Environment-friendly floating net cage culture research in Indonesia

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Abstract. Reservoirs and lakes are widely used for fisheries, both capture fisheries and aquaculture. Aquaculture fisheries that develop in reservoirs or lakes include floating net cages culture (FCC) and pen culture. Besides impacting the economy and employment opportunities, aquaculture activities through FCC can decrease water quality from uneaten feed and fish metabolism residue. For this reason, an environmentally friendly FCC is needed to reduce aquaculture waste. This paper reviews the development of ecologically friendly FCC research in Indonesia. Several studies on environmentally friendly FCC include double net FCC, bio-cages, carpel FCC, windowed, and triple layer FCC. Double net FCC still allows the remaining uneaten feed and feces to settle. Bio-cage research is in the innovation model stage and has no prototype or laboratory tests. Windowed FCC, made with a closed system and a few gaps for circulation, can accommodate aquaculture waste and not spread into the waters, but fish grow slower than other FCC. The loop bio-phytoremediation of FCC or Smart FCC has three layers that can accommodate waste, and the waste will be used for plants that function as filters and phytoremediators of waste. Smart FCC is an aquaponic system modified to be applied in reservoirs/lakes.

1. Introduction

Reservoirs or lakes are stagnant waters widely used for fishing activities, capturing fisheries, and aquaculture. The aquaculture proliferating in reservoirs and lakes is floating net cages (FCC). At first, the community carried out cultivation activities in the FCC as compensation for the community affected by the construction of the reservoir. The FCC in reservoir waters is an alternative to changing the profession from rice field farmers to fish farmers. The use of reservoirs for FCC is, in principle, permitted, provided it does not exceed

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the carrying capacity of the reservoir and does not interfere with the primary function of the reservoir as a hydroelectric power plant [1].†

The FCC has an impact on the community and the aquatic environment. The FCC can increase fish production capacity [2,3]. The aquaculture business has had a positive impact on the economic development of the local community. The FCC business could improve the community's economy well reduce poverty and unemployment [4]. Some of the advantages of FCC, such as relatively easy maintenance and high production, have led to high community interest in doing business in this field [5]. The existence of FCC also has an impact on the social conditions of the community, such as increasing employment because one worker can handle 4-8 plots of FCC, increasing people's insight, maintaining relations between one culture and another culture and all other communities that provide benefits for the life and development of the surrounding community and empowerment community which is carried out through the development of FCC business forms the character of a more independent and creative community [3,4,6,7].

The disadvantages of FCC include accelerating eutrophication due to excess nutrients from uneaten feed and increasing dissolved solids and nutrients in the water column from aquaculture activities [8]. Uneaten feed and feces from FCC that accumulate can reduce water quality [9], such as in the case of Lake Maninjau, which had 17,000 plots of FCC in 2017, where this number was three times the carrying capacity of 6,000 plots according to Agam Regency Regional Regulation No. 5 of 2014. As a result, there was sedimentation of feed at the bottom of the lake, which is estimated to have reached 95.34 % and had an impact on the mass death of fish, namely 160 tons in Lake Maninjau in February 2018, with a loss of around IDR 3.75 billion [10].

Research on aquaculture technology in environment-friendly FCC is urgently needed to prevent losses from aquaculture activities. The purpose of writing this paper is to know the results of research on environmentally friendly FCC that has been conducted in Indonesia

2. Development of an environment-friendly FCC research

Floating net cages are a method of pisciculture in cages that consists of four fundamental patterns of pisciculture, namely: 1. Fixed cages are a form of fish cages where stakes are attached to the bottom of the water. 2. Submerged cages are a form of fish cages that are submerged in water and depend on buoys/floating frames. 3. An off-bottom cage is usually made of wooden/bamboo boxes, placed on the bottom of fast-flowing water, and given weight/anchor. 4. This floating net cage (FCC) is attached to a frame supported by floaters [1].

