ISSN: 2642-9020

Research Article

Journal of Marine Science Research and Oceanography

Performance Of Nile Tilapia *Oreochromisniloticus* (L) In Cages of Varied Stocking Densities

Philemon Nsinda[1]*, Benedicto Kashindye[2], Magreth Musiba[2], and Amon Shoko[3]

[1]Tanzania Fisheries Research Institute, Sota Sub-station, Box 46, Shirati, Rorya, Tanzania

[2]Tanzania Fisheries Research Institute, Mwanza centre, Box 475, Mwanza, Tanzania

[3]Tanzania Fisheries Research Institute, TAFIRI Headquarters, Box 9750, Dar, salaam, Tanzania

***Corresponding author**
Philemon Nsinda, Tanzania Fisheries Research Institute, Sota Sub-station, Box 46, Shirati, Rorya, Tanzania

Submitted: 20 Oct 2021; **Accepted**: 23 Oct 2021; **Published**: 26 Oct 2021

Citation: *Philemon Nsinda, Benedicto Kashindye, Magreth Musiba, and Amon Shoko (2021) Performance of Nile tilapia Oreochromis niloticus (L) in cages of varied stocking densities. J Mari Scie Res Ocean, 4(3): 231-237.*

Abstract

Cage culture is a new venture in Tanzania, and the knowledge of stocking density in cages is still needed. Growth performance of Nile tilapia, Oreochromis niloticus (L) stocked in cages of varied stocking densities and their impacts on waters were evaluated for 212 days in Shirati Bay of Lake Victoria. We started with fingerlings of 18.0±2.1 g, 19.9±14.7 g, and 18.5 ± 8.0 g mean weights. They were raised in cages at stocking densities of 70 (Treatment I), 100 (Treatment II), and 130 fish/ m3 (Treatment III) each in triplicates. We recorded monthly fish weights and lengths, total nitrogen, total phosphorus, ammonia, and micro-benthos. Parameter such as dissolved oxygen, pH, temperature, and transparency were all monitored weekly. The final average fish weights were 374.1±59.8g in treatment I, (194.8 ± 63.7g) in II, and (273.2±20.6g) in III. Percentage fish survival was the highest in treatment I (76.7%), followed by II (65.4%) and III (54.3%). Specific growth rate, production and yield was the highest in treatment I, and significantly different from treatments II and III (p <0.05). This indicates that Nile tilapia flourished well in the lowest stocking density. Water quality parameters were within the range of fish culture throughout the study and observation of water depth, distance from the shoreline, and the prevailing water currents showed lack of adverse environmental effect caused by fish cage culturing.

Key words: Nile Tilapia, Density, Cage, Lake Victoria, Productivity

Introduction

Fish farming in Africa is a new venture started in the 1920s, and intensified thereafter when pond fish culture trials of tilapia established in Central Africa by 1940s [1-3]. Cage culture like pond fish culture is among fish farming systems of however, more relatively shorter history in Africa than pond culture system [4,5]. The culture started sometime back by retaining fish as means for holding suitable quantity after catching them alive until when they are sent to market [6]. These practices were later spread to most of the tropical and subtropical regions of Africa in the 1970s [7,8].

Cage fish culture is normally operated in public water bodies such as lakes, rivers, reservoirs, and costal sheltered areas and in so doing creates an alternative activity, especially for the communities with scarce land. Operations of cage requires lower capital investment, offer increased management flexibility and have lower production costs compared to ponds and raceways. Another advantage of using cages is breeding cycle of fish like Nile tilapia is disrupted allowing rearing of mixed-sex populations to grow without problems of sexual maturity, leading to stunting; a major constraint in pond tilapia culture system [9].

