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ORIGINAL ARTICLES

Limnological Evaluation of the Fisheries Potentials of a Ghanaian Reservoir

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ABSTRACT

Morpho-edaphic Index (MEI), and total nutrient input have been applied to the Dawhenya reservoir in Ghana from August 2006 to July 2007 to estimate existing fish yield and future potential productivity. The estimated existing fish yield from the reservoir was about 38.44 kg/ha. In the Dawhenya reservoir, 12 species belonging to 8 genera were encountered out of which 7 genera were fin fishes while the remaining genus was a shell fish. During the dry season, eight fish species were sampled and *Barbus macrops* contributed the highest (71.6 %) and *Oreochromis niloticus* the lowest (0.2 %) by weight while in the wet season five fish species were collected and *Barbus macrops* contributed the highest (85.3 %) and *Macrobrachium vollenhovenii* the lowest (2.1 %) of total weight of fish in drag net catches. Estimates of *b*-values ranged from 2.793 in *Sarotherodon galilaeus* to 3.267 in *Macrobrachium vollenhovenii*. Only *Barbus macrops* growth pattern in the reservoir was isometric meaning there was an equal increase in length and weight during growth, while *Macrobrachium vollenhovenii*, *Macrobrachium macrobrachion* and *Sarotherodon galilaeus* growth patterns were allometric, meaning increases in length and weight of the species were not equal during growth. The general physicochemical parameters monitored during the study period fell within the ranges suitable for fisheries and aquatic life in reservoirs, except for phosphates which were outside recommended ranges. Observations of pH showed that the reservoir was slightly alkaline. Agricultural activities within the catchment area of the reservoir should be monitored and controlled to prevent nutrient enrichment since the inhabitants were predominantly peasant farmers.

Key words: limnology, fish yield, finfish, shell fish, morpho-edaphic, reservoir.

Introduction

The utilisation of reservoirs for fish production, besides other primary uses, has become common practice in many countries, especially industrialised ones, where a number of reservoirs are managed for the production of annual harvestable fish crops. Several limnological parameters such as conductivity, total dissolved solids, water quality and reservoir morphometry have been used in estimating potential fish yields from reservoirs. The most widely accepted method was the morpho-edaphic index (MEI) developed by Ryder, R.A., 1965. This present study aims at determining the fish yield of the Dawhenya reservoir after four decades of impoundment using limnological parameters and morpho-edaphic index.

Materials and methods

The study was conducted in the Dawhenya impoundment. The area lies within latitudes 5^0 04^1 N and 6^0 00^1 N and longitudes 0^0 10^1 W and 0^0 05^1 E. It has a catchment area of about 500 km^2 at the Dam site and a mean depth of 5.4 m. The catchment lies entirely within the Accra Plains IDA, (1992).

Monthly readings of temperature, pH, dissolved oxygen content, conductivity, and turbidity were taken from four sampling sites in the field using the Water Quality Checker or probe Fresenius *et al.,* (1988). The probe was immersed in the water at each of the four sampling stations and the mode for each of the above parameters pressed and the figure registered on the screen recorded. Three readings, about 30.0 cm below the water surface was taken at each of the four sampling sites for each of the above parameters and the average found and recorded. Water samples were also taken from the same depth at each station with a 2.0-litre Hydro-

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Bios Kiel TP water sampler to the laboratory for nutrient content analysis.

The nutrients analysed were phosphates and nitrates using a Hach DR2010 direct-reading spectrophotometer and pre-package reagents within 24 hours after sampling. About 25 ml of the water taken to the laboratory was measured into a reaction bottle and Phos Ver 3 reagent added and swirled. The sample was then allowed to stand for 2 minutes and readings taken at 890 nm from the spectrophotometer as the concentration of phosphates at the sampling site. Blue colour indicated the presence of phosphates in the sample. Another 25 ml of water was measured into a reaction bottle and Nitra Ver 5 reagent added and shaken for 1 minute. The sample was allowed to stand for 5 minutes and the readings taken at 400 nm from the spectrophotometer as the concentration of nitrates at the sampling site. Brown colour indicated the presence of nitrates in the sample.

