Available online at www.worldnewsnaturalsciences.com

World News of Natural Sciences

An International Scientific Journal

WNOFNS 44 (2022) 215-230 EISSN 2543-5426

The condition of seagrass meadow in the waters of Kelapa Dua Island, Seribu Islands, Jakarta, Indonesia

Syawaludin A. Harahap[1,*], Donny J. Prihadi[1], R. Ahmad Gussaoki[2]

[1]Depertment of Marine Science, Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Jalan Ir. Soekarno Km. 21 Jatinangor, Sumedang 45363, West Java, Indonesia

[2]Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Jalan Ir. Soekarno Km. 21 Jatinangor, Sumedang 45363, West Java, Indonesia

*E-mail address: syawaludin.alisyahbana@unpad.ac.id

ABSTRACT

Seagrass is a higher-level plant that can live immersed in water in the aquatic environment near the coast. Seagrass colonies form a seagrass ecosystem that functions as a support in coastal waters which is strongly influenced by processes that occur in the sea and land. This ecosystem has a function as a primary producer, a recycler of nutrients, and a stabilizer of the bottom of the waters, as a habitat for biota, a place for spawning, a place for nurturing and foraging for various marine biota, and can protect the coast from the erosion process because it functions as a wave absorber and traps sediments. The field survey was conducted in April 2014 for seagrass observations and measurement of water condition parameters. The purpose of this study was to determine the types and conditions of seagrass on Kelapa Dua Island. The quadrant transect method was applied to seagrass observations carried out at 3 stations with each station consisting of 9 1m × 1m quadrant transect plots, then analyzed using a descriptive-quantitative approach. The results of the measurement of water quality parameters in the form of temperature ranged from 30.30 – 32.60 °C, the salinity of the waters in this study was in the range of 31.70 – 35.70‰. The pH value ranges from 7.40 – 7.75. DO levels ranged from 6.30 – 6.90 $mg \cdot L^{-1}$. The nutrients in the form of N and P were in the range of 1.19 - 1.79 $mg \cdot L^{-1}$ and 0.22 - 0.25 mgL^{-1}, respectively. Meanwhile, seagrass observations found three types of seagrass, namely *H. uninervis*, *T. hemperichii*, and *H. ovalis*. The lowest percentage of seagrass cover was at station 1, which was 7.8% and the highest was at station 2, which was 36.11%

(Received 02 August 2022; Accepted 23 August 2022; Date of Publication 24 August 2022)

with a diversity index ranging from zero to 0.94. The type of sediment at the research site has the characteristics of gravel sand.

Keywords**:** Coverage percentage, Marine ecosystem, Marine vegetation, Primary production, Species diversity

1. INTRODUCTION

Seagrass is a higher-level plant that can live immersed in water in the aquatic environment near the coast. Taxonomically, seagrass belongs to the Angiosperms group whose life is limited to the marine environment. Seagrasses are monocots, with at least four families and about 12 genera [1]. This plant has a morphological structure consisting of roots, stems, leaves, flowers, fruits, and seeds [2, 3]. Seagrasses colonize an area through the spread of sexually produced fruit (propagules) [4]. Seagrass grows from the intertidal zone to a depth of approximately 90 meters, however, the majority of seagrasses are limited to a depth of less than 20 m [5, 6].

Seagrass ecosystems function as supports in coastal waters which are strongly influenced by processes that occur in the sea and land [7]. Many organisms are ecologically and biologically strongly influenced and dependent on the existence of seagrass ecosystems [8, 9]. Seagrass ecosystems in coastal areas have a function as primary producers [10], nutrient recyclers and bottom stabilizers, [11], as a habitat for biota, a place for spawning, a place for nurturing and foraging for various marine biota [12–16], protects the coast from erosion because it functions as a wave absorber and traps sediments [17–20].

As one of the productive shallow sea ecosystems [21], Seagrass beds can store carbon stocks in marine ecosystems [22–25]. With varying cover, this ecosystem can produce primary productivity ranging from 1400 - 5100 $mg{\cdot}C{\cdot}m^{-2}{\cdot}day^{-1}$ [10]. Besides having biophysical and ecological potential, seagrass also has pharmacological potential. The results showed that seagrass contained bioactive compounds, namely secondary metabolites that could enable the preparation of innovative drugs, food supplements, and nutraceuticals for the management of several diseases and metabolic syndromes [26].

Based on the results of monitoring in various countries, shows that seagrass ecosystems around the world are facing the threat of damage due to disturbed habitat and reduced area [27, 28]. The damage is caused by eutrophication, turbidity, climate change, and other factors such as increased nutrients and runoff [16, 29–32]. Not only ecosystem damage, according to [31], but also, one in five seagrass species are listed as endangered, vulnerable, or near threatened and at high risk of extinction according to the IUCN red list criteria.

In Indonesia, seagrass ecosystems are also under widespread pressure to decline [33, 34]. For example, seagrass cover on Pari Island (the Seribu Islands) decreased by 25% from 1999 to 2004, presumably due to a large number of developments on the island [35]. In this research, the location is Kelapa Dua Island, which is one of the islands in the Seribu Islands region. Kelapa Dua Island was chosen as the research location based on the consideration that the ecosystem in this area is very complex, consisting of coral reef ecosystems, seagrass beds, and mangrove forests. Thus, it shows that the seagrass meadow area has considerable potential to be managed and utilized by the community and to support fishery production in coastal areas.

Based on field observations, the amount of seagrass cover on Kelapa Dua Island has been damaged which resulted in the degradation of seagrass beds. The damage to seagrass is more caused by human factors than natural factors. The destructive human activities include pollution of household materials, construction activities, dredging, and reclamation of beaches. For this reason, it is necessary to conduct this study to know the condition of the seagrass ecosystem which includes species diversity, species density, and seagrass cover on Kelapa Dua Island. This information is expected to be taken into consideration in efforts to recover seagrass. According to [36-38], seagrass can recover because it can re-colonize disturbed grasslands with the expansion of rhizomes, the presence of seed banks, and rehabilitation efforts.

2. MATERIALS AND METHODS

2. 1. Studi Area and observation stations

This research is located on Kelapa Dua Island (**Figure 1**). Geographically located at the coordinates 5°38'57.48"S and 106°34'1.56’E with an area of only about 1.9 hectares. Administratively, this island is located in Kelapa Island Village, North Seribu Islands District, Seribu Islands Administrative District, Jakarta [39].