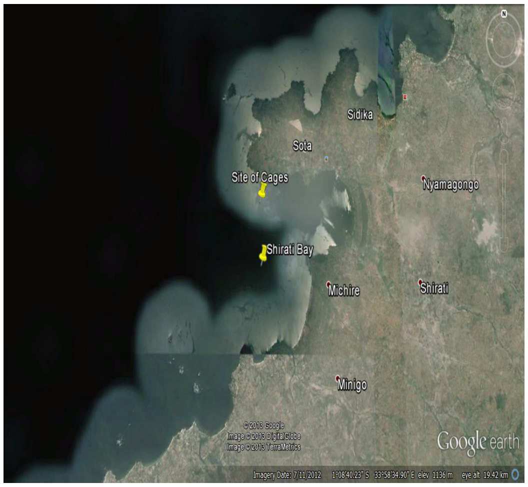
Experience has shown that some form of permit or licensing system is required for effective monitoring and management of cage culture because they are said to impact environment negatively through pollution and problems associated with ownership. This occurs when cages are set in public water resource with poor management [10,11]. In Tanzania, like many other countries in the world, restricts fish cage culture practices in public waters until some protocols are observed (Tanzania Fisheries Act, 2003). Of recently, however, Kenya and Uganda started both medium and large-scale cage fish culture operations in Lake Victoria [12]. They did so to fill up gaps following decline in catches reported at many landing sites of the lake [13,14]. Major courses of fish decline were reported to have been brought by rampant use of illegal fishing gears and methods, poor management of the fisheries resources, and high fishing pressure fueled by hiking demand of fish protein required to feed an increasing human population (about 40 million people) found in the Lake Victoria Basin [15].

Tanzania has recently, though in small pace, allowed cage culture in her public waters including of Lake Victoria. This new endeavour in fish farming technology has necessitated a study on cage fish culture to observe its viability, undertaking, and any negative environmental impact of these cage fish farming on public waters. For fish farming to succeed, issues such as proper selection of fish seed, feeds, good culture management is of paramount importance. This is because harvests at the end each production cycle is highly depend on among other factors, the number of fish stocked in the farm, food given and rates of fish growth in response to management of the culture system.

The majority of tilapia species farmed in Tanzania now are extensively or semi-intensively reared for subsistence in ponds, tanks, haps or cages [16]. They can grows well at high stocking densities in the confinement tanks when good water quality is maintained. But use of high stocking density as a technique to maximize water usage, and thus increaseing stock production shown to have an adverse effect on growth [17]. In this paper information on the performance of Nile tilapia under various stocking densities in cages of varied stocking densities, and iimpacts of cage culture on the lake water environment will be evaluated to gain knowledge and experience towards cage fish culture management in Tanzania.

Materials and Methods

The study was carried out for 212 days with purpose to determine growth performance of Nile tilapia, Oreochromis niloticus (L) reared in cages of varied stocking densities and observe their impact on the lake waters. Cages for the experimental were located at 108'3.78" S and 33059'45.46" N in Shirati Bay of Lake Victoria, Tanzanian (Figure 1). Nine cube shaped cages of 2m × 2m × 2m were mounted net bags of uniform mesh sizes of 1.5 cm each in triplicate. They were stocked Nile tilapia fingerlings in cages set away from nursery grounds to expose them to wave actions at mean depth of 6.1 ± 0.8 m and far from the lake shore at about 300 m offshore.



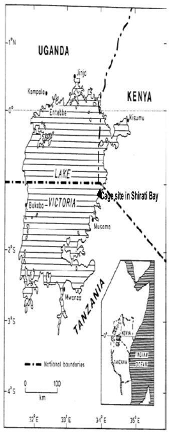


Figure 1: Site for Nile tilapia cage culture in Shirati Bay of Lake Victoria, Tanzania.

At stocking, ffingerlings had initial mean weights of 18.0±2.1 g, 19.9±14.7 g, and 18.5 ± 8.0 g. Stocking densities of each set of cage were 70, 100, and 130 fish/ m3 referred to as treatments I, II, and III, respectively. Fish were fed 25% crude protein (Ugachick, feeds imported from Uganda) at feeding ration of 5% per body weight three times a day at 1000 hrs, 1300 hrs and 1600 hrs East African time. We randomly sampled a total of 90 fish, 10 from each cage and 30 fish per treatment (representing a stocking density) a month. For calculation of production at the end of the study, we recorded an aaverage monthly increment in weights and lengths.

