrass ecosystem. The direct benefits are the presence of seagrass is associated with biota commonly used as food sources such as *Siganus* sp and sea cucumbers. There are efforts made by the community to maintain the sustainability of the seagrass ecosystem, which is known as *sasi*.

Keywords: Ecosystem services, pacific-ocean, Papua, seagrass

Abbreviations: Cr: *Cymodocea rotundata*; Ea: *Enhalus acoroides*; Ho: *Halophila ovalis*; Hp: *Halodule pinifolia*; Hu: *Halodule uninervis*; Si: *Syringodium isoetifolium*; Th: *Thalassia hemprichii*

INTRODUCTION

Indonesia is a maritime country that has abundant marine wealth (Roshitafandi et al. 2018). Seagrass is a type of vegetation that lives in coastal waters and estuaries, and along with biotic and abiotic elements, seagrass forms an ecosystem called seagrass beds. Seagrass beds have various important ecological roles, such as sediment stabilizers in coastal areas and estuaries, habitat and feeding ground for marine biota, and regulating the global carbon cycle (Chiu SH et al. 2013; Nordlund et al. 2016; Moussa et al. 2020). In addition to the ecological role, the seagrass ecosystem directly contributes to food provision for coastal communities, like fish, gastropod, etc. (Wahyudin et al. 2018).

Seagrass ecosystems have a wide distribution globally with the highest centers of diversity are in the Indo-Pacific waters (Short et al. 2007). Seagrasses in the Indo-Pacific waters are found in intertidal and subtidal areas with 24 species of seagrass having been identified so far (Short et al. 2007). Fourteen species of seagrasses occur in Indonesian waters, including *Cymodocea rotundata, C. serrulata, Enhalus acoroides, Halodule pinifolia, Halodule uninervis, Halophila decipiens, H. minor, H. ovalis, H. spinulosa, H. sulawesii, H major, Syringodium isoetifolium, Thalassia hemprichii,* and *Thalassodendron ciliatum*, while 2 species are found in the herbarium collections, namely *H. beccarii* and *Ruppia maritima* (Sjafrie et al. 2018; Kurniawan et al. 2020). Until 2017, the area of seagrass beds in Indonesian waters had an extent of

293.464 hectares (Sjafrie et al. 2018) with most of them in moderate condition (Hernawan et al. 2021).

While Indonesia contributes to more than half of seagrass diversity in the world, yet information about the seagrass ecosystem in Indonesian waters is limited (Yaakub et al. 2018). The vast extent of Indonesian waters with diverse geographical conditions is one of the obstacles in collecting data related to the condition of seagrass beds in Indonesian waters. Moreover, in the eastern part of the country, which is generally less explored areas than other regions. This is also worsened by the lack of funds and researchers to support studies on seagrass ecosystems in Indonesian waters (Fortes et al. 2018). These obstacles result in limited information related to seagrass ecosystems in the Indo-Pacific waters, especially Southeast Asian waters (Waycott et al. 2009; Ooi et al. 2011).

The northern waters of Papua are part of the Indo-Pacific tropical waters, which are included as marine biodiversity hot spot areas. The area is predicted to be the center of diversity of the seagrass ecosystem (Short et al. 2007). Studies related to the structural conditions of seagrass ecosystems are very important, especially to enrich information related to the biological diversity and ecosystem services delivered by seagrass beds that are beneficial to support the sustainability of living organisms. This research aims to investigate the diversity, coverage and distribution of seagrass in three small islands in the northern waters of Papua, namely Liki Island, Befondi Island, and Meossu Island, as well as to study the ecosystem services provided by the seagrass.

MATERIALS AND METHODS

Study area and period

This research was conducted in November 2018 at three small outermost islands in the Pacific Ocean, precisely in the northern waters of Papua, Indonesia. This research is part of the Nusa Manggala Expedition organized by the Research Center for Oceanography, Indonesian Institute of Sciences (LIPI). There were three locations for data collection in this study, namely Liki Island, Befondi Island and Meossu Island (Figure 1). The coordinate for each research station is presented in Table 1. Liki Island and Befondi Island are inhabited by people, while Meossu Island is not inhabited.