The research station consists of 3 observation stations, namely:

Station 1: It is located in the southwest part of the waters of the Kelapa Dua island at a position 05° 38'59,7"S and 106°33'52,2"E. This area is an area that is close to human activities, one of which is close to the pier.

Station 2: Located in the western part of the waters of Kelapa Dua Island at the position of 5°38'58.57"S and 106°33'50.28"E. This area is an area that has the potential for pollution because the area is adjacent to fish farming activities using floating net cages and machines as production tools. Indirectly, these waters are indicated to be contaminated with organic matter because production waste is disposed of in the aquatic environment.

Stasiun 3: Located in the northern part of the waters of the island of Kelapa Dua at a position 5°38'56.59"S and 106°33'59.18"E. The area is an area adjacent to the mangrove cultivation area.

2. 2. Method

This research was conducted in April 2014. The method used in this research is the observation method, namely by surveying to collect data on the condition of seagrass in the form of seagrass species, the number of stands, and environmental conditions and activities on Kelapa Dua Island. Observations of each station are carried out at the same hour at low tide because these conditions are the most ideal time for observations.

Measurement and observation area sampling technique using a 1m x 1m quadrant transect. Placement of quadrant transects was placed on seagrass colonies which were first discovered in as many as 3 transect plots following the transect line drawn from the shoreline to 50m to the sea. Observations at each station are grouped into 3 substations with each substation distance being 10m (**Figure 2**). Measurement of water physicochemical parameters was carried out both in-situ and ex-situ at each station. The measured aquatic environmental parameters are presented in **Table 1**.

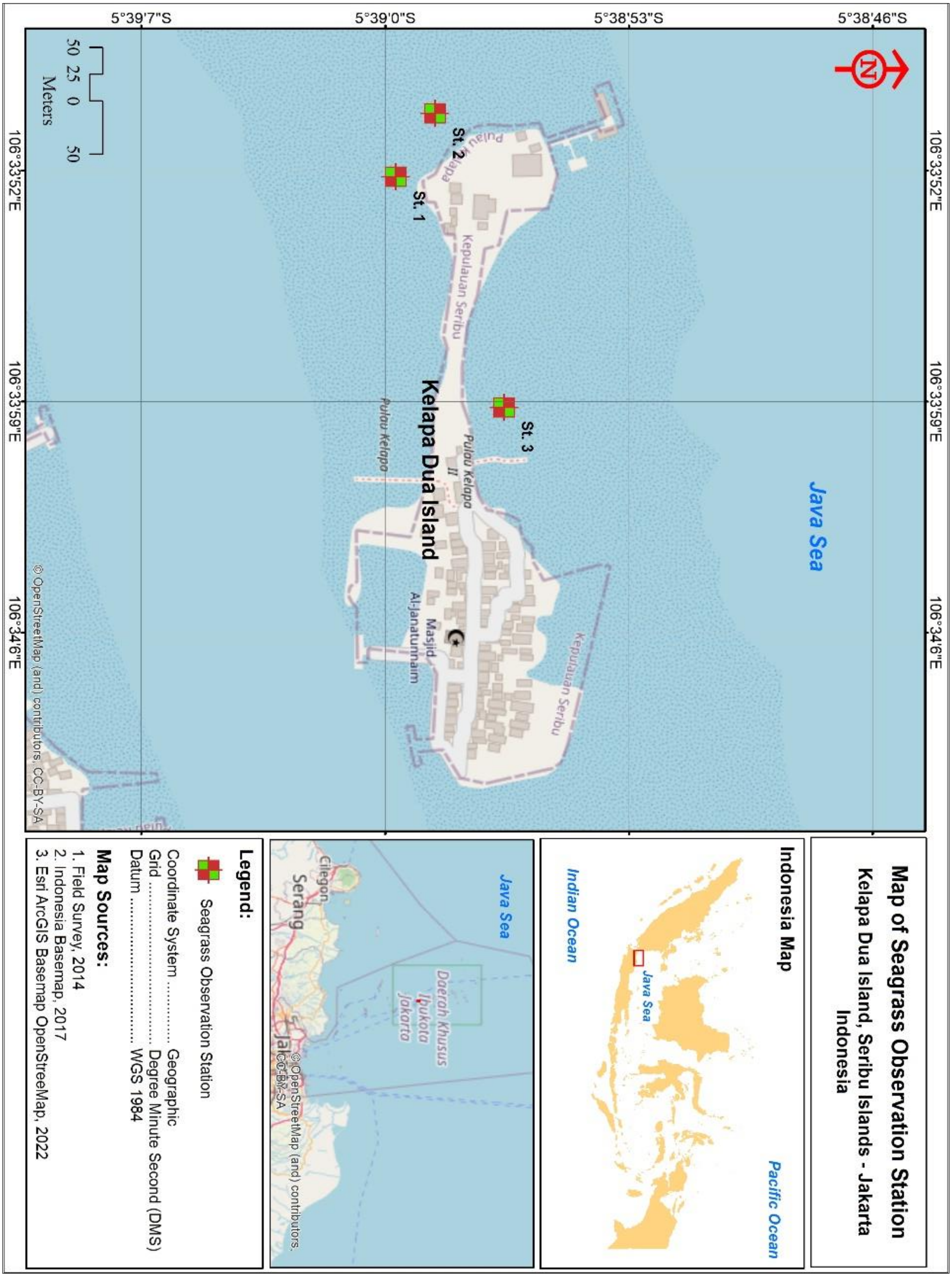

Figure 1. Map of research locations and observation stations.

Table 1. Parameters of the measured aquatic environment and the tools used.