Activities of FCC are engaging because the selling price of yield fish is more stable than the selling price of fish caught by fishermen which tends to fluctuate and provides more profit compared to capture effort at 97.14% [11]. However, there are impacts from FCC activities such as environmental pollution, changes in fish community structure, and sedimentation [8], so research on environmentally friendly cage culture continues to be developed. Several studies on environmentally friendly FCC in Indonesia include:

2.1. Layered nets or double nets of FCC

Initially, aquaculture activities through FCC were single-net FCC. However, the feeding of the pump system causes much feed to be wasted or uneaten and accumulates and decomposes at the bottom of the waters, thereby degrading water quality. If turnover, it will contaminate the waters and can cause mass death of fish. To minimize feed wastage, a dual netting arrangement was implemented. In this system, carp inhabit the inner or upper nets, while tilapia occupy the outer or lower nets. Carp fish are given pelleted feed, while tilapia are not given feed because tilapia will utilize the uneaten feed of carp that escapes from the upper net. This system is expected to reduce the impact of environmental pollution and add value to tilapia. The double net FCC trial in the Jatiluhur Reservoir used an upper net cage measuring 1xlxl m (submerged part 1 m^3) and a bottom net cage measuring 3x3x8 m3 (submerged part 1,3x1.3x1.5 m^3) (Figure 1). From this system, the added value of tilapia is equal to getting additional production from tilapia, ranging from 49.48% - 17.24% (32.24%) [12].

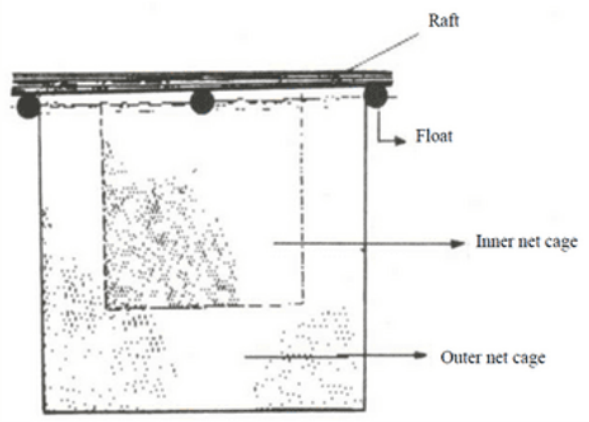

Fig. 1. Double mesh marine cage system with outer and inner layers [12]

Meanwhile, the layered net cage or doublet net FCC tested in Lake Maninjau slightly differed from those tested in the Jatiluhur Reservoir. The layered FCC trial at Lake Maninjau used a size of 5 x 5 x 3 m for the inner layer nets (two nets) and a size of 12.5 x 6 x 5 m for the outer layer nets (one net) (Figure 2). The fish tested were carp in the inner nets and tilapia in the outer nets, like a study by Pratiwi et al. (1998). From this system, value-added production of tilapia produces additional tilapia production of 4.31% - 6.45% [13].

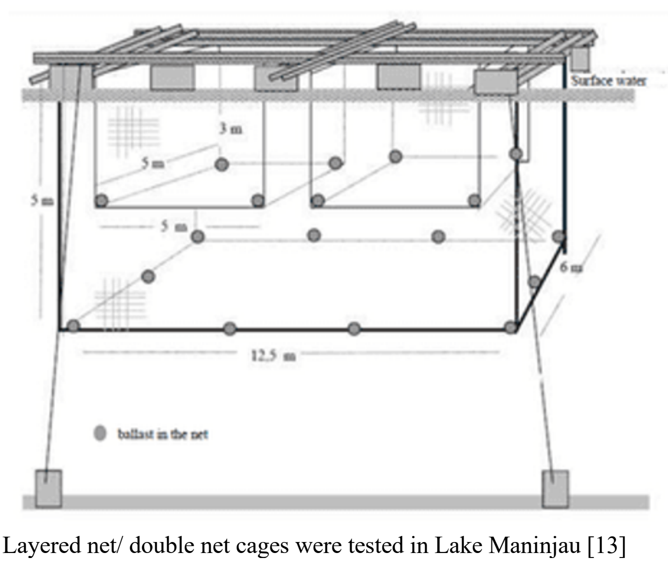

Fig. 2. Layered net/ double net cages were tested in Lake Maninjau [13]

The two types of layered FCC show that some of the uneaten feed from carp in the inner nets will be utilized by tilapia in the outer nets. So the cage system can improve feeding efficiency and further reduce the impact of excess pelleting. However, it is still possible for the spread of uneaten feed and sedimentation to occur faster than utilization by tilapia.

