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Cage Culture and its Impact on Physico-Chemical Characteristics in Selected Reservoirs of Tamilnadu

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Abstract The present investigation was carried out in four reservoirs of Tamil Nadu namely, Mettur, Thoppiar, Poondi reservoirs and Kolavai lake, for a period of 6 months from March–August, 2014, where the cage culture has been already initiated by the state fisheries department. The water and sediment samples were collected from these selected reservoirs at point and non-point sources of the cage culture units and analyzed for their physico-chemical parameters. The plankton diversity, chlorophyll content, heterotrophic bacterial load and total *E. coli* population were also assessed from these reservoirs. During the study period, pH, sulfate, nitrate and BOD values were found within the permissible range for drinking water quality (BIS, 2012). The alkalinity values were found optimum in all the four reservoirs, except in Thoppiar reservoir. Among the four reservoirs, nitrite and phosphate values were observed maximum at Mettur dam. The average chlorophyll content (39.10 µg/l) was noticed at Kolavai lake. The sediment characteristics such as pH, electrical conductivity, total organic carbon and available phosphorus values were also found within the standard limit. The maximum plankton count (4.07 × 105 Nos./m^3) was observed at Thoppaiyar Dam. The optimum water and sediment quality characteristics and the absence of *E. coli* observed in these selected cage culture unit clearly showed that the small cage farming in the reservoirs does not have major environmental impacts on the water and sediment quality.

Keywords Sediment, Chlorophyll, Ammonia, Nitrite, Nitrate.

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Introduction

Cage culture is commonly practiced worldwide in both freshwater and marine environments, including open ocean, estuaries, lakes, ponds and reservoirs [1]. Generally growing fish in cages may have negative envi-

ronmental consequences. Cage cultured fish are entirely dependent on formulated diets. Relatively small portion of the organic matter and inorganic nutrients in feed applied to cages is transformed to fish biomass. It is estimated that for every ton of fish production in cage culture, 132.5 kg of nitrogen and 25.0 kg of phosphorus are released into the environment [2]. Furthermore, for tilapia cage culture, it was reported that 81—90% of carbon is lost from the cages to the surrounding environment [3]. For a reservoir where there is not much exchange of water, accumulation of these wastes potentially results in water quality deterioration such as eutrophication and anoxic water as reported in lake Cirata in Indonesia [4].

The possible consequences associated with cage culture farming include discharge of particulate and dissolved nutrients through uneaten waste feed, fecal matter and excretory products [5]. This may negatively impact the environment by causing anoxic conditions in sediments (due to organic enrichments) underlying the cages, thus changing the invertebrates abundances and compositions. In addition it may cause eutrophication due to nutrient enrichment of the water column [6]. Several studies have reported that nitrogen and phosphorus released from fish cage can affect chemical parameters of sediment [7, 8].

Increased nutrients in cages lead to changes in plankton assemblages and therefore the most affected ecological attributes are species composition, richness, diversity and species abundance of the planktonic assemblages. Furthermore farmed fish may escape and interact with other fish in the wild, the results of which is the spreading of diseases and parasites. All these may result into ecological simplicity, and decrease in genetic diversity (due to genetic dilution) and increased mortality of the wild stocks (due to transferred diseases).

Extensive studies on the ecological aspects and fisheries of certain lakes, rivers and reservoirs have already been made by several workers [9, 10]. However, the environmental impact of cage culture is often ignored and rarely subjected to study. There are no reported directly on the environmental impact of cage culture on the water quality of reservoirs of Tamilnadu.

Materials and Methods

The present investigation was carried out at four selected locations in Tamilnadu viz., Mettur Dam, Thoppiar Dam, Poondi Reservoir and Kolavai lake, in which the cage culture had been already initiated by the State Fisheries Department. In each reservoir, 12 cages were installed in two rows. Each cage size is 4 × 4 × 3 m with mesh size of 2 mm. GIFT tilapia and *Pangassius* sp were stocked at the rate of 60/m^3. The fishes were fed with floating pellet feed.

