African Journal of Agriculture and Food Science
ISSN: 2689-5331
Volume 5, Issue 1, 2022 (pp. 44-53)
www.abjournals.org

A COMPARATIVE STUDY ON THE SELECTED ENVIRONMENTAL PARAMETERS WITHIN THE CAGE, POND AND THE WILD OF WINAM GULF OF L. VICTORIA

Steve Omari Ngodhe*, Emmy Kerich, Okeyo Owuor and Paul Mutai

University of Eldoret, P.O Box 1125-30100 Eldoret

*Corresponding author's email address: mcomaristeve26@yahoo.com

Cite this article:

Ngodhe S.O., Kerich E., Owuor O., Mutai P. (2022), A Comparative Study on the Selected Environmental Parameters Within the Cage, Pond and the Wild of Winam Gulf of L. Victoria. African Journal of Agriculture and Food Science 5(1), 44-53. DOI: 10.52589/AJAFS-OBCHMB8P

Manuscript History

Received: 30 Jan 2022

Accepted: 23 Feb 2022

Published: 17 March 2022

ABSTRACT: *The main aim of this study was to compare the environmental variables between water inside the caged fish, open ponds and open waters of Winam Gulf. Selected water quality parameters from the 20 ponds, 30 cages and wild were measured in-situ using electronic meters. Water temperature, DO, pH and salinity did not differ significantly in the different study areas ($p>0.05$) while Total Dissolved Solids (TDS) registered a significant difference between the culture systems (pond and cage) and the wild ($p<0.05$). This was attributed to the fact that the study areas were all within the same geographical space and there was lack of variation in micro-climatic conditions during the study period, while the differences in TDS could be as a result of over fertilization of ponds, leading to algal bloom. The environmental variables were within the Food and Agricultural Organization (FAO) of the United Nations recommended limits for fish production.*

KEYWORDS: Environmental parameters, cage, pond wild, Winam Gulf, L. Victoria.

Article DOI: 10.52589/AJAFS-OBCHMB8P
DOI URL: https://doi.org/10.52589/AJAFS-OBCHMB8P

INTRODUCTION

Background Information

Sustainability in aquaculture production requires a very healthy production procedure; availability of healthy fish fry and fingerlings are just one of the major and very critical requirements. The ecological water condition where the fish is living is dependent on the occurrence, abundance, composition and magnitude of parasite infestations and therefore, there should be a good relationship between the environment the fish is living in and the fish itself (Charo-Karisa, 2006; Delwar *et al*., 2011). Hossain *et al*. (2007), on their study on physico-chemical parameters such as water temperature, alkalinity, ammonia concentration, dissolved oxygen (DO), pH and total hardness, found out that there is a very strong effect of these parameters on fish health and their resistance and resilience against the disease-causing agents. In a different study, Aguilar *et al*. (2005) indicated that disease transmission can be greatly favored and influenced by environmental conditions such as reduced oxygen concentration, overcrowding, poor hygiene, temperature variations, and availability of intermediate and final hosts in aquaculture systems and other surrounding aquatic ecosystems.

