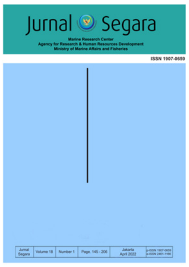

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BIODIVERSITY AND AQUATIC VEGETATION SUCCESSION IN BIAWAK ISLAND MARINE PROTECTED AREA, INDRAMAYU-WEST JAVA

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ABSTRACT

The existence of aquatic vegetation in the coastal waters is correlated with the water quality parameters. Seagrass and macroalgae are aquatic plants often found to form a coastal ecosystem that depends on water quality, both physically and chemically. Research on the existence of aquatic plants in Biawak Island, Indramayu, West Java, was conducted in 2016 and 2019 by combining in situ data and secondary data. The purpose of this study was to observe the dynamics of seagrass ecosystems as aquatic plants on Biawak Island and their correlation with the succession that occurred in the aquatic environment in Biawak Island as part of the Biawak Archipelago Marine Protected Area (MPA). The research method integrates a descriptive analysis and its correlation between the submerged aquatic plants and their environment. The results showed that seagrasses in Biawak Island tend to disappear and be replaced by macroalgae. The type of seagrass found in 2016 was Enhalus Acoroides covered by epiphytes perished in 2019. The abundance of macroalgae, especially Halimeda macroloba, indicates the existence of nutrient enrichment and high turbidity, causing the seagrass to be replaced by macroalgae. Another biodiversity found in the region was clams and sea cucumber, while branching coral conditions experienced bleaching and degradation. An environmental condition contains high nutrients strengthening the nutrient enrichment for a particular time. Therefore, integrated management regarding terrestrial and shipping lines track needs to be addressed to maintain the sustainability of the natural resources in the Biawak archipelago.

Keywords: Aquatic vegetation succession, biodiversity, Biawak Islands.

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INTRODUCTION

Biawak Island or Bonpies Island is one of the three islands in the Indramayu Regency (besides Gosong Island and Candikian Island), located approximately 50 km from the Indramayu coast (Java Island) and shaping an archipelago. These three islands are included in Biawak Archipelago Marine Protected Area (MPA) based on Indramayu Regent Decree No. 556 / Kep.528 Diskanla / 2004 issued on 7 April 2004 as a Conservation and Marine Tourism Area (Purba & Harahap, 2013). Biawak Archipelago MPA is a regional conservation and located at the coordinates as follows: 1) Biawak Island 06°56' 022'' S and 108°22' 015'' E; 2) Gosong Island 5°52'076" S and 108° 24' 337'' E; 3) Candikian Island 5°48'089" S and 108°24' 487'' E (KKJI-KKP, 2016).

Biawak Island has a lighthouse as a navigational guide built by the Kingdom of the Dutch East Indies in 1872 and is still functioning today. The lighthouse and additional facilities, such as housing and communication facilities managed by The Ministry of Transportation, the Republic of Indonesia play a significant role in the island for sea transportation around the region. Biawak Island condition is still considered natural with the existence of the monitor lizard (*Varanus salvator*) as its native animal and enshrined to be the official name of the island besides Rakit or Bonpies.

Coastal ecosystems in Biawak island consisted of mangrove ecosystems, coral reef ecosystems, seagrass ecosystems and coastal forest ecosystems. The coverage percentage of seagrass ecosystems in 2013 varies from 5% to 10%, dominated by *Enhalus acoroides* that live around the island (Purba & Harahap, 2013). This condition is considered a low percentage cover, which raised questions regarding factors and issues in the region. The mangrove ecosystem naturally grows on Biawak Island with approximately 80 ha surrounding the island, compared to the whole area of about 120 ha, as shown in Figure 1 (Indramayu Regency, 2014). The types of mangroves found in Biawak Island consist of various mangroves that are rare and scarcely found on the North Coast of Java. Types of mangroves that grow in Biawak Island include *Sonneratia spp*, *Avicennia sp*, *Bruguiera sp*, *Rhizophora sp*, *Ceriops sp*, *Acanthus sp*, *Lumnitterae*, *Xylocarpus sp*, *Aegiceras sp*, *Nypa sp*, and *Herrera sp* (KKJI-KKP, 2016).

Based on the previous study related to the ecosystem which is exposed to high nutrient enrichment within a period can cause degradation, both in freshness and quality, including stress, which can be threatened by the sustainability diagram using dead or replaced by algae and phytoplankton (Green & Webber, 2003; Cardoso *et al*., 2004).