No.	Waters Parameters	Unit	Measuring instrument	Measurement Place
1	Temperature	°C	*Thermometer*	In situ
2	Salinity	$^{0}/_{00}$	Refractometer	In situ
3	Clarity	%	*Secchi disk*	In situ
4	Depth	meter	Estimating Line	In situ
5	Acidity	pH	pH Meter	In situ
6	Dissolving oxygen	Ppm	DO Meter	In situ
7	Nitrate	$mg.L^{-1}$	Spectrometer	Ex situ
8	Phosphate	$mg.L^{-1}$	Spectrometer	Ex situ

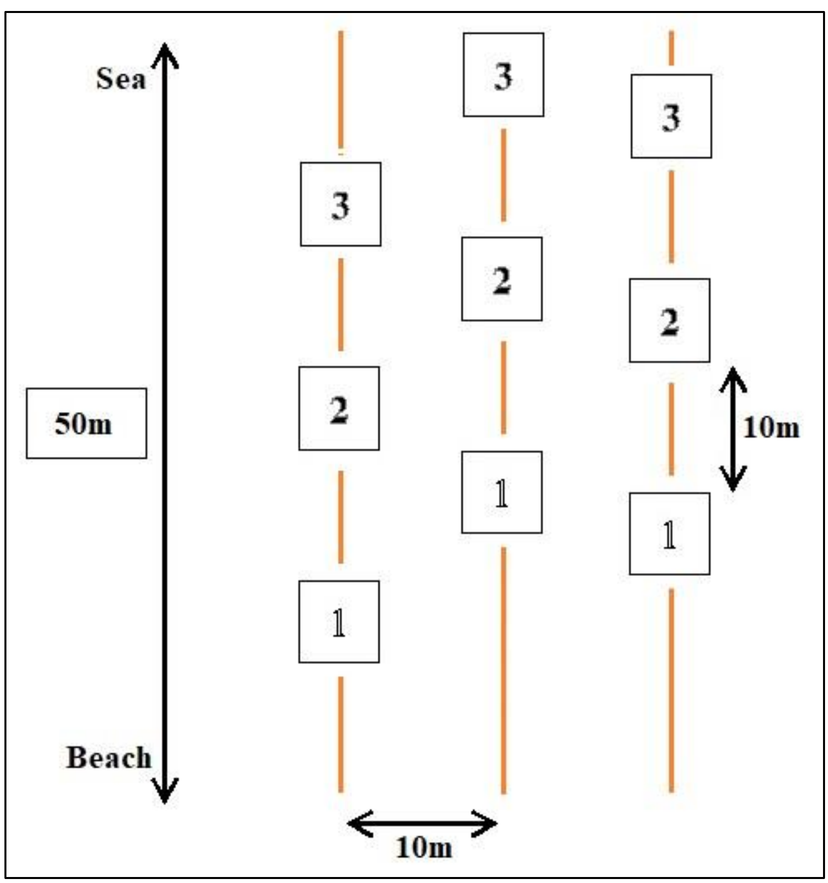

Figure 2. Illustration of the placement of the quadrant transects for each station.

2. 3. Data Processing

The diversity index is a measure of community wealth as seen from the number of species in an area and the number of individuals in each species [40].

$$\mathbf{H' = -\sum[(ni/N) \times ln\ (ni/N)]}$$

where H' is the diversity index, ni is the number of individual species–i, and N is the total number of individual species. The criteria for seagrass diversity based on the index value are $H' \leq 1$ means low species diversity, $1 < H' \leq 3$ means medium species diversity, and $H' > 3$ is high species diversity.

The density of seagrass species is the number of seagrass stands per unit area. Seagrass density is calculated based on seagrass inventory guidelines [41] as follows:

$$\mathbf{D = \frac{N}{A}}$$

where D is the density (number of stands.m^{-2}), N is the number of stands, and A is the area (m^2).

One of the parameters to see the condition of seagrass is to know the percentage of seagrass cover. Species cover is the area covered by seagrass species [42]. The criteria for seagrass conditions based on the percentage of cover (%) were >75% very good, 50-75% good, 25-49% moderate, and <25% bad. The equation to determine the percentage of seagrass cover can be seen in the following equation:

$$\mathbf{Coverage}\ (\%) = \frac{\mathbf{Total\ area\ of\ coverage\ to\ -\ i}}{\boldsymbol{Total\ sampling\ area}}\ \mathbf{x\ 100}\%$$

3. RESULT AND DISCUSSION

3. 1. Waters parameter conditions

The bottom substrate in the form of gravel sand with water quality conditions at the three observation stations is relatively no significant difference (**Table 2**). This is due to the characteristics of the waters at the three stations which are not much different. Seagrass ecosystems are limited by several environmental factors, namely temperature, light, salinity, depth, basic substrate, nutrients, and seawater movement (waves, currents, tides) [43–45]. The main requirement for optimum seagrass growth is in shallow water, which has a soft substrate and clear waters. Brightness is an environmental factor that gives the largest relative contribution to seagrass life, followed by temperature and salinity parameters. While pH is the factor that gives the lowest effect [46]. Furthermore, seagrasses are highly responsive to toxic substances and changes in nutrient concentration and hydro-morphology [47–49].

The water temperature at the research site ranged from 30.30 – 32.60 °C with an average temperature of 31.43 °C. Meanwhile, according to [43, 50], Seagrasses that live in the tropics can grow optimally at temperatures of 28 – 30 °C. The water temperature at the research location which is relatively higher than the optimum temperature for seagrass growth can be caused by the brightness, depth of the waters, and temperature measurements made on the surface of the waters. Shallow waters will receive a higher intensity of sunlight than deeper waters so the temperature in shallow waters will be higher than in deeper waters. We can see that the depth of the waters at the research site is less than 50 cm with an average depth of only 32.20 cm and the brightness of the waters is 100%, which means that the penetration of sunlight reaches the bottom of the waters. Light is needed by seagrass to carry out the process of photosynthesis.

Table 2. Value of environmental quality parameters of Kelapa Dua Island waters.

No.	Waters Parameter	Observation Station			Average
		Station 1	Station 2	Station 3	
1	Temperature (°C)	30.30	31.40	32.60	31.43
2	Clarity (%)	100.00	100.00	100.00	100.00
3	Depth (cm)	38.30	33.30	25.00	32.20
4	Salinity (‰)	31.70	35.70	34.00	33.80
5	Acidity (pH)	7.65	7.75	7.40	7.60
6	Dissolving oxygen ($mg.L^{-1}$)	6.90	6.70	6.30	6.63
7	Nitrate ($mg.L^{-1}$)	1.35	1.19	1.79	1.44
8	Phosphate ($mg.L^{-1}$)	0.22	0.25	0.24	0.24

The salinity of the waters in this study was in the range of 31.70 – 35.70‰ with an average of 30.80‰. In general, seagrasses live entirely in seawater with a salinity of 32–35‰ [51]. This shows that the salinity around Kelapa Dua Island is very suitable for seagrass growth. However, seagrass can still live and grow in the salinity range of 10 – 40‰. Salinity that is too high or too low can be a limiting factor for the spread of seagrass, inhibit the germination of seagrass seeds, cause osmotic stress and reduce disease resistance.

