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Community Structure Hydrophyte, Periphyton and Water Quality Encircle Fish Cage Negara River South Kalimantan, Indonesia

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ABSTRACT

Anthropogenic activities within and around the Negara River ecosystems are the main threat to the dynamics of the diverse structure of aquatic plant communities and periphyton The purpose of this study was to analyze the environmental conditions of the waters around the river fish cage area of the Negara South Kalimantan, Indonesia using data hydrophyte, periphyton, and water quality. Sampling was carried out purposively from May to June 2022, in areas that were densely hydrophytes, near and far from fish cages. Hydrophyte, periphyton and water quality samples were collected at the beginning of each month based on a 1x1 m^2 plot. Furthermore, the calculation of the biological index for hydrophytes and periphyton and their relationship to water quality at each location were carried out. The identification results showed a total of 10 families for hydrophytes and 6 classes for periphyton. The average total abundance of hydrophytes was 25,580 individuals/m^2 and periphyton was 639,364 individuals/cm^2. The highest abundance was at STA-1 in June, with the highest number of species found in the same month. Hydrophytes species that were always found were free-floating types (*Eichornia crassipers* and *Salvinia molesta*), while for periphyton are Chrysophyta. The community structure is classified as unstable with moderate diversity. No dominance of certain species was found, and the waters were classified as having been polluted with organic matter. Parameters of temperature, dissolved oxygen (DO), pH, phosphate and current also contributed to the increase in hydrophytes and periphyton.

INTRODUCTION

Hydrophytes are the group of spermatophytes that reproduce vegetatively, and multiply twice as much in 7 until 10 days, and have special organs that are could be adapted to the aquatic environment **(Suwasono, 1996; Afiyah *et al.*, 2020)**. Massive increase in hydrophytes in Negara rivers could be reduce fish resources, hinder water transportation, fishery activities, sedimentation, and purification that stimulates the growth of other plants **(Nurfitri *et al.*, 2011; Chen *et al.*, 2014; Grand-Clement *et al.*,

2015; Zhuangrui and Wong, 2016). Hydrophytes are invasive plants that are adequate to survive and grow rapidly as a threat to waters, especially in locations around cages so that they can cause death in cultured fish.

The activity of fish cages increases the concentration of nutrients, pH, temperature and pollution, so that the water quality downturn **(Nguyen, 2015; Ismail *et al.*, 2021)**. The composition of organic waste in the waters of the Negara's rivers is very high, due to decay and accumulation of hydrophytes in the bottom waters, fish feed waste and the large amount of household waste that enters the waters **(Indrayati and Hikmah, 2018)** as sediment. This increase in in organic waste accumulation leads to eutrophication waters become annoxia (loss of oxygen) due to over activited by oxygen-consuming organisms **(Schaumburg *et al.*, 2004; Tavernini *et al.*, 2011)**. In the transpiration process, hydrophytes in massive numbers have potential to remove surface water up to four times compared to other plants **(Soedarsono *et al.*, 2013)**.