Fish samples were caught using a drag net (½ inch mesh size) constructed by a local fisherman purposely for this project, between 9:00 am and11:30 am (for day sampling) and 10:30 pm and 11:45 pm (for night sampling) during the sampling period. The sampling was done twice for both the dry season: November and February and wet season: April and June. The samples were taken to the laboratory and each individual identified using keys by Dankwa *et al.,* (1999).

Estimates of the potential fish yield were obtained using the physico-chemical characteristics of the reservoir and the relationship $Y=23.281\ MEI^{0.447}$. Marshal, B.E. (1984). Where Y is the potential fish yield in kg/ha, MEI is morpho-edaphic index, which is given in μS/cm and is estimated by dividing the mean conductivity by the mean depth Ryder *et al.,* (1974).

Results and Discussion

The mean sampling sites variations in physicochemical parameters during the study period recorded a minimum temperature value of 27.8 °C in site 3 and a maximum of 28.0 °C in site 1 and a mean value of 27.9 ± 0.03 °C (standard error, s.e) (Figure 1). Site 4 recorded a minimum of 7.67 mgl^{-1} and site 3, a maximum of 7.71 mgl^{-1} dissolved oxygen and a mean of 7.7 ± 0.01 mgl^{-1} (Figure 2). Values recorded for conductivity were a minimum of 137.6 μScm^{-1} for site 3 and a maximum of 138.3 μScm^{-1} in site 2 and mean value of 137.9 ± 0.2 μScm^{-1} (Figure 3). For turbidity, site 3 recorded the minimum value of 46.1 mgl^{-1} while site 4 recorded the maximum value of 52.6 mgl^{-1} and a mean value of 48.8 ± 1.5 mgl^{-1} (Figure 4). Mean site values of pH ranged from a minimum of 7.76 in site 3 to a maximum of 7.96 in site 1 with a mean value of 7.8 ± 0.05 (Figure 5). Site 3 recorded the lowest nitrates content of 0.84 mgl^{-1} while site 2 recorded the highest value of 0.87 mgl^{-1} with a mean value of 0.85 ± 0.01 mgl^{-1} (Figure 6). Phosphate content ranged from 0.16 mgl^{-1} in site 4 to 0.19 mgl^{-1} in site 1 and a mean value of 0.18 ± 0.01 mgl^{-1} (Figure 7).

In the Dawhenya reservoir, 12 species belonging to 8 genera were encountered out of which 7 genera were finfishes while the remaining genus was a shell fish (Table 2). During the dry season, eight fish species were sampled and *Barbus macrops* contributed the highest (71.6 %) and *Oreochromis niloticus* the lowest (0.2 %) while in the wet season five fish species were collected and *Barbus macrops* contributed the highest (85.3 %) and *Macrobrachium vollenhovenii* the lowest (2.1 %) of total weight of fish in drag net catches (Table 3).

The Length-weight relationship parameters for 4 species (belonging to 3 families, and 3 genera) are presented in Table 4 along with available information on length range and growth pattern. Estimates of **b** ranged from 2.793 in *Sarotherodon galilaeus* to 3.267 in *Macrobrachium vollenhovenii*. Only *Barbus macrops* growth pattern was isometric meaning there is an equal increase in length and weight during growth, while *Macrobrachium vollenhovenii*, *Macrobrachium macrobrachion* and *Sarotherodon galilaeus* growth patterns were allometric, meaning increases in length and weight of the species were not equal during growth.

Table 1: Mean monthly conductivity of the four sampling sites of the Dawhenya reservoir

Months	Site 1	Site 2	Site 3	Site 4
August, 2006	113	114	112	112
September	125	121	121	121
October	130	132	134	133
November	136	133	134	143
December	140	138	140	140
January, 2007	145	146	146	147
February	158	160	159	163
March	166	164	163	163
April	135	139	135	135
May	135	138	135	135
June	135	135	135	134
July	136	135	135	137
Mean	129.5	137.9	126.3	138.6