Table 1. Coordinate information for each research station

Station	Latitude (ºS)	Longitude (ºE)
Station 1 (Liki)	1.62248ºS	138.74451ºE
Station 2 (Liki)	1.62207ºS	138.74731ºE
Station 3 (Liki)	1.6047ºS	138.70901ºE
Station 4 (Liki)	1.59291ºS	138.73541ºE
Station 5 (Meossu)	0.33468ºS	132.16341ºE
Station 6 (Meossu)	0.34488ºS	132.16139ºE
Station 7 (Befondi)	0.03884ºS	132.19106ºE

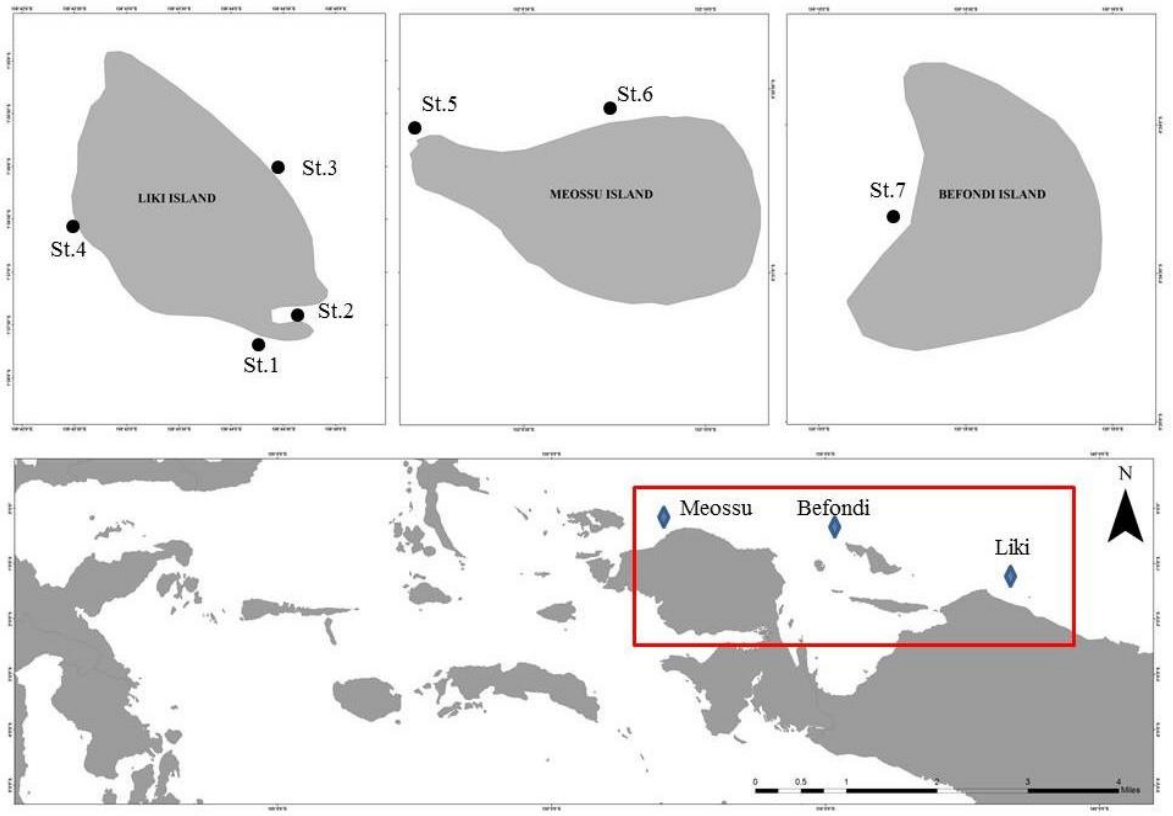

Figure 1. Map of research location in three small islands of northern Papua, Indonesia

Data collection on diversity, structure, coverage and distribution of seagrass

The number of a station at each location was determined based on the representation of the seagrass ecosystem found on each island. Samplings of seagrass ecosystems were carried during low tide conditions. Data regarding the diversity and structure of seagrass were collected using the line transect method referring to Rahmawati et al. (2017) with modification. The transect was started at the point where seagrass was found and ended at the edge where no seagrass was found. Observations were carried out every 10 m on a line transect using a 50x50 cm square plot. Total coverage and distribution of seagrass were measured by calculating the percentage of observation area covered by seagrass using the method used by Rahmawati et al. (2017). The value of seagrass cover ranged from 0-100% and seagrass cover was measured for the total cover and the coverage of each type of seagrass. Each type of seagrass found in the study area was identified using a manual guidebook (Rahmawati et al. 2017).