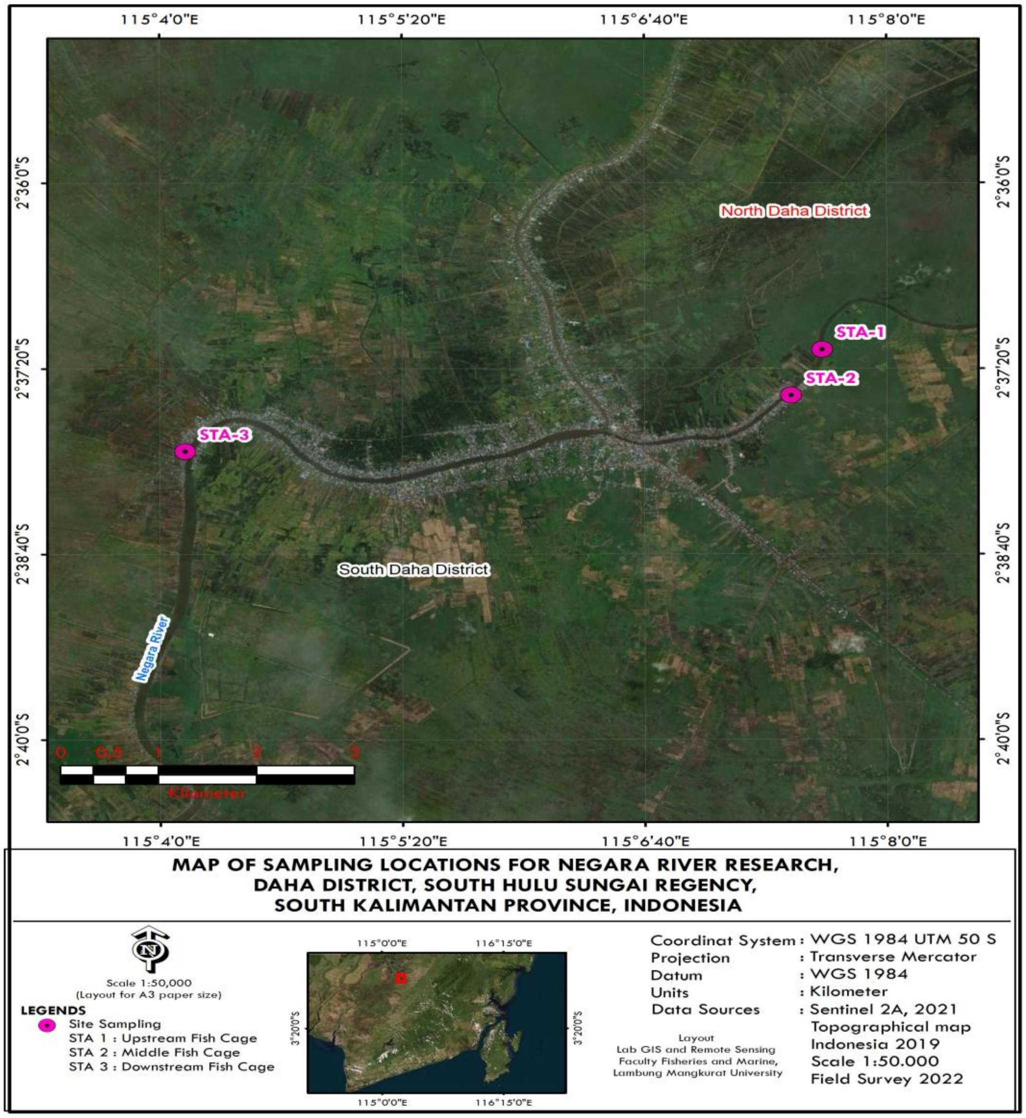
Changes in the structure of hydrophytes and periphyton cause a dissolved oxygen deficit and decline fishery production as an rise in organic waste and marker of polluted load in waters **(Ansari *et al.*, 2011; Tavernini *et al.*, 2011; Rastetter *et al.*, 2013; Zhao *et al.*, 2013)**. Water monitoring has been carried out based on the components of water quality parameters and even included in Indonesian regulations. This mechanism cannot be followed by fish farming groups due to limited funds to analyze a number of parameters. Another alternative is to use the abundance structure of periphyton and hydrophytes as water quality indicators and biofilters (**Stephenson *et al.*, 2008; Bere and Tundisi, 2010; Lobo *et al.*, 2010)**.

Submerged and free-floating hydrophytes have the benefit of being a habitat for various types of periphytons and aquatic insects that are a source of food for carnivorous fish. The important role as an indicator in the network of trophic levels in the waters of lakes and reservoirs cannot be represented by fish and plankton **(Jeppesen *et al.*, 2011)**. This research is the first study to look at the interaction between hydrophytes and periphyton in waters from the biological index. Therefore, the purpose of this study was to analyzed the environmental conditions of the waters around the river fish cage area of the Negara of South Kalimantan, Indonesia using hydrophyte, periphyton, and water quality support data. The resulting hydrophyte and periphyton structure is expected to indicate water pollution in fisheries activities in the Negara river.