Physical and chemical parameters of water were recorded from five sampling stations 1, 2, 3, 4, and 5. Station 1 was located at inshore about 75 m near the cages, station 2 represented site at the middle of the cages, station 3 was placed in between the cages, station 4 was assigned an extreme end of cages toward the offshore, and the last station 5 was a place of the offshore waters located between 50 m and 500 m away from the cages. Data was collected weekly at 0900 hrs including data on water quality such as dissolved oxygen, pH level; temperature and transparency. Other parameters we recorded are Ammonia, SRP, Total Nitrogen, Nitrates, Total phosphorus and Chlorophyll-a. We collected these samples randomly twice in sixty days within Shirati Bay (108'3.78" S and 33059'45.46" N) of Lake Victoria. We used a 1-litre Van Dorn water sampler to sample at the surface, mid, and 0.4 meter above the lake bottom. Samples were preserved on ice box pending analysis in the laboratory. We also sampled Macrobenthos twice in sixty days using an Ekman grab sampler. Samples were taken by performing two hauls of the grab sampler, mixed them together to make one composite sample. Organisms were separated from sediments in a net of 500µm.

Data were analyzed in MINITAB version 13.1 for windows and comparison of fish mean weights between treatments over the study period was made using a paired t-test [18]. Analysis of variance (ANOVA) was used also to compare fish means weights with physical and chemical parameters [19]. We identified and analysed macro-invertebrates according to [20-22].

Results

We stocked a total of 7,041 Nile tilapia in cages for a period of 212 days. The highest percentage survival was in treatment I (76.7%) followed by treatment II (65.4%), and the least in treatment III (54.3%) (Table 1). Fish increased at a specific growth rate (SGR) of 1.03 in treatment I, a value significantly different ($p<0.05$) from SGR of fish in treatments II (0.52) and III (0.50). Likewise, an average daily growth (ADG) of fish in treatment I was the highest (1.0kg/day), but no significant difference ($p>0.05$) was noted between treatments II and III (Figure 2). This may have lead to the highest fish production in treatment I (210.2 kg) and significantly different ($p<0.05$) from that of treatments II (94.2 kg) and III (106.7 kg). Feed conversion ratio (FCR), on the other hand was the lowest (1.7) in treatment I and significantly different ($p<0.05$) from the observed values for fish in cages of treatment II (3.6) II and III (2.6).

Table 1: Nile tilapia growth performance in cages of varied stocking densities in Shirati Bay of Lake Victoria.

Stocking density	Treatment I	Treatment II	Treatment III
	70 fish/m^{3}	100 fish/m^{3}	130 fish/m^{3}
Number of fish restocked in cages	1521^{a}	2400^{b}	3120^{c}
Average weight at stocking (g)	18.0±2.1^{a}	19.9±14.7^{a}	18.5 ± 8.0^{a}
Average weight at harvest (g)	374.1±59.8^{a}	194.8 ± 63.7^{c}	273.2±20.6^{b}
Grow-out (days)	172^{a}	170^{a}	171^{a}
Biomass Growth Rate (kg/day)	1.03^{b}	0.56^{a}	0.67^{a}
No. fish at harvest	1167^{a}	1570^{b}	1694^{b}
Survival (%)	76.7^{c}	65.4^{b}	54.3^{a}
Specific Growth Rate (SGR)	1.03^{b}	0.65^{a}	0.66^{a}
Food conversion ratio (FCR)	1.7^{a}	3.6^{c}	2.9^{b}
Production (kg/cage)	210.2^{c}	94.2^{a}	106.7^{b}
Yield (kg/m3)	26.3^{c}	11.8^{a}	13.3^{b}
Production rate (kg/day) or ADG	1.0^{b}	0.6^{a}	0.7^{a}
Relative biomass production (kg/m3)	29.7^{c}	17.8^{a}	20.6^{b}

Note: Values followed by different superscripts (a, b and c) in a row are significantly different at $p<0.05$