The ecological conditions of aquatic ecosystems, i.e., both physical and chemical characteristics of a water body, have been found to be very critical in controlling the biological productivity of most of the aquatic ecosystems. In order to maintain and keep the ecological integrity of the aquatic ecosystem, the physical and chemical aspects of water quality are vital. The physical and chemical characters of a water body in any aquatic ecosystem could influence and determine the type and composition of parasitic fauna (Kennedy, 1990; Otachi, 2009). The nature and characteristic of parasitic infestation of fish populations in any confined ecosystem is affected by a variety of living and non-living factors. Some of the most common abiotic factors which are recognized to have a very strong influence on parasitic infestation in any confinement include temperature, pH, DO content, alkalinity, and conductivity, among others. According to Gaffar (2007), the effect of water temperature on the fishes is an important factor for infestation rate of parasites. For example, various species of fish parasites have different behaviours and react differently to variations in water temperature where they are found. According to Marcogliese and Cone (1996), the composition structure, abundance, diversity and quantity of the parasite community of eel (*Anguila rostrata*) was highly dependent on water pH. When the pH of water increases, the snails which are the intermediate hosts of digenean trematodes get affected and the trematode parasites could be prohibited from proliferation. A different study by Dzika and Wyżlic (2009) found out that gammarids which are intermediate hosts of acanthocephala developed and metamorphosed more intensely and more acanthocephalan parasites could prevail. Halmentoja *et al*. (2000) further did a study on the reactions and response of parasites of perch to acidified water in two different artificial lakes in Finland and their result revealed a decrease in the number of metazoan parasite species and in their abundance in low pH waters. However, very high species diversity was observed in more alkaline waters as compared to lakes with pH approximating neutral.

MATERIALS AND METHODS

Lake Victoria is at 1135 m a.s.l. and by area, the second largest freshwater lake in the world at 69'485 km^2. Its shoreline is shared by Kenya (6 %), Uganda (45 %) and Tanzania (49 %). It

Article DOI: 10.52589/AJAFS-OBCHMB8P
DOI URL: https://doi.org/10.52589/AJAFS-OBCHMB8P

lies in a shallow depression between the Great Rift Valley and the western Albertine Rift, and has an average and maximum depth of 132 m and 265 m respectively. The lake's surface level varies by up to 3 m—mostly in response to rainfall—to a smaller extent due to managed outflows (Awange & Ong'ang'a, 2006). Pelagic waters in Lake Victoria are stratified, seasonally variable and receive nutrients mainly through diffuse atmospheric deposition (Njiru *et al*., 2012).

Winam Gulf is a 1400 km^2 large bay with a 550 km shoreline located entirely in Kenya, in the northeast of Lake Victoria. It is connected to the main basin only by the 3 km wide Rusinga channel. An even narrower but deeper channel south of Rusinga Island used to allow for better circulation, but was closed by a causeway built in 1980. Average and maximum depth in the Winam Gulf are 6 m and 68 m respectively (Fig. 1). The physico-chemical conditions in the Winam Gulf are very much unlike those in the pelagic area of the main basin. The water is too shallow to be persistently stratified, and the four major tributaries entering the Winam Gulf account for 37.6 percent of all surface water inflow into the whole of Lake Victoria, including large amounts of terrigenous constituents. Agriculture and fertilization are extensive in the area around the Winam Gulf. Main cultivation periods are from December to February and July to September. An increase in sedimentation and nutrient content in the gulf due to land degradation, surface run-off and soil erosion has been observed throughout the past decades, while a proposed increase of atmospheric deposition remains disputed (Gordon *et al*., 2009). Triplicate temperature, dissolved oxygen (DO), salinity, total dissolved solid (TDS) and pH readings were taken *in situ* by water quality multi-probe meter (OAKTON^R, Model pH/Mv/ºC METER, Singapore) at a depth of 10 cm below the water surface for each of the sampling sites between January to August 2018 and recorded.

Fig. 1: Map showing L. Victoria, Winam Gulf and drainage system (Source: Osumo, 2001)

Article DOI: 10.52589/AJAFS-OBCHMB8P
DOI URL: https://doi.org/10.52589/AJAFS-OBCHMB8P