Identification of seagrass ecosystem services

The ecosystem services delivered by the seagrass were identified by interviewing public figures who live around the islands. In addition to the interviews, direct observations were also carried out to identify existing seagrass ecosystem services. The observation of seagrass ecosystem services referred to the research of Nordlund et al. (2016). The observed ecosystem services include cultural ecosystem services, provisioning ecosystem services, regulatory ecosystem services, and supporting ecosystem services.

RESULTS AND DISCUSSION

Seagrass species diversity and distribution

There were seven species of seagrass in the studied area consisting of *Cymodocea rotundata* (Cr), *Enhalus acoroides* (Ea), *Halophila ovalis* (Ho), *Halodule pinifolia* (Hp), *Halodule uninervis* (Hu), *Syringodium isoetifolium* (Si), and *Thalassia hemprichii* (Th). The distribution of seagrass species found at each research location is presented in Table 2.

Table 2. Diversity and distribution of seagrass species in the north coast of Papua

Species	Liki	Befondi	Meossu
Cymodocea rotundata	+	+	+
Enhalus acoroides	+	-	+
Halodule pinifolia	+	-	+
Halodule uninervis	+	-	+
Halophila ovalis	+	-	+
Syringodium isoetifolium	+	-	-
Thalassia hemprichii	+	+	+

Based on the information presented in Table 1, it can be seen that there were seven species of seagrass found in Liki Island, two species in Befondi Island, and six species in Meossu Island. The research by McKenna et al. (2002) in the waters of Raja Ampat found 10 types of seagrasses, namely *C. rotundata, C. serrulata, E. acoroides, H. uninervis, H. pinifolia, H. ovalis, H. spinulosa, S. isoetifolium, T. Hemprichii* and *T. ciliatum.* The research by Tomascik et al. (1997) in Biak waters found 8 species of seagrass, including *C. rotundata, C. serrulata, E. acoroides, H. uninervis, H. pinifolia, H. ovalis, S. isoetifolium* and *T. hemprichii.* Hernawan et al. (2021) stated that a good seagrass bed can be determined by the number of seagrass species that reach more than 7 species. The diversity of seagrass species in a habitat indicates the level of the seagrass ecosystem's resilience to the various threats. The more species found, the greater the possibility of the system to survive (Unsworth et al. 2015).

There are differences in the number of seagrass species found in north Papua waters, according to the results of previous studies. Differences are generally found in several types of seagrass that are pioneer and opportunist, such as seagrasses from the genera of *Halophila* and *Cymodocea.* Pioneer and opportunistic seagrasses are generally small and have rapid growth and short lifespan than the persistent seagrass species (Kilminster et al. 2015). Based on these characteristics, the presence of these seagrass species is probably not supported by environmental conditions. Another difference is the discovery of the seagrass species *Thalassodendron ciliatum* that lives in rock fragments as a substrate and is located between the border of the seagrass ecosystem and the coral reef ecosystem (Hernawan et al. 2021). This species has limited distribution in Indonesian waters (Sjafrie et al. 2018).

There were two species of seagrass found across all research sites, namely *C. rotundata* and *T. hemprichii*. This seagrass species had a very high occurrence rate at the study site and can be found in almost all areas of the seagrass ecosystem (Figure 2). Both types of seagrass are easy to adapt to aquatic environmental conditions (Kawaroe et al. 2016). In addition, these two species of seagrass are key species in the Indo-Pacific region (Waycott 2011; Kilminster et al. 2015). *T. hemprichii* is a very dominant type of seagrass found in Indonesian waters, with a high distribution rate from east to west Indonesia (Hernawan et al. 2021).

The characteristics of the seagrass ecosystem at the research location were generally mixed vegetation where each seagrass ecosystem was composed of more than one type of seagrass. The combination of colonizing seagrass groups (*Halophila, Halodule*), opportunistic seagrasses (*Cymodocea, Syringodium*), and the dominance of persistent seagrass groups (*Enhalus, Thalassia*) in the study area have an impact on the level of seagrass resistance to threats in the aquatic environment (Kilminster et al. 2015). Liki Island had an average seagrass ecosystem width of 120 m from the shoreline to the edge (Figure 2). Meossu Island had the largest seagrass ecosystem width than the other stations with 210 m from the shoreline to the edge. Befondi Island had the smallest seagrass ecosystem width

than the other stations with 30 m. The limited width of the seagrass ecosystem in Befondi Island is due to the steep coastal characteristics and high waves, resulting in the seagrasses not developing optimally (Kawaroe et al. 2016).