2.2. Chapel FCC

This system improves the layered FCC previously carried out in Lake Maninjau by researcher Triyanto et al. (2015). Chapel FCC is an FCC system with a chapel, a waste storage bag made of fabric and nylon gauze. The experiment used a cage net measuring 3 x 3 x 3 m^3 with a mesh size of 1.5 inches. The chapel measures 4 x 4 x 4 m3 (Figure 3) and is placed outside the cage nets to accommodate waste. The chapel is installed 0.2 m below the water level. There is a minimum distance of 50 cm between the cage nets and the chapel, which aims to facilitate the lifting of the nets already filled with waste that has been accommodated at the bottom of the chapel. Every 3-5 days, the waste collected in the chapel is taken by sliding the sides of the nets to make it easier to collect the remaining feed in the chapels. The chapel with cloth material experienced clogging on all sides of the chapel. A few days before collection, the dissolved oxygen levels are already deficient (about 2 mg/L), and the fish become stressed because waste deposits cover the very dense texture of the fabric and inhibit water flow and oxygen exchange. Experimental results with nylon gauze chapel for 60 days with a total feed of 200 kg produced waste that could be lifted by 34.9 kg of wet weight or the equivalent of 19.4 kg of pellets or dry waste so that the efficiency of nylon gauze chapels was 67% [14]. The weakness, especially the system for removing waste from the chapel, requires improvements to the design, construction, and materials of the chapel and equipping the chapel with a vacuum system to minimize waste escaping from the chapel

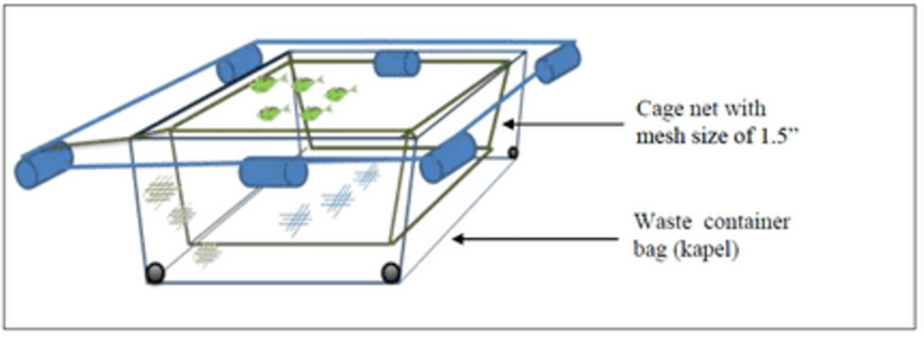

Fig. 3. Chapel system of FCC [14]

2.3. Bio-Cage

Bio-Cage Technology which is friendly to the water environment is an FCC improvement technology by developing an environmental Floating Bio-Cage design with Eco-technology engineering. Principles Bio Cage applies eco-technology based on recycling principles using mycobacteria. The Bio-Cage component has components like layered FCC [12,13] by adding two other components. Bio-Cage components consist of 4 parts, namely 1). Components are forming the inner net; 2). Outer layer net components; 3). Component of the bag catching the remaining waste in the bottom segment, and 4). Bio-septic cages that function as a neutralizer for uneaten feed fish. The principle of Bio-Cage (Figure 4) is neutralizing the remaining uneaten feed fish using local micro-bacteria for decomposing waste to adapt to the environment. Uneaten feed and tilapia feces collected in bags will be processed using a bio-septic container that is suspended and placed on the bottom of the FCC. The bio-septic container placed local micro bacteria to decompose waste [5]. The principle of Bio-Cage refers to bioremediation to improve water quality by channeling used aquaculture water to a waste treatment tank. Aquaculture waste treatment tanks are generally equipped with biological filters, which can hup to the development of nitrifying bacteria [15].