RESULTS

The mean monthly physico-chemical water quality parameters at the cages, ponds and wild from the month of January (1) to August (8) 2018 is shown in Table 1. In cages, physico-chemical water quality parameters did not show any significant difference between the sampled months (p>0.05)$L\ =L\ =$. The highest temperature was recorded in January with a mean of 26.8±0.41 ºC and the lowest registered in the month of May with a mean of 24.8±0.29 ºC, with the rest of the months falling within the range. The highest dissolved oxygen (DO) concentration was recorded during the month of March with a mean of 5.6±0.14 mg/l and the lowest was in February with a mean of 4.1±0.11 mg/l. Similar to DO, the highest pH was recorded in the month of March with a mean of 7.3±0.18, same with what was recorded in May (7.3±0.14). The rest of the months registered a pH value of 7.1 save for January which recorded 7.2±0.15. Salinity concentration was quite low during the study period. The highest was 0.14 mg/l which was recorded in March, June, July and August while the lowest was 0.12 mg/l registered in the months of January, February and April. In May, 7.2±0.15 mg/l was recorded. Total dissolved solids (TDS) were highest in the month of January with a mean of 28.8±0.45 mg/l and lowest in February which recorded a mean of 18.4±0.32 mg/l. The rest of the months registered a value close to the highest mean (Table 1).

In ponds, there were no significant differences on the water quality physico-chemical parameters between the months (p>0.05). Just like in cages, ponds registered the highest mean temperature in the month of January 28.8±0.48 ºC and the lowest during the month of June 24.8±0.45 ºC. On the other hand, DO was also highest in the month of January recording a mean of 5.4±0.16 mg/l and lowest during the month of March and July with a monthly mean of 4.2±0.12 mg/l and 4.2±0.16 mg/l respectively. The month of August recorded the highest value of pH with a mean of 7.6±0.15 and the lowest pH recorded during the month of April and May—7.1±0.15 and 7.1±0.13 respectively. The highest salinity concentration 2.8±0.10 mg/l was recorded from the month of April throughout to August while the lowest concentration of 2.1±0.10 mg/l was recorded in January and February. Concentrations of TDSs were very high all through the sampling period. The highest was recorded during the month of March (480±10.1 mg/l) and the lowest in January and February (360±8.52 mg/l and 360±7.99 mg/l respectively).

In the wild, temperature was highest during the months of January, February, March and April (26.2±0.53, 26.5 ±0.41, 26.0 ±0.37 and 26.5±0.43 ºC respectively) and the lowest were recorded in the rest of the months where the mean values were all 25 ºC. Concentrations of DO almost follow a similar trend but only that the highest was recorded in the month of August with a mean of 7.0±0.15 mg/l and the lowest recorded during the month of June with a mean of 5.5±0.12 mg/l. pH had a range between 7.0 in the months of May, June and August and 7.2 in the months of January, April and July. Salinity did not change much with the ranges between 0.14±0.02 mg/l in January and 0.12±0.01 mg/l in March, while TDS concentration was highest in the month of June recording a mean of 24.0±0.5 mg/l and lowest in February recording a mean of 16.8±0.22 mg/l. Just like in the cage and pond, the wild also showed no statistical difference in the physico-chemical water quality parameters between the months during the study period (p>0.05) (Table 1).

Article DOI: 10.52589/AJAFS-OBCHMB8P
DOI URL: https://doi.org/10.52589/AJAFS-OBCHMB8P

Table 1: Mean monthly (± SEM) of physico-chemical water quality parameters measured in cages, ponds and wild during the study period

