Plankton and its potential utilization for climate resilient fish culture

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Abstract. Climate change has had an impact on coastal ecosystems, especially on the north coast of Jeruksari Village, Pekalongan Regency. The purpose of this study was to determine the plankton profile and water quality conditions at the demonstration plot locations, for climate-resilient fish farming activities and their potential future use. This research was conducted in Jeruksari Village, Pekalongan Regency in November-December 2021, by collecting data by purposive sampling. The parameters observed were: the plankton profiles, which included the diversity index and the plankton dominance index, as well as water quality parameters, consisting of salinity, pH, temperature, dissolved oxygen and total dissolved solid parameters. The results showed that the value of water quality parameters was still in accordance with the water quality standards intended for fish farming activities, namely pH 8.0±0.10, salinity 18±3.53, dissolved oxygen 5.41±0.38, temperature 28.21±0.32, and total dissolved solid 5.09±0.41. The value of the plankton diversity index (H') was of 0.50-1.92, which means the level of diversity and stability of plankton in the waters is in moderate status. While the dominance index (D) obtained a score of 0.12-0.66, which means that there is no dominance of certain species, because the dominance index value tends to approach 0. The plankton genera found in this study included the Chlorophyceae, Cyanophyceae, Crysophyceae, Dinophyceae and also one zooplankton genus, namely *Tintinnopsis* sp. The conclusion of this study is that, based on the plankton profile structure and the dynamic conditions of the water quality parameters studied, the plankton community in the aquatic ecosystem in aquaculture cages has the potential to be used as natural food for cultured fish, with a water quality profile that tends to be stable.
Key Words: climate change, coastal, floating cage, tidal flood, water quality.

Introduction. Climate change has had a very broad impact on ecosystem changes in coastal waters (Chapman et al 2020). The impact of climate change on coastal ecosystems has an impact on the resultant sea level rise and soil erosion resistance (Funtes-Santos et al 2021). The resultant impacts of climate change in coastal areas force land conversion and regional relocation, so that the extraordinary impacts of climate change pose challenges for coastal communities to adapt to current conditions (O'Donnell 2021). On the coast of Pekalongan Regency, rising sea levels trigger tidal inundation. Rob inundation has occurred in the Tirto and Wonokerto sub-districts since 2010, which has caused 388.11 ha of paddish land due to permanent tidal inundation (Kasbullah & Marfai 2014). Fish farming activities are one of the community's choices to adapt to the impacts of climate change in the coastal environment (Ahmed & Turchini 2021).

Fish farming is a productive aquaculture activity that can be developed in coastal waters or inland waters (Ariadi et al 2021a). However, the tidal flood in Pekalongan also caused damage to the land for plugged-in ponds and losses, because many fish were released due to overflowing water (Marfai et al 2014). Adaptive fish farming methods using floating net methods were tested through a program for inclusive-communities to increase the adaptive capacity of coastal communities and areas at risk of climate change (Indonesia and the Philippines). The use of floating cage cultivation is one of the popular aquaculture concepts developed for fish farming activities in coastal and offshore areas

(Beveridge 2004). The advantages of cultivation with floating cage ponds include being more adaptive to environmental conditions, higher stocking density and lower production costs (Aizonou et al 2021).

In aquaculture activities, important parameters that play a vital role in the success of aquaculture are the presence of plankton and the dynamics of fluctuations in water physics parameters (Ariadi et al 2021b). Plankton are aquatic microorganisms that are unstable and their movements are strongly influenced by currents and water waves (Ariadi et al 2019b; Wafi et al 2021). The structure of abundance and diversity of plankton is a form of biological indicator of the condition of an aquatic environment (Tulsankar et al 2021). Meanwhile, water quality is a scientific parameter that describes the conditions that exist in aquaculture ecosystems (Ariadi et al 2019c). Plankton and water quality are key parameters that play an important role in the course of the fish culture cycle (Gilles et al 2013).