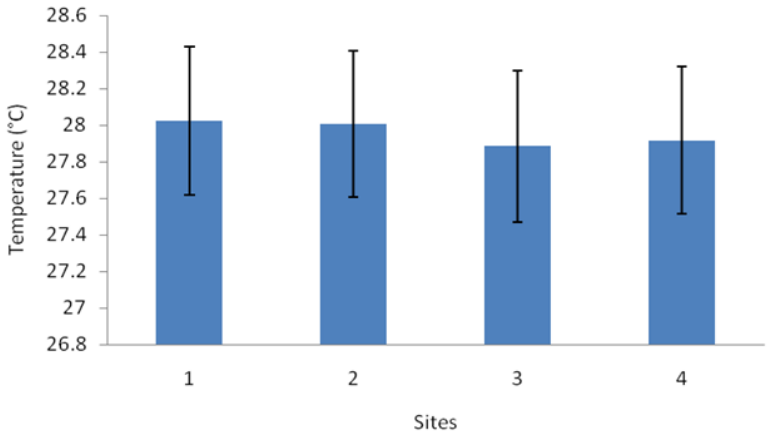

Fig. 1: Mean site temperature (˚C) with standard error bars

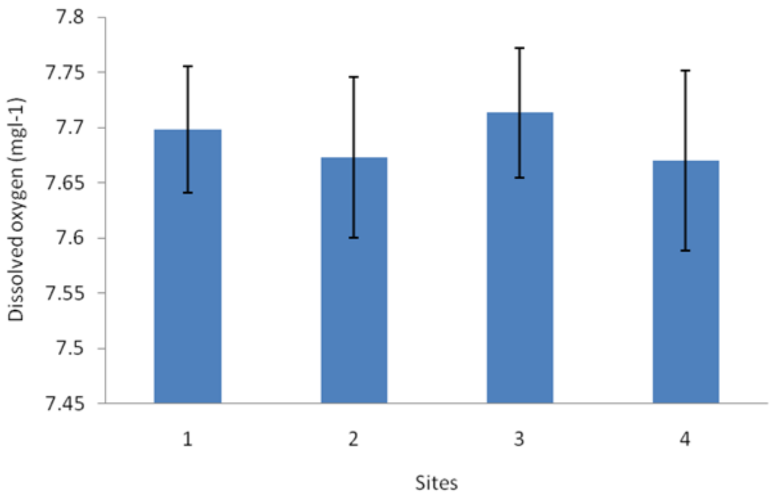

Fig. 2: Mean site dissolved oxygen content (mgl^{-1}) with standard error bars

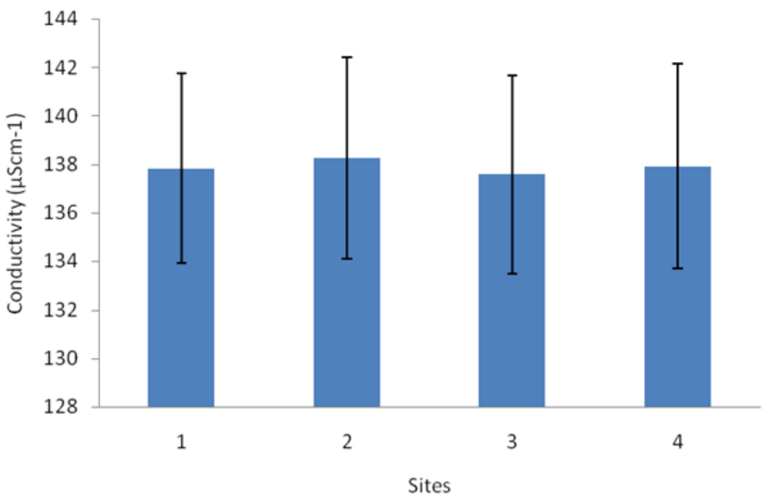

Fig. 3: Mean site conductivity (μScm^{-1}) with standard error bars

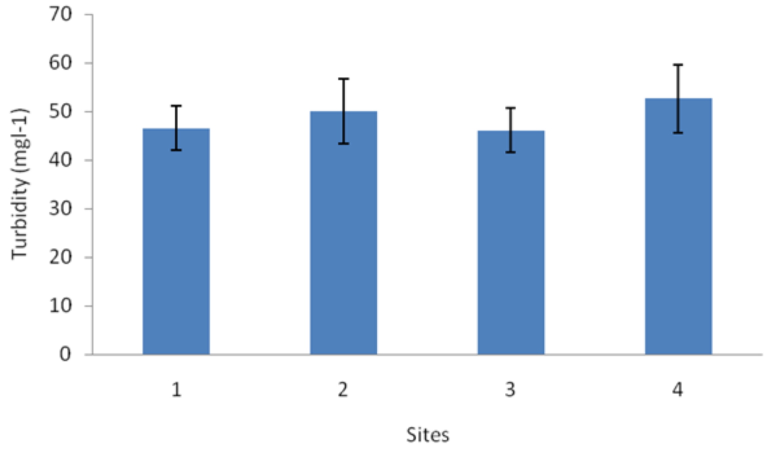

Fig. 4: Mean site turbidity (mgl^{-1}) with standard error bars