Month /Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cage								
Temp.	26.8±0.41	26.6±0.39	25.4±0.46	24.5±0.38	24.8±0.29	25.5±0.42	26.5±0.35	26.2±0.45
DO	4.4±0.12	4.1±0.11	5.6±0.14	5.3±0.13	5.1±0.15	4.9±0.11	5.2±0.13	5.3±0.15
pH	7.2±0.15	7.1±0.13	7.3±0.18	7.1±0.16	7.3±0.14	7.1±0.12	7.1±0.14	7.1±0.17
Sal	0.12±0.02	0.12±0.01	0.14±0.02	0.12±0.01	0.13±0.02	0.14±0.02	0.14±0.01	0.14±0.02
TDS	28.8±0.45	18.4±0.32	26.4±0.35	25.5±0.43	26.5±0.55	24.5±0.44	27.5±0.48	26.6±0.46
Pond								
Temp.	28.8±0.48	27.8±0.57	28.5±0.60	26.8±0.42	25.5±0.44	24.8±0.45	25.2±0.55	26.5±0.50
DO	5.4±0.16	5.3±0.14	4.2±0.12	4.8±0.13	4.5±0.14	4.8±0.15	4.2±0.16	4.4±0.13
pH	7.5±0.19	7.3±0.16	7.6±0.18	7.1±0.15	7.1±0.13	7.5±0.17	7.4±0.14	7.6±0.15
Sal	2.1±0.10	2.1±0.10	2.7±0.10	2.8±0.10	2.8±0.10	2.8±0.10	2.8±0.10	2.8±0.10
TDS	360±8.52	360±7.99	480±10.1	420±9.55	450±9.65	460±9.75	450±8.97	450±9.66
Wild								
Temp.	26.2±0.53	26.5±0.41	26.0±0.37	26.5±0.43	25.7±0.44	25.5±0.48	25.7±0.47	25.8±0.36
DO	6.4±0.15	5.9±0.11	5.8±0.14	6.2±0.16	5.8±0.17	5.5±0.12	6.2±0.18	7.0±0.15
pH	7.2±0.16	7.1±0.13	7.1±0.12	7.2±0.10	7.0±0.12	7.0±0.15	7.2±0.13	7.0±0.13
Sal	0.14±0.02	0.14±0.01	0.12±0.01	0.13±0.01	0.13±0.02	0.14±0.02	0.14±0.01	0.14±0.02
TDS	19.3±0.33	16.8±0.22	19.5±0.36	19.5±0.31	18.5±0.24	24.0±0.53	22.5±0.46	18.6±0.33

There was a variation in the overall mean temperature in the study sites. Ponds recorded the highest mean temperature of 26.85±0.84 ^{0}C followed by wild (26.45±0.65 ^{0}C), then the least mean was recorded in cages (25.88±0.67^{0}C). There was a significant difference in the mean temperatures in the study sites (p=0.02). DO also recorded a slight variation between cages and ponds. Higher concentrations were recorded in the wild with a mean concentration of 5.98±0.96 mg/l, then the cage had a mean of 4.98±0.20 mg/l, while the pond registered the lowest mean concentration of 4.80±0.66 mg/l. The variance in pH was very minimal with the lowest recorded in the wild (7.09±0.39) and the highest in the pond (7.45±0.26) and lastly, the cage had a mean value of 7.17±0.35. There was no significant difference between the sites. Salinity concentrations were low in both cage and wild with mean concentrations of 0.13±0.02 and 0.12±0.03 mg/l respectively, with the highest mean registered in the pond (2.64±0.55 mg/l). There was a significant difference between (pond and cage) and (pond and wild) (p=0.01; p=0.014 respectively) and there was no significant difference between cage and wild (p>0.05). The TDS recorded the highest variance with the pond recording a mean concentration of 447.15±10.63 mg/l with cage coming a distant second with a mean concentration of 25.49±0.85 mg/l, followed closely by the wild recording a mean of 19.39±0.98 mg/l. There was a significant statistical difference between the study sites (p=0.01) (Table 2).

Article DOI: 10.52589/AJAFS-OBCHMB8P
DOI URL: https://doi.org/10.52589/AJAFS-OBCHMB8P

Table 2: Common physico-chemical values (mean ± SE) of the study sites

Parameters	Cage	Pond	Wild
Temp.(^{0}C)	25.88±0.67	26.85±0.84	26.45±0.65
DO (mg/l)	4.98±0.20	4.80±0.66	5.98±0.96
pH	7.17±0.35	7.45±0.26	7.09±0.39
Salinity (mg/l)	0.13±0.02	2.64±0.55	0.12±0.03
TDS (mg/l)	25.49±0.85	447.15±10.63	19.39±0.98