This research aims to examine the conditions of seagrass, macroalgae, and submerged benthic biodiversity in Biawak Island and its correlation to the aquatic environment in Biawak Archipelago MPA.

METHODOLOGY

Study Site

Research activities on Biawak Island, part of Biawak MPA, Central Java. Five sampling points measure water quality surrounding the island and three

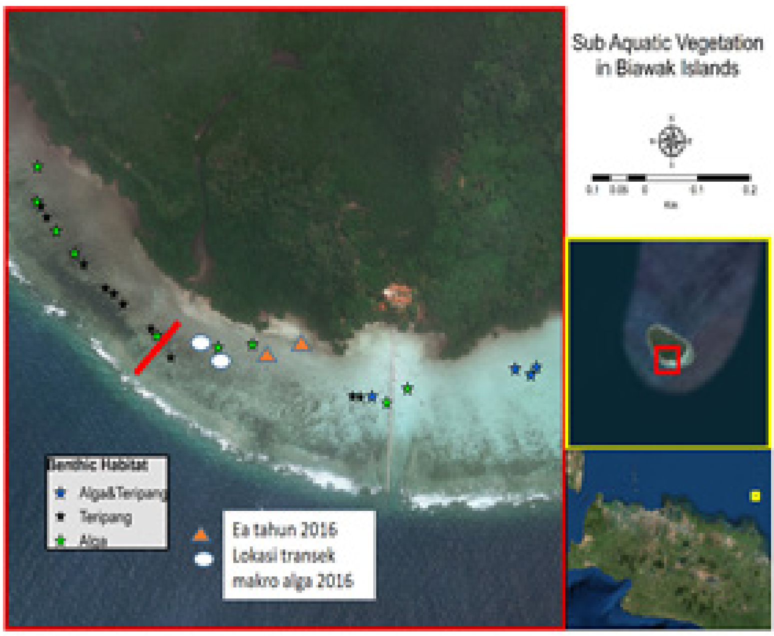


Figure 1. Study site.

sampling points for submerged macro-algae and seagrass vegetation observation. Sampling points are based on interviews with the local people, the lighthouse observer, and the fisherman's experience (Figure 1).

Data collecting and sampling methods

The sampling method was carried out by purposive sampling and expected to represent the research site based on the seagrass beds or macroalgae location. The sampling site also considers accessibility of the seagrass beds and macroalgae location, whether by boat or walk. Data of seagrass or macroalgae were collected using the Seagrass-Watch method by drawing line transects perpendicular to the coastline (McKenzie *et al*., 2003). Transect line pulled as long as 50 meters, then a square frame with 50 x 50 cm^2 was placed systematically with a distance between squares of 10 meters, depending on the length of the seagrass beds. The distance between transects ranged from 50-100 meters depend on the width of the seagrass beds. Random transects are carried out by throwing a square frame from the location near the mainland to the end of the transect consecutively.

The parameters taken in every station were the percentage of seagrass beds canopy cover/macroalgae inside each square frame 50 x 50 cm^2 with a visual estimation method based on Seagrass-Watch standard method (McKenzie *et al*., 2003). The coverage percentage was the total percentage of seagrass beds/macroalgae covered and the cover percentage of each type of seagrass beds/macroalgae inside the square frame. Environmental condition in 2016 such as temperature, salinity, and pH were measured using in situ method, while nitrate, phosphate, and silicate analyzed in Proling laboratory, belonging to Bogor Agriculture Institute (IPB). In contrast, observation in 2019 only measures the in situ environmental data compared to 2016 with laboratory analysis.

Data Analysis

Structure community analysis for submerged vegetation such as seagrass beds/macroalgae conducted to observe the general condition of the coastal ecosystem continued with benthic biodiversity explanation using descriptive analysis in the surrounding region. Secondary data were gathered from various sources related to Biawak Archipelago MPA and analyzed to support the primary data or in situ findings regarding benthic vegetation in Biawak Island.

RESULTS AND DISCUSSION

Existing Condition of Seagrass and Macroalgae Ecosystem

Observation carried out in the seagrass ecosystem in October 2016 in Biawak Island found *Enhalus acoroides* species with low density in the shape of fewer than six spots, where each spot consists of 1-6 seagrass individuals. The same observation in April 2019 showed degradation in seagrass condition, where no more track from the seagrass found in 2016, even though another spot of the same seagrass found in the eastern part of the island, which has a bigger size and mostly covered by epiphytes and threatens its sustainability due to unhealthy environment, especially the water quality.