The degree of acidity of the waters (pH) at the research station ranged from 7.40 to 7.75 with an average value of 7.60. According to [51], The optimum pH for seagrass growth ranged from ~ 8.0 – 8.2. Meanwhile, according to [52], The optimum pH value for seagrass growth is in the range of 7.3 – 9.0. Based on this reference, the pH of the waters around Kelapa Dua Island is still suitable for seagrass growth.

Dissolved oxygen (DO) levels at the research station ranged from 6.30 – 6.90 $mg \cdot L^{-1}$ with an average value of 6.63 $mg \cdot L^{-1}$. DO has an important role in seagrass growth. Seagrass requires a continuous supply of oxygen so that the metabolic processes in the tissues continue to run [53, 54]. The amount of dissolved oxygen in water can be affected by the respiration of aquatic biota and the use of nitrifying bacteria in the nitrogen cycle process [55].

Nutrients that affect the growth of seagrass are nitrogen (N) and phosphorus (P). The composition and concentration of nutrients will greatly affect the survival of an organism [56]. Based on data compilation, seagrass meadow nutrients around the world are at an average nitrate concentration of 0.49 $mg \cdot L^{-1}$ and an average phosphate concentration of only 0.06 $mg \cdot L^{-1}$ [6]. At the research site, the N value in the waters has an average concentration of 1.44 mg·L-1. While the average value of P content is 0.24 $mg \cdot L^{-1}$. This shows that the content of N and P measured at the research station has a high content.

According to [57], The main source of N in waters comes from household waste and agricultural waste such as animal and human waste. Meanwhile, P has the main source of the decomposition of organic matter in the sediment. The distribution of sediment concentrations is influenced by the movement of currents which are dominated by tidal currents [58, 59]. Other sources of P in waters can also come from weathering of rocks, and industrial, domestic, and agricultural wastes [60].

3. 2. Seagrass Diversity

The seagrass diversity values obtained in the waters of Kelapa Dua Island from the calculation of field data have differences from each observation station. Looking at the observed data, the diversity of seagrass in the waters of Kelapa Dua Island is categorized as low because from the three stations observed there were only three types of seagrass, namely *Thalassia hemprichii*, *Halophila ovalis* and *Halodule uninervis*. The diversity index value of each station ranged from zero to 0.94. The diversity index has a value of $H' < 1$, so it is included in the criteria for low species diversity. This is caused by the presence of one type of seagrass that dominates. The waters around Kelapa Dua Island have fewer types of seagrass compared to several other locations in Indonesian waters, for example in the waters of Teluk Awur and Prawean Jepara, 4 species were found [61], and as many as 8 in the waters of Bali's Pandawa Beach [62], in the bay of Ambon as many as 5 species [43], etc.

Species diversity is also influenced by environmental stability factors, food chain patterns, sediment types, and also competition between organisms [61, 63-64]. These factors are variables whose complexity affects each other so it is quite difficult to describe. Seagrass diversity reflects evolutionary origins and ongoing patterns of colonization and is consistent with patterns of biodiversity from many other aspects of the biosphere [3].

3. 3. Seagrass Species Density

Seagrass observations at station 1, which is the southwest part of the waters of Kelapa Dua Island, only found one type of seagrass, namely the type of *H. uninervis* with the average number of stands of all types of seagrass at this station was 48.33 $stands.m^{-2}$. Meanwhile, at station 2, which is located in the western waters of Kelapa Dua Island, 2 types of seagrass were found, namely, *H. uninervis* and *T. hemprichii* with the average number of stands of all seagrass species at this station was 222.44 $stands.m^{-2}$. Station 2 is a station where seagrass grows with the highest density level of the other stations. The number of seagrasses that dominates station 2 is *H. uninervis* with a density of 211.00 $stands.m^{-2}$. While the total density for the type of *T. hemprichii* was 11.44 $stands.m^{-2}$.

At station 3, the types of seagrass are more diverse. Station 3, which is located in the northern part of the waters of Kelapa Dua Island, is a station that is located close to the mangrove cultivation area. The average total stands of seagrass species at station 3 were 65.00

stands.m^{-2}. The most dominating seagrass species was *T. hemprichii* with a density of 37.11 stands.m^{-2}. Then the type of seagrass is *H. uninervis* with a density of 20.11 stands.m^{-2}. Seagrass species *H. ovalis* was the lowest type of seagrass at station 3 with a density of 7.78 stands.m^{-2}. Overall, the highest average density of seagrass species was found in *H. uninervis* with a density value of 296.44 stands.m^{-2}, followed by *T. hemprichii* with a total density of 48.55 stands.m^{-2} and *H. ovalis* 7.78 stands.m^{-2} (**Figure 3**). Variations in the composition and density of seagrass can be caused by environmental influences [65]. This may be the reason why there is no even distribution of seagrass in this research location.