DISCUSSION

- **Temperature**

Temperature is a very important physico-chemical variable in fish farming that affects fish metabolic rate (FAO, 2006). It also affects the toxicity and the reaction rate of other chemicals, such as ammonia, which are very detrimental to fish besides influencing the solubility of gases in water, including atmospheric oxygen which is only useful in a solution. Kiran (2010) observed that temperature fluctuation also affects the development of natural food sources of fish such as phytoplankton and zooplankton, hence impacting negatively to fish productivity. High temperatures in any aquatic ecosystem lead to increase in the metabolic activities of aquatic organisms and at the same time reduces the concentration of dissolved oxygen in water (Afzal *et al.*, 2007). The recommended range for good performance of warm water fish, according to FAO (2006), is between 25 and 32 ^{0}C. Very low temperatures cause stagnation of fish growth and at times kill fish, and very high temperatures also reduce the solubility of atmospheric oxygen and enhance fish stress which may lead to fish death.

During the entire period of study, surface water in the Winam Gulf exhibited a narrow range of temperature (24.5–26.8^{0}C), (24.8–28.8^{0}C) and (25.5–26.5^{0}C) in cage, pond and wild respectively. This may be due to almost the same intensity of solar radiation experienced during the study period in the gulf and also absence of micro-climatic variations in temperatures during the study period. The study by Escalera-Vazquez and Zambrano (2010) also recorded a similar trend where they indicated that the majority of the tropical lakes show a relatively constant solar radiation which results in narrow seasonal ranges of both air and water temperatures. Winam Gulf surface water temperature showed a constant slight rise and fall from January to April, a slight drop in May followed by another rise and fall in the subsequent months. There was generally high solar radiation over the Gulf region during the period when surface water temperature was observed to rise and that is why the wild and cage temperature showed a similar trend since it is the same ecosystem. The heat content and temperature in the water column were higher from January to March than April to August; this could further be attributed to difference in cloud clarity which directly affects the intensity of the solar radiation incident to the lake surface. There was rarely a cloud cover from January to March 2018 and this is why the temperature at this time was higher than the periods that experienced some slight rains, i.e., April till August 2018. This is not in agreement with the study done by Ayroza *et al.* (2013), who stated that higher temperatures in the rainy season have been associated with deep

Article DOI: 10.52589/AJAFS-OBCHMB8P
DOI URL: https://doi.org/10.52589/AJAFS-OBCHMB8P

reservoirs that have a long residence time, favoring thermal and chemical stratification in the rainy season. This may be because they only study the thermal difference in a small water body and only during the rainy season unlike this study which considered both ponds and open waters of the Winam Gulf. A comparison between this study and Kaggwa *et al.* (2011) revealed the same trend where they both agree that the smaller the surface area exposed to solar radiation, the higher the temperature.

In each month when measurements were made, water temperatures in the open waters and cages were nearly the same during the study period. Different sampled ponds also showed the same temporal variation but with higher values than the gulf. The high temperature in ponds could be as result of the smaller surface area exposed to solar radiation than the area in open waters of the gulf. This could be also as a result of depth as most ponds are barely 1 m deep as compared to gulfs where some points are too deep. Other possible reasons for the slight variations include: Some sampled areas were more enclosed than others and their temperature tended to be slightly lower, e.g., areas around Kendu-Bay; influence by the inflowing rivers such as R. Nyando, Awach, Sondu-Miriu and Kibos that enter the Gulf also could have lowered its temperature when it rains. Ingole *et al.* (2009) alluded that differences in temperature in any culture system is influenced by environmental variables such as air, temperature, humidity, wind and solar energy.