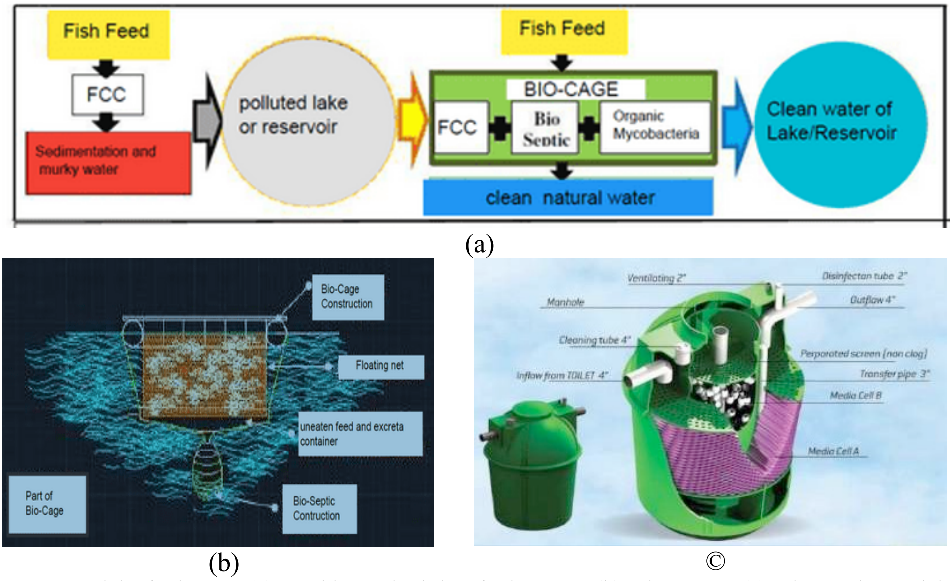

Fig. 4. Model of Bio-cage(a) working principle of Bio-cage; (b) Bio cages, (c) Bio-septic model of neutralizing fish feed residue [5]

Bioremediation is defined as the process of decomposing organic waste or biological pollutants. One of the bioremediation agents that can be applied is bacteria. Bacteria, which act as organic waste bioremediators, can grow by utilizing organic matter as a protein source to increase their biomass [12]. An example of bioremediation is water quality improvement, such as reducing ammonia and nitrite, by utilizing the ability of microorganisms. Several nitrifying bacteria, such as Nitrosomonas and Nitrobacter, can degrade ammonia to nitrite and nitrate [15]. The benefits of bioremediation in agriculture can increase the decomposition of organic matter in aquaculture water and improve the ecology of the aquaculture environment by minimizing toxic gases such as ammonia, nitrite, hydrogen sulfide, methane, and others [16].

Laboratory and prototype bio cage tests have yet to be carried out, so further research is needed [5]. To make use of bacteria that break down organic substances, one must consider the environmental factors that foster the proliferation of these bacteria. These environmental factors prevent and suppress pathogenic bacteria growth [17].

2.4. Smart FCC

Smart or loop bio-phytoremediation FCC is an FCC with water management through recirculation and plants. This aquaponic system has been modified to be applied in open waters such as reservoirs or lakes [18,19] Smart FCC combines feed storage techniques with waterproof materials and water recirculation, which can also be applied to double nets [20]. The Smart FCC is an FCC that can reduce the input of organic pollutants from wasted feed and fish excretion [18]. Aquaponics is the integration of aquatic and hydroponic cultivation activities (soilless horticultural cultivation) in which water derived from aquaponic activities is used for agricultural cultivation activities [21], thereby purifying the water [22,23]. Plant growing media in aquaponics can be coconut husk, gravel, and others, but this is not used to provide plant nutrition. Previously, Bangladeshi researchers experimented on the Integrated floating cage aquageoponics system (IFCAS) (Figures 5 and 6), where there were differences between the plant media and the aquaponic system, which is a system that utilizes dry pond mud collected from the same pond as a plant anchoring medium. As this provides additional nutrients, the system is best described as aquageoponics, where aqua, geo, and ponic mean pond water, pond mud/soil, and culture, respectively [22].

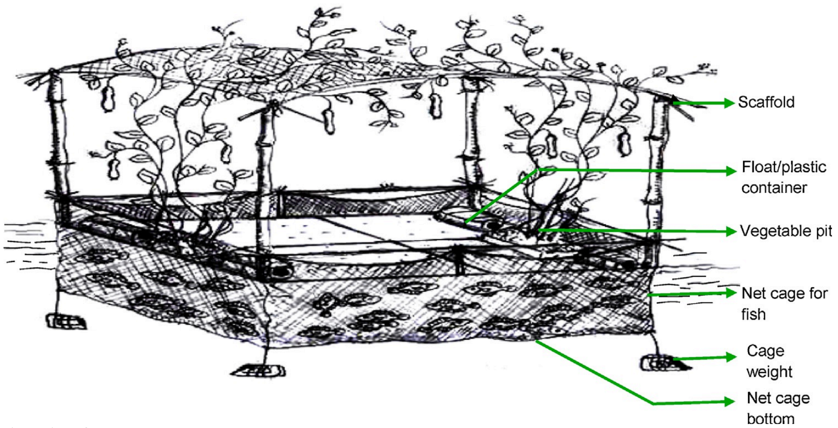

Fig. 5. Sketch of IFCAS [22]

