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Evaluation of Floating Net Cage (FNC) in Penerusan Bay, Bali Based on Their Plankton Community

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Abstract. Floating net cages (FNC) are one of the common methods to cultivate fish, in Indonesia, affecting the physicochemical and biological parameters. This study evaluated the water quality conditions in two different FNCs based on the physiochemical and biological parameters. There were four locations to be sampled: two FNC (snappers (KP) and groupers (KR)) and two control sites that were placed outside of FNC (Non-KP and Non-KR). Several water physicochemical parameters were measured, and the plankton community was identified. The observation showed the total suspended solid (TSS) (2.57–2.64 mg/L), pH (8.26–8.3), biochemical oxygen demand (BOD) (0.75–1.52 mg/L) and orthophosphate (P) (0.008–0.044 mg/L). Furthermore, in certain sites, some parameters did not meet the Indonesian Government Standard No. 22 in 2021, including nitrate concentration (KP, Non-KP, and KR), dissolved oxygen (KR and Non-KR), and P (KR and Non-KR). Meanwhile, the phyto- and zooplankton diversity index (H') was 3.61-4.69 and 1.27-2.54, which confirmed that the level of diversity of phyto- and zooplankton was high and moderate status. Four sites showed low phyto- and zooplankton dominance levels and were distributed evenly ($E \geq 0.81$). This study concludes that based on water quality parameters, KP and KR did not meet the Indonesian Government Regulation in some parameters, but they had a stable ecosystem based on the phyto- and zooplankton structure community.

1 Introduction

Penerusan Bay, known for its rich marine biodiversity [1], and potential for aquaculture, has seen a growing interest in Floating Net Cage (FNC) systems that operate traditionally and unconventionally. This farming method is an innovative aquaculture approach that utilizes open water bodies for fish farming, offering advantages such as efficient space utilization and economic benefits. Additionally, regular feeding and less presence of competitors and predators can improve the seafood productivity in FNC. However, the change in an ecosystem because of the presence of FNC in aquatic environments may raise potential

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ecological changes, including the plankton community at the lowest level of the trophic cascade [2].

Plankton consists of phytoplankton and zooplankton, which are the base of the aquatic food chain. Phytoplankton serve as primary producers that convert nutrients to biomass, sustaining higher trophic levels [3]. Zooplankton, in contrast, is in the second tropic level as the prey of planktivorous fish. Several studies show the decline of zooplankton abundance and the shift in community composition. For example, the decreased number of native mysid shrimp, *Neomysis mercedis*, impacts the availability of fish and other higher tropics in the San Fransisco Estuary. The shift in the peak abundance of copepod *Eurytemora affinis* also influences the number and taxa of young fishes [4]. Therefore, any alterations in plankton community composition and dynamics can have cascading effects throughout the aquatic ecosystem.

The distinct types of fish food and feeding frequency that are given to the farmed fishes contribute to the availability of micro and macronutrients in the aquatic. Moreover, the food exceeds, pellets, and faeces add more nutrients to the environment during decomposition by involving bacteria and microorganisms. It results in the alteration of physicochemical parameters and the plankton community change. A study indicates that the excessive nutrients of phosphorus $\geq$ 0.1 mg/L promote the growth of Cyanophyta, which initiates Cladocera growth [5]. Another research shows aquatic ecosystems with low dissolved oxygen and high biochemical oxygen demand cause a rise in specific diatom, such as *Nitzschia* sp. and *Cyclotella* sp. [6]. However, it is essential to investigate the impact of FNC on the plankton community and physicochemical parameters since it plays a prominent role in the local economy. The objectives of the present study were to investigate the effects of FNC on the physicochemical aquatic parameters and plankton community.

2 Materials and methods

2.1 Area study

Penerusan Bay (8°07'44.4"S, 114°36'08.6"E) is in the Banyuwedang, Bali, where the FNC grows well, and we observed more than ten FNCs. Because this study compared not only different types of farmed fish but also outside of the farming area, there were four sites the two sites were snappers farming (KP) and groupers farming (KR), and the rest were right outside of the snappers farming (Non-KP) and groupers farming (Non-KR) (Figure 1).