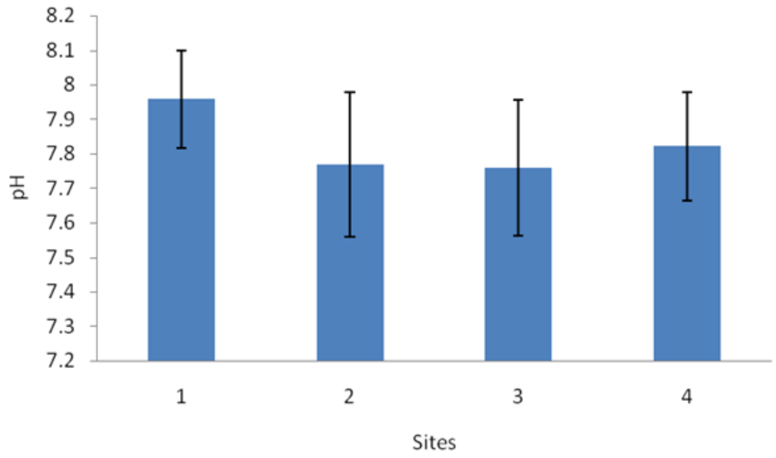

Fig. 5: Mean site pH with standard error bars

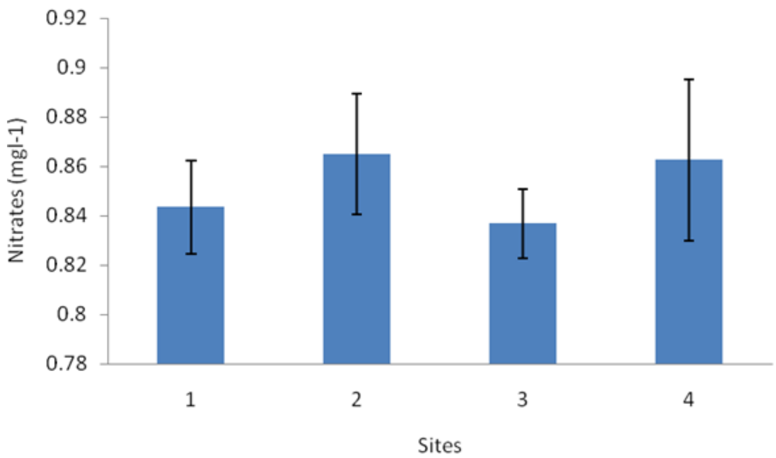

Fig. 6: Mean site nitrates content (mgl^{-1}) with standard error bars

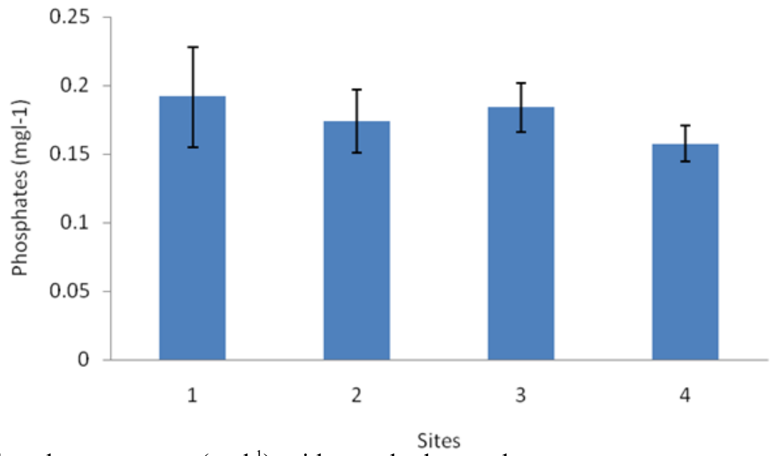

Fig. 7: Mean site phosphates content (mgl^{-1}) with standard error bars

The estimated potential fish yield of the Dawhenya reservoir (Y) from the morpho-edaphic indices (MEI) was 38.44 kg/ ha. This was obtained from the relationship:

$$Y = 23.281 \times \frac{\text{mean conductivity of all 4 sites}^{(0.447)}}{\text{Mean depth}}$$

$$= 23.281 \times \frac{133.078^{0.447}}{5.4}$$

$$= 38.44 \text{ kg/ha}$$

Table 2: Checklist of fish species in the Dawhenya reservoir

No.	FAMILY	SPECIES	DESCRIPTION
1	Anabantidae	*Ctenopoma petherici*	Fin fish
2	Cichlidae	*Hemichromis fasciatus*	
	Oreochromis niloticus		
	Sarotherodon galilaeus		
	Tilapia zillii	Fin fish	
3	Clariidae	*Clarias gariepinus*	Fin fish
4	Cyprinidae	*Barbus macrops*	Fin fish
5	Gobiidae	*Nematogobius maindroni*	Fin fish
6	Mormyridae	*Marcusenius abadii*	Fin fish
7	Osteoglossidae	*Heterotis niloticus*	Fin fish
8	Palaemonidae	*Macrobrachium macrobrachion*	
	Macrobrachium vollenhovenii	Shell fish	

Table 3: Species composition by weight in drag net catches during the dry and wet seasons in the Dawhenya reservoir

Species	Dry season (%)	Wet season (%)
Sarotherodon galilaeus	10.5	ND
Oreochromis niloticus	0.2	2.5
Tilapia zillii	5.9	4.2
Hemichromis fasciatus	8.4	5.9
Macrobrachium vollenhovenii	2.5	2.1
Heterotis niloticus	0.2	ND
Barbus macrops	71.6	85.3
Nematogobius maindroni	0.7	ND

ND = No data collected

Table 4: Length-weight relationship parameters and related statistics for the most abundant fish species caught in the Dawhenya reservoir (PA: positive allometric, **IS:** isometric, **NA:** negative allometric).

FAMILY/SPECIES	a	b	r^2	L_{min} (cm)	L_{max} (cm)	Growth pattern
PALAEMONIDAE Macrobrachium vollenhovenii	0.009	3.267	0.881	2.6	14.0	PA
PALAEMONIDAE Macrobrachium macrobrachion	0.027	2.864	0.560	4.9	10.5	NA
CICHLIDAE Sarotherodon galilaeus	0.081	2.793	0.968	6.0	12.0	NA

CYPRINIDAE *Barbus macrops*	0.010	2.934	0.621	5.5	9.1	IS

Discussion:

Fish yield:

Reservoirs in the tropics are noted to be more productive than those in the temperate regions Jackson, D.C. and G. Marmulla, (2001). According to Marshall, B. and M. Maes, (1994). estimated fish yields in deep tropical reservoirs ranged from 10 – 50 kg/ha/year while that of shallow tropical reservoirs ranged from 30 – 150 kg/ha/year. The 38.44 kg/ha fish yield obtained for the Dawhenya reservoir in the Accra Plains in southern Ghana was lower than those estimated for some reservoirs in northern Ghana i.e. Achubunyi (75.0 kg/ha) and Mahama (90.19 kg/ha) Abban *et al.,* (1994); Botanga (86.98 kg/ha) and Libga (97.19 kg/ha) Quarcoopome, *et al.* (2008); and Jebba (40 kg/ha) Adeniji, H.A. (1991), Bakolori (50 kg/ha), Oyun (125.72 kg/ha) Mustapha, M.K., (2009) in Nigeria. This could be due to the depth and high conductivity value of the Dawhenya reservoir since deep reservoirs are less productive Marshall, B. and M. Maes, (1994).

The estimated fish yield in the Dawhenya reservoir is however higher than those of Kubani (38 kg/ha) Balogun, J.K. and U.J. Aduku, (2005); Kainja (3.5 – 4.7 kg/ha) Balogun, J.K. and M.O. Ibeun, (1995); and Volta (12 kg/ha) Ryder *et al.,* (1974). This could be due to the great mean depths of these large reservoirs/lakes in Africa.