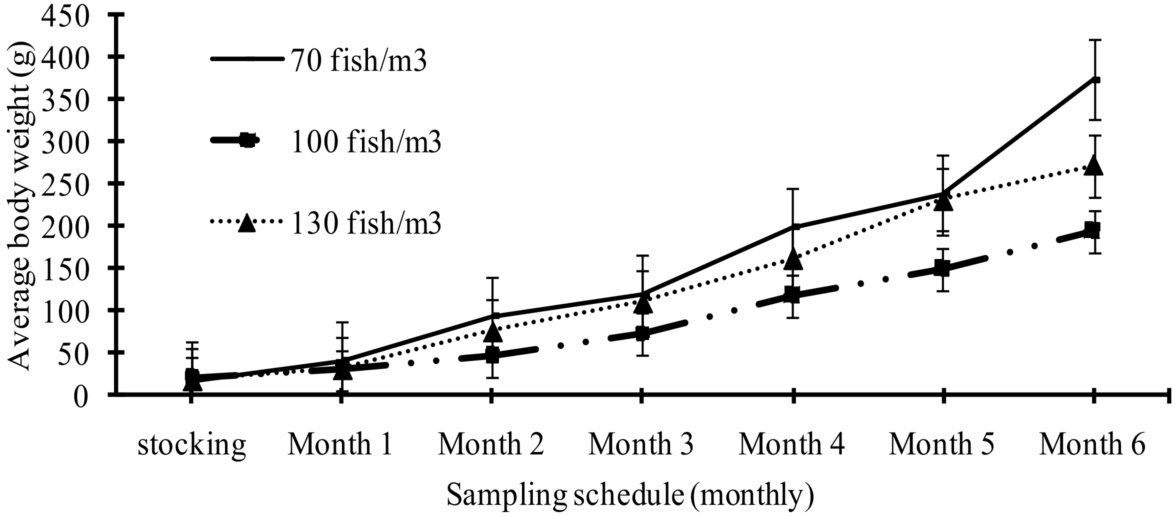


Figure 2: Nile tilapia growth performance in cages of varied stocking densities.

Physio-chemical parameters of water including dissolved oxygen (DO (mg/l), pH level, transparency, and temperature (0C) indicated slight decrease at stations 1, and 2 (near the cages) in the inshore waters. The parameters also decrease relatively at station numbers 3 (inside the cages) and 4 at the extreme end of cages, but towards the offshore waters located (control point) at between 50 m and 500 m away from the cages we noted an increase of these water parameters (Figure 3). Temperature was slightly higher within the cage area (26.170C) and decreased gradually towards an offshore water station (25.380C) with an average temperature of 25.800C throughout the study period. The pH level on the other hand, showed trivial decrease with increasing depth from station 1 in the inshore (7.72) to station 5 in the far offshore waters (6.46) with an overall average pH of 6.73. Figure 4 show changes in depth (m), DO (mg/l), pH level, transparency and temperature (0C) over the sampling period. One Way ANOVA for the test of significance in differences of the measured initial and final physical and chemical parameters indicated insignificant differences at p> 0.05.

Water samples indicated a notable increase in Total Nitrogen (TN) from 482µg/l±3.1 to 1,034.5µg/l ±282, Total Phosphorus (TP) from 89.8µg/l ± 3.7 to 106.8µg/l ±24.5, and Ammonia (NH4-N) doubled from 168.3µg/l ±22.0 to 365µg/l 126.2. An increase in invertebrate community particularly bivalves and gastropods were also noted as signs of activeness in the area where cages are set.

