Indian J. Fish., 69(4): 28-35, 2022
DOI: 10.21077/ijf.2022.69.4.125726-03

Water quality parameters and nutrient status of selected reservoirs in Tamil Nadu, India

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ABSTRACT

The present study was undertaken to assess the interrelation between water quality and nutrient status of three reservoirs situated in Tamil Nadu, India. These three reservoirs are managed by the Public Works Department (PWD) with the fisheries aspects falling under the purview of Tamil Nadu State Fisheries Department. In each reservoir, inflow and outflow sections were identified as sampling sites. A total of six sampling sites were fixed and monthly sampling for water and fish was conducted during the period from October 2019 to June 2020. The various physico-chemical parameters such as temperature, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), total volatile solids (TVS), turbidity, DO, pH, alkalinity, hardness, chloride, sulphate, biological oxygen demand (BOD) and chemical oxygen demand (COD) were analysed. Biological parameters like chlorophyll-a and primary production as well as various nutrient parameters were also analysed in the collected water samples. All the physical and chemical water quality variables showed significant variation ($p<0.05$) in their concentrations within various months and between stations. All the water quality parameters were observed to be within the prescribed limits. The results indicated under-exploitation of fishes from the reservoirs and suggest ways to improve fish yields and livelihood of local fisher community.

Keywords: Fish catch, Nutrients, Reservoir, Water quality

Introduction

The reservoirs play an important role in the developmental process of India and also have an integral role in fisheries and livelihood security of the local community. Utilisation of reservoirs in a proper manner for fisheries can act as a powerful vehicle for poverty easing (Sarkar *et al.,* 2015). Reservoirs are considered as a significant asset for fisheries enhancement in inland open waters (Lianthuamluaia, 2019). India has an assortment of freshwater assets that comprises of 10,551,201 ha area, spread over different geo-climatic areas as lakes (729,532 ha), oxbow lakes and cut-off meanders (104,124 ha), high altitude wetlands (124,253 ha), waterlogged wetlands (450,795 ha), riverine systems and streams (5,350,067 ha), as well as reservoirs and tanks (3,792,430 ha) (Panigrahi *et al.,* 2011). The Indian reservoirs are situated in the tropical region with high nutrient turnover favouring natural productivity (Sarkar *et al.,* 2018). Physico-chemical and biological characteristics of the reservoirs determine the health of the reservoirs (Venkatesharaju *et al.,* 2010). Environmental parameters are the key factors for the conservation and management of fish populations (Pease *et al.,* 2011). Reservoirs form basis for large-scale water management systems with their multi-functionality features and they help in adjustment of natural run-off with its seasonal variations and irregularity of climate to meet the increasing demand for irrigation, agriculture, domestic and industrial water supply as well as navigation (Chalapathi *et al.,* 2018b).

In India, especially Tamil Nadu State has very high potential for reservoir fisheries, since the state has 69 reservoirs with total water surface area of 58,462 ha. Based on water surface area, reservoirs are classified as large, medium and small reservoirs. In Tamil Nadu, approximately 2 large reservoirs, 9 medium and 58 small reservoirs are present with water spread area of 23,222, 19,577 and 15,663 ha respectively. Tamil Nadu is situated in the southern part of India and flanked by Eastern Ghats and Western Ghats along the Northern and Western boundaries meeting at Nilgiri Hills (Palaniswamy *et al.,* 2015). Tamil Nadu is rich in the assortment of freshwater assets (3.08 lakh ha) as streams, rivers, channels (7400 km), major reservoirs (52000 ha), irrigation tanks (98000 ha), lakes and reservoir fisheries development tanks (158000 ha) as well as cold water lakes. Small reservoirs of Tamil Nadu are logistically suitable for fish cultivation, mainly because of its manageable size (Sugunan, 1995). The various tanks (~3000) that lie in the semi dry fields of Thoothukudi and Tirunelveli districts are fed by seven perpetual rivers *viz.,* Thamiraparani River and its tributaries: Manimutharu,

Pachaiyar, Kodumudiyar, Gadananathi, Ramanathi and Nambiar which form the lifeline of about 50 lakhs of people living in the landscape. Due to poor adoption of science-based stocking procedures, fish production in reservoirs are declining. Reservoir fish production could be improved by utilising various methodologies consolidating better harvesting methods, fertilisation, stock upgrading and extensive aquaculture (Kolding and Zwieten, 2006).