Measurements conducted on macroalgae overlay for three sampling points resulted the average of sampling point approximately 51.7±11.13% of

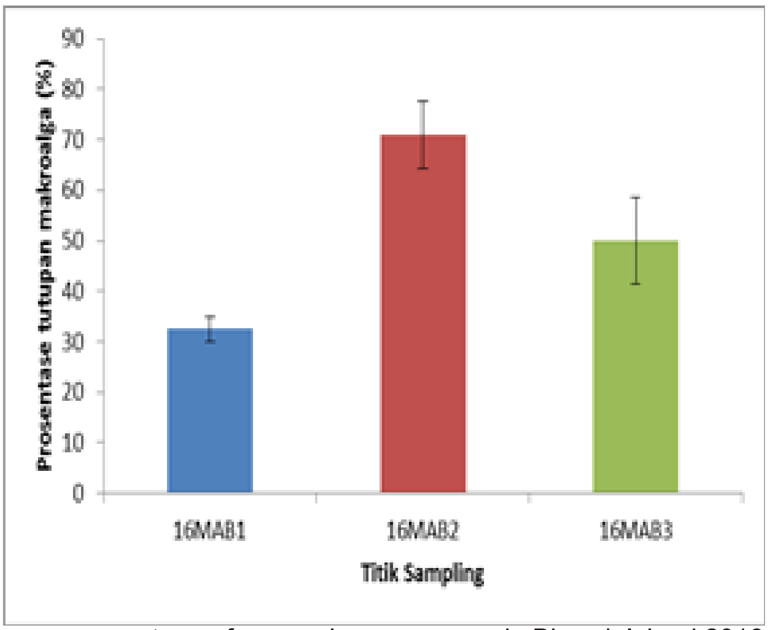


Figure 2. The average percentage of macroalgae coverage in Biawak Island 2016.

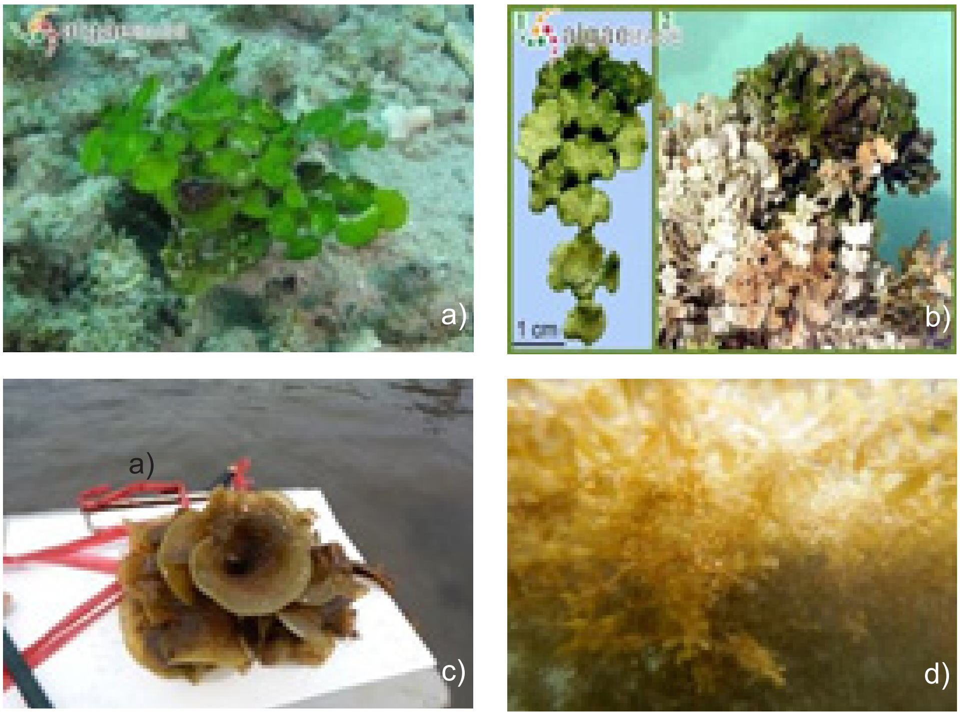


Figure 3. *Halimeda macroloba* (a) *Halimeda opuntia* (b (source: www.algaebase.org/) *Padina sp* (c) *Sargassum sp* (d). (source: survey 2016)

macroalgae covered the seabed in Biawak Island (Figure 2). The dominant algae species that form the overlay are Halimeda opuntia and Halimeda macroloba (Figure 3). At the same time, *Padina sp* and *Sargassum sp* were spotted even though they were not as massive as the *Halimeda sp* (Figure 4) , also known as green algae containing carbonate. Based on the observation in both years (2016 and 2019), macroalgae Padina sp existence in 2016 was better in quantities compared to 2019, while macroalgae Sargassum vanished in 2019. The average macroalgae overlay in 2019 ranged from 2 – 60%, with an average of about 13.4%, dominated by white sand from 23 random plots along the southern Biawak Island.