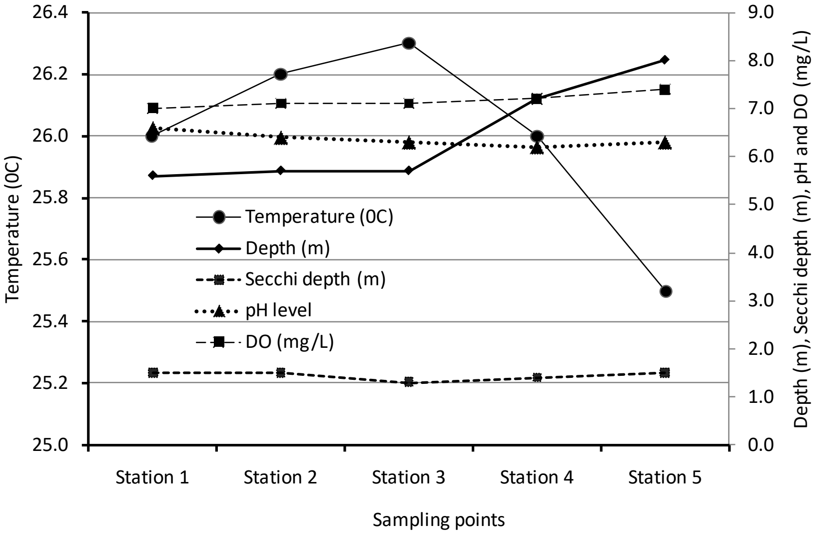


Figure 3: Physical and chemical parameters of water recorded from five sampling points

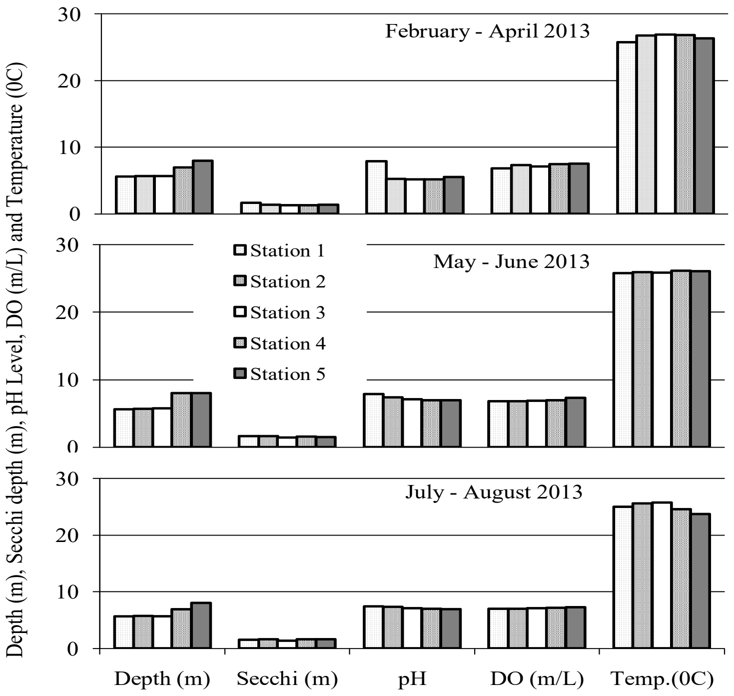


Figure 4: Changes in physical and chemical parameters of water recorded during Nile tilapia cage culture in Shirati Bay of Lake Victoria, Tanzania.

Discussion

Fish farming is an activity intended to maximize fish production from aquaculture systems while maintaining the best ecosystem services of water [23]. Although there were few fish in treatment I, but indicated the highest performance in terms of weight gain and survival. It is known that stocking density significantly affect water quality, with significantly higher dissolved oxygen and pH [23]. Weight gain in fish is associated also among other factors with the accretion of water, proteins, carbohydrates, fats, and minerals. Difference in fish growth rates occurs when they deposit nutrients at different rates and, consequently, have different feed requirements [24]. These amount of components deposited per unit of live weight gain is not constant, but rather changes with fish species and size, and feeds used. Within the same species, different families or groups of individuals (strains) have different genetic makeup and often differ in terms of growth potential [25].

The amount of feed required to produce 1 kg of fish in aquaculture systems is called feed conversion ratio (FCR). In this study, the value was lower for fish in treatment I (1.7) than in the other treatments. The differences in FCR among treatment, results from complex factors i.e. abiotic and biotic factors that are taking place in the water environment. Major factors influencing FCR in fish is temperature and quantity of dissolved oxygen in water, type of food, and age of fish [26]. With exception of treatment I, FCR in treatments II and III were above 2.5, which is however, the maximum value attained by most tilapia cage aquaculture systems in Africa [26]. Other reasons for high FCR in treatment II and III may be extensive feed wastage, congestion and other numerous parameters still not under control, such as the impact of natural productivity, and variation in appetite of the fish. In this study, fish attained mean weight of 374.1 g in cage with treatment I, and 273.2 g in treatment III and 194.8 g in cages of treatment II conforming to their FCR values. Mean weights attained were however, within the range of 200 to 500 g, which is the size of Nile tilapia targeted in most of West African countries [26].