MATERIALS AND METHODS

Study area

This research was conducted from May to June 2022, located in the waters of Negara rivers Hulu Sungai Selatan, Indonesia (2° 34' 40' S and 115° 9' 20'E). The research location was divided into three stations represented different hydrophytic densities and floating cages in the upstream (STA-1), middle (STA-2), and downstream (STA-3) (Figure 1).



Figures 1. Map of sampling locations

Samples collection, identification of hydrophytes and periphyton

Hydrophytic samples were taken using a transect plots measuring 1x1 m^2, at all sites. Transect coverage includes areas with dense hydrophytes, near cages and far from influences. Periphyton samples were collected from the hydrophytes (roots, stems and leaves). Sampling was carried out in the dry season of early May and June 2022, at low tide. Hydrophyte samples were identified morphologically based on **Pancho, J V. (1978)**; **Sandra Holmes (1983)**; **Van Steenis (2008)**; **Tjitrosoepomo (2009)** and the application of PlantNet Plant Identification Ver 3.2.6. Identification of periphyton samples refers to **Presscott (1974); Bigg and Kilroy (2000); Huyn L and Serediak (2006); Bellinger and Singee (2010)**. Samples for water quality parameters of temperature, brightness, dissolved oxygen (DO), pH, nitrates, phosphates and currents used for support.

Ecological Index :

The index values for hydrophytes include the type of vegetation, abundance index, Shannon-Wiener diversity, evenness index, and dominance index. The same index assessment was also carried out on periphyton, except for vegetation covered.

Statistical analysis

Statistical analysis was carried out to determine the difference in the value of the hydrophyte and periphyton indexes between locations on water quality, using the one-way ANOVA test **(Sokal and Rohlf, 1995)** with a significance level of 95%.

RESULTS

1. The structure of hydrophyte and periphyton communities

The hydrophyta identified study site during the observation period were 10 families, while the periphyton were 6 classes. The highest abundance for hydrophytes was in STA-1 in June, while the largest number of species found in the same month. Hydrophyte species that always found were free-floating species (Eichornia crassipers and Salvinia molesta), and Chrysophyta for periphyton. The composition of periphyton plankton in freshwater ecosystems is less than marine ecosystems **(Dodson *et al.,* 2009; Rahayu *et al.,* 2013; Widyarini *et al.,* 2017, Yunandar *et al.,* 2020, Dharmaji *et al.,* 2021)**. In this study, it was seen that the composition of the phylum Chrysophyta dominated its spread more than Chlorophyta and Cyanobacteria (Table 1). While the composition of the dominant hydrophytes were from the families Pontederiaceae and Salviniaceae (Table 2).

2. Abundance of hydrophytes and periphytons

The average value of hydrophyte abundance obtained from STA-1 to 3 was 7,505 ind/m^2, 3,710 ind/m^2 and 1,575 ind/m^2, respectively. The highest hydrophyte abundance was in STA-1, while the lowest was in STA-3 at 1,575 ind/m^2. It was different from periphyton which has the highest average abundance value at STA-2 66,550 cells/liter and STA-1 59,895 cells/liter while the lowest at STA-3 is 47,795 cells/liter. Periphyton abundance values in STA-2 were located in floating cages that were not close to market activities and residents. Periphytons from the phylum Chrysophyta was found to be the most dominant in all observation sites.

3. Index diversity, uniformity, dominance, number of hydrophyte and periphyton taxa

The components of diversity, evenness, dominance, and the number of taxa in hydrophytes and periphytons inform that the type of hydrophyte has to impact on the dynamics of periphyton (Figures 2 and 3). The diversity and number of identified taxa increased in the free-floating hydrophyte type and decreased in the submerged and emerging types. Based on different observation times, hydrophyte diversity index values ranged from 0.61 - 1.71. The highest diversity value was in STA-1 June and the lowest was in STA-3 in the same month. This value informs that the species richness of the habitat in the study area was generally in moderate condition. The uniformity value was categorized as evenly distributed between 0.79 – 0.95, although the composition of the plants differed between stations. The lowest index value was in STA-1 in May with a value of 0.79 but increased in June, which reflects the circumstance the level competition between hydrophyte, calm waters, and weak waters. The dominance value includes was in the low category between 0.19 – 0.58, although, in STA-3 June, it was higher than STA-1 and STA-2. The lowest dominance value is in STA-1. Overall, the evenness index value was distributed, and the dominance index value was low. This illustrate the hydrophyte spesies in the Negara rivers has uniform populations, so that the dominant family low.