Based on the description above, the purpose of this study was to determine the plankton profile and water quality conditions on the tidal flood inundated paddish land which was developed as a demonstration plot for climate-resistant fish farming activities and the potential for its future use. It is hoped that in the future coastal communities affected by tidal inundation can create an adaptive fish farming concept that is resistant to the impacts of climate change in coastal areas (Ariadi et al 2020b).

Material and Method

Description of the study sites. This research was conducted in floating cage fish farming in Jeruksari Village, Pekalongan Regency. Sampling was carried out by purposive sampling on 8 plots of aquaculture cages which were carried out every 4 days for 2 months of fish cultivation (November-December 2021). The parameters observed were plankton profiles and water quality parameters which included salinity, pH, temperature, dissolved oxygen and Total Dissolved Solid (TDS).

Data measurement. The plankton profile observed was the identification of species, plankton abundance, plankton diversity and plankton dominance index. Plankton samples were taken from the cage water column using a water sampler and then stored in a 50 ml sample bottle to which Lugol's solution had been added. Furthermore, the plankton samples were observed using a haemocytometer Neubauer™ to see the type and number of individual plankton densities. Then the abundance of plankton is calculated using the formula introduced by Ariadi et al (2019b):

$$\text{Abundance (cell mL}^{-1}\text{)} = ((Z \times F)/V)) \times 100$$

Where:
Z - the number of identified individual plankton species;
F - the calculated area of the haemocytometer box;
V - the volume of the sample water.

In order to determine the diversity index plankton species were identified and counted with the haemocytometer, then the Shannon-Wiener index formula was applied, as follows Ariadi et al (2019b):

$$H' = \sum_{i=1}^{n} pi \ln pi$$

Where:
H' - Shannon-Wiener diversity index;
pi - ni/N; ni=number of individuals of the i species;
N - the total number of individuals.

The plankton dominance index is calculated based on the following formula Ariadi et al (2019b):

$$D = \sum_{i=1}^{s} (pi)^2$$

Where:
D - Simpson dominance index;
Ni - number of individuals of the i species;
N - total number of individuals;
S - number of genera.

In situ measurements were made for the following water quality parameters: salinity measured using a refractometer, pH measured using a pH meter, dissolved oxygen and temperature measured using a DO meter YSI550i and total dissolved solid measured using a TDS meter.

Statistical analysis. The data are grouped based on the sampling time, then data were analyzed descriptively using Microsoft Excel. Furthermore, data were analyzed statistically by using the SPSS software ver. 16.

Results and Discussion

Floating cage design. The floating cage used in this climate-resilient fish culture is made of materials that are easily available in the surrounding environment, such as bamboo, nets, ropes and stones. Floating cage ponds enable the adaptive management of the culture (Fialho et al 2021). Adaptive cultivation activities will indirectly support a higher level of harvest productivity (Ariadi et al 2020a). The design of aquaculture cages at the research site is also adapted to the biophysical character of the existing environment.

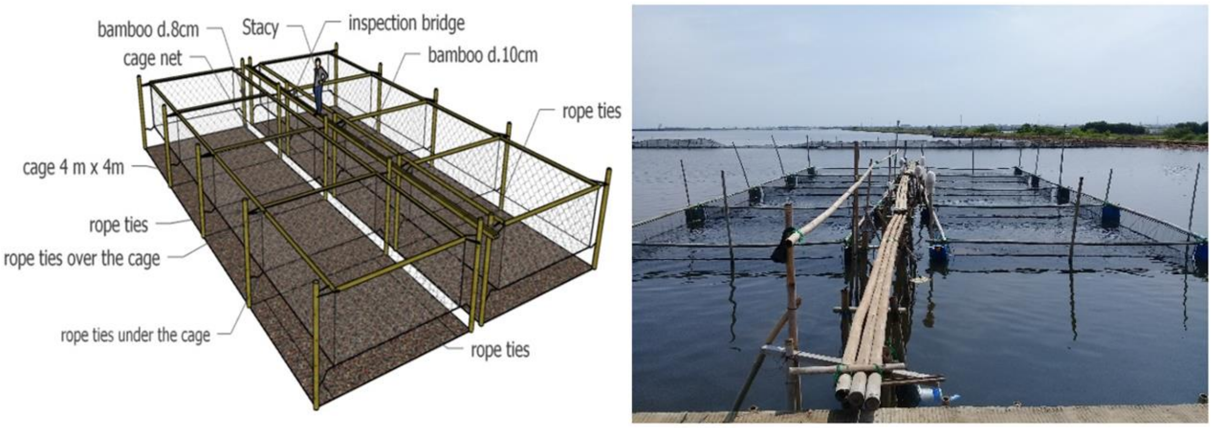

Figure 1. Floating cage design for fish culture (original photo).