Physicochemical parameters:

Dissolved oxygen is essential to all forms of aquatic life. Bagenal, T., (1968) reported that dissolved oxygen level is related to reproduction in fishes, because fecundity is directly correlated to fish size (length and body weight). The oxygen content of natural waters varies with temperature, turbulence, atmospheric pressure and photosynthetic activity of algae and plants. The solubility of oxygen decreases as temperature increase. In freshwaters, dissolved oxygen at sea level ranges from 15 mgl^{-1} at 0 °C to 8 mgl^{-1} at 25 °C. Concentrations in unpolluted waters are usually close to, but less than 10 mgl^{-1} Chapman, D. and V. Kimstach, (1996). Concentrations below 2 mgl^{-1} may lead to the death of most fish. The dissolved oxygen range of 7.67 to 7.71 mgl^{-1} recorded in the current study was within the acceptable ranges quoted by Chapman, D. and V. Kimstach, (1996): (< than 10 mgl^{-1}). Conductivity of a water body is sensitive to variations in dissolved solids, mostly mineral salts. This is important because it measures the productivity potential of the water body. The conductivity of most freshwater bodies ranges from 10 μScm^{-1} to 1000 μScm^{-1} Chapman, D. and V. Kimstach, (1996). The conductivity obtained in this study (112.8-164.3 μScm^{-1}) was within this range and hence suitable for development of fisheries resources in the reservoir. At a given temperature, pH indicates the intensity of the acidic or basic character of a solution and is controlled by the dissolved chemical compounds and biochemical processes in the solution. The pH of freshwater bodies ranges from 6.0 to 9.0 Chapman, D. and V. Kimstach, (1996) or 5.0 to 10.0 Bennett, G.W. (1970). The pH range of 7.24 to 8.8 obtained in this study was within these ranges. The pH recorded in this study also shows that the impoundment was slightly alkaline.

Impounded systems can have nitrates concentrations up to 5 mgl^{-1}, but often less than 1 mgl^{-1} Chapman, D. and V. Kimstach, (1996). Concentrations in excess of 5 mgl^{-1} usually indicate pollution by human or animal wastes, or fertilizer run-off. In lakes, concentrations in excess of 0.2 mgl^{-1} tend to stimulate algae growth and indicate possible eutrophic conditions Roberts, G. and T. Marsh, (1987). The range recorded in this study was from 0.8 to 0.98 mgl^{-1} and hence, within the acceptable limits, and therefore suitable for fisheries resources in the impoundment. Phosphorus on the other hand is generally the limiting nutrient for algal growth, and therefore, controls the primary productivity of a fresh water body Roberts, G. and T. Marsh, (1987). Phosphorus is rarely found in high concentrations in freshwaters as it is actively taken up by plants Tait, R.V. and F.A. Dipper, (1998). High concentrations of phosphates can indicate the presence of pollution and are largely responsible for eutrophic conditions. In most freshwaters, it ranges from 0.005 mgl^{-1} to 0.02 mgl^{-1} Chapman, D. and V. Kimstach, (1996). The range of 0.09 mgl^{-1} to 0.34 mgl^{-1} recorded in this study falls outside that reported by Chapman, D. and V. Kimstach, (1996). Pollution of the impoundment could be due to fertilizer run-off within the catchment area Victor, R. and A.E. Ogbeibu, (1985) and nutrient enrichment of the impoundment Kronvang, B. (1992) since the inhabitants were predominantly peasant farmers IDA, (1992). From Pearson's correlation analysis, there was no significant correlation ($p < 0.05$ (2-tailed)) between the physicochemical parameters of the sampling stations in the study, implying homogeneity of the entire water body.

Conclusion:

In the Dawhenya reservoir, 12 fish species belonging to 8 genera were encountered out of which 7 genera were fin fishes while the remaining genus was a shell fish. During the dry season, eight fish species were sampled and *Barbus macrops* contributed the highest (71.6 %) and *Oreochromis niloticus* the lowest (0.2 %)

by weight while in the wet season five fish species were collected and *Barbus macrops* contributed the highest (85.3 %) and *Macrobrachium vollenhovenii* the lowest (2.1 %) of total weight of fish in drag net catches and the estimated existing fish yield from the reservoir was about 38.44 kg/ha. The general physicochemical parameters monitored during the study period fell within the ranges suitable for fisheries and aquatic life in reservoirs, except for phosphates which were outside recommended ranges. to redress this situation, agricultural activities within the catchment area of the reservoir should be monitored and controlled to prevent nutrient enrichment since the inhabitants were predominantly peasant farmers.

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