Routine monitoring of water quality parameters is important for the conservation, management and sustainable use of reservoir fishery resources of Tamil Nadu. In the present work, selected reservoirs *viz.,* Manimutharu, Gadana and Vadakkupachaiyar, located along Western Ghats were monitored and interrelation between water quality parameters and nutrient status of these reservoirs was assessed. So far, much work has not been performed on the above mentioned aspects in reservoir productivity studies. Therefore, the present study aims to investigate the variations in the physico-chemical characteristics of water in the inflow and out flow sections of the selected reservoirs and to assess the seasonal variations in nutrient levels of the selected reservoirs.

Materials and methods

Site selection and sampling

In each reservoir, two sites *i.e.*, the inflow section and outflow section were identified for water quality analysis. A total of six sampling sites were identified *viz.,* MR_1 (8.634485°N; 77.416631°E) - the inflow section of Manimutharu Reservoir; MR_2 (8.660169°N; 77.421363°E) - the outflow section of Manimutharu Reservoir; GR_1 (8.797515°N; 77.307187°E) - the inflow section of Gadana Reservoir; GR_2 (8.796789°N; 77.312326°E) the outflow section of Gadana Reservoir; VR_1 (8.545187°N; 77.520846°E) - the inflow section of Vadakkupachaiyar Reservoir and VR_2 (8.542292°N, 77.520255°E) - the outflow section of Vadakkupachaiyar Reservoir. The detailed maps of the study areas are shown in Fig. 1. The features of the three selected reservoirs are given in Table 1. This study was carried out during the period from October 2019 to June 2020. Sampling was carried out fortnightly from the 6 sites identified, 2 each from 3 reservoirs and the samples were transported to the laboratory in ice box.

Analysis of physico-chemical parameters of water

Water temperature was measured in the field using mercury thermometer with a range of 0 to 100°C with reading accuracy of 0.1°C. pH and total dissolved solids (TDS) were measured using 'ELICO' pH meter. The electrical conductivity (EC) was measured with the help of 'ELICO CM 183-EC-TDS' analyser. For dissolved oxygen (DO) estimation, water samples were fixed immediately after the collection and estimated by Winkler's titration method (APHA, 2012) in the lab. The other parameters such as total suspended solids (TSS), total volatile solids (TVS), turbidity, alkalinity, hardness, chemical oxygen demand (COD), biological oxygen demand (BOD), chloride, CO_2, calcium, magnesium and chlorophyll-a

(a) (b) (c)

Fig. 1. Maps showing the study areas in (a) Manimutharu Reservoir; (b) Gadana Reservoir and (c) Vadakkupachaiyar Reservoir

Table 1. Features of reservoirs selected for the study

Features	Manimutharu Reservoir	Gadana Reservoir	Vadakkupachaiyar Reservoir
Location of the dam	8.653804°N, 77.413418°E	8.798229°N, 77.308140°E	8.541588°N, 77.522512°E
Length of the dam	9605 ft.	5569 ft.	10203 ft
Full reservoir level (FRL)	118 ft.	85 ft.	50 ft.
Water spread area @ FRL	940 ha.	80 ha	184 ha
Capacity of the dam	5511 M.c.ft.	352 M.c.ft.	442 M.c.ft
Year of construction	1958	1974	2002

were analysed by the standard methods (APHA, 2012). Sulphate was estimated by gravimetric method with ignition of residue (APHA, 2012). Water samples were filtered through Whatman filter paper No. 41 and inorganic nutrients like nitrite (NO_2-N), nitrate (NO_3-N), phosphate (PO_4^{3-}) and silicate (SiO_2) were analysed using spectrophotometer (PerkinElmer, Lambda 25) as per the standard protocol of APHA (2012). Sodium and potassium were analysed by Deep Vision Microprocessor Flame Photometer. Total Kjeldahl nitrogen (TKN) was measured by KELPLUS Automatic Nitrogen estimation system. Primary productivity was estimated by light and dark bottle method. All the analyses were done in duplicates and the mean values were taken for final evaluation.