The water, sediment and plankton samples were collected once in a fortnight from these selected reservoirs at cage site and two control sites (5 m and 10 m away from the cage site). The water samples were collected in clean plastic containers without any air bubbles and labeled in the field. The sediment samples were collected with the help of snapper and brought to the laboratory in the polythene bags. The sediment samples were oven dried at 60°C for 24 h and grounded well and subjected for analysis.

Water quality parameters such as dissolved oxygen, temperature, alkalinity, hardness, total suspended solids, total dissolved solids, total organic carbon, ammonia-N, nitrate-N, nitrite-N, inorganic phosphorus, BOD, COD and sulfate were analyzed as per the procedures of APHA [11]. The sedimentary organic carbon was estimated by K-Jeldahl method. The biological parameters such as plankton diversity and chlorophyll content were also analyzed. The total *E. coli* population was enumerated once in a month from these reservoirs.

Results and Discussion

Water quality parameters are of much importance in fish culture system for the good growth of fishes, especially in the case of cage culture system under controlled condition. The dissolved oxygen content of the reservoir water was found optimum both at cage (3.89 to 9.71 mg/l) and control sites (4.38 to 10.6 mg/l) in all reservoirs (Figure 1). Water temperature plays an important role in creating layers of different densities in water column during thermal stratification which results in the uneven distribution of nutri-

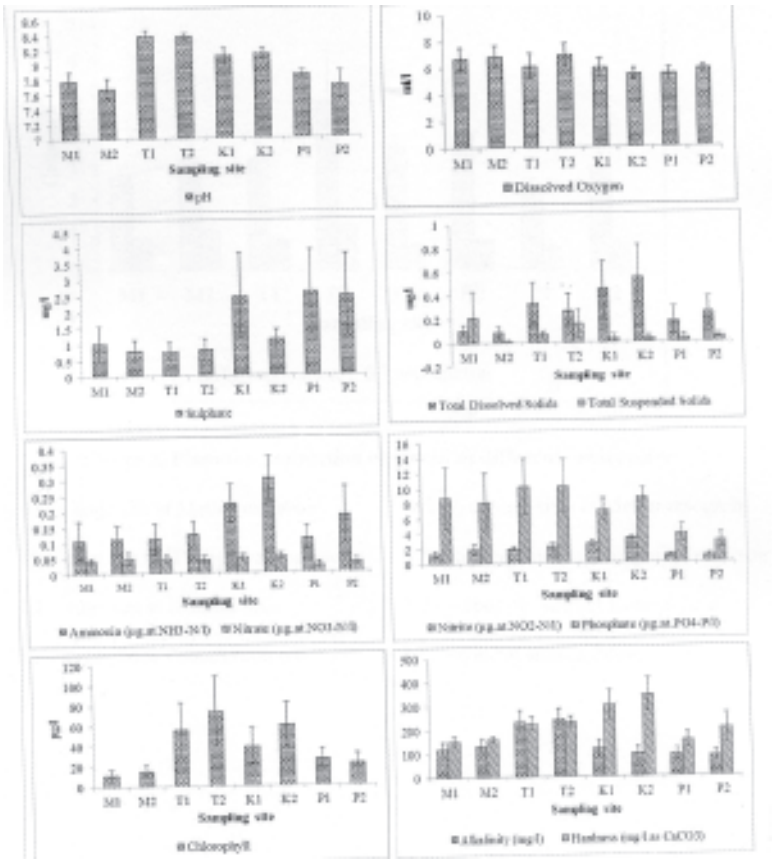

Fig. 1. Water quality parameters observed at different reservoirs. M_1–cage site at Mettur reservoir, M_2–control sites at Mettur reservoir, T_1–cage site at Thoppaiyar reservoir, T_2–control sites at Thoppaiyar reservoir, K_1–cage site at Kolavai lake, K_2–control sites at Kolavai lake, P_1–cage site at Poondi reservoir, P_2–control sites at poondi reservoir.