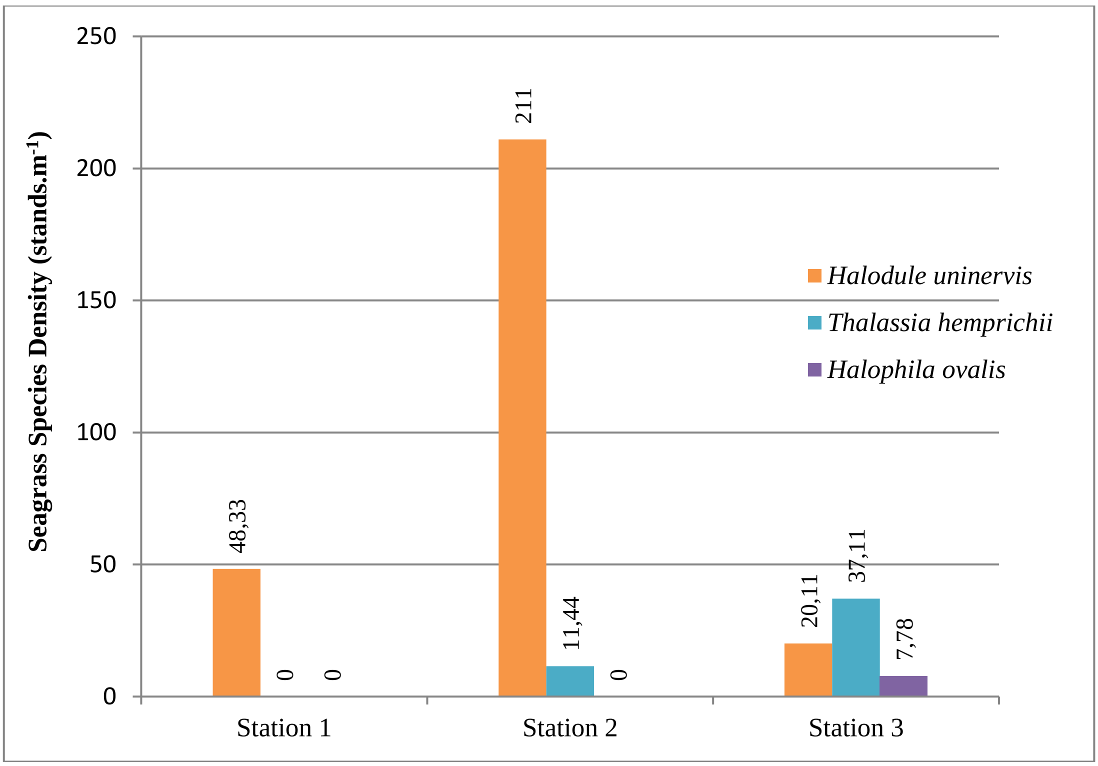

Figure 3. The density of seagrass species at each station.

3. 4. Seagrass Coverage

The results of the observations of the three stations found that there was an association between two different types of seagrass at the two stations. As at station 2 and station 3, associations were found between seagrass species *H. uninervis* and *T. hemprichii* (**Figure 4**). Seagrasses can form small groups to form large fields. Seagrass communities in tropical waters tend to be characterized by the presence of mixed vegetation consisting of several seagrass species [66] so mixed vegetation is one of the characteristics of the vegetation form of seagrass beds in Indonesia.

Station 1 is a station that is overgrown with seagrass with a seagrass cover percentage of 7.89% which is included in the bad category. This can be caused because station 1 is a location that is quite influenced by human activities. The condition of polluted waters causes seagrass conditions to become worse [16].

Station 2 is a station that is overgrown with seagrass with the highest level of cover among other stations. The percentage of seagrass cover at station 2 was 36.11% which was included in the medium category. The number of seagrasses that dominated station 2 was *H. uninervis* with a total species cover of 31.1%. Meanwhile, for the type of *T. hemprichii* the total species cover was 5%. Station 2 is a station that is located close to pomfret fish farming. The high amount of seagrass cover may be influenced by fish farming activities in that location. The rest of the feed or fish manure that is dissolved and settles in waters containing organic matter can trigger the rapid growth of seagrass because it becomes a natural fertilizer. Organic matter is one of the vital components of seagrass communities. The availability of organic matter in nature can be a limiting factor for seagrass growth [67].

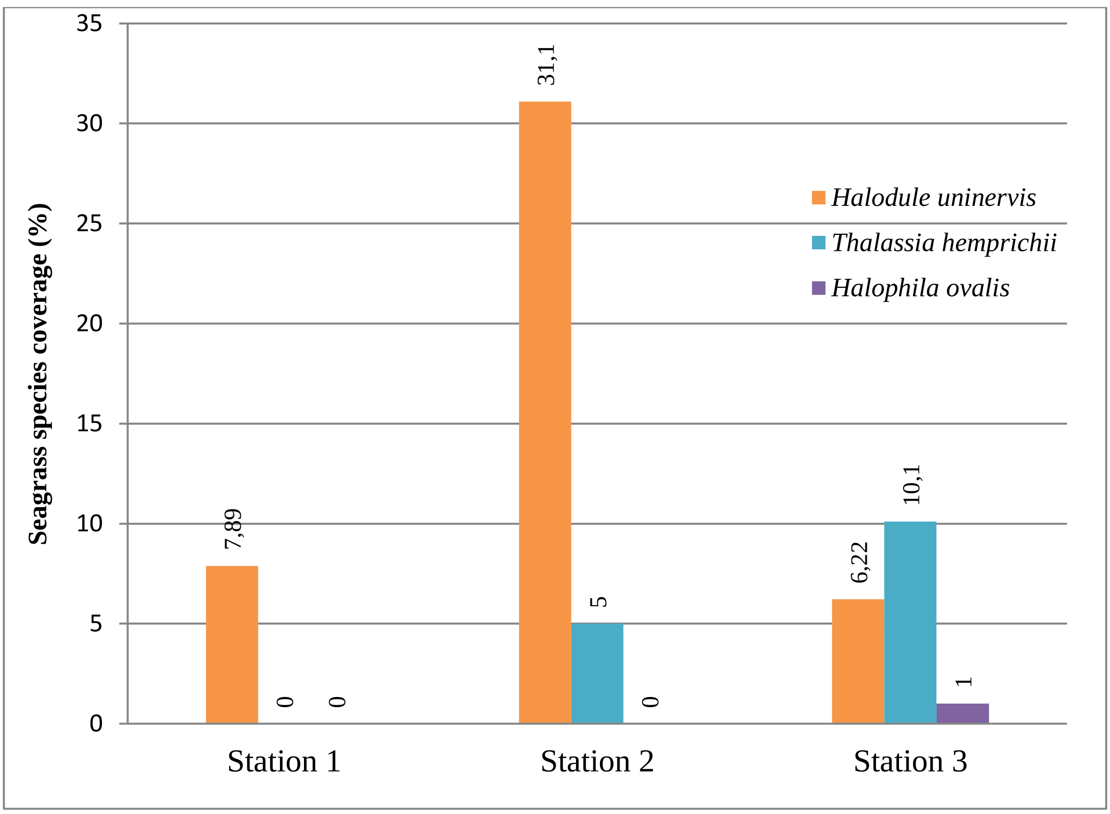

Figure 4. Percentage of seagrass coverage per station.

The seagrasses found at station 3 were *H. uninervis*, *T. hemprichii* and *H. ovalis*. The percentage of seagrass cover at station 3 was 17.33% but it was included in the bad category. Of the three types of seagrass found, the most dominating type of seagrass was *T. hemprichii* with a total species cover of 10.1%. This was followed by the seagrass species *H. uninervis* with a total species cover of 6.2%. While the type of seagrass *H. ovalis* is the lowest type of seagrass at station 3 with a total species cover of 1%.

According to [68], the percentage of seagrass cover can change periodically, for example monthly. Changes in the distribution of seagrasses occur at the micro-scale over a very short period because seagrasses are constantly responding to the local environment [3].