Collection of fish production data from reservoirs

The total fish production details were collected from the office of Assistant Director of Fisheries (ADF), Manimutharu for Manimutharu Reservoir and the office of the ADF, Tirunelveli for Gadana and Vadakkupachaiyar reservoirs.

Statistical analysis

The mean and standard error of the experimental results were calculated using SPSS ver. 25. Graphical analyses were performed using Microsoft Excel and the statistical determination involving ANOVA and correlation matrix in SPSS software ver. 25. A confidence level of 95% was selected in order to strictly determine the significant difference between the water quality and nutrient parameters in all the three reservoirs.

Results and discussion

Variation in physical water quality parameters

The concentration of physical parameters such as water temperature, EC, TDS, TSS, TVS and turbidity were measured monthly and the results are shown in Fig. 2. The overall value of water temperature varied significantly ($p<0.05$) between 24.5ºC to 30.07ºC in all the three reservoirs. The maximum temperature value was observed in outflow section at Manimutharu Reservoir (MR_1) during summer season. The EC values ranged from 67.31 to 313.83 µS cm^{-1}. The maximum EC value (313.83 µS cm^{-1}) was recorded at inflow section of Manimutharu Reservoir in summer season. High EC in summer season indicates the high evaporation rate and presence of eutrophic conditions in water body (Kibira and Webber, 2000; Oniye *et al.,* 2002; Abubakar *et al.,* 2020). The minimum value of EC was observed in outflow section of Vadakkupachaiyar Reservoir during the wet season. The observed lower conductivity during wet season could be as a result of an increase in dilution brought about by heavy rain (Oniye *et al.,* 2002; Abubakar *et al.,* 2020).

In this study, the TDS content of water samples collected from the reservoirs varied significantly ($p<0.05$) between 0.2 and 2.74 mg l^{-1}, which is below the limit value of 500 mg l^{-1} (WHO, 1984) acceptable for potable use. Similar findings were reported by Anusya Devi *et al.* (2015) with the value of 0.12 to 0.81 mg l^{-1} in Mettur and Poondi reservoirs and Karthick *et al.* (2016) in Kadamba Tank with the value of 0.06 to 1.37 mg l^{-1}. The maximum TDS value of 2.74 mg l^{-1} was observed during summer season due to loss of water because of evaporation and concentration of salts present in water (Sharma and Capoor, 2010). The minimum TDS value of 0.19 mg l^{-1} was observed during monsoon season at the outflow section of Vadakkupachaiyar Reservoir. Similar observations of minimum TDS value in rainy season have been reported by Chinnaiah and Rao (2011). In the present study, the minimum TDS value observed during monsoon season might be due to the dilution of water (Sawant and Chavan, 2013). The TSS values ranged from 3.83 to 10.06 mg l^{-1} in all the three reservoirs. The high level of TSS observed in summer season might be due to sudden rainfall and discharge of urban effluents into the reservoir. The decrease in TSS might be due to absence of inflow of water.

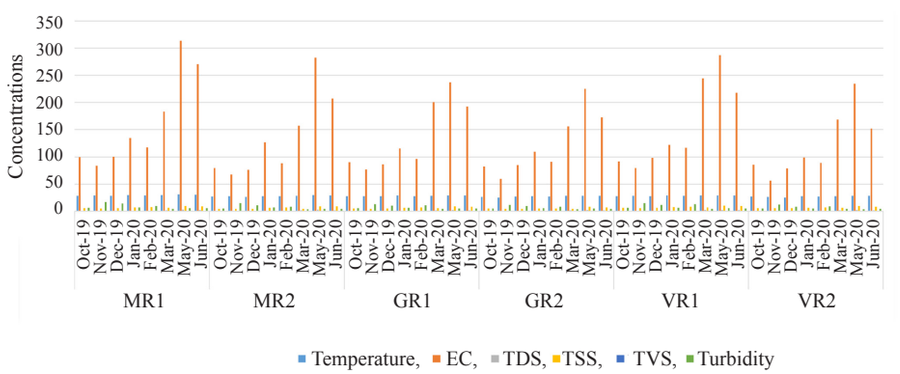

Fig. 2. Spatio-temporal variation in concentrations of physical water quality parameters in reservoirs