ents and dissolved gases. The water temperature above 30°C causes high mortality rate in the cage culture of tilapia in Tasik Kenyir reservoir in Malaysia [12, 13]. The water temperature of these selected reservoirs in the present study ranged from 29 to 34°C at cage sites and the maximum temperature was observed during summer months. High water temperature in most of the water bodies are experimenced due to the low water level, high air temperature and clean atmosphere [14]. In Odathurai reservoir, Erode district, Tamilnadu, the reported temperature range was 24.5 to 30.20 C [15]. The pH values ranged from 7.4 to 8.5 at the cage site with an average value of 8.02. The observed values were within the desirable limit from 6.5 to 8.5 as recommended by Bureau of Indian standards [16]. The total alkalinity may be used as the tool for the measurement of productivity. In the present study the alkalinity ranged between 8–370 mg/l. There was no significant difference in the alkalinity values observed at cage sites with respect to their control site in all the reservoirs. These values were found optimum in all the reservoirs, except in Thoppiar reservoir, where maximum of 370 mg/l was observed. This shows that water at Thoppiar reservoir is alkaline and the increase in higher alkalinity may not be due to cage culture. The higher alkalinity values in summer

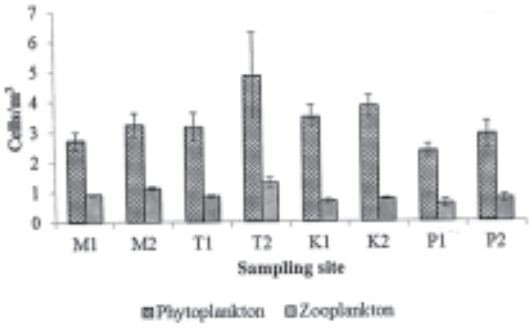

Fig. 2. Plankton population observed at different reservoirs. M_1–cage site at Mettur reservoir, M_2–control sites at Mettur reservoir, T_1–cage site at Thoppaiyar reservoir, T_2–control sites at Thoppaiyar resevoir, K_1–cage site at Kolavai lake, K_2–control sites at Kolavai lake, P_1–cage site at Poondi reservoir, P_2–control sites at poondi reservoir.

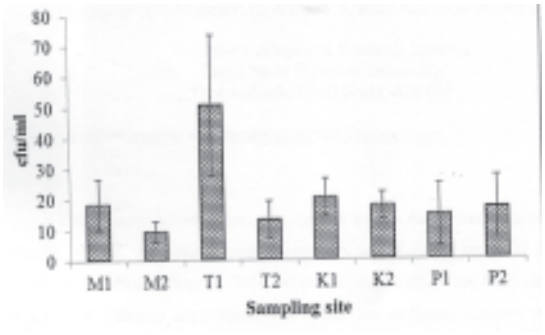

Fig. 3. Total Plate Count (TPC) observed at different reservoirs. M_1–cage site at Mettur reservoir, M_2–control sites at Mettur reservoir, T_1–cage site at Thoppaiyar reservoir, T_2–control sites at Thoppaiyar resevoir, K_1–cage site at Kolavai lake, K_2–control sites at Kolavai lake, P_1–cage site at Poondi reservoir, P_2–control sites at poondi reservoir.

season may be due to photosynthetic rate. The alkalinity values of Indian reservoirs ranges between 40 and 240 mg/l [17].

In the present study, the minimum hardness value of 74.07 mg/l was found at the cage site of Poondi reservoir. The maximum hardness value of 492.49 mg/l was observed at cage site as well as control site of Kolavai lake, indicating higher concentration of calcium and magnesium in the lake water. However, the hardness values were below the desirable limit of 300 as $CaCO_3$ mg/l as recommended by Indian standard [16]. All the reservoir water could be grouped under moderately hard category except Kolavai lake. Sulfate concentration in the entire reservoir ranged from traces to 9.07 mg/l. The level of sulfate was higher in cage sites when compared to control site in all selected reservoirs, however, these values were found within the permissible range for drinking water quality [18]. The dulfate content of Ramsagar reservoir ranged from 1.50 to 8.87 mg/l. The values of BOD provide information regarding quality of water and helps in deciding the suitability of water for consumption. The range of BOD and COD values was 0.2 to 8.24 and 0.08 to 37.29 mg/l respectively. Similar BOD value was reported in Ramsagar reservoir, India and the COD values ranged from 3.60 to 17.40 mg/l [19].