- **Dissolved Oxygen (DO)**

The dissolved oxygen concentrations in the Winam Gulf surface water and the nearby inland ponds were relatively high. The mean concentrations varied very little between the cages and open waters during the present study period. This relatively high concentration of dissolved oxygen in the gulf could be as a result of high phytoplankton densities which was very evident by the greenish color of the water and also the atmospheric oxygenation which was evident by the wind that blows from the lake towards the shore. The high photosynthetic biomass is ecologically accompanied by high photosynthetic rates. The high phytoplankton biomass could be as a result of increased nutrient inputs into the gulf through the flowing rivers, especially during the rainy season. The shallowness of the gulf also renders it prone to stirring of the water by winds causing nutrients to be released from the sediments into the water, thus leading to increased productivity (Magagula *et al*., 2010). The concentrations in the cages and ponds in the entire gulf and its shore were slightly lower and this was attributed to high stocking density of *Oreochromis niloticus* in the cages. The fish consumes the available dissolved oxygen and could as well deplete it if the concentration is low. There could also be the cage-net effect on free circulation of water which could have also lowered the rate at which the atmospheric oxygen dissolves in water. This is augmented by other wastes that get into the gulf and ponds, rendering the concentration at the cages and ponds lower than the open waters. The concentration in the entire gulf and surrounding ponds were relatively lower during some rainy periods than dry spells; this was attributed to the introduction of organic matter through the rivers and run-off from agricultural lands; hence, it lowers the oxygen content of the water due to the consumption of oxygen during decomposition. This is supported by Mwaura (2006) who stated that lack of water circulation and other pollutants in water negatively affect the rate at which atmospheric oxygen dissolves in water. The numerous car wash and open air garages within the shores of L. Victoria also play a part in the reduction of oxygen in the gulf. With the blocked storm drains in the town, engine oil emanating from these car wash and garages is washed into the lake during the rains. Various patches of oil films are a common feature

Article DOI: 10.52589/AJAFS-OBCHMB8P
DOI URL: https://doi.org/10.52589/AJAFS-OBCHMB8P

associated with urban centers especially during the rainy season. Such films reduce the aeration process of the water and thus lower oxygen content.

- **pH, Salinity and TDS**

Just like temperature, pH, according to ICAR (2006), has been reported to affect the metabolism and the physiological processes of aquatic organisms as well as the toxicity rate of ammonia. In the current study, the water pH remained fairly constant in open waters of the gulf, cages and also the ponds over the period of the present investigations with values ranging between 7.0 and 7.6. There was, however, a marked trend of a slight increase in pH values during the rainy season which was not statistically significant. This is mainly due to the effect of dilution of the gulf water by direct precipitation and runoff. River run-off normally has a lower pH than the lake water while rain water has a pH of about 7.0. During the rainy season, the effect of dilution outweighs the effect of carbon dioxide released during respiration by fish and other aquatic biota, which would lower the pH. The relatively higher algal and zooplankton densities in open waters and ponds could have resulted into the release of more carbon dioxide into the water, thereby lowering the pH. Distribution of pH was nearly uniform throughout the water surface and column. The pH of the Winam Gulf does not appear to change considerably over a long period of time. This is because of the homogeneity of the physico-chemical parameters (i.e., rainfall pattern, water depth, amount of dissolved and suspended particles, and chemical pollutants, among others) in the entire gulf and its surrounding. This study is in agreement with Mkare *et al*. (2010) who found out that shallow, tropical water bodies are often characterized by homogeneity in physico-chemical parameters due to complete mixing within the water column.

Biologically, as carbon dioxide is removed, carbonate accumulates and gives away hydroxyl ions leading to pH increase. Aquatic vegetation and plants can continue to use the small amounts of carbon dioxide available at pH values above 8.3, and bicarbonate may be absorbed by plants and some of the carbon from bicarbonate may be used in photosynthesis, thus lowering the pH. Mwaura (2006) also points out that the type of soil and lacustrine sediments could be associated with bicarbonate and carbonate ions and could also affect the pH either by raising or lowering it, depending on the soil and sediment type.