The fish commodities cultivated in these cages are milkfish and tilapia fish, which are relatively easy to cultivate and are sold for a fairly high price (Ariadi & Abidin 2019). The duration of a cultivation cycle for tilapia and milkfish ranges from 2-3 months (Fialho et al 2021). Thus, the concept of cultivation with a relatively cheap production capital and for a relatively short period of fish rearing is very profitable to be carried out regularly.

Water quality parameters. Table 1 shows the average value of water quality parameters during the fish farming periods. Water quality parameters tend to fluctuate stable during the fish farming periods. From the water quality parameters measured, namely temperature, dissolved oxygen, salinity, pH and the number of dissolved particles, the majority are still in accordance with the water quality standards for fish farming activities, as presented in Khan et al (2017). The existence of stable and feasible water quality parameters strongly support the productivity rate of the fish farming cycle and increases the level of harvest productivity (Ariadi et al 2019c).

The total dissolved solid parameter value is quite high due to the location of the cages in the estuary area, thus allowing the accumulation of suspended particles from river or sea waste. Total dissolved solid, that comes from the accumulation of organic matter and suspended solids in aquatic ecosystems, generally originates from household and industrial waste (Weber-Scannell & Duffy 2007). A high value of total dissolved solid can interfere with the sunlight penetration into the water column, so that the photosynthetic activity by phytoplankton becomes less than optimal (Mustapha 2017).

Table 1

Water quality during fish culture periods

Ponds	*Water quality parameters*				
	Total dissolved solids	*Temperature*	*Dissolved oxygen*	*Salinity*	*pH*
B1	4.98±1.31 Min 2.92 Max 7.76	28.07±1.72 Min 25.20 Max 31.25	5.32±0.74 Min 4.10 Max 6.38	18±3.53 Min 10 Max 25	8.0±0.10 Min 7.7 Max 8.1
B2	4.97±1.41 Min 3.28 Max 7.82	28.00±1.54 Min 26.00 Max 31.00	5.43±0.51 Min 4.25 Max 6.15	18±3.53 Min 10 Max 25	8.0±0.10 Min 7.7 Max 8.1
B3	4.99±1.28 Min 3.21 Max 7.52	28.46±1.60 Min 26.50 Max 31.25	5.35±0.56 Min 4.15 Max 6.15	18±3.53 Min 10 Max 25	8.0±0.10 Min 7.7 Max 8.1
B4	4.98±1.12 Min 2.95 Max 6.59	28.39±1.56 Min 26.50 Max 31.10	5.43±0.53 Min 4.20 Max 6.21	18±3.53 Min 10 Max 25	8.1±0.11 Min 7.7 Max 8.1
N1	5.14±1.28 Min 2.88 Max 7.49	28.26±1.61 Min 26.00 Max 31.25	5.37±0.71 Min 4.15 Max 6.38	18±3.53 Min 10 Max 25	8.0±0.11 Min 7.7 Max 8.1
N2	5.22±1.12 Min 3.05 Max 7.37	28.11±1.64 Min 26.25 Max 31.10	5.43±0.78 Min 4.15 Max 6.90	18±3.53 Min 10 Max 25	8.0±0.11 Min 7.7 Max 8.1
N3	5.13±1.25 Min 3.12 Max 7.49	28.21±1.69 Min 26.10 Max 31.15	5.43±0.74 Min 4.10 Max 6.85	18±3.53 Min 10 Max 25	8.0±0.11 Min 7.7 Max 8.1
N4	5.30±1.15 Min 3.05 Max 7.49	28.18±1.59 Min 26.38 Max 31.25	5.49±0.68 Min 4.15 Max 6.90	18±3.53 Min 10 Max 25	8.0±0.11 Min 7.7 Max 8.1
*Water quality standard	0.13	25-30	>4	15-35	6.6-8.5

*FAO (2020).