The TVS values ranged from 0.115 to 0.825 mg l^{-1} at the outflow and inflow sections of Manimutharu and Vadakkupachaiyar reservoirs. The inflow section of all the studied reservoirs showed that the values ranged from 0.285 to 0.825 mg l^{-1}. The observed results were higher than the values recorded in previous study conducted by Iqbal *et al.* (2004) from river Soan. Aquatic systems receive runoff carrying silt and clay solids, therefore often possessing light turbidity (Deepa *et al.,* 2016). The maximum value was recorded during monsoon season at the inflow section of Manimutharu Reservoir. Significant difference ($p<0.05$) was observed in the values between physical water quality variables ($p<0.05$) among the stations and between the months of sampling during the study period.

Variations in chemical water quality parameters

The monthly variations of all chemical water quality parameters of the three reservoirs are shown in Fig. 3. In the present investigation, DO at inflow and outflow sections of Manimutharu, Gadana and Vadakkupachaiayar reservoirs revealed that the values lie between 2.6 and 8.6 mg l^{-1}. Maximum DO values were recorded during monsoon season (8.6 mg l^{-1}) owing to enhanced solubility of oxygen with low temperature and mixing of large quantities of water. High dissolved oxygen during monsoon season could also be due to an increased rate of photosynthesis caused by increased density of phytoplankton. The findings reported that lower dissolved oxygen content was observed during summer season and this might be due to decomposition of organic matter.

The level of CO_2 in the inflow water ranged between 0 mg l^{-1} in the month of May (summer) and 6.49 mg l^{-1} in the month of December (monsoon). The low concentrations or absence of CO_2 recorded might be due to the alkaline nature of the reservoir water. The higher values observed during monsoon seasons might be due to the decreased photosynthetic rates and decomposition of organic matter that entered into the reservoir through runoff. Similar observations were also reported at Raipur Reservoir by Saxena and Saksena (2012) and in Sarvepalli Reservoir (Chalapathi *et al.,* 2018a). In case of pH, the inflow water fluctuated between 6.39 in the month of November 2019 and 8.07 in the month of June 2020. The decrease in pH value observed during monsoon could be attributed to greater inflow of water due to precipitation.

The minimum and maximum alkalinity values were recorded at Manimutharu Reservoir (19 mg l^{-1}) and Gadana Reservoir (69 mg l^{-1}) in the month of December 2019 and May 2020, respectively. In low alkalinity waters, the influence of photosynthesis on pH is greater because of their low buffering capacity. The alkalinity values fluctuated between 30.5 and 64.5 mg l^{-1} in the inflow water. The higher values of alkalinity observed in summer might be due to the effect of pH on the relative proportions of different forms (CO_2, HCO_3 and CO_3) of inorganic carbon. Hardness values ranged from 65.06 to 365.36 mg l^{-1} as $CaCO_3$ in all the reservoirs. This higher range might be due to the low water level in the reservoir and the rate of evaporation is high during the summer season (Kumar, 2000). The higher value of chloride concentration (46.79 mg l^{-1}) observed during summer might be due to the rise in temperature, water evaporation (Verma *et al.,* 2012) and higher organic waste (Sonawane, 2011). The sulphate values of the selected reservoirs ranged from 1.02 to 7.81 mg l^{-1}. Not much difference in the sulphate values was observed between the inflow and out flow sections of the three reservoirs.

BOD values of water in the inflow sections fluctuated between 1.4 mg l^{-1} in the month of May 2020 (summer) and 4.8 mg l^{-1} in the month of November 2019 (winter monsoon) with a variation of 3.4 mg l^{-1}, whereas in outflow section, BOD of water ranged from 2.4 mg l^{-1} in the month of May 2020 (summer) to 6.2 mg l^{-1} in the month of December 2019 (winter monsoon) with a variation of 4.2 mg l^{-1}. The values for COD in both the inflow and