Fish survival rate was the lowest in treatment III (54.3%), which has the highest stocking density (130 fish/m3). Stress associated with transport at stocking, careless fish handling during monthly sampling, and fish kills usually resulting from low dissolved oxygen may be among the low survival [27]. It is from this regard that water quality management is considered key to successful cage fish culture and wastes such as uneaten food, faecal and urinary normally released freely around cages to the water environment should regularly be monitored [28]. To allow health ecosystem services, cages were set 4 m above the bottom to allow free movements of wastes and circulation of dissolved oxygen to support good growth and health of fish.

Dissolved oxygen values and transparency decreased slightly from nearby to inside cages indicating effects of wastes release from cage systems, the phenomena reported also by [29,30]. They noted these changes in water quality parameters of the water column as an indicative of pollution and self-inflicted water quality-related problems, which affect cage farms in lakes and reservoirs. Dissolved oxygen and transparency values recorded in the offshore sampling points at between 50 m and 500 m, were relatively higher than those near to the cages implying that appropriate sitting is the best practice in cage fish farming. In this regard, Beveridge et al., suggested to maintain a minimum of three parts per million (3 ppm) or DO of 5 mg/l at temperature between 250C-300C as ideal conditions for Nile tilapia farming in fresh waters [31].

Temperature values from 240C to 270C recorded in this study were within the ideal range for good tilapia growth (recommended values are 250C to 300C) [26,31]. But we noted a declining trend in water transparency inside (1 m) and outside (2 m) the cages. These variations were meagre throughout the sampling period, implying a relatively low quantity of suspended soil, organic material (detritus), and plankton (floating or suspended microscopic plants and animals) within and away from the cages site. Low transparency is a mirror of high-water turbidity. In this study light, penetration dropped lead to fish kills when the upwelling of anoxic hypolimnetic waters occurs during mixing and should not fall beyond 100 ppm [32].

Levels of pH declined trivially from 5.6 to 9.8 with increasing depth. These values deviated slightly from the best pH range of 6 to 9 for tilapiine to survive positively, yet had no negative impacts because the values can extend between 5 and 10 [33]. Water currents observed were between 10-20 cm/ sec said to be within the recommended values for the growth of tilapiines in cages at suitable sites [34]. Within this range, the water current and oxygen supply to fish is good rendering permanent water exchange between water bodies inside and outside to reduce negative influence on the environment.

Nutrients examined in this study were Total Nitrogen, Nitrate, and Nitrites, and Ammonia, Total Phosphorus, and Chlorophyll-a. They were all varied during the study period. All life needs nitrogen (a nutrient and component of protein) for growth and survival. However, too much nitrogen can cause adverse health effects (in drinking water) or environmental degradation (especially in coastal waterways).

Total Nitrogen is an essential nutrient for plants and animals. Any excess amount of nitrogen in a waterway may lead to low levels of dissolved oxygen and negatively alter various plant life and organisms. In the environment, excess nitrogen can cause over-stimulation of growth of aquatic plants and algae. Excessive growth of these organisms, in turn, can clog water intakes, use up dissolved oxygen as they decompose, and block light to deeper waters [35]. The most important long-term effect of Nitrogen deficiency on photosynthesis is a decrease in leaf growth, resulting in reduced total production of photosynthate [36].

Large quantities of Total nitrogen loading brought into the lake is contributed mainly by runoff waters through the catchment from agricultural activities. In this study, values of Total Nitrogen, Nitrate and Ammonia after stocking of fish in cages were higher (912 ± 113.0 µg/l, 43.2 ± 156.0 µg/l, 14.3 ± 12.0 µg/l) than previous findings recorded in the same site i.e., 861.1 ± 176.0 µg/l, 26.1 ± 9.6 µg/l and 157.6 ± 192.8 µg/l, respectively (TAFIRI, 2005). An acceptable range of total nitrogen in fresh water is 3.0 mg/L to 32.8 mg/L, and 10 mg/L is the standard for human drinking water [37].