Seagrass coverage

The seagrass cover at each research location is presented in Figure 3. The results indicate that the range of seagrass cover at the study site was 31.35% - 82.24%. The highest value of the seagrass cover was 82.24% found in the waters of Liki Island, 63.23% on Meossu Island, and 31.25% on Befondi Island. The low coverage of seagrass on Befondi Island is likely due to the high waves around the seagrass ecosystem. These factors have an impact on the sustainability of seagrass since seagrasses are generally able to live well in calm coastal water (Kawaroe et al. 2016). Seagrass ecosystems in Liki Island and Befondi Island had >60% of the cover value, which according to the Ministry of Environment Regulation no 200 the Year 2004, seagrass with more than 60% coverage indicates a healthy ecosystem.

The high seagrass cover in Liki Island and Meossu Island is likely due to the maintained condition from the impact of human activities. According to Unsworth et al. (2015) and Hemminga and Duarte (2000), seagrass cover resembles the resilience of seagrass to environmental conditions, as happened to the seagrass ecosystem in some locations in Vanuatu, South Pacific (Lincoln et al. 2021).

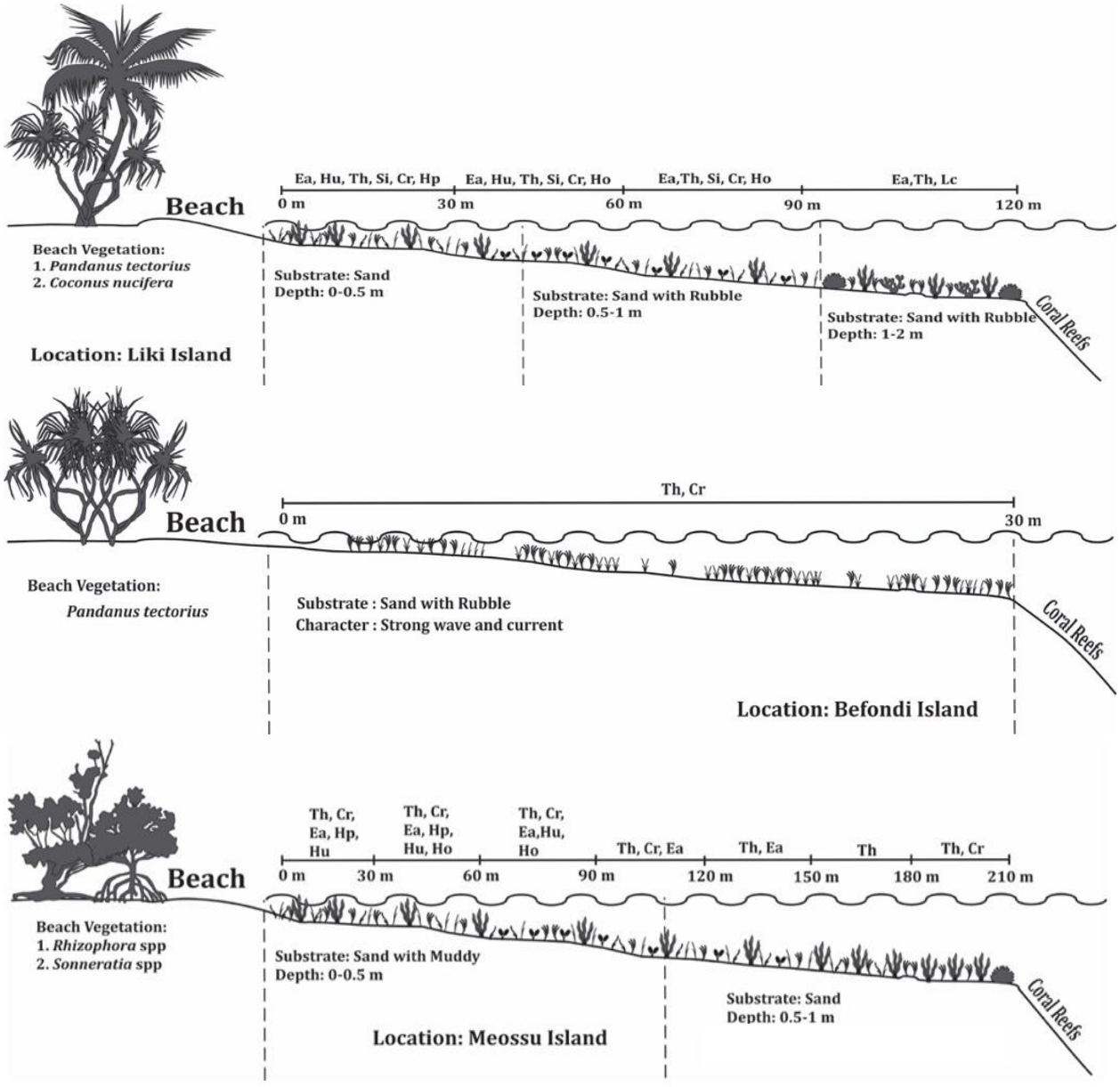

Figure 2. Distribution of seagrass species at three research sites in three small islands of northern Papua

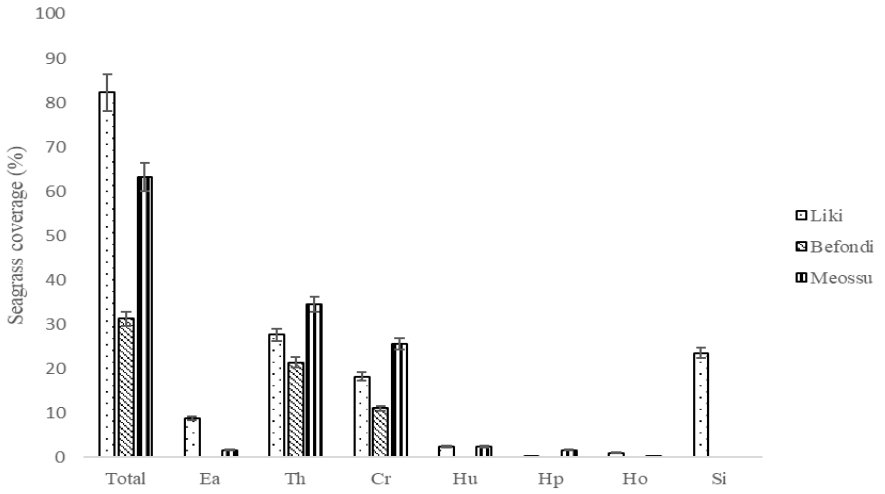

Figure 3. Seagrass coverage at three research sites in three small islands of northern Papua, Indonesia

Seagrass cover in Liki Island and Meossu Island had a very high value than the average seagrass cover in Indonesian waters (39%) (Hernawan et al. 2021). The results of this study indicate that seagrass cover in east Indonesian waters has very good conditions. The eastern waters of Indonesia have better seagrass cover than the western part of