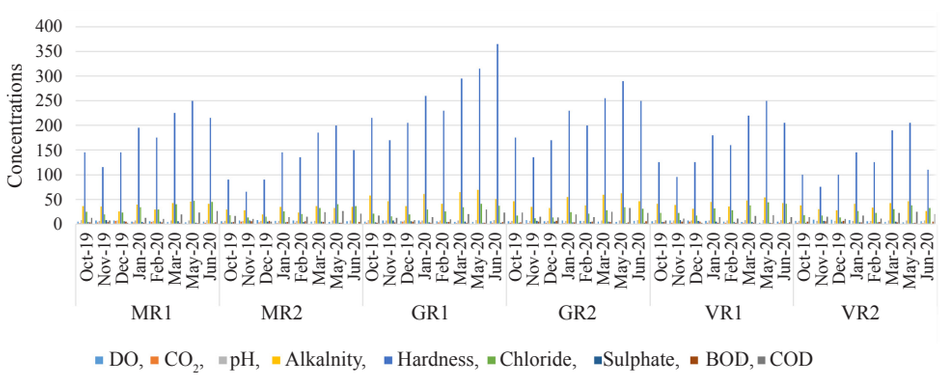

Fig. 3. Spatio-temporal variation in concentrations of chemical water quality parameters in reservoirs

outflow water ranged from 2 to 32 mg l^{-1}. The low COD values observed during the study period indicates that there might be absence of organic matter. Boyd (1998) reported that less than 50 mg l^{-1} of COD is suitable for fish culture, hence all three reservoirs were found to be suitable for fish culture. The data also showed that the concentrations of all chemical water quality parameters significantly ($p<0.05$) varied between the stations and between the months of sampling during the study period.

Variations in biological water quality parameters

In all the reservoirs, seasonal variations in the value of biological parameters such as chlorophyll-a and gross primary productivity (GPP) were observed. The monthly variations of biological water quality parameters in the three reservoirs are shown in Fig. 4. Among all the reservoirs, Gadana Reservoir showed the maximum concentration of chlorophyll-a (62.65 mg m^{-3}), both in inflow and outflow water. Lower concentration of chlorophyll-a was recorded in Vadakkupachiyar Reservoir and the values ranged from 8.85 mg m^{-3} to 18.35 mg m^{-3}. During the study period, the concentration of chlorophyll-a significantly varied ($p<0.05$) between the stations and months of sampling and overall maximum chlorophyll-a concentration was observed during the month of May (summer) in all the reservoirs, which might be due to maximum light penetration and higher plankton density. Moreover in this study, the TSS values recorded were very low which facilitates light penetration and photosynthesis. Kallio (1994) also indicated that warm summer periods may cause high chlorophyll-a concentrations. The minimum value observed during monsoon might be due to high turbidity and less availability of light as evidenced from earlier reports given by Padmavathy *et al.* (2017). The GPP values did not show significant variation ($p>0.05$) between the stations and months of sampling in this study. Overall, the highest GPP value (0.71 mgC m^{-3} h^{-1}) was recorded during the monsoon season and lowest value (0.24 mgC m^{-3} h^{-1}) was noticed during the summer season. Similar observation of GPP value has been recorded by Rajan and Samuel (2016).

Nutrient status of the reservoirs

All the nutrient parameters analysed in this study showed significant variation in their concentrations between different months and stations. The nitrite concentrations in all the three reservoirs were in the range of 0.04 to 0.92 µg l^{-1} (Fig. 5). The higher concentration of nitrite (0.92 µg l^{-1}) during the monsoon season is attributed with the influx of nutrients to the reservoirs along with the runoff (Saxena and Saksena, 2012). The minimum nitrite value of 0.04 µg l^{-1} was observed at outflow section

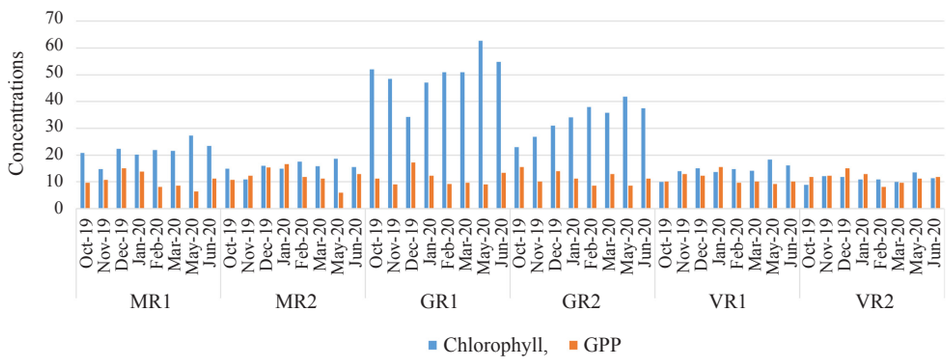

Fig. 4. Spatio-temporal variation in concentrations of biological water quality parameters in reservoirs