The shrinkage of algae covers in 2019 compared to 2016 happened due to the weather condition during the survey. In 2016 the survey was conducted in October with calmer and smooth weather, while in 2019, the weather was stormy, causing the research activities postponed for three days by the authorities. According to this condition, as predicted previously that many macroalgae have been removed from the substrate (ground) and carried away by the strong current, where *Sargassum sp*. is known to have a life cycle that is affected by seasons (Brok *et al*., 2018),

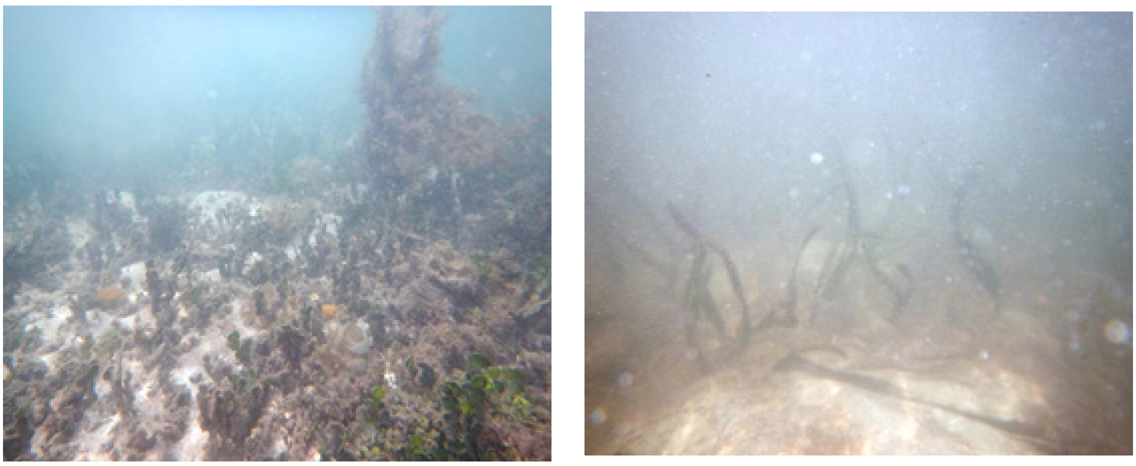


Figure 4. Macroalgae overlay in Biawak Island 2016 (above) and Enhalus acoroides covered with epiphytes (below) (source: survey 2016).

which have holdfast and bladder (air bubbles) so that they can float in the surface (Kadi, 2005).

Benthic Biodiversity in Biawak Island

Various benthic biodiversity was found during the 2019 survey in the intertidal area of the Biawak Islands, especially on the southern side. Two small giant clams (*Tridacna maxima*) with pale color were spotted, which were considered unhealthy conditions based on their appearance. In 2014, Pratama (2015) found more small giant clams surrounding Biawak Island, which concluded the differences in water quality and a healthy ecosystem. Besides, various types of sponges and young fish, sea cucumbers, branched corals, porites, and sea urchins exposed.

Several types of mangroves identified in 2016. Four mangrove species were found on Biawak Island, namely *Rhizophora apiculata*, *Rhizophora mucronata*, *Avicennia marina* that lives toward the sea and *Xylocarpus granatum* found towards the land. The total amount of carbon from the mangrove biomass calculated at around 102.62 $MgCha^{-1}$ (P3SDLP, 2016). Sunarto *et al*. (2013) found only two types of mangroves: *Rhizophora sp* and *Avicennia sp* with a density average of 700 trees/ha categorized as low density.

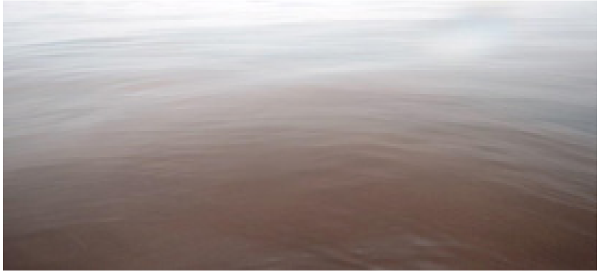
The Quality of Aquatic Environment and Sediment In Biawak Island

Besides the field measurements for aquatic vegetation (seagrass and macroalgae), in situ measurement was carried out, combined with laboratory analysis for water quality and its sediment in 2016, while in 2019 only in situ measurements with multi parameter equipment. Based on both measurements, the role of water quality and its correlation with biota suitability can be seen based on Environmental Minister Decree No. 51, the year 2004, related to biota and seagrass growth in coastal waters.