***Salinity and pH water**.* The salinity and pH values of the waters during the study period experienced fairly dynamic fluctuations (Figure 2). Fluctuating salinity and pH values were caused by uncertain weather changes at the research site. Weather fluctuations will affect the ecological dynamics in coastal aquatic ecosystems (Ariadi et al 2020b). The highest decrease in salinity value occurred for a fish culture period of 31 days, while the highest decrease in pH occurred for a fish culture period of 40 days. Low salinity levels and high water pH values will determine the level of colloid particles in the waters to increase slowly (Ritvo et al 2003; Ariadi et al 2019a).

The salinity dynamic fluctuation values at the age of 31-34 days is due to the fact that this period is a transition period from rainy to summer weather. The condition of the transitional season will affect the level of decrease or increase in salt or mineral compounds in coastal aquatic ecosystems that take place dynamically (Bal et al 2021). Meanwhile, the pH value tends to dynamically fluctuate when the age is 25-49 days, which also stands for the transition season. pH fluctuating values will affect the level of biochemical processes in aquaculture waters (Ritvo et al 2003). Thus, unpredictable weather will have a direct influence on fluctuations in pH and salinity values in fish culture cages.

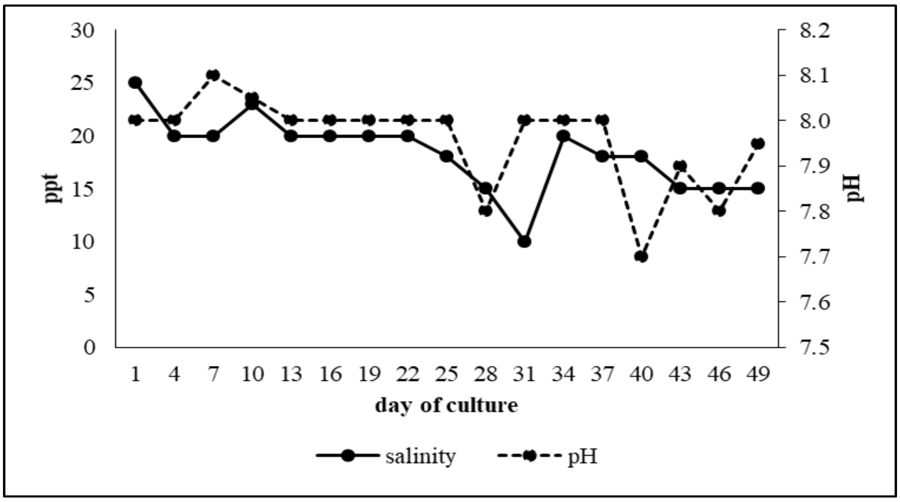

Figure 2. Salinity and pH water during fish culture periods.

Total dissolved solids and dissolved oxygen. The concentration of the amount of dissolved solids in the study pond has a fluctuation graph similar to the level of oxygen solubility (Figure 3). That is, there is a correlation between the increase in dissolved solids content and the increase in the oxygen solubility in the water. Thus, it can be hypothesized that the dissolved particle solids increase in the waters comes from the increase in the number of phytoplankton populations, so that the phytoplankton can increase the solubility of oxygen in the waters through the process of photosynthesis. Increasing the photosynthetic process in waters is influenced by the plankton abundance and environmental factors (Xing et al 2019). In addition, the increase of dissolved particle solids and oxygen solubility will also affect the decomposition process by aquatic microorganisms (Ariadi et al 2019c).