This can be caused by changes in the weather and the level of turbidity of the waters. These changes are mainly due to human activities such as natural rock mining, hill leveling, and sea dredging for industrial expansion and port development [69].

4. CONCLUSIONS

The bottom substrate of the waters around Kelapa Dua Island is gravel sand. The condition of the water parameters around Kelapa Dua Island has a relatively high surface temperature, which is at an average temperature of 31.43 °C. The salinity of the waters has an average value of 30.80‰. The average value of the pH of the waters is 7.60. The mean DO is 6.63 $mg \cdot L^{-1}$. Salinity, pH and DO parameters are very suitable for seagrass growth. Nutrient content in water is relatively high with an average nitrogen (N) of 1.44 $mg \cdot L^{-1}$ and phosphorus (P) of 0.24 $mg \cdot L^{-1}$.

There were only 3 types of seagrass found at the research site, namely *H. uninervis*, *T. hemprichii* and *H. ovalis*. *H. uninervis* is a seagrass species that dominates both its density and coverage. A seagrass diversity index is included in the low category. Based on the percentage of cover, which is 7.8 – 36.11%, the seagrass conditions in Kelapa Dua Island are categorized as poor to moderate.

Acknowledgement

Our gratitude goes to the Marine Research Laboratory (MEAL), Faculty of Fisheries and Marine Science, Padjadjaran University for supporting the provision of equipment for field surveys. Thanks also to all who helped carry out this research.

References

[1] A. W. D. Larkum, R. J. Orth, and C. M. Duarte, Seagrasses: Biology, ecology and conservation. Dordrecht: Springer (2006).

[2] E. P. Green and F. T. Short, World atlas of seagrasses. Berkeley, USA: University of California Press (2003).

[3] F. Short, T. Carruthers, W. Dennison, and M. Waycott, Global seagrass distribution and diversity: A bioregional model. *J. Exp. Mar. Bio. Ecol.* 350(1–2) (2007) 3–20.

[4] K. H. Mann, *Ecology of Coastal Waters: With Implications For Management*, 2nd ed. Malden, USA: Wiley-Blackwell (2000).

[5] C. M. Duarte, Seagrass depth limits. *Aquat. Bot.*, 40(4) (1991) 363–377.

[6] M. A. Hemminga and C. M. Duarte, Seagrass Ecology, 1 ed. Cambridge, United Kingdom: Cambridge University Press (2000).

[7] M. H. Azkab, Structure and function in seagrass communities. *Oseana* 25(3) (2000) 9–17

[8] R. Pratiwi, Association of crustaceans in seagrass ecosystems in the waters of Lampung Bay. *Ilmu Kelautan* 15(2) (2010) 66–76

[9] J. A. Vonk, M. J. A. Christianen, and J. Stapel, Abundance, edge effect, and seasonality of fauna in mixed-species seagrass meadows in southwest Sulawesi, Indonesia. *Mar. Biol. Res.* 6(3) (2010) 282–291.

[10] P. L. A. Erftemeijer, R. Osinga, and A. E. Mars, Primary production of seagrass beds in South Sulawesi (Indonesia): a comparison of habitats, methods and species. *Aquat. Bot.* 46(1) (1993) 67–90

[11] C. Satrya, M. Yusuf, M. Shidqi, B. Subhan, D. Arafat, and F. Anggraeni, Seagrass diversity in Banten Bay, the Province of Banten. *Jurnal Teknologi Perikanan and Kelautan* 3(1) (2012) 29–34

[12] T. Kikuchi and J. M. Peres, Consumer ecology of seagrass beds in *Seagrass Ecosystems: A Scientific Perspective*, C. P. McRoy, and C. Helffrich, Ed. New York: Marcel Dekker, Inc, (1977) 147–193

[13] M. Dorenbosch, M. G. G. Grol, I. Nagelkerken, and G. van der Velde, Seagrass beds and mangroves as nurseries for the threatened IndoPacific Humphead wrasse, Cheilinus undulatus and Caribbean Rainbow parrotfish, Scarus guacama. *Biol. Conserv.* 129 (2006) 277–282

[14] M. Dorenbosch, M. C. van Riel, I. Nagelkerken, and G. van der Velde, The relationship of reef fish densities to the proximity of mangrove and seagrass nurseries. *Estuar. Coast. Shelf Sci.* 60 (2004) 37–48

[15] S. Tebay and D. C. Mampioper, Potential study of seagrass and interaction pattern of seagrass fishery resources utilization (Case Kampung Kornasoren and Yenburwo, Numfor, Papua). *J. Trop. Fish. Manag.* 1(1) (2017) 59–69

[16] S. Rahmawati, T. H. E. Threat, T. O. Seagrass, and M. Community, The threat to seagrass meadow community. *Oseana* 36(2) (2011) 49–58

[17] B. Ondiviela, I. J. Losada, J. L. Lara, M. Maza, C. Galván, T. J. Bouma, and J. van Belzen, The role of seagrasses in coastal protection in a changing climate. *Coast. Eng.* 87 (2014) 158–168

[18] I. R. B. Reeves, L. J. Moore, E. B. Goldstein, A. B. Murray, J. A. Carr, and M. L. Kirwan, Impacts of seagrass dynamics on the coupled long-term evolution of barrier-marsh-bay systems. *J. Geophys. Res. Biogeosciences* 125(2) (2020) 1–19

[19] R. K. James, A. Lynch, P. M. J. Herman, M. M.van Katwijk, B. I.van Tussenbroek, H. A. Dijkstra, R. M.van Westen, C. G.van der Boog, R. Klees, J. D. Pietrzak, C. Slobbe, and T. J. Bouma, Tropical biogeomorphic seagrass landscapes for coastal protection: Persistence and wave attenuation during major storms events. *Ecosystems* 24(2) (2021) 301–318

[20] M. Potouroglou, J. C. Bull, K. W. Krauss, H. A. Kennedy, M. Fusi, D. Daffonchio, M.a M. Mangora, M. N. Githaiga, K. Diele1, and M. Huxham, Measuring the role of seagrasses in regulating sediment surface elevation. *Sci. Rep.* 7(1) (2017) 1–11

[21] C. M. Duarte and C. L. Chiscano, Seagrass biomass and production: A reassessment. *Aquat. Bot.* 65(1–4) (1999) 159–174

[22] V. X. H. Phang, L. M. Chou, and D. A. Friess, Ecosystem carbon stocks across a tropical intertidal habitat mosaic of mangrove forest, seagrass meadow, mudflat and sandbar. *Earth Surf. Process. Landforms* 40(10) (2015) 1387–1400

[23] I. Angrelina, A. Sartimbul, and A. J. Wahyudi, The potential of seagrass beds on the coast of Putri Menjangan as a carbon sequestration ecosystem on Bali Island. *IOP Conf. Ser. Earth Environ. Sci.* 241(1) (2019) 1-8.