Visually, the condition of waters surrounding reef flat in Biawak Island is considered low turbidity (relatively clear), except during the transition season when the mostly stormy condition causes the sediment in the seabed to mix and more fisherman activities hide from the storm. The sediments taken from Biawak Islands are brownish-red particles, which thought to be cysts from various types of microalgae in Dinoflagellate group. Several types of microalgae, such as *Pyrodinium bahamense* var *compressum* known for its characteristics in unsupportive environmental conditions, can become cysts that can last for years (Widiarti, 2004; Panggabean, 2006). When the waters experience nutrient enrichment that supports their growth, these cysts can break, develop and multiply several times supported by a specific condition that can generate algae bloom (Widiarti, 2004; Panggabean, 2006). This condition strengthens the fact that unique findings were brownish and reddish water in the southern part of the island (personal interview with the lighthouse guard, 2019). However, based on its type as an open water island, the algae bloom event was not widespread and assumed that the microalgae turned back into cysts.

Based on table 1, it can be seen that the nitrate nutrient and phosphate surpassed the quality ambient. Higher value assumed originated from the mainland, and water pollution from ships or boats traveled through Biawak Island territory. Seagrass, which is a true plant with roots and leaves, is known to obtain nutrients for its growth in two ways absorbing nutrients in the water column through the leaves and absorbing nutrients in the substrate through the root system, which will also reach the leaves (Erftemeijer *et al*., 1993). The high nutrient content in the water causes the substrate value to be multiplied in the water so that it can be one of the reasons for the gradual loss of seagrass, which is replaced by macroalgae (Erftemeijer *et al*., 1992; Cardoso *et al*., 2004; Kennish, 2009; Boesch, 2019).

Figure 5. Degraded clam found in Biawak Island.



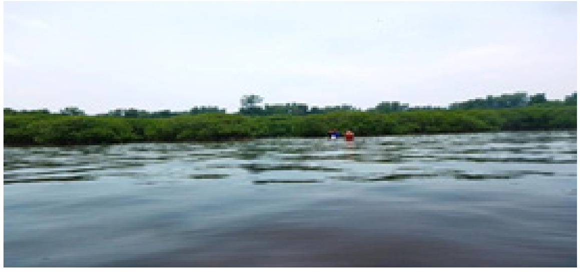


Figure 6. Aquatic environment in the Biawak Island reef flat, October 2016.

Physical properties parameters in the sediment such as sediment texture were analyzed and separated into four types (coarse sand, fine sand, dust, and clay) (Table 2).

Texture sediment in the study site showed a balance value between sand and dust. Visual conditions are generally white, native marine sediments high in carbonate content. Carbonate sediment comes from coral fragments and shells with the process of time and physical activity of waves into the size of sand and dust. It is known that the morphology of the waters of Biawak Island is included in the rather steep, deep and undulating category (Ramadhan *et al*, 2016) surrounded by coral reefs. The texture of coarse sand sediments which is proportional to the size of the dust, indicates that high water turbidity levels are strengthened by high turbidity values (Table 1).

Study on Seagrass Succession Caused by Environment Degradation

Seagrass loss events start from the small-sized plants, which unable to compete with macroalgae, while the bigger size will disappear slowly if the environmental state remains in eutrophication conditions (Green & Webber, 2003; Cardoso *et al*., 2004; Burkholder *et al*., 2007; Kennish, 2009). Succession on submerged vegetation in this location occurred, which proven by the macroalgae coverage outweighed seagrass, even though the bigger size remains.