Salinity values were generally low during the study period. The low salinity of Lake Victoria can be attributed to high precipitation and high inputs of fresh water by the inflowing rivers. The much lower precipitation in some other lakes, specifically in the Rift Valley, the seasonality of the rivers that feed them, underground seepage and the high rates of evaporation cause high salinity in the lake water through concentration of ions (Njuguna, 1982).

The slightly high salinity concentrations in ponds (2–3 mg/l) could be due to surface run-off which brings dissolved salts from the rocks over which it flows together with nutrients from agricultural land, especially during the rainy season. When water evaporates, the dissolved salts remain and their concentration increases and since the pond surface area is smaller than the open waters, the evaporation rate becomes higher and more intense in ponds than in open waters. This could have been the reason why the salinity in ponds was high compared to the gulf.

Article DOI: 10.52589/AJAFS-OBCHMB8P
DOI URL: https://doi.org/10.52589/AJAFS-OBCHMB8P

Agricultural practice has been shown to influence nutrients and total dissolved solids (TDS) in water. Human activities such as fertilization and cultivation could have contributed to high total dissolved solids and turbidity as this results in increased phytoplankton biomass according to Johnson *et al*. (1997).

It is most likely that high concentration of total dissolved solids in ponds could have been as a result of pond fertilization which is recommended for algal growth. Most ponds were over-fertilized and therefore realized algal bloom as a result of high nutrient concentration. It could also have been increased by the soil particles eroded river banks getting into the ponds via run-off during rainy season. Unlike in open waters where there is a high rate of dilution, these particles usually settle in the deeper layers of the lake. The differences in depth and the surface area exposed to TDS caused the statistical difference in the TDS concentration between open water and the ponds.

REFERENCES

Afzal M. Rab A.; Akhtar N., Khan M.F. Barlas A., and Qayyum M. (2007): Effects of Organic and Inorganic fertilizers on the growth performance of bighead carp 77 (Aristichthys nobilis) in polyculture system. *International Journal of Agriculture and Biology*, 9(6): 931-933.

Aguilar, A., Alvarez, M. F., Leiro, J. M., & Sanmartin, M. L. (2005): Parasite populations of the European eel (Anguilla anguilla L.) in the Rivers Ulla and Tea (Galicia, northwest Spain). *Aquaculture*, *249*(1), 85-94.

Awange, J.L., and Ong'ang'a, O. (2006). Lake Victoria: Ecology, Resources, Environment (Berlin, Germany: Springer Verlag).

Ayroza, D. M., G, N. M., Ayroza L M D S, Carvalho E D, Ferraudo A S, & Camargo A F M. (2013). Temporal and Spatial Variability of limnological characteristics in areas under the influence of Tilapia cages in the Chavantes reservoir, Paranepanema River, Brazil. *Journal of the World Aquaculture Society*, *44*(6), 814-825.

Charo-Karisa, H. (2006). Selection for growth of Nile tilapia (*Oreochromis niloticus L.*) in low-input environments (PhD Thesis) Wageningen Universiteit (169pp.).

Delwar, M., Kabil, M., & Habibur, M. (2011). Water quality parameters and incidence of fish diseases in some water bodies in Natore, Bangladesh.

Dzika, E., & Wyżlic, I. (2009). Fish parasites as quality indicators of aquatic environment. *Zoologica Poloniae*, *54*(1-4), 59-65.

Escalera-Vazquez, L., & Zambrano, L. H. (2010). The effect of seasonal variation in abiotic factors on fish community structure in temporary and permanent pools in a tropical wetland. *Freshwater Biology* , *55*(12), 2557-2569.

Food and Agricultural Organization. FAO (2006). State of World Aquaculture 2006. FAO Fisheries Technical paper 500. Rome: FAO Fisheries Department.

Gaffar, R.A. (2007). Seasonal variation and histopathology of helminth parasites in the fish *Lutianus argentimaculatus* (Forsk, 1775) red snapper. Ph.D. thesis, University of Karachi, Pakistan, p. 705.