The maximum BOD value was noticed in Mettur Dam, which indicates higher organic load when compared to other reservoirs. The chlorophyll content in all the reservoir waters ranged from 1.08 to 151.7 µg/l at cage site and from 1.45 to 171.51 µg/l at control site. The maximum chlorophyll content of 151.70 µg/l was observed in the cages of Thoppiar reservoir.

Ammonia is the prime source of nitrogenous waste from excretion of fish, uneaten feed and decomposition of plant. Due to intensive aquaculture activities, the primary source of ammonia is from excessive fish feed [19]. In the present study, the higher ammonia concentration of 0.515 µg.at.NH_3-N/l was observed at cage site of Kolavai lake and the values were found slightly lower than the previous reports [20–23]. Nitrite concentration of Nova Avanhandava reservoir ranged from 2.69 to 3.49 µg/l [24]. The maximum nitrite value of 3.896 µg.at.NO_2-N/l was observed at cage site of Kolavai lake and minimum of 0.502 µg.at.NO_2-N/l was noticed at Poondi reservoir. Nitrate

values ranged from 0.0037 to 0.0928 µg.at.NO_3-N/l in all the reservoirs. Similar nitrate level was noticed in the Ramsagar reservoir [18]. The organic nitrogen fractions such as ammonia –N and nitrite –N values found slightly higher at control sites than the cage sites in the present study. There is not much variation in the nitrate values of cage and control sites.

Phosphorus is considered as an important element limiting algal growth. Reservoir with phosphorus concentration between 30 and 100 µg/l are categorized under Eu – polytrophic. In the present study, Mettur and Thoppiar dam showed maximum phosphate concentration of 28.76 and 28.43 µg.at.PO_4-P/l respectively. Poondi reservoir showed minimum value of 0.0032 µg.at.PO_4-P/l. The availability of phosphate is of a very low order and rarely exceeds 0.1 mg/l in Indian reservoirs, except for a shorter period during the monsoon [19]. The two way ANOVA performed with water quality parameters showed significant difference between cage and control sites in all the four reservoirs (p<0.05).

Plankton

Increased nutrients in cages lead to changes in plankton assemblages and therefore the most affected ecological attributes are species composition, richness, diversity and species abundance of the planktonic assemblages. On the basis of presence, absence and dominance of certain type of planktonic forms level of water pollution can be assessed. The phytoplankton population was found maximum (4.07×10^5 count/m^3) at Thoppaiyar Dam and minimum (0.96×10^5 count/m^3) at Mettur reservoir (Figure 2). The overall plankton count was found higher at control site than the cage site. The optimum water temperature, exuberant sunshine with adequate essential nutrients might have induced the rapid growth of plankton.

Sediment quality

The sediment quality characteristics such as pH, electrical conductivity, total organic carbon and available phosphorus were analyzed both at cage and control sites of all the four reservoirs. Reservoirs with soil pH ranging from 6.5 to 7.5 (circum neutral pH) are categorized as medium productive ones and Mettur Dam and Kolavai lake comes under this category. Reservoirs with alkaline soil having a pH exceeding 7.5 are considered highly productive and this category includes Thoppiaru Dam and Poondi reservoir. There is no difference in the pH value of cage and control sites. The electrical conductivity of the reservoirs ranged from 4.2 to 89.19 mS with the maximum value at Kolavai lake and minimum at Mettur reservoir.