2.2 Water and plankton sampling

A liter of water was taken per replication for physicochemical parameters and put in the plastic bottle. Temperature, pH, dissolved oxygen (DO), salinity, total suspended solids (TSS), and total dissolved solids (TDS) were measured on-site. The water sample was kept in a cooler box to be transferred to the laboratory for biochemical oxygen demand (BOD), nitrate Kjeldahl (N), and orthophosphate (P). For phytoplankton, three liters of water were taken vertically, and it was filtered by plankton net mesh size of 25 μm. Ten milliliters of concentrated sample was transferred into a thirty milliliters bottle, then formalin 4% and $CuSO_4$ were added into it for preservation. Plankton was observed by using a microscope (100×) and was identified based on several reference books identification [7-9].

2.3 Data analysis

The plankton community was examined by using ecological indices, such as the diversity index (Shannon – Wiener) (H'), dominance index (Simpson) (Id), and evenness index (E). Physicochemical parameters were analyzed statistically to determine the variance among sites using SPSS 25.

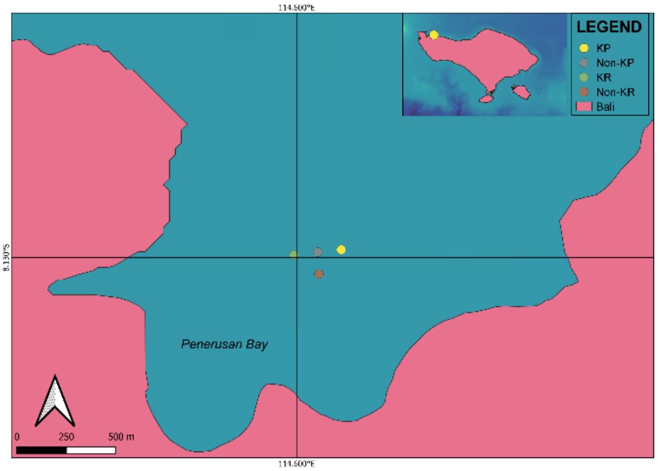


Fig. 1. Four sites of research are in the open area in Penerusan Bay, Banyuwedang

3 Results and discussions

3.1 Physicochemical parameters in FNCs and Non-FNCs

The aquatic physicochemical parameters in all sites varied, and some parameters in each place showed insignificant differences, including temperature, conductivity, TSS, BOD, and salinity. Meanwhile, based on Indonesia Government Regulation No. 22 in 2021 for Marine Biota [10], some of the parameters in all sites met the standard, such as TSS (≤ 20 mg/L), temperature (28-32°C), pH (7-8.5), and BOD (≤ 20 mg/L) (Table 1).

Table 1. Comparing the physicochemical parameters among four observation sites at Panerusan Bay

No.	Parameter	Site				Standard *
		KP	Non-KP	KR	Non-KR	
1.	Temperature (°C)	26.63 ± 0.25^{a}	26.17 ± 0.70^{a}	26 ± 0.35^{a}	25.67 ± 0.47^{a}	28 – 30
2.	Conductivity (mS/cm)	50.23 ± 0.21^{a}	50.4 ± 0.10^{a}	50.4 ± 0.10^{a}	50.3 ± 0.10^{a}	-
3.	TSS (mg/L)	2.57 ± 0.12^{a}	2.57 ± 0.12^{a}	2.64 ± 0.00^{a}	2.64 ± 0.00^{a}	≤ 20
4.	TDS (ppm)	8343.3 ± 166.53^{ab}	8233.3 ± 49.33^{a}	8480 ± 311.77^{b}	8566.7 ± 5.77^{c}	-
5.	DO (mg/L)	5.08 ± 0.19^{b}	5.03 ± 0.36^{ab}	4.79 ± 0.05^{a}	4.77 ± 0.07^{a}	> 5
6.	BOD (mg/L)	1.52 ± 1.11^{a}	0.98 ± 0.43^{a}	1.13 ± 0.41^{a}	0.75 ± 0.11^{a}	≤ 20
7.	pH	8.26 ± 0.01^{a}	8.28 ± 0.01^{b}	8.3 ± 0.0^{bc}	8.3 ± 0.01^{c}	7 – 8.5
8.	Salinity (%)	36 ± 0.00^{a}	35.33 ± 0.58^{a}	35.67 ± 0.58^{a}	34.67 ± 1.15^{a}	33 – 34
9.	N (mg/L)	0.066 ± 0.021^{ab}	0.069 ± 0.008^{b}	0.061 ± 0.01^{ab}	0.046 ± 0.008^{a}	0.06
10.	P (mg/L)	0.014 ± 0.00^{b}	0.008 ± 0.00^{a}	0.044 ± 0.046^{b}	0.017 ± 0.00^{b}	0.015