Gordon, S., Walsh, M., Castro, A., and Maoulidi, M. (2009). An Overview of the Main Environmental Issues Affecting Kisumu and Lake Victoria's Winam Gulf (New York,United States: Millenium Cities Initiative).

Article DOI: 10.52589/AJAFS-OBCHMB8P
DOI URL: https://doi.org/10.52589/AJAFS-OBCHMB8P

Halmentoja, A., Valtonen, E.T., Koskenniemi, E. (2000). Perch (Perca fluviatilis L.) Parasites reflect ecosystem conditions: a comparison of natural lake and two acidic reservoirs in Finland. Int. J Parasitol. 30: 1437-1444.

Hossain, M. D., Hossain, M. K., & Rahman, M. H. (2007). Water quality parameters and incidence of fish diseases in some water bodies in Natore, Bangladesh. *Journal of Life and Earth Science*, *2*(2), 27-30.

Indian Council of Agricultural Research (ICAR) (2006). Handbook for Fisheries and Aquaculture: Directorate of Information and Publications of Agriculture, New Delhi 110-112. Pp. 755

Johnson, L.L., Stehr, C.M, Olson, O.P, Myers, M.G, Pierce, C.A, Wigren, B.B, McCain, S.M. and Varanasi U. (1997). Chemical contaminants and hepatic lesions in winter flaunder (*Pleuronectes americanus)* from the Northeast Coast of the United States. Environmental Science Technology, 27:2759-2771

Kaggwa, M. N., Liti, D. M., & Schagerl, M. (2011). Small tropical reservoirs and fish caage culture: a pilot study conducted in Machakos district, Kenya. *Aquaculture International*, *19*, 839-853.

Kennedy, C. R. (1990). Helminth communities in freshwater fish: structured communities or stochastic assemblages? In Parasite *communities: Patterns and processes* Springer *Netherlands.* pp. 131-156.

Kiran B.R. (2010). Physico-chemical characteristics of fish ponds of Bhadra Project at Krnataka *rasayan journal of chemistry*. Vol 3. No. 4. 671-676.

Magagula, C. N., Mansuetus, A. B., & Tetteh, J. O. (2010). Ecological health of the Usuthu and Mbuluzi rivers in Swaziland based on selected biological indicators. *African Journal of Aquatic Science, 35*(3), 283-289.

Marcogliese, D.J., Cone, D.K. (1996). On the distribution and abundance of eel parasites in Nova Scotia: influence of pH. J Parasitol., 82: 389-399.

Mkare, T. K., Manyala, J., Mulanda , C., & Mbaru, E. (2010). Relation between phytoplankton composition and abundance aand physico-chemical characteristics of Chepkanga dam, Eldoret, Kenya. *Lakes and Reservoirs: Research aand management, 15*, 111-118.

Mwaura, F. (2006). Some aspects of water quality characteristics in small tropical man-made reservoirs in Kenya.*African Journal of Scienec and Technology* (No.1),82-96.

Njiru, M., Nyamweya, C., Gichuki, J., Mugidde, R., Mkumbo, O., and Witte, F. (2012).
Increase in Anoxia in Lake Victoria and its Effects on the Fishery. In Anoxia, P. Padilla,ed. (Rjeka, Croatia), pp. 99–128.

Njuguna, S.G., (1982). Nutrient-Productivity relationships in tropical Naivasha Basin lakes, Kenya. PhD thesis. University of Nairobi. 300p

Osumo, W. M. (2001). Effects of water hyacinth on water quality of winam gulf, lake victoria kenya marine fisheries research institute university of akureyri and marine research institute (steing@unak.is).

Otachi, E. O. (2009). Studies on occurrence of protozoan and helminth parasites in Nile tilapia (*O. niloticus*) from central and eastern provinces, Kenya: MSc thesis, Egerton University.

Article DOI: 10.52589/AJAFS-OBCHMB8P
DOI URL: https://doi.org/10.52589/AJAFS-OBCHMB8P