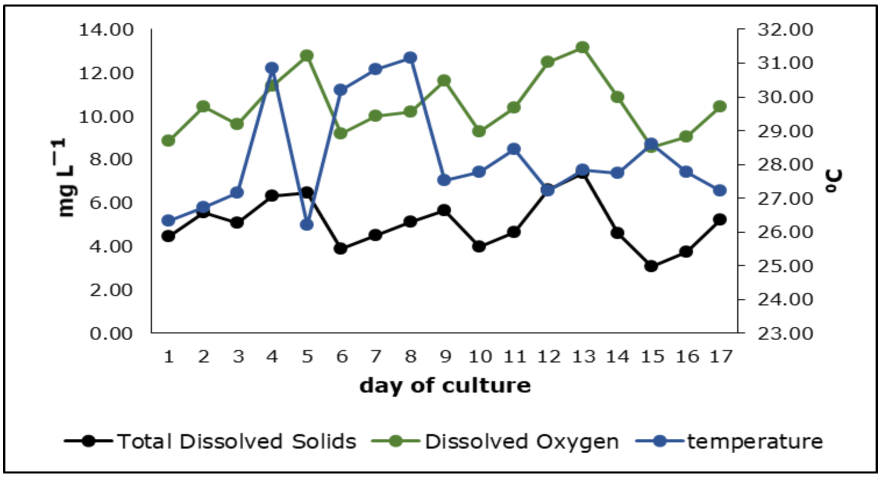

Figure 3. Total dissolved oxygen and dissolved oxygen during fish culture periods.

The oxygen solubility levels in these waters are also influenced by temperature fluctuations value in the waters (Figure 3). The water temperature increasing will determine the oxygen solubility decrease in the pond ecosystems (Ariadi et al 2019). Temperature fluctuations in the waters may also be caused by the dynamics of the solubility from dissolved particle solids due to feed waste and other aquaculture inputs in the cages. The temperature and dissolved organic particles in aquaculture ecosystems will tend to fluctuate seasonally at each cultivation time period (Sutherland et al 2020).

Plankton abundance. The abundance of plankton found in the aquaculture cages based on their genus can be seen in Table 2. Plankton from the Crysophyta class has a higher diversity of genera than others. Some plankton from the Crysophyta class in the food chain ecosystem in aquaculture ponds act as limiting factors (Clouzot & Varolleghem 2019). Crysophyta type plankton are very good to be used as live feed in aquaculture cultivation activities. The biological development of plankton Crysophyceae is strongly influenced by the conditions of the waters in the environment around the aquaculture ponds (Hossain et al 2017).

Table 2

Genus of plankton community during fish culture periods

Family	*Chloropyceae* (cell mL^{-1})	*Cyanophyceae* (cell mL^{-1})	*Crysophyceae* (cell mL^{-1})	*Dinophyceae* (cell mL^{-1})	*Zooplankton* (cell mL^{-1})
Genus	*Chlorella* sp. (1.76×10^6)	*Oscillatoria* sp. (1.00×10^6)	*Amphora* sp. (3.80×10^5)	*Peridinium* sp. (3.00×10^4)	*Tintinnopsis* sp. (3.00×10^4)
	Oocystis sp. (6.00×10^4)	*Anabaena* sp. (3.50×10^5)	*Cyclotella* sp. (2.20×10^5)	*Noctiluca* sp. (1.00×10^4)	
	Chlamydomonas sp. (1.00×10^4)	*Chroococcus* sp. (3.00×10^4)	*Nitzschia* sp. (6.00×10^4)	*Gymnodinium* sp. (1.00×10^4)	
		Anabaenopsis sp. (8.00×10^4)	*Amphiprora* sp. (4.00×10^4)		
		Microcystis sp. (9.00×10^4)	*Chaetoceros* sp. (1.00×10^4)		
		Gomphosphaeria sp. (1.00×10^4)	*Scenedesmus* sp. (2.00×10^4)		
			Skeletonema sp. (2.00×10^4)		

The existence of diverse plankton genus will make the aquaculture waters to be a better habitat. The N and P ratio proportions in sufficient and appropriate waters will allow plankton to carry out massive succession (Smith et al 2019). Plankton with more diversity indicates that the waters are very fertile (Ariadi et al 2021a). In open water, plankton can be used as an ecological indicator to assess the feasibility of aquatic community (Xu et al 2016).