Table 1. The presence of periphytons found in the waters of Negara's rivers

Phylum	Class	Species	STA-1	STA-2	STA-3
Cyanobacteria	Cyanobacteria	*Oscillatoria sp.*	+	+	+
		Scytonema	+	-	-
		Lyngbya sp.	+	-	-
		Arthrospira	+	+	-
Chrysophyta	Bacillariophyceae	*Eunotia bilunaris*	+	+	+
		Navicula sp.	+	+	+
		Nitzschia	+	+	+
		Synedra	+	+	+
		Asterionella	-	+	-
		Pinnularia sp.	+	+	+
		Pinnularia viridis	-	+	-
		Melosira	-	+	-
		Eunotia pectinalis	+	+	+
		Cymbella	-	+	-
Chlorophyta	Chlorophyceae	*Chlorotylium cataractum*	+	+	-
		Gonatozygon sp.	+	+	+
		Asterococcus	+	+	-
		Geminella	+	+	+
		Cladophora	-	+	-
		Mesotaenium	+	-	-
		Stigeoclonium	-	+	-
		Ulothrix	-	-	+
		Aphanochaete sp.	-	-	+
Charophyta	Zygnematophyceae	*Closterium*	+	-	-
		Spinoclosterium cuspidatum	+	-	-
		Penium	+	+	+
		Spirogyra	+	-	+
		Genicularia	+	+	-
		Mougeotia	+	-	-
Arthropoda	Harapacticoida	*Harpaoticoida copepeda*	+	-	-
Ciliophora	Oligotrichea	*Loxophyllum*	-	-	+

Table 2. The presence of hydrophytic species in the waters of Negara's rivers

Type	Family	Species	STA-1	STA-2	STA-3
Emergent plant	Fabaceae	*Mimosa pudica*	+	-	-
	Cyperaceae	*Cyperus sp*	+	-	-
	Poaceae	*Glyceria maxima*	-	+	-
	Onagraceae	*Jussiaea repens*	-	+	-
		Ludwigia peploides	-	+	-
	Nymphaeaceae	*Nymphea sp*	+	-	-
Free floating	Pontederiaceae	*Eichornia crassipers*	+	+	+
	Salviniaceae	*Salvinia molesta*	+	+	+
	Ceratophyllaceae	*Ceratophyllum demersum*	-	+	-
	Hydrocharitaceae	*Hydrilla verticilata*	+	+	-
Submerged	Penthoraceae	*Penthorum sedoides*	-	-	+

In line with the hydrophytes, the periphyton diversity index values generally ranged from 0.99 to 2.39 in moderate conditions. The highest diversity index value was at STA-1 June and the lowest was at STA-3 May. The uniformity index value was included in the even category between 0.76 - 0.90, although the number of plants in STA-3 was less. The lowest uniformity index value was in STA-3 June with a value of 0.76, but in the previous month there was an increase.