[24] J. W. Fourqurean, C. M. Duarte, H. Kennedy, N. Marbà, M. Holmer, M. A. Mateo, E. T. Apostolaki, G. A. Kendrick, D. Krause-Jensen, K. J. McGlathery and O. Serrano, Seagrass ecosystems as a globally significant carbon stock. *Nat. Geosci.* 5(7) (2012) 505–509.

[25] W. Kiswara, Preliminary study: Ability of seagrass beds as carbon stock and carbon sink at Pari Island, Jakarta. *Oseanologi and Limnol. di Indonesia* 36(3) (2010) 361–376

[26] C. M. P. Gono, P. Ahmadi, T. Hertiani, E. Septiana, M. Y. Putra, and G. Chianese, A Comprehensive update on the bioactive compounds from seagrasses. *Mar. Drugs* 20(406) (2022) 1-37)

[27] F. T. Short and S. Wyllie-Eciieverria, Natural and human-induced disturbance of seagrasses. *Environ. Conserv.* 23(1) (1996) 17–27.

[28] M. Waycott, C. M. Duarte, T. J. B. Carruthers, R. J. Orth, W. C. Dennison, S. Olyarnik, A. Calladine, J. W. Fourqurean, K. L. Heck, Jr., A. R. Hughes, G. A. Kendrick, W. J. Kenworthy, F. T. Short, and S. L. Williams, Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proc. Natl. Acad. Sci. U. S. A.* 106(30) (2009) 12377–12381

[29] F. T. Short and H. A. Neckles, The effects of global climate change on seagrasses. *Aquat. Bot.* 63(3–4) (1999) 169–196.

[30] R. J. Orth, T. J. B. Carruthers, W. C. Dennison, C. M. Duarte, J. W. Fourqurean, K. L. Heck Jr., A. R. Hughes, G. A. Kendrick, W. J. Kenworthy, S. Olyarnik, F. T. Short, M. Waycott, and S. L. Williams, A global crisis for seagrass ecosystems. *Bioscience* 56(12) (2006) 987–996

[31] F. T. Short, B. Polidoro, S. R. Livingstone, K. E. Carpenter, S. Bandeira, J. S. Bujang, H. P. Calumpong, T. J. B. Carruthers, R. G. Coles, W. C. Dennison, P. L. A. Erftemeijer, M. D. Fortes, A. S. Freeman, T.G. Jagtap, A. H. M. Kamal, G. A. Kendrick, W. J. Kenworthy, Y. A. La Nafie, I. M. Nasution, R. J. Orth, A. Prathep, J. C. Sanciangco, B. van Tussenbroek, S. G. Vergara, M. Waycott, J. C. Zieman, Extinction risk assessment of the world's seagrass species. *Biol. Conserv.* 144(7) (2011) 1961–1971

[32] W. Kiswara, The impact of the industrial area expansion on the decline of seagrass beds in Banten Bay, West Java in National Seminar in the impact of development on coastal areas (1994) 1–11.

[33] R. K. F. Unsworth, R. Ambo-Rappe, B. L. Jones, Y. A. La Nafie, A. Irawan, U. E. Hernawan, A. M. Moore, L. C. Cullen-Unsworth, Indonesia's globally significant seagrass meadows are under widespread threat. *Sci. Total Environ.* 634 (2018) 279–286

[34] I. Karlina, F. Kurniawan, and F. Idris, Pressures and status of seagrass ecosystem in the coastal areas of North Bintan, Indonesia. *E3S Web Conf.* 47 (2018) 1–6

[35] N. D. M. Sjafrie, U. E. Hernawan, B. Prayudha, I. H. Supriyadi, M. Y. Iswari, Rahmat, K. Anggraini, S. Rahmawati and Suyarso, Indonesia seagrass meadow status 2018. Jakarta, Indonesia (2018).

[36] R. N. Rollon, J. E. Vermaat, and H. M. E. Nacorda, Sexual reproduction in SE Asian seagrasses: The absence of a seed bank in Thalassia hemprichii. *Aquat. Bot.* 75(2) (2003) 181–185

[37] A. Alagna, G. D'Anna, L. Musco, T. V. Fernández, M. Gresta, N. Pierozzi, and F. Badalamenti, Taking advantage of seagrass recovery potential to develop novel and effective meadow rehabilitation methods. *Mar. Pollut. Bull.* 149 (2019) 1-12

[38] A. D. Irving, J. E. Tanner, and G. J. Collings, Rehabilitating seagrass by facilitating recruitment: Improving chances for success. *Restor. Ecol.* 22(2) (2014) 134–141.

[39] BPS-Statistics of Kepulauan Seribu Regency, Kepulauan Seribu Regency in figures 2021. Jakarta, Indonesia: BPS-Statistics of Kepulauan Seribu Regency (2021).

[40] C. J. Krebs, Ecology: The experimental analysis of distribution and abundance, 6 ed. Essex, England: Pearson Education Limited (2014).

[41] M. H. Azkab, The guidelines of the seagrass inventory. *Oseana* 24(1) (1999) 1–16

[42] M. F. Fachrul, *Bioecological sampling method*, 1 ed. Jakarta, Indonesia: Bumi Aksara (2007).

[43] M. J. Rugebregt, C. Matuanakotta, and M. Syafrizal, Species diversity, seagrass cover, and water quality in Ambon Bay Waters. *J. Ilmu Lingkungan* 18(3) (2020) 589–594

[44] F. T. Short, R. G. Coles, and C. Pergent-Martini, Global seagrass distribution in *Global seagrass research methods*, F. T. Short, R. G. Coles, and C. A. Short, Ed. Amsterdam, The Netherlands: Elsevier Science B.V (2001) 5–30

[45] E. W. Koch and J. J. Verduin, Measurements of physical parameters in seagrass habitats in *Global seagrass research methods*, 1 ed., F. T. Short, R. G. Coles, and C. A. Short, Ed. Amsterdam, The Netherlands: Elsevier Science B.V (2001) 325–344

[46] P. M. J. Tuapattinaya, Relations factor physical chemistry environment with the seagrass beds (seagrass) in coastal waters village Suli. *Biosel Biol. Sci. Educ.* 3(1) (2014) 54–67

[47] D. Krause-Jensen, S. Sagert, H. Schubert, and C. Boström, Empirical relationships linking distribution and abundance of marine vegetation to eutrophication. *Ecol. Indic.* 8(5) (2008) 515–529

[48] R. Arévalo, S. Pinedo, and E. Ballesteros, Changes in the composition and structure of Mediterranean rocky-shore communities following a gradient of nutrient enrichment:

Descriptive study and test of proposed methods to assess water quality regarding macroalgae. *Mar. Pollut. Bull.* 55(1–6) (2007) 104–113.