Indonesia (Unsworth et al. 2018; Hernawan et al. 2021). This is presumably due to a large number of human activities in the western part of Indonesia than in the eastern. Some activities that threaten seagrass cover include oil pollution, wastes, construction, cultivation, sedimentation, destructive fishing, etc.

Thalassia hemprichii had the highest value of seagrass cover across all study sites than the other seagrass species. *T. hemprichii* can adapt to various aquatic environmental conditions despite the persistent group of seagrasses (Kilminster et al. 2015). This type of seagrass is also cosmopolitan in Southeast Asian waters and can live in various habitat conditions (Waycott et al. 2004). In addition to the northern waters of Papua, *T. hemprichii* also have the highest cover values, such as in the Riau Islands, Tanimbar Islands, Thousand Islands, and Talaud Islands (Kawaroe et al. 2016). *T. hemprichii* also dominates in Tayando-Tam Island, Southeast Maluku (Fitrian et al. 2017).

Seagrass ecosystem services

Ecosystem services are classified into four categories, including provisioning, regulating, supporting, and cultural services. Seagrass ecosystem services as provisioning include food provision for humans, which is generated from the seagrass association with another biota such as fish and shellfish. Seagrass ecosystem services as regulating include carbon sequestration, sediment stabilization, and protection of coastal areas. Seagrass ecosystem services as supporting are habitats for fish, vertebrates, invertebrates, food providers for marine organisms, and nursery areas. Cultural ecosystem services include education, research, heritage values, and spiritual values (Sjafrie et al. 2018). Based on the results of the study, the seagrass ecosystem services in Liki, Befondi and Meossu Island are presented in Table 3.