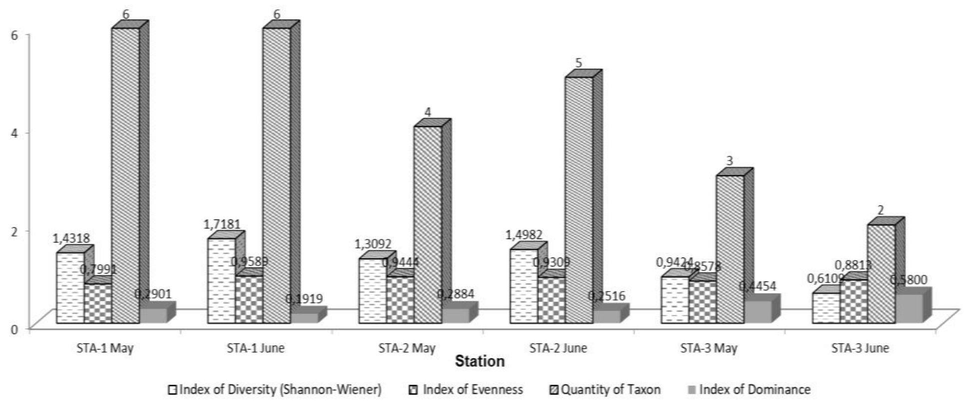


Figure 2. Index of diversity, dominance, evenness and quantity of taxa hydrophyta

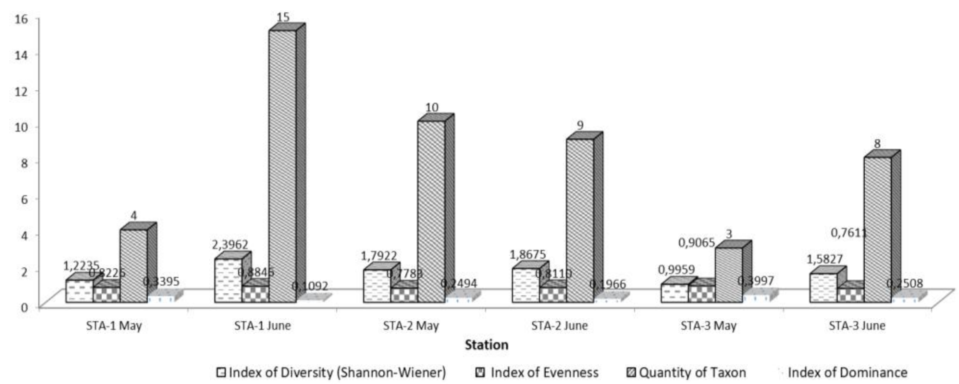


Figure 3. Index of diversity, dominance, evenness and quantity of taxa periphyton

This condition indicates that there had been a decrease in the uniformity index of hydrophytes. The dominance value was in the low category between 0.10 - 0.39 even though on STA-3 May it was higher than STA-1 and STA-2. The lowest dominance value was in STA-1. Overall, the uniformity index value was evenly distributed, while the dominance index value was low. This illustrates the condition of the periphyton species in Sungai Negara having uniform population uniformity, so that no species dominates.

4. Comparison of hydrophyte index values, periphytons, and water quality between locations and their relationship

The parameters of current, dissolved oxygen, phosphate, abundance, diversity, dominance and number of taxa were interact components with each other in the aquatics of the Negara rivers, based on analysis of variance (one-way ANOVA) (Table 3). In contrast to swamp waters, the parameters of pH and dissolved oxygen as limiting factors

(Schagerl *et al.*, 2009; Chaparro *et al.*, 2018; Sofarini *et al.*, 2019; Yunandar *et al.*, 2020). The current was a limiting factor in river waters, that can easily wash away free floating hydrophytes. The hydrophytes drifted to a quiet STA-1, resulting in a build-up of organic matter and nutrients. Contributions from feed residues, river flows and organic matter runoff from surrounding swamps help accelerated the growth rate of hydrophytes in STA-1 and STA-2. The invasiveness of hydrophytes through allelopathic mechanisms contributes to a more aggressive spread.

Table 3 The results of one-way ANOVA test of water quality between stations in the Negara river on the value of hydrophyte and periphyton biological index with a confidence level of 0.05

Parameter	Location	Mean Difference (inter zona)	Sig. Anova	Levene test	Sig. Post Hoc Tests	Conclusion
Current	STA-1 vs STA-2	0.14500(*)	0.044	0.000	0.044	Significantly
	STA-3 vs STA-1	0.18000(*)	0.025		0.025	
Dissolved Oxygen (DO)	STA-1 vs STA-2	0.8000(*)	0.019		0.019	
Phosphate	STA-1 vs STA-2	0.13000 (*)	0.026		0.026	
	STA-1 vs STA-3	0.14500 (*)	0.015		0.015	
Abundace	STA-1 vs STA-3	5.930(*)	0.049		0.049	
Diversity	STA-1 vs STA-3	0.7983(*)	0.026		0.026	
	STA-2 vs STA-3	0.62705(*)	0.049		0.049	
Dominance	STA-1 vs STA-3	0.27170(*)	0.030		0.030	
	STA-2 vs STA-3	0.24270(*)	0.040		0.040	
Taxa	STA-1 vs STA-3	3.50000(*)	0.009		0.009	
	STA-2 vs STA-3	2.00000(*)	0.041		0.041	