Note:
KP: Snappers farming, Non-KP: Outside of snappers farming, KR: Groupers farming, Non-KR: Outside of groupers farming
The different alphabet that is added after SD shows a variation based on the ANOVA test (α 0.05)
*Based on Indonesia Government Regulation No. 22 in 2021 for Marine Biota

The amount and frequency of feeding of KP and KR were different, with snappers receiving food more frequently than grouper. It might impact the measured parameters in this study, such as TDS, DO, BOD, N and P. In detail, Non-KR, right outside of groupers farming, had the most abundant TDS, and it means that the amount of dissolved organic matter and inorganic salts, including sodium, potassium, calcium, magnesium, chloride, bicarbonates, and sulfates is more generous than the other locations. Non-KR laid near the seashore might be affected not only by seafood farming but also by different anthropogenic activities, such as farming, water use, industry process, and mining, some studies state these activities contribute to the amount of dissolved matter [11, 12].

However, the BOD levels in farming sites were higher than in non-farming and KP that received more food than KR got more BOD amount than KR. The portion of dissolved oxygen is needed by microorganisms to break down biodegradable organic matter when the BOD is low, the water has low counts of microorganisms, and vice versa. Along with previous studies, BOD goes up gradually following the amount of dissolved organic matter in aquatic ecosystems and the Bagmati River [13, 14]. The other details, N and P figures in the farming site (KP and KR) did not show significant differences with all two non-farming sites. Previous studies claim that excess food, dead organisms, and fish waste contribute significantly to the N-P content in aquatic ecosystems [15].

3.2 Plankton community response among sites

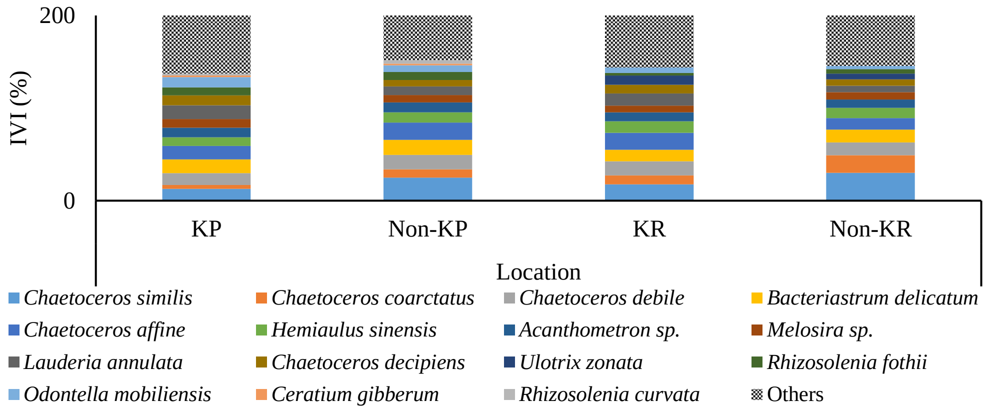
The number of phytoplankton and zooplankton taxa was higher in Non-KR and KP. The total of phytoplankton individuals in each location identified that eutrophic conditions did not happen (number of phytoplankton < 1000 ind./mL) whereas Non-KP had the most sufficient phytoplankton number (9307 ind./L). Dominance index (Id) shows that there was no dominant species either phytoplankton or zooplankton (Id < 0.5) and it is supported by the evenness index that shows that the plankton was distributed uniformly in all sites (E > 0.6). The diversity level of phytoplankton in all sites is classified as high, while the zooplankton's is medium (Table 2).