It is estimated that more than 70% of organic matter entering into the sediment of the reservoir comes from autochthonous sources and the macrophytes are the major source of organic matter. The total organic carbon of the sediment samples of these reservoirs ranged from 2.39 to 11.2% and the maximum was found at Thoppiaru dam. Unlike carbon, phosphorus cycle is long and it takes many years for recycling. The available sedimentary phosphorus ranged from 3.98 to 5.98 mg/100g and the maximum was observed at Poondi reservoir. This study clearly reveals that the sediment characteristics were within the desirable limits. The ANOVA results revealed that, pH, electrical conductivity, total organic carbon and available phosphorus of the sediment samples were not statistically significant.

Microbial assessment

The reservoir water is being used for drinking purpose, it is essential to enumerate the microbial load of each reservoir due to cage culture farming. Environment rich in organic matter favor the proliferation of microorganism. The microbial load (TPC) was maximum (50×10^4 cfu/ml) at Thoppiar reservoir, and minimum (1.25×10^4 cfu/ml) at Poondi reservoir/ml (Figure 3). The site with floating net cages exhibited contamination with faecal streptococci than other sampling sites [22]. But, in the present study, *E. coli* count was nil throughout the sampling period, which shows the suitability of water for human consumption.

Conclusion

The overall increase in the nutrient levels like ammo-

nia, nitrite, nitrate and phosphate values were found higher at control site than the cage sites. It is clear that only the mass input of exogenous nutrients may cause negative impact on water quality. The cage culture activity with the minimum number of cages (12 numbers) for short term duration does not have noticeable impact over the water quality at cage sites, but the long term effects are need to be monitored for the sustainability of cage farming. The physico-chemical parameters of all the four reservoir waters were within the desirable limit as recommended by the Bureau of Indian Standards, 105000 for fish culture, irrigation and drinking water [16]. The optimum physico-chemical properties of water and sediment in the reservoirs couples with absence of *E. coli* clearly indicates that the small cage farming units do not have major environmental impact on the water and sediment quality of the reservoirs.