Total Phosphorus is another essential nutrient for plants and animals. It is naturally limited in most fresh water systems because it is not as abundant as carbon and nitrogen; introducing a small amount of additional phosphorus into a waterway can have adverse effects. Sources of phosphorus include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, decomposition of organic matter, and commercial cleaning preparations. Total Phosphorous recorded in this experimental study was lower (8.5.8± 25.0 µg/l) than an acceptable range for total phosphorus (10 µg/L to 40 µg/L). This may be accounted as due to local seasonal conditions and the nutrient enrichment caused by waste food and metabolic wastes produced by fish. However, they were within the values recorded from other parts of the lake [2]. Hence, the noted values observed in this study, may not necessarily be caused by cage fish farming since, they were within tolerable ranges.

Conclusion

Of the three stocking densities, Nile tilapia grew best in cages of lower stocking density than in high stocking densities. It means increasing stocking density can boost production but should be accompanied by quality feeds and thoroughly water quality management within and around cage systems. The values of water quality recorded throughout the study were within ranges found elsewhere in the lake. An indication that fish cages culture did not have alarming negative impacts on the water environment. However, continuous monitoring of factors such as water quality parameters, water currents, and water volume is needed to ensure they are within recommendable values for fish cage culture.

Acknowledgement

We wish to recognize the late Dr Jean Ndikumana, the Project Livestock and Fisheries Programme Officer of the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) for his supervisory role and guidance during the study. The authors are also gratefully to the ASARECA project for funding the study as well as the TAFIRI staff for their valuable cooperation during the execution of this study. Lastly, but not least, thanks are extended to everybody who contributed to the good of this paper.