Table 2. Dominance, evenness, and diversity indexes in four locations: phytoplankton and zooplankton

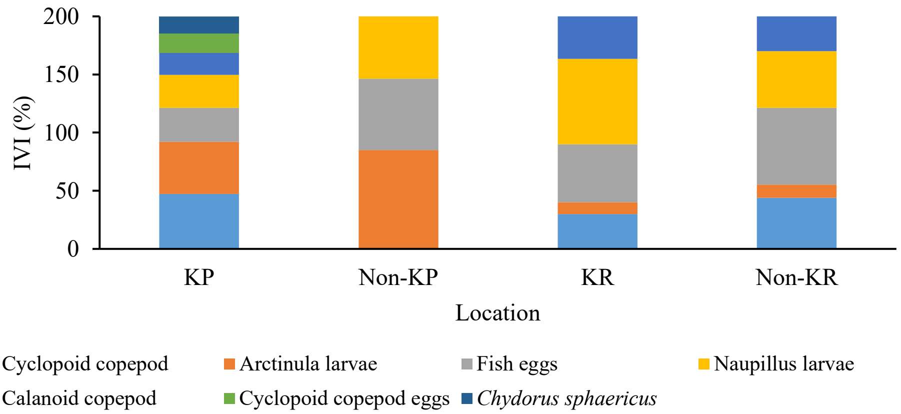
Location	Taxa Richness		Abundance (ind./L)		H’		Id		E	
	Phyto-	Zoo-	Phyto-	Zoo-	Phyto-	Zoo-	Phyto-	Zoo-	Phyto-	Zoo-
KP	28	7	3032	117	4.04	2.54	0.07	0.19	0.84	0.91
Non-KP	27	3	9307	157	3.72	1.27	0.10	0.48	0.78	0.80
KR	26	3	5569	30	4.69	1.46	0.08	0.37	1.00	0.92
Non-KR	30	5	7184	202	3.61	2.01	0.12	0.28	0.74	0.87

Note:
KP: Snappers farming, Non-KP: Outside of snappers farming, KR: Groupers farming, Non-KR: Outside of groupers farming

Plankton is at the lowest trophic level and is affected directly by sunlight and nutrient availability, especially phytoplankton as producers. At the lowest trophic level, the portion of phytoplankton is relatively plentiful than the higher tropic level to provide more biomass [16]. Since some plankton cannot move actively, and the water current has more energy to move them from one area to another, the number of plankton in each area might be affected [17]. *Chaetoceros* genus was noticed in every location of this study and several studies explain that this Diatom is one of the most abundant and diverse diatom genera in the phytoplankton of the world's ocean [18, 19]. Because of their high nutritional value, various *Chaetoceros* species are frequently farmed as feed for aquaculture of shellfish, shrimp, and fish [20, 21]. Furthermore, certain *Chaetoceros* species was used as biological markers in studies of marine environmental change [22] and to remove antibiotic contaminants from wastewater [23]. For zooplankton, because of their cosmopolite distribution, Copepods was in every site, except Non-KP. Previous studies state that Copepods are a type of tiny crustacean that is found in all aquatic habitats and serves as a vital connection between primary producers and greater predators and they have 13 unique life phases (egg, six nauplii, five copepodite stages, and adult) [24]. Copepods are a useful instrument for assessing the impact of marine pollution throughout coastal regions because they respond swiftly to diverse types of stressors in different ways (e.g., lower fecundity, gender bias, molecular responses, and mortality). In Northeast Taiwan, the abundant level of copepods shows serious response to water temperature.



(a)



(b)

Fig. 2. Important value index of phytoplankton (a) and zooplankton (b) in four sites
Note: KP: Snappers farming, Non-KP: Outside of snappers farming, KR: Groupers farming, Non-KR: Outside of groupers farming

Finding no dominant species with even plankton distribution in this study raised a signal that no single taxa has a major competitive edge or is exercising strong control over the ecosystem. On the other hand, many species coexist with roughly equal access to resources and habitat space. It can be a feature of mature and stable ecosystems when competition has resulted in more equitable resource allocation among species. Moreover, a high level of diversity is conceived when domination and uneven distribution do not exist. The heterogeneity and structurally complex habitat provide niches for various organisms, increasing diversity [25].

4 Conclusion

This study concludes that some of the physicochemical parameters met the Indonesian Government Regulations, including TSS, temperature, pH, and BOD in all sites. On the other hand, the FNC activity which was represented by KP and KR produced slightly higher N and P contaminants and was above the standards. Meanwhile, the biological parameters, phyto- and zooplankton communities, showed a stable community that was indicated by no dominant taxa with even distribution and medium-high diversity.

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