The rate of periphyton abundance was supported by currents and dissolved oxygen. The diversity index, uniformity, and dominance of periphyton were related and influenced by phosphate as a aquatic nutrient. Phosphate was a limiting factor for the survival and growth process of periphyton in waters. Phosphate levels that do not meet the tolerate limit will cause a decrease in periphyton, and vice versa. This was in according to **Gazali *et al.* (2013)** which states that periphyton depends on its tolerance and sensitivity to changes in the biotic and abiotic environment.

DISCUSSION

Community structure can be used as a biological indicator, because it is easy to respond to environmental changes. The response is in the form of changes in species composition or an increase in the dominance community. The environmental changes on a small scale could be modification structure of communities **(Odum, 1993)**. The hydrophyte community acts as a producer for herbivorous fish, periphyton and benthic so that their availability affects the community at the trophic level above it. Competition between types of hydrophytes, presence of predators is biotic factor, while the physico-chemical of waters and human activities are abiotic components for existence of hydrophytes **(Cronk and Fennessy, 2001; Elger *et al.*, 2004)**. The existenced of free-floating hydrophytes in all locations was a form of morphological adaptation from the stem surface to become rhizomes or stolons. In addition, the stem could be float because it has a large air cavity which aims to increased the absorption of oxygen from the air during anaerobic. The physiological adaptation of hydrophytes by producing mucus aims to protected the body from decay due to all or part of its body being submerged in water.

Free-floating hydrophytes are characterized by soft, shiny leaves, and a wax coating to protect the leaves from physical and chemical disturbances. However, this type performs the transpiration mechanism excessively so that the volume of water decreases and has the potential to experience drought in water bodies. The rhizosphere zone has form hydrophytic roots which release oxygen throughout the surface of the root hairs. Oxygen flows to the roots through the intercellular space stems or air passage holes (aerenchyma) as a means of transporting oxygen from the atmosphere **(Tangahu and Warmadewanthi, 2001)**. Oxygen released by roots in 1 day ranges from 5 to 45 mg/m^2 of plant root area **(Tangahu and Warmadewanthi, 2001; Khiatuddin 2003; Hindarko, 2003)**. Free-floating hydrophytes also act as fish protectors from predators that avoid migration at low tide, as well as a place to lay eggs. The emerging hydrophytes are favored by kissing gouramy *(Helostoma temminckii)* as spawning grounds, protection from predatory fish and fish attractors in the river.

Massive abundance of hydrophytes can accelerate siltation, reduce water volume, decrease fishery yields due to dissolved oxygen deficit, no diffusion process, problems with agricultural pests, and vectors of human diseases. The composition of Chrysophyta periphytons dominates in presence and quantity because there were biological indicators in changes water quality. In addition, Chrysophyta have adaptability, cosmopolite, resistant to extreme conditions, high reproductive power, and one of the main sources in the food chain **(Rangpan, 2008; Pasisingi *et al.,* 2014; Juadi *et al,.* 2018)**. One example of Chrysophyta was Synedra which can be used as an indication of a decline in water quality (pollution). Synedra species talent withstands unfavorable changes in environmental conditions because they have layered envelope cells **(Conradie, 2008)**. In addition, Synedra was could be to survive in a low-nutrient (oligotrophic) environment with low nitrogen and phosphate concentrations. This was because Synedra able to accumulate nutrients and store them as food reserves in the form of insoluble polymers **(Venter, 2003)**. Large-leaf type hydrophytes were preferable to periphytons than small ones, because those with larger (stronger) morphology have more stable substrate conditions. Similarly with old ages, the older aquatic plants have different composition and density of periphyton from that of the younger ones. This was due to the process of attachment and the formation of periphyton colonies which take a long time **(Russel, 1990)**. The type of substrate greatly determines the process of colonialization and the composition of periphytons, which was related to the ability and sticking device. The ability of periphyton stick to the substrate determines its existence against strong currents or waves that can destroy it. Attach to the substrate, periphytons have various sticking devices, namely: (1) Rhizoids, as in Oedogonium and Ulothrix; (2) Long or short gelatinous stalks, as in Cymbella, Gomphonema and Achnanthes and (3) Sphaerical gelatinous pads reinforced with lime or not, as in Rivularia, Chaetophora and Ophyrydium. The type of Ciliophora periphyton that acts as a zooplankton found around the Negara river fish cages was lower than the Barito Marabahan River, and the highest was in the waters of the Bangkau swamp **(Dharmaji *et al.,* 2020; Dharmaji *et al.,* 2021)**.