Research by Green & Webber (2003) found that the productivity of *Thalassia testudinium* in Jamaican waters was higher in oligotrophic (less nutrient) waters compared to eutrotrophic (nutrient-rich) waters. It indicates that seagrass in need of nutrients for growth is not as much as macro algae. A similar thing was obtained by Cardoso *et al* (2004) at the Mondego estuary, Portugal; the eutrophication that had taken

Table 1. Field observation results

Parameter		Oct 2016 Ave	Oct 2016 Stdev	Apr 2019 Ave	Apr 2019 Stdev	Ambient MoE#	Ambient Reference
Chemical	pH	8.1	0.17	7.85	0.04	7-8.5	7.3-9*
	DO1	7.4	0.91	6.15	0.66	>5	
	Salinity	31.3	0.17	30.34	0.13	33-34	24-35**
	Amonia	0.01	0.006	0,023	0.010	0.3	
	Nitrate	0.5	0.04	##	##	0.008	
	Nitrite	0.02	0.006	##	##		
	Ortophosphate1	0.03	0.014	##	##	0.015	
	Silicate1	0.86	0.06	##	##		
Physics	Turbidity3	12.5	15.81	2.98	8.41	<5	
	Temperature (°C)	30.3	0.3	29.99	0.14	28-30	23-32***
	Clarity4	10	4.06	##	##	>3	

1=mg/L; 2=PSU; 3=NTU; 4=m; # MoE No 51 year 2004 3rd Attachment ##=no data; * Setiawan *et al*., 2013; **Lee *et al*., 2007; *** Hilman *et al*., 1989

Table 2. Size of sediment grain

Grain Size	Sediment Texture Peercentage: Coarse Sand (2-0.25 mm)	Fine Sand (0.25-0.05 mm)	Dust (0.05 - 0.002 mm)	Liat (<0.002 mm)
Average	49.66	0.71	44.32	5.31
Stdev	15.93	0.18	13.06	4.58

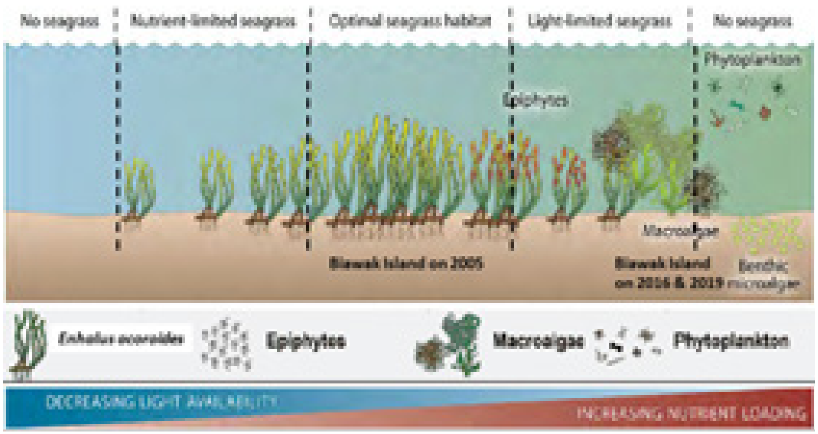


Figure 7. Effect of nutrient enrichment on seagrasses (modified Kennish, 2009).

place replaced the seagrass *Zostera noltii* into a sedimentary expanse with opportunist algal macro so that it changed the benthic macro-food chain pattern in that location from herbivores to detrivores.

The remaining *Enhalus acoroides* that existed in Biawak Island waters can be caused by the size and characteristics of the seagrass, which is categorized as durable seagrass with its root ability to grasp the substrate. This condition delaying the succession between seagrass and macroalgae compared to other types of seagrass, which smaller and more vulnerable, as proven by the absence of other seagrass species, even its litter on the island during fieldwork. Macroalgae cover, which *Halimeda* and *Sargassum* found stretched with an area of more than 50m X 50m in 2016 and vanished in 2019.

There are still more than a few individuals in Biawak Island that can be caused by seagrass which is greater than the success between seagrass and macro-algae, which takes longer to be lost/replaced with smaller types of seagrass. It is evidenced by the absence of both seagrass litter that floats and from other species in the field and when along a flat reef to the edge. The algal macro expanse published by *Halimeda* and *Sargassum* was found to stretch more than 50m x 50m (Figure 2) in 2016, while 2019 was no longer found. Based on that, the eutrophication predicted happened for a while and contributed to the succession of small seagrass species and replaced by macroalgae, leaving *Enhalus acoroides* in bad condition covered by epiphytes, which supported by low water quality as shown by the dead rhizome found adjacent to the living seagrass as indication of environmental degradation in the island. This condition in accordance with the nutrient enrichment from eutrophication and subsequently increases turbidity, reduces the clarity in the water column, which worsens the environmental condition on the island and allows epiphytes to grow, dominate the seagrass and threaten their existence to macroalgae (Cardoso, *et al*., 2004; Burkholder *et al*., 2007; Govers *et al*., 2014; Lapointe 2019).