There were 11 seagrass ecosystem services identified in Liki Island. The unidentified ecosystem services indicate that there is a lack of research on seagrass ecosystem services. According to the interview results, the community gets the ecosystem services that come from the seagrass ecosystem. The high seagrass cover in Liki Island has an impact on the abundance of seagrass association biota. The biota association in seagrass ecosystem in Liki islands such as *Siganus*, sea cucumber, bivalves, and crab. The people in Liki Island usually do fishing for consumption or sale. *Siganus* sp. is the main biota from seagrass beds. In addition, there are clams and sea cucumbers. The high seagrass cover in Liki Island also has an impact on the presence of marine endangered species. The community reported that dugong and turtles use the seagrass ecosystem as a habitat for foraging, according to the study by Nugraha et al. (2019) that found seagrass ecosystem in the eastern part of Liki Island as feeding ground for dugong. Dugong is megafauna that has a high dependence on seagrasses such as *Halophila*, *Halodule*, and *Syringodium* (Idris et al. 2020).

In addition, all of the respondents perceived that the presence of seagrass has a role in sediment stabilization and protection of coastal areas. The presence of *E. acoroides* in Liki Island is presumably has contributed to this. *E. acoroides* has the largest morphometric than other types of seagrass, resulting in a better role in controlling chemical and physical activities around its environment (Hackney et al. 2004). Seagrass ecosystem service that is also important is carbon sequestration. Globally, seagrass ecosystems can absorb carbon up to 165.6 MgC/ha (Fourqurean et al. 2012). The ability of carbon adsorption by seagrass is affected by the density and biomass of seagrass (Wahyudi et al. 2020). The research results by Nugraha et al. (2020) showed that the average carbon absorption from seagrass biomass in Liki Island was 294.67 g C/m2, Befondi Island was 18.04 g C/m2 and Meossu Island was 151.35 g C/m2.

Table 3. Seagrass ecosystem services in three small islands of northern Papua, Indonesia

Ecosystem services	Location		
	Liki	Befondi	Meossu
Cultural services			
Education	+	+	+
Research	+	+	+
Heritage Value	-	-	+
Spiritual Value	-	-	+
Supporting services			
Fish habitat	+	+	+
Avertebrate habitat	+	+	+
Vertebrate habitat	+	-	+
Nursery ground	+	+	+
Feeding ground	+	+	+
Regulating services			
Carbon regulation	+	+	+
Coastal protection	+	-	+
Sediment stabilisation	+	-	+
Provisioning services			
Source of food from biota association	+	-	+

The existence of the seagrass ecosystem on Befondi Island was perceived to not provide many benefits for the local community. It was due to the poor condition of the seagrass ecosystem (de la Torre-Castro et al. 2014). The result of observations showed that the seagrass ecosystem on Befondi Island had a role as a sedentary habitat for several marine organisms.

There were 13 identified seagrass ecosystem services in Meossu Island. There are ecosystem services that distinguish Meossu Island and other islands, such as seagrass ecosystem services in spiritual and heritage aspects. The seagrass ecosystem in Meossu Island is managed by *sasi* system. The *sasi* system is a form of marine resource management that has been implemented for generations and in collaboration with the church. Almost all marine biota that is the target of consumption are regulated by the *sasi* system, such as fish, bivalves, sea cucumbers, gastropods, and crabs. This sasi system is widely practiced by people in eastern Indonesia to maintain the sustainability of marine resources. Besides Meossu Island, *sasi* systems are found in the Tanimbar Islands (Kawaroe et al. 2016). During the prohibition period in the *sasy* system, all community members were prohibited to take certain biota and the punishment imposed by the church was very strict. Generally, people living in the Pacific Ocean have a culture of maintaining the sustainability of marine resources, including the seagrass ecosystem (McKenzie et al. 2021).

The implementation of the *sasi* system on the seagrass ecosystem in Meossu Island presumably affects the resilience of the seagrass ecosystem in these waters, which was indicated by the high occurrence of pioneer seagrass species. The occurrence of pioneer seagrass species indicates that the seagrass ecosystem has a very good level of resilience (Marshall et al. 2007). The community stated that the preservation of the seagrass ecosystem on Meossu Island could be proven by the frequent occurrence of biotas such as turtles and dugongs.

In conclusion, there were seven types of seagrass found in this study. Seagrass ecosystems in Liki Island had the highest cover than other islands. *T. hemprichii* had the highest occurrence rate at the study site. The condition of the seagrass ecosystem was healthy in Liki Island and Meossu Island, resulting in a greater number of ecosystem services provided by the seagrass and benefiting the community.

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