The diversity index value was generally in a balanced ecosystem condition and moderate ecological pressure. This means that there were no dominant or minority species found in the observations. The value of the diversity index of hydrophytes and periphyton did not differ extreme between the floating cage locations. The high and low diversity index indicates the feasibility of the location of the availability of natural food for aquaculture activities **(Chandrasoma and Pushpalatha, 2018)**. The evenness index value was inversely proportional to the diversity index due to current intensity. The distribution of hydrophytes was quite even with differences in spesies between each station due to factors of aquatic environmental conditions. Types of life and ways of adaptation of each plant to aquatic environmental. The evenness index does not depend on the number of individuals of each spesies, but on other factors **(Brower *et al.*, 1990; Sherin K. Sheir *et al.*, 2020)**. Chrysophyta is a periphyton better known as *navicula sp*, which is favored by omnivorous fish **(Bucholtz *et al.*, 2009)**. The existence of periphyton contributes to the existence of potential fish resources **(Thirunavukkarasu *et al.*, 2013)** because it plays a dual role as a first-level consumer and a second-level consumer that connects plankton and nekton **(Pratono *et al.*, 2012)**.

The conditions of physico-chemical parameters and the presence of type of hydrophytes in Negara's rivers are inseparable from dynamic currents, spill over from swamps, and run off. The contribution of phosphate in the waters of Negara river comes from the waste of the remaining detergents, food scraps, and human waste that utilizes these waters. According to **Zaher *et al.*, (2021)** flood positively changes water quality by adding more dissolved oxygen and nutrients, thereby affecting producer composition, distribution, and abundance. The low evenness value of the hydrophyte and periphyton populations illustrates the uneven distribution of individuals with low dominance, so that only organisms that can survive can be found. Variables of temperature and sunlight, dissolved oxygen, phosphate and water acidity (pH) as components of periphyton and hydrophyte growth. The emergence of Ciliophora which is a parasite measuring 30-50 µm in size, starting its life cycle by eating blood cells and cellular debris in the kidneys and stomach of fish, was a threat to the activities of fish cages. Factors supporting the development of Ciliophora were ammonia and high organic matter which produce low dissolved oxygen. Fish infected with this parasite show clinical and pathological symptoms in the form of white spots on the infected body parts and become sores, ulcers filled with cilia, and increased mucus production. Meanwhile, the behavioral symptoms of the affected fish were generally gasping for air, swimming near the surface of the water with difficulty breathing, rubbing the body on the walls and bottom of the cage **(Hardi, 2015)**.

CONCLUSION

The community structure approach is one of the methods for monitoring the quality of the aquatic environment with a local biota approach. This technique underlies the use of aquatic biota instruments in lotic water ecosystems. The environmental conditions around the fish cages had been polluted from organic matter. It was characterized by the abundance of Chrysophyta and free-floating hydrophytes that utilize it for growth. Current was a limiting factor for growth. Ciliophora which causes fish disease was a threat in fish cage aquaculture. This was due to the high interaction of ammonia and organic matter, which results in a deficit of dissolved oxygen.

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