Overall, based on the existing of plankton community structure, the plankton at the research site is appropriate for being used as live feed. The planktonic chloropyceae and crysophyceae have good protein content values as fish and shrimp feed (Novriadi et al 2021). Meanwhile, other plankton genera identified at the research site, such as cyanophyceae and dinophyceae, are classified as minor.

***Plankton diversity index and dominance index**.* The value of the diversity index and the dominance of plankton in the aquaculture ponds can be seen in Figure 4. The value of the plankton diversity index (H') in this study ranged from 0.50-1.92, which means that, on average, the level of diversity and stability of plankton in the aquaculture pond ecosystem is quite moderate. A value of the H' index ranging from 1-3, means that the level of biological diversity and stability of the microorganism habitat is between relatively moderate and good (McQuatters-Gollop et al 2019). Meanwhile, if for the plankton dominance index (D) in the floating caged waters the value is between 0.12-0.66, it means that the level dominance of certain species in the community is from very low to moderately high. The dominance index is an important parameter that reflects the ecological character and biological structure in the water ecosystem (Gao et al 2018).

The values of the plankton diversity and dominance index which is quite good means that it indicates that the bioecological parameters in the waters used as the location of aquaculture activities are quite good. The value of biological parameters, such as stable plankton and bacteria will have an impact on the balance of environmental ecosystems that tend to be productive (Ariadi et al 2021a). In addition, the level of plankton abundance, which tends to be stable, will affect the availability of live feed that is always available for fish cultured (Pratiwi et al 2011). The availability of plankton as live feed and environmental bioindicator agents in aquaculture activities is a key indicator for us in navigating the fish farming cycle (Ariadi et al 2020a).

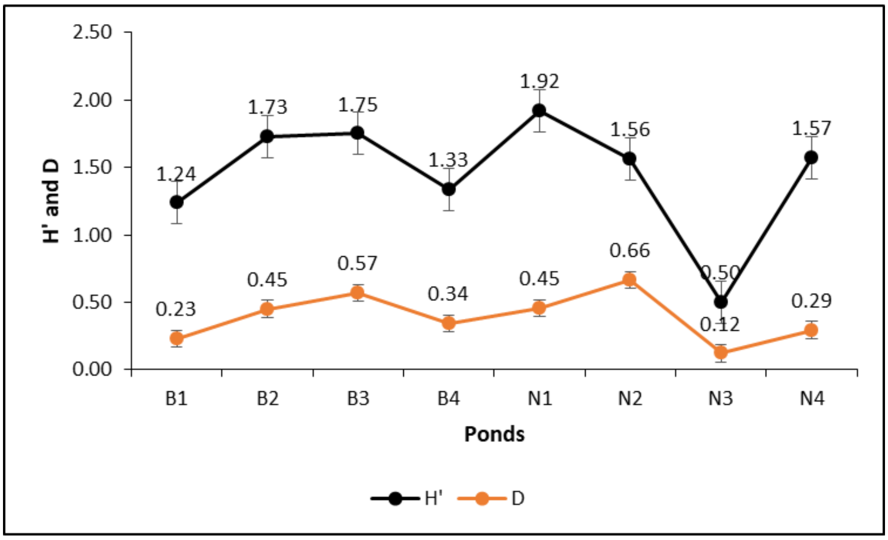

Figure 4. The diversity index and dominance index of plankton.

Plankton dominance. The plankton dominance in the pond has a correlation to the level of oxygen solubility in the waters which is described by the equation y=0.0161x + 5.3334 (Figure 5). The R^2 value from the regression equation is 0.5264, which means that every 1 mg L^{-1} increase in dissolved oxygen will affect to increase of plankton diversity index value at 52.64%. The dynamics of fluctuations and oxygen depletion in the waters will affect the level of plankton diversity and the plankton dominance in these aquatic ecosystems (Takarina et al 2019). Thus, the dynamics of the plankton ecosystem will have consequences for various physical, chemical and biological processes in the waters (Hendrajat & Sahrijanna 2018).