References

1. Huang YCA, Huang SC, Hsieh HJ, Meng PJ, Chen CA (2012) Changes in sedimentation, sediment characteristics and benthic macro faunal assemblages around marine cage culture under seasonal monsoon scales in a shallow-water bay in Taiwan. J Expt Marine Biol and Ecol 422—423 : 55—63.
2. Islam MS (2005) Nitrogen and phosphorus budget in coastal and marine cage aquaculture and impacts of effluent loading on ecosystem: Review and analysis towards model development. Marine Poll Bull 50 : 48—61.
3. Gondwe SJ, Guildford RE, Hecky RE (2011) Carbon, nitrogen and phosphorus loadings from tilapia fish cages in Lake Malawi and factors influencing their magnitude. J Great Lakes Res 37 : 93—101.
4. Hayami Y, Ohmori K, Yoshino K, Garno YS (2008) Observation of anoxic water mass in a tropical reservoir: The cirata reservoir in Java, Indonesia. Limnology 9 : 81—87.
5. Masser M (2008) What is cage culture? SRAC, Publ No. 160.
6. Ngupula GW, Ezekiel CN, Kimirei IA, Mboni E, Kashindye BB (2012) Physical and chemical characteristics of the Tanzanian inshore and offshore waters of Lake Victoria in 2005–2008. Afri J Aquatic Sci 37 : 339—345. http://dx.doi.org/10.2989/16085914.2012.712503
7. Porrello S, Tomassetti P, Manzueto L, Finoia MG, Mercatali I, Stipa P (2005) The influence of marine cages on the sediment chemistry in the Western Mediterranean Sea. Aquaculture 249 : 145—158.
8. Kullman MA, Podemski CL, Kidd KA (2007) A sediment bioassay to assess the effects of aquaculture waste on growth, reproduction and survival of *Sphaerium simile* (Say) (Bivalvia: Sphaeriidae). Aquaculture 266 : 144—152.
9. Zeng T, Li H (2006) Impact analysis and management strategy of cage culture on water environment of Feilaixia Reservoir. Guangdong Water Resour and Hydropower 4 : 71—85.
10. Salami IR, Rahmawati S, Sutarto RIH, Jaya MP (2008) Accumulation of heavy metals in freshwater fish in cage aquaculture at cirata reservoir, West Java, Indonesis. New York Academy of Sciences 1140 : 290—296. [doi:10.1196/annals.1454.037]
11. APHA (2012) Standard methods for the examination of water and waste water (22nd edn.). Washington DC.
12. Siti-Zahrab A, Misri S, Padilah B, Zulkafli R, Kua BC, Azila A, Rimatulhana R (2004) Pre-disposing factors associated with outbreak of Streptococcal infection in floating cage-cultured tilapia in reservoirs, pp 129. In: 7th Asian Fisheries Forum 04 Abstracts. The Triennial meeting of the Asian Fisheries Society held during 30th Nov—4thDec 2004 at Penang, Malaysia, pp 420.
13. Siti-zahrah A, Padilah B, Azila R, Rimatulhana R, Shahidan H (2008) Multiple streptococcal species infection in cage-cultured Red Tilapia But showing similar clinical signs, pp 313—320. In: Bonded-Reantaso, M.G., Mohan CV, Crumlish M, Subasinghe RP (Eds.), Disease in Asian Aquaculture VI. Fish Health Section, Asian Fisheries Society, Manila, Philippines, pp 505.
14. Thirupathaiah M, Samatha C, Sammaiah C (2012) Analysis of water quality using physico-chemical parameters in lower manair reservoir of Karimnagar district, Andhra Pradesh. Int J Environ Sci 3 : 172—180.
15. Murugesan VK, Palaniswamy R, Manoharan S (2003) The influence of water quality on the productivity of reservoirs in Tamil Nadu. Sugunan VV, Vinci GK, Katiha PK, Das MK (eds.), In: Fisheries Enhancements in Inland Waters- Challenges ahead. Proceedings of the National Symposium on Inland Fisheries, April 27–28. Special publication. Inland Fisheries Soc Ind Barrackpore 2003 : 33—37.
16. Hujare MS (2008) Seasonal variation of physico-chemical parameters in the perennial tank of Talsande, Maharashtra. Ecotoxicol Environ Monit 18 : 233—242.
17. BIS (2012) Indian Standard for drinking water-specification (Second revision), Bureau of Indian Standard, New Delhi, pp 15.
18. Karnatak G, Kumar V (2013) Potential of cage aquaculture in Indian reservoirs. Int J Fish and Aqua Studies 1 : 108—112.
19. Garg RK, Rao RJ, Uchchariya D, Shukla G, Salsena DN (2010) Seasonal variations in water quality and major threats to Ramsagar reservoir, India. Afri J Environ Sci Tech 4 : 61—76.
20. Jiwyam W (2012) Extensive net cage culture of Nile Tilapia (*Oreochromis niloticus*) fingerlings in nutrient-entiched pond. Our Nature 10 : 61—70.
21. Nyanti L, Hii KM, Sow A, Norhadi I, Ling TY (2012) Impacts of Aquaculture at different Depths and Distances from cage culture sited in Batang Ai Hydroelectric

Dam Reservoir Sarawak, Malaysia. World Appl Sci J 19 : 451—456.
22. Gorlach-Lira K, Pacheco C, Carvalho LCT, Junior HNM, Crispim MC (2013) The influence of fish culture in floating net cages on microbial indicators of water quality. Braz J Biol 73 : 457—463.
23. Nsonga A (2014) Indigenous fish species a panacea for cage aquaculture in Zambia: A case Kambashi out-growing scheme. IJFAS 2 : 102—105.
24. Hallare AV, Factor PA, Santos EK, Hollert H (2009) Assessing the Impact of Fish Cage Culture on Taal Lake (Philippines) Water and Sediment Quality Using the Zebra fish Embryo Assay Philippine. J Sci 138 : 91—104.