Fig. 6. Model of IFCAS [23]

Meanwhile, Smart's FCC research, which integrated aquaculture and hydroponic activities, resulted in the following:

2.4.1. Windowed smart FCC

The pond uses waterproof material measuring 7m long, 7m wide, and 2.5 m deep, with a water circulation window measuring 1m long and 50 cm wide on two sides of the FCC. There are six windows, and the distance between windows is 50 cm. This circulation window functions to circulate water between the FCC and reservoir waters. The remaining wasted fish feed and feces will be accommodated at the bottom of the pond and lifted by sweeping and pumping. The purpose of providing a window is to keep water circulating so that the lack of oxygen in the pond can be minimized, but the feed does not spread and still fall in the Smart FCC. Pool windows are made on the sides of the pool using a ¾ inch net so that they become semi-closed. (Figure 7). The remaining feed that is collected at the bottom of the pond is lifted by sweeping and pumping and then accommodated in a holding tank, and then distributed to hydroponic plants as a source of plant nutrition (Figure 8) [18,19].

Fig. 7. Windowed of Smart FCC

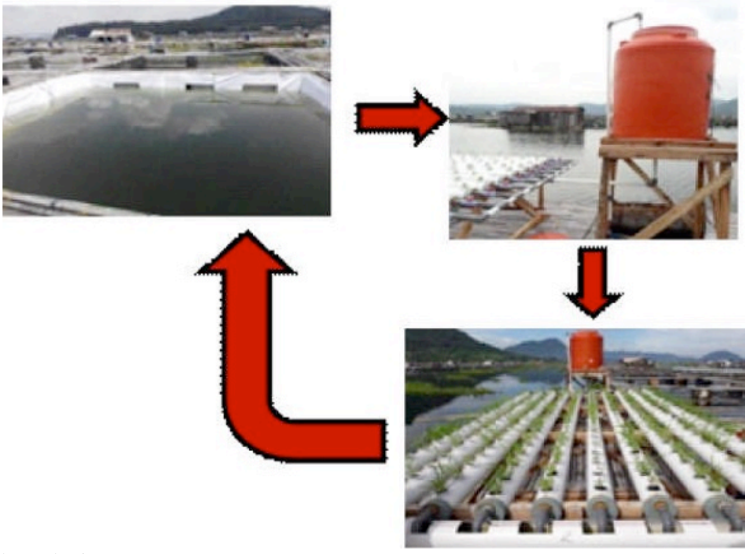

Fig. 8. Windowed of Smart FCC System [18,19]

The Smart window cage system using water spinach as a hydroponic plant and biofilter can reduce the content of $P\text{-}PO_4$, $N\text{-}NO_3$, and organic matter after passing through the aquaponic plants respectively from 6.3-84.8%; 4.1 -77.7% and 8.8-90.71% [18]. This windowed Smart FCC still needs construction improvements, especially the system for lifting waste so it does not interfere with the water quality and technology that makes it easier to harvest fish.

2.4.2. Three-layer Smart FCC

In 2021 research in the Jatiluhur Reservoir using a Smart FCC with a double net consisting of two upper nets measuring 7 x 7 x 3 m and a bottom net measuring 14 x 7 x 6 m. This FCC is an improvement over the Smart windowed construction. The Smart FCC consists of 3 (Figure 9) layers: the surface, second, and third. The first layer of the net is covered with a cover on each side to a certain depth below the water surface. This layer functions so the fish feed does not spread into the waters because the cover layer hampers it, and the remaining wasted feed will sink to the bottom. The second layer is the circulation layer, namely a net without a cover so that it functions as a place for water and air exchange so that the air needs for fish are met. The third layer is a waterproof layer made of tarpaulin or geomembrane. It is made like an inverted cone that directs fish feed that is not eaten by fish toward the waste collection tube and wasted feed residue [24]. The principle of this FCC (Figure 10) is similar to that of the Smart FCC with a windowed [18]; the results of sucking up the remaining feed waste that collects in the collection bag is accommodated in the tank and flowed to the phytoremediation component, namely the hydroponic component and artificial wetlands. Hydroponic plants use water spinach, and artificial wetland plants use vetiver. After the phytoremediation, components flow into a physical filter consisting of layers of limestone, sand, and palm fiber [24,25]. Water spinach was chosen because it grows fast and can reduce nitrite by 88.15%, nitrate by 69.49%, phosphate by 48.38%, and organic matter by 42.86%]26]. While vetiver can reduce P concentrations by up to 98% after 3-4 weeks and 71-74% N in 4-5 weeks [27].