[49] J. M. Neto, D. V. Barroso, and P. Barría, Seagrass Quality Index (SQI), a Water Framework Directive compliant tool for the assessment of transitional and coastal intertidal areas. *Ecol. Indic.* 30 (2013) 130–137

[50] Nybakken and J. Willard, Marine biology: An ecological approach, 5th ed. New York: Benjamin Cummings (2001).

[51] A. W. D. Larkum, M. Pernice, M. Schliep, P. Davey, M. Szabo, J. A. Raven, M. Lichtenberg, K. E. Brodersen, and P. J. Ralph, Photosynthesis and metabolism of seagrasses in Seagrasses of Australia: Structure, ecology and conservation, A. Larkum, G. Kendrick, and P. Ralph, Ed. Springer International Publishing (2018) 315–342.

[52] R. C. Phillips and E. G. Menez, Seagrasses. Washington D.C.: Smithsonion Institution Press (1988).

[53] J. Borum, K. Sand-Jensen, T. Binzer, O. Pedersen, and T. M. Greve, Oxygen movement in seagrasses in Seagrasses: Biology, ecology and conservation, A. W. D. Larkum, R. J. Orth, and C. M. Duarte, Ed. Dordrecht, The Netherlands: Springer (2006) 255–270

[54] P. A. Staehr, J. M. Testa, W. M. Kemp, J. J. Cole, K. Sand-Jensen, and S. V. Smith, The metabolism of aquatic ecosystems: History, applications, and future challenges. *Aquat. Sci.* 74(1) (2012) 15–29

[55] P. Felisberto, S. M. Jesus, F. Zabel, R. Santos, J. Silva, S. Gobert, S. Beer, M. Björk, S. Mazzuca, G. Procaccini, J. W. Runcie, W. Champenois, A. V. Borges, Acoustic monitoring of O_2 production of a seagrass meadow. *J. Exp. Mar. Bio. Ecol.* 464 (2015) 75–87

[56] D. Suhanda, M. S. Yuniarti, Y. Nurul Ihsan, and S. A. Harahap, Nutrient concentration and population of macrozoobenthos in Ciletuh Bay, Sukabumi District, West Java. *IOP Conf. Ser. Earth Environ. Sci.* 406(1) (2019) 1–13.

[57] Y. Amelia, M. R. Muskananfola, and P. W. Purnomo, Distribution of sediment structure, organic material, nitrate and phosphate at the Estuary of Morodemak. *Maquares* 3(4) (2014) 208–215.

[58] S. A. Harahap, L. P. S. Yuliadi, and J. N. Sinulingga, Surficial sedimentary at the bottom in waters surrounding the arisen land of Putri Island, Karawang - Indonesia. *World Sci. News* 151 (2021) (2020) 95–109.

[59] S. A. Harahap, L. P. S. Yuliadi, N. P. Purba, and A. A. Aulia, Mapping of sediment on the waters around Panjang Island, Banten Bay, Indonesia. *J. Geosci. Eng. Environ. Technol.* 6(2) (2021) 99–106.

[60] S. I. Patty, H. Arfah, and M. S. Abdul, Nutrients (phosphate, nitrate), dissolved oxygen, and dissolved pH and their relation to productivity of Jikumerasa Waters, Buru Island. *J. Pesisir and Laut Tropis* 1(1) (2015) 43–50.

[61] I. Riniatsih, A. Ambariyanto, E. Yudiati, R. Hartati, W. Widianingsih, and R. T. Mahendrajaya, Diversity species and condition of seagrass ecosystem in Teluk Awur and Prawean Jepara. *IOP Conf. Ser. Earth Environ. Sci.* 236 (2019) 1-4.

[62] K. B. P. Mahesswara, N. L. Watiniasih, and I. W. Darya Kartika, the Community structure of seagrass beds in Pandawa Beach aquatic, Bali. *Simbiosis* 9(1) (2021) 12-21

[63] J. A. Vonk, M. J. A. Christianen, J. Stapel, and K. R. O'Brien, What lies beneath: Why knowledge of belowground biomass dynamics is crucial to effective seagrass management. *Ecol. Indic.* 57 (2015) 259–267

[64] L. J. McKenzie, S. M. Yaakub, R. Tan, J. Seymour, and R. L. Yoshida, Seagrass habitats of Singapore: Environmental drivers and key processes. *Raffles Bull. Zool.* 34 (2016) 60–77

[65] R. Hartati, A. Santoso, H. Endrawati, I. Riniatsih, W. L. Saputra, and R. Triaji, Variations in composition and density of seagrass species in Ujung Piring Waters, Jepara Regency. *J. Kelaut. Tropis* 20(2) (2017) 96–105

[66] S. English, C. Wilkinson, and V. Baker, Seagrass communities in Survey manual for tropical marine resources, 2 ed., Townsville, Australia: Australian Institute of Marine Science (1997) 239–272

[67] P. L. A. Erftemeijer and J. J. Middelburg, Sediment-nutrient interactions in tropical seagrass beds - A comparison between a terrigenous and a carbonate sedimentary environment in south Sulawesi (Indonesia). *Mar. Ecol. Prog. Ser.* 102(1–2) (1993) 187–198

[68] E. I. Ahmad-Kamil, R. Ramli, S. A. Jaaman, J. Bali, and J. R. Al-Obaidi, The effects of water parameters on monthly seagrass percentage cover in Lawas, East Malaysia. *Sci. World J.* 2013 (2013) 1–8

[69] F. Setiawan, S. A. Harahap, Y. Andriani, and A. A. Hutahaean, Seagrass change detection using remote sensing technology and its relation with carbon storage in Banten Bay. *J. Perikanan and Kelautan* 3(3) (2012) 275–286