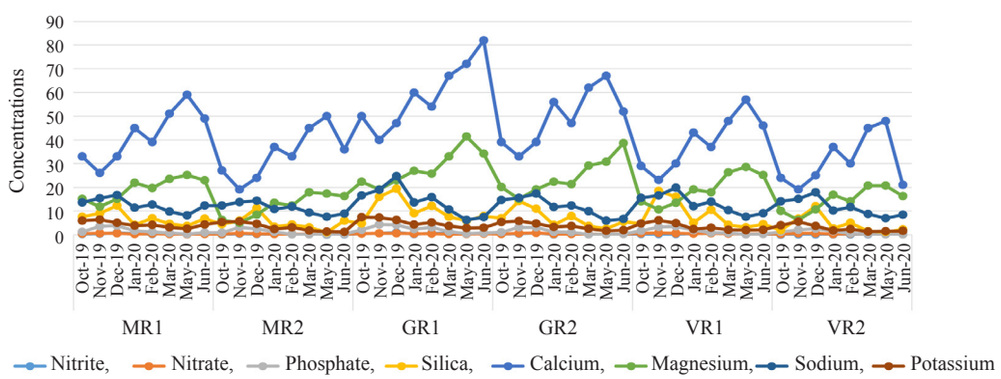

Fig. 5. Spatio-temporal variation in concentrations of nutrient parameters in reservoirs

of Manimutharu Reservoir during the summer season (May 2020) which may be due to high evaporation of water and zero water inflow (Thilaga *et al.,* 2005; Prabhahar *et al.,* 2012).

The nitrate values in all the three reservoirs ranged between 0.16 and 0.762 µg l^{-1}. Maximum value of nitrate (0.762 µg l^{-1}) recorded during the monsoon season in the reservoirs might be due to entry of atmospheric washouts, agricultural runoff, domestic sewage, washing activities and surface run off (Sonawane, 2011). Low nitrate concentrations reorded during the summer season, could be attributed to the assimilation of algae as well as other biological and chemical processes in water (Rajashekhar *et al.,* 2007). Boyd (1998) has recommended optimum range of nitrate for fish culture as 0.1-3.0 mg l^{-1}. Since, nitrate concentration recorded in all the three reservoirs fall within the optimum range, the reservoirs are found suitable for fish culture.

In case of phosphate, the values ranged from 0.05 to 4.19 µg l^{-1} in all the three reservoirs (Fig. 5). The highest concentration was recorded at outflow area of Gadana Reservoir during the month of November 2019. Akindele *et al.* (2013) professed that this seasonal pattern can easily be linked to allochthonous inputs from the nearby terrestrial surfaces in the rainy season which can increase their concentrations in water bodies. Silicates are the most abundant element found in rocks and form a major component in the structure of diatoms and in the growth of algae. Since diatoms are major component of primary producers in water bodies, their utilisation alters the concentration of dissolved silica in reservoirs (Lianthuamluaia *et al.,* 2013). In the present study, Gadana Reservoir recorded the maximum value of silica at 19.39 µg l^{-1} in the inflow area of reservoir during the monsoon season (November, 2019).

In the present study, the calcium concentration recorded in the reservoirs ranged from 19 to 82 mg l^{-1}. The minimum concentration of 19 mg l^{-1} calcium was observed at outflow section of Manimutharu Reservoir during monsoon season (November 2019). Lower level of calcium recorded during the monsoon season might be due to biotic community utilisation (Jain *et al.,* 2011). According to the findings of Ohle (1938), the three reservoirs studied are classified as calcium rich waters, because during most of the months, calcium level of water was above 25 mg l^{-1}, except for few months in monsoon season. Maximum magnesium concentration of 41.44 mg l^{-1} was noted at the inflow section of Gadana Reservoir during summer season (May 2020). The maximum level of magnesium observed in summer season could be due to less amount of water in reservoir which can increase the concentration of magnesium, bacterial decomposition of organic matter and intake of magnesium by phytoplankton (Garg *et al.,* 2009).