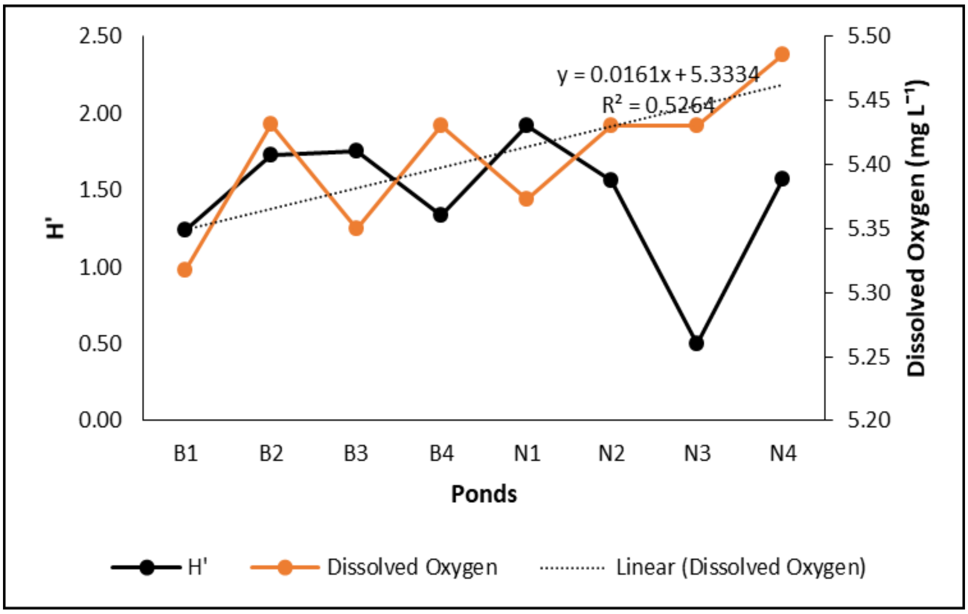

Figure 5. Correlation of plankton dominance with dissolved oxygen.

The dynamic level of plankton dominance indicates that the primary productivity conditions in these waters tend to be stable. Aquatic primary productivity is a fundamental indicator that has a major impact on the energy utilization process in aquatic ecosystems (Verma & Srivastava 2016). In addition, the existence of the dominance and diversity of plankton will also have an influence on the grazing levels and on the biogeochemical cycle of the waters (Yang et al 2020). Thus, there are so many influences from the presence of plankton in the waters, making the role of these microorganisms very important.

Overall, the value of water quality fluctuations in the cage ecosystem is still quite stable and in accordance with the water quality standard index for fish farming, except for the total dissolved solids parameter. The fluctuation of water quality is influenced by the weather factors and by the amount of aquaculture input loads (Chapman et al 2020). Weather conditions and fluctuations in water quality parameters, that take place dynamically, have consequences for the dynamics of the plankton abundance and dominance in the aquaculture waters (Murphy et al 2019). Thus, apart from the primary productivity factor, the cycle of plankton dominance in aquaculture waters will continue to run dynamically due to the impact of climate change.

At the aquaculture cages, there were found as many as 5 plankton genera, consisting of 19 phytoplankton species and 1 zooplankton species, with a moderate level of diversity and a low species dominance index. The moderate plankton diversity index and the low species dominance index indicate that the plankton population in these waters tends to be stable and good conditions (McQuatters-Gollop et al 2019). The level of stability of abundance and dominance of plankton will correlate with the grazing process and the predation chain in aquatic ecosystems (Valenzuela-Sanchez et al 2021). The plankton dominance index also has a mathematical correlation with the level of oxygen abundance in aquaculture waters cycle (Dhar & Baghel 2016).

Conclusions. Based on the structure of the plankton profile and the dynamic conditions of the studied water quality parameters, it was determined that the plankton community in the aquatic ecosystem in aquaculture cages has the potential to be used as live feed for cultured fish, with a water quality profile that tends to be stable.

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Conflict of interest. The authors declare no conflict of interest.

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