The succession process of aquatic vegetation between seagrass and macroalgae subsequently

Figure 8. (A) Seagrass *Enhalus acoroides* in front of Biawak Island jetty in 2005 (Oni, 2012). (B) sand overlay with only 4 small saplings (survey 2019).

with the algae bloom, which inlines with the nutrient enrichment (eutrophication) continuously (Cardoso *et al*., 2004; Kennish, 2009; Boesch, 2019).

The same case happened on Biawak Island in 2005, where there was an abundance of *Enhalus acoroides* in front of the jetty but vanished within 14 years (Figure 8A). Before 2016, there were no *Enhalus acoroides* in front of the jetty. However, it was found on the western side of the jetty, adjacent to the mangrove ecosystem with an unhealthy condition covered by epiphytes and rooted rhizome (Figure 8B).

Eutrophication is a global problem, that impacts on another biodiversity such as the disapearance seagrass ecosystem. Need more effort with a direct program to restore, rehabilitate, reduce or eliminate the main causative factor such as fisheries productivity and anthropogenic input from inland. Restoration efforts need to be done by reducing or eliminating the main factors such as nutrient input sources due to human activities from the mainland by managing in integrated management from upstream to downstream, management of marine culture such as seaweed and shellfish with methods that pay more attention to sustainability, related regulations with land, coastal and marine management that are binding (Duarte & Krause-Jensen, 2018; Boesch, 2019).

CONCLUSION

The seagrass ecosystem in Biawak Island experienced degradation in quantity and quality as the comparison of the existence between 2016 and 2019 condition, shows a significant differentiation. The succession trend of macroalgae to the seagrass ecosystem occurred slowly, proven by the transformation of submerged vegetation and its size. The existence of seagrass on Biawak Island, especially *Enhalus acoroides* considered based on its durability and is known as firm aquatic vegetation that survives even though covered by epiphytes.

Water quality degradation, whether caused by natural phenomena or human intervention, can influence the health of the adjacent environment. This condition happened due to human intervention, which considered a significant cause of seagrass ecosystem degradation on Biawak Island. This condition also affects other ecosystems surrounding Biawak Island, such as coral bleaching and the declining number of sea cucumbers on Biawak Island compared to 2016.

The role of seagrass ecosystem service is essential in maintaining the coastal environment and fisheries' productivity to keep both balances. Sustainable observation is important to monitor the seagrass existence related to the nature of seagrass ecology, which can be degraded if mismanaged in the adjacent environment.

Regulation and zonation already take place, but monitoring needs improvement to suit the regulation. The establishment of a Marine Protected Area might be useful in order to protect the ecosystem and limit the access of human intervention directly, which can give more opportunity for nature to recover automatically.

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REFFERENCE

Boesch, D.F. (2019). Barriers and Bridges in Abating Coastal Eutrophication. *Frontiers in Marine Science, 6*,123. doi: 10.3389/fmars.2019.00123

Brooks, M.T., Coles, V.J., Hood, R.R., & Gower, J.F.R. (2018). Factors controlling the seasonal distribution of pelagic Sargassum. *Mar Ecol Prog Ser, 599*, 1-18. doi.org/10.3354/meps12646

Burkholder J.M., & Tomasko, D.A., & Touchette, B.W. (2007). Seagrasses and eutrophication. *Journal of Experimental Marine Biology and Ecology, 350*(1-2), 46–72.

Cardoso, P.G., Pardal, M.A., Lillebo, A.I., Ferreira, S.M., Raffaelli, D., & Marques, J.C. (2004). Dynamic changes in seagrass assemblages under eutrophication and implications for recovery. *J Exp. Mar. Biol. Ecol, 302*(2), 233-248.

Duarte, C.M., & Krause-Jensen, D. (2018). Intervention Options to Accelerate Ecosystem Recovery From Coastal Eutrophication. *Frontiers in Marine Science, 5*, 470. doi:10.3389/fmars.2018.00470

Erftemeijer, P.L.A., Middelburg., & Jack, J. (1993). Sediment-nutrient Interaction In Tropical Seagrass Beds: a Comparasion between a Terigeneus and a Carbonat Sedimentary Environmental in South Sulawesi. *Marine Progress Series, 102*, 187-198.

Green, S.O., & Webber, D.F. (2003). The effects of varying levels of eutrophication on phytoplankton and seagrass (Thalassia testudinum) populations of the southeast coast of Jamaica. *Bulletin of Marine Science -Miami, 73*(2), 443-455.