According to Boyd (1998), the optimum range of sodium in freshwater is <500 mg l^{-1} and for potassium, it is 0.5 to 10 mg l^{-1}. The sodium values of the three reservoirs ranged from 5.85 to 24.75 mg l^{-1} and potassium values ranged from 1.2 to 7.35 mg l^{-1}. This showed that all the three reservoirs studied fall under the prescribed limit and the reservoirs are suitable for fish culture and irrigation purposes.

Fish production in the selected reservoirs

During the present study, the average fish production of Manimutharu, Gadana and Vadakkupachaiyar reservoirs were 4.48, 7.87 and 1.57 kg ha^{-1} respectively. The fish production in these reservoirs did not show significant variation ($p>0.05$) within months and between stations during the study. Among the three reservoirs examined, maximum fish catch was recorded in Gadana Reservoir during May 2020 and minimum catch was recorded form Manimutharu Reservoir during February 2020. Fish production was observed to be low when compared with the average annual fish production of 30 kg ha^{-1} reported for Indian reservoirs (Paul *et al.,* 2017). The fish catch reports of Manimutharu Reservoir showed that, there was higher fish catch in past years (personal communication from ADF, Manimutharu, 2020). Very recently the Manimutharu Reservoir which was under the control of the PWD has been transferred to the Forest Department. This transfer of management has created a situation where the reservoir falls under the reserve forest leading to restrictions in fishing. This coupled with lack of seed stocking in the reservoir could have led to the decline in catches. In Gadana and Vadakkupachaiyar reservoirs, fish seed stocking is routinely carried out during the month of December. However, due to lack of proper licensing, very less fishermen are being permitted to carry out fishing activities, which might be the reason for the low fish catches recorded. Therefore, it could be observed that the stocked fishes are not being properly exploited in the above said reservoirs. The results of correlation analyses indicated a positive correlation between the values of fish production and GPP (r=0.228), nitrite (r=0.06), nitrate (r=0.77), phosphate (r=0.66), silicate (r=0.429) and total Kjeldahl nitrogen (TKN) (r=0.0947) in Manimutharu Reservoir. The results of correlation analysis revealed the existence of positive correlation between fish production and certain water quality parameters *viz.,* chlorophyll-a (r=0.708), calcium (r=0.61) and magnesium (r=0.827) in Gadana Reservoir. Similarly positive correlation was observed in Vadakkupachaiyar Reservoir *viz.,* chlorophyll-a (r=0.555), calcium (r=0.509) and magnesium (r=0.582). Such positive correlation between the nutrient parameters in the reservoirs and respective fish production reveals that the reservoirs are in good productivity stage. However,

low fish catches indicate lower levels of exploitation and it could be concluded that proper management of these reservoirs based on productivity levels would help to improve the fish yield as well as pave way for the socio-economic upliftment of the local fishermen.

The present study examined the monthly variations in the water quality parameters in the three reservoirs at six sampling locations. Fish production data of the selected reservoirs were also assessed to determine the productivity status. The results of observed water quality parameters indicate that these are within the prescribed limits and significant variations ($p<0.05$) were observed in their concentrations within sampling months and between stations. Considering the results of all the physico-chemical and nutrient parameters studied, the three reservoirs are found to be suitable for fish culture. The recommendations suggested for increasing fish production in these reservoirs are: Fish seeds need to be stocked preferably during June to July; Proper fishing practices can be permitted at regular intervals; There is need for appointing watch and ward to prevent poaching; Cage culture in Manimutharu Reservoir and pen culture in Gadana Reservoir are advisable for increasing fish production; The capacity of seed rearing in Gadana Fish Seed Rearing Centre can be increased as the water is highly productive and Predatory fish species observed in Vadakkupachaiyar Reservoir needs to be removed by following recommended management measures to improve the overall fish catch of the reservoir.

Acknowledgements

This work formed part of PG Research of the first author and he wishes to thank the respected guide and members of the Advisory Committee for the guidance and help in carrying out the research work. The authors wish to thank Tamil Nadu Dr. J. Jayalaithaa Fisheries University for the necessary facilities provided during the study period.

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Date of Receipt : 23.06.2022
Date of Acceptance : 06.12.2022