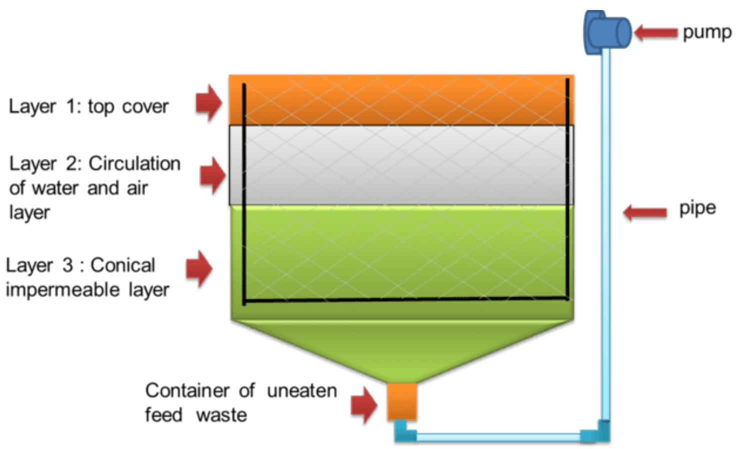

Fig. 9. Three layers of Smart FCC [20,26]

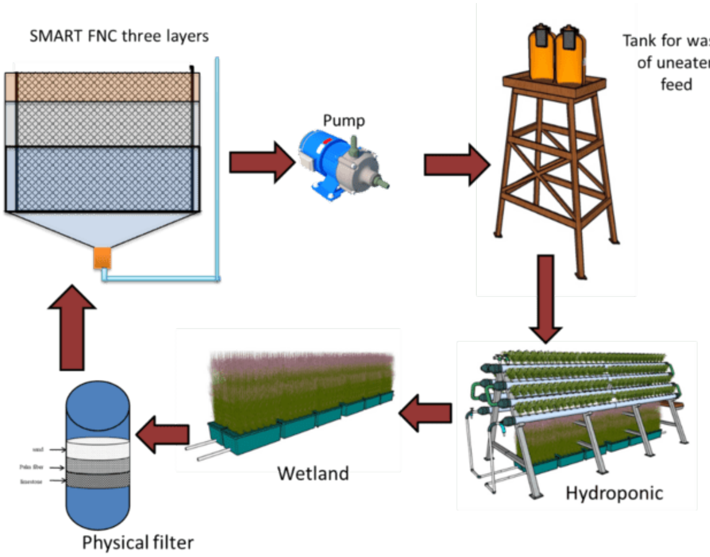

Fig. 10. Principal of three layers of Smart FCC [26]

Based on the explanation, SMART FCC has several advantages, namely:

1. Reducing the load of waste input into the waters
2. Integrated technology for fish-vegetable cultivation so that it can support household protein needs to ensure food security
3. Utilizing feed waste as fertilizer for hydroponic cultivation to reduce the production costs of horticultural crops. Vegetable plant products in the form of organic plants
4. Prevent and control eutrophication [19].

3 Conclusion

Based on the description above, several studies on environmentally friendly FCC have been conducted. These include double-layer FCC, chapel FCC, Bio-Cage, and Smart FCC, including windowed and 3-layer. Environmentally friendly FCC aims to reduce the input of waste from aquaculture activities in FCC, mainly uneaten feed and fish excreta. However, research on environmentally friendly cages is still needed so the community can quickly adopt them around the reservoir/lake and local water conditions.

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Declarations of author contribution

Lismining Pujiyani Astuti, Andri Warsa, Didik Wahju Hendro Tjahjo, and Tarzan Sembiring contributed as the primary contributor to this paper. All authors read and approved the final paper.

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