Govers, L.L., Lamers, L.P.M., Bouma, T.J., de Brouwer, J.H.F., van-Katjwik, M.M. (2014). Eutrophication threatens Caribbean seagrasses – An example from Curaçao and Bonaire. *Marine Pollution Bulletin, 89*(1-2), 481-486. DOI:10.1016/j.marpolbul.2014.09.003

Hillman, K., Walker, D.I., Larkum, A.W.D., & McComb, A.J. (1989). *Productivity and nutrient limitation. In: Larkum*, A.W.D.,McComb, A.J., Shepherd, S.A. (Eds.), Biology of Seagrasses: A Treatise on the Biology of Seagrasses with Special Reference to the Australian Region. Elsevier, Amsterdam, pp. 635–685.

[Kab Indramayu] Kabupaten Indramayu Dinas Pemuda dan Olahraga Kebudayaan dan Pariwisata. (2016, in Indonesian). Preparation of the Master Plan for the Development of Marine Tourism on Biawak Island, Indramayu Regency. https://www.scribd.com/doc/305609781/Bab-4-Analisis-Kondisi-Tapak

Kadi, A. (2005, in Indonesian). Some Notes On The Occurrence Of Genus Sargassum In Indonesian Waters. *Oseana, 30*(4), 19-29.

Kennish, M.J. (2009). Eutrophication of Mid- Atlantik Coastal Bays. *Bulletin of the New Jersey Academy of Science, 54*(3), 1-8.

[KKJI-KKP] http://kkji.kp3k.kkp.go.id/index.php/basisdata-kawasan-konservasi/details/1/79 [30 December 2016]

[KMNLH] (2004, in Indonesian). Decree of the State Minister of the Environment No. 51. 2004. Regarding Seawater Quality Standards.10 pp.

Lapointe, B.E., Herren, L.W., Brewton, R.A., & Alderman, P.K. (2020). Nutrient over-enrichment and light limitation of seagrass communities in the Indian River Lagoon, an urbanized subtropical estuary. *Science of the Total Environment, 699*. https://doi.org/10.1016/j.scitotenv.2019.134068

Lee, K-S., Park, S.R., & Kim, Y.K. (2007). Effects of irradiance, temperature, and nutrients on growth dynamics of seagrasses: A review. *Journal of Experimental Marine Biology and Ecology, 350*(1), 144–175. doi:10.1016/j.jembe.2007.06.016

McKenzie, L.J., Campbell, S.J., & Roder, C.A. (2003). *Seagrasswatch: Manual for mapping & monitoring seagrass resources by the community (citizen) volunteers 2sd edition*. The state of Queensland, Department of Primary Industries, CRC Reef. Queensland. pp 104 .

Panggabean, L.M.G. (2006, in Indonesian). Dinoflagellate Cyst Of Hab Causative. *Oseana, 31*(2), 11-18.

Pratama, A.M., Harahap, S.A., & Riyantini, I. (2018, in Indonesian). Spatial – Temporal Correlation of Current Patterns with Distribution of Kima (Tridacna sp) in the waters of the Indramayu Biawak Island. *Jurnal Geomaritim Indonesia, 1*(1), 9-13.

Purba, N.P., & Harahap, S.A. (2013, in Indonesian). *Small Islands of Indonesia Marine Perspective Edition Lizard-Gosong-Candikian*. Unpad Press. 46 hal.

[P3SDLP] Pusat Penelitian da Pengembangan Sumber Daya Laut dan Pesisir. (2016, in Indonesian). Coastal Ecosystem Blue Carbon Assessment in Conservation and Rehabilitation Areas. Kegiatan Riset TA 2016.

Ramadhan, M.H., Widada, S., & Ismanto, A. (2016, in Indonesian). Bathymetry Mapping for Determination of Shipping Routes in the Waters of Biawak Island, Indramayu Regency. *Jurnal Oseanografi, 5*(2), 243-250.

Setiawan, D., Riniatsih, I., & Yudiati, E. (2013, in Indonesian). Study of the Relationship of Water Phosphate and Sediment Phosphate on the Growth of Seagrass Thalassia Hemprichii in the waters of Teluk Awur and Panjang Island, Jepara. *Journal Of Marine Research, 2*(2), 39-44.

Sunarto., Riyantini, I., Ihsan, Y.N., & Harahap, S.A. (2013, in Indonesian). Study of Marine Resources on Biawak Island and its Surrounding Seas, Indramayu Regency, West Java. Final Report on Leading Higher Education Research.

Widiarti, R. (2004, in Indonesian). The Presence of Cysts of Dangerous Microalgae Types in Lampung Bay. Kompas, Saturday 26 June 2004. https://www.researchgate.net/publication/314263882 [akses 12 april 2020]