References

1. Powles H (1987) Research priorities for African Aquaculture, IDRC. 1987:199.
2. Beveridge M C M, Phillips M J, Dugan P, Brummett R (2010) Barriers to aquaculture development as a pathway to poverty alleviation and food security. In OECD (Ed.) Advancing the Aquaculture Agenda: Workshop Proceedings 2010: 345-359.
3. Benedicto Boniphace Kashindye, P Nsinda, R Kayanda, G W Ngupula, C A Mashafi, et al. (2015) Environmental impacts of cage culture in Lake Victoria: the case of Shirati Bay-Sota, Tanzania. Springer Plus 4: 475.
4. FAO (2010) The state of world fisheries and aquaculture. Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations, Rome.
5. URT (United Republic of Tanzania) (2003) Amendment of the Fisheries Act No 6 of 2003: 42.
6. Masser M (1988) What is Cage Culture? Southern Regional Aquaculture Center, Publication No. 160. Division of Agricultural Sciences and Natural Resources. Oklahoma State University.
7. Osofero S A, Otubusin S O, J A Daramola (2007) Effect of stocking density on Nile tilapia (Oreochromis niloticus (Linnaeus 1757) growth and survival in bamboo – net cages trial.
8. Brummett R E, J Lazard, J Moehl (2008) African aquaculture; realizing the potential. Food Policy 33: 371-385.
9. Fortes Romeo D (2005) Review of techniques and practices in controlling tilapia populations and identification of methods that may have practical applications in Nauru including a National Tilapia Plan.
10. Penczak T, Galicka W, Molinski M, Kusto E, Zalewski M (1982) The enrichment of a mesotrophic lake by carbon, phosphorus and nitrogen from the cage aquaculture of rainbow trout, Salmo gairdneri. J Appl Ecol 19: 371-93.
11. Phillips M J, et al (1983) Cage farm management. Fish Farmer 6:14-16.
12. Halwart M, J F Moehl (2004) FAO Regional Technical Expert Workshop on Cage Culture in Africa. Entebbe, Uganda, 20-23 October 2004. FAO Fisheries Proceedings. FAO 2006: 113.
13. LVFO (2011) Report of the lakewide acoustic survey, 4th Sep.3rd October 2011. – EAC Partnership Funds- Support to Monitoring Surveys, Lake Victoria Fisheries Organisation, Jinja, Uganda. 2011:79.
14. Welcomme R, Lymer D (2012) An audit of inland capture fishery statistics – Africa. FAO Fisheries and Aquaculture Circular, FAO. 2012: 61.
15. Jason Bremner, David Lopez-Carr, Alex Zvoleff, Narcisa Pricope (2013) Using New Methods and Data to Assess and Address Population, Fertility, and Environment links in the Lake Victoria Basin. XXVII IUSSP International Population Conference Busan, South Korea 2013: 26-31.
16. Francis Pius Mmanda, Deogratias Pius Mulokozi, Jan Erik Lindberg, Anna Norman Haldén, Matern Mtolera, et al. (2020) Fish farming in Tanzania: the availability and nutritive value of local feed ingredients, Journal of Applied Aquaculture 32: 341-360.
17. Abdul Malik Daudpota, Illahi Bux Kalhoro, Sajjad Ali Shah, Hameeda Kalhoro, Ghulam Abbas (2014) Effect of stocking densities on growth, production and survival rate of red tilapia in hapa at fish hatchery Chilya Thatta, Sindh, Pakistan. Journal of Fisheries 2:180-186.
18. MINITAB Statistical Software for Windows, Minitab version 13.1. (2000) Minitab copyright incorporated.
19. Steel R D G, J H Torries (1980) Principles and procedure of statistics. Biometric approach, 2nd Ed. McGraw Hill Book Co. Inc. New York.
20. Brown D S (1994) Fresh water snails of Africa and their medical importance. London: Taylor & Francis 1994: 608.
21. Mandahl-Barth G (1973) A field guide to African freshwater snails.2. East African species. Charlottenlund: Danish Bilharziasis Laboratory.
22. Mandahl-Barth G (1988) Studies on African freshwater bivalves. Charlottenlund: Danish Bilharziasis Laboratory.
23. Herrera L C (2015) The effect of stocking density on growth rate, survival and yield of GIFT tilapia (Oreochromis niloticus) in Cuba: case study fish farm La Juventud. United Nations University Fisheries Training Programme 2015: 1-29.
24. Zaikov A, I Iliev, T Hubenova (2008) Investigation on growth

rate and food conversion ratio of wels (Silurus glanis L.) in controlled conditions, Bulg J Agric Sci 14: 171-175.

25. Bureau B P, Azevedo P A, Tapia-Salazar M, Cuzon G (2000) Pattern and cost of growth and nutrient deposition in fish and shrimp: Potential implications and applications. In: Cruz -Suárez, L.E., Ricque-Marie, D., Tapia-Salazar, M., Olvera-Novoa, M.A. y Civera-Cerecedo, R., (Eds.). Avances en Nutrición Acuícola V. Memorias del V Simposium Internacional de Nutrición Acuícola. 19-22 Noviembre, 2000. Mérida, Yucatán, Mexico.
26. Ofori J K, Dankwa H R, Brummett R, E K Abban (2009) Producing Tilapia in Small Cage in West Africa. WorldFish Center Technical Manual No. 1952. The WorldFish Center, Penang, Malaysia. 2009: 16.
27. Marianne E Meding, Lel J Jackson (2003) Biotic, chemical, and morphometric factors contributing to winter anoxia in prairie lakes. Ecology Division, University of Calgary, 2500 University Drive NW, Calgary, Alberta T2N 1N4, Canada. Limnol Oceanogr 48: 1633-1642.
28. Beveridge M C M, M J Phillips (1993) Environmental impact of tropical inland aquaculture. In: Environment and Aquaculture in Developing Countries (Pullin, R.S.V., H. Rosenthal and J. L. Maclean, (Eds.) ICLARM Conf Proc 1993: 213-236.
29. Barica J (1976) Nutrient dynamics in eutrophic inland waters used for aquaculture. Philippines, Thailand, Hong Kong. SCS/76/WP/24. South China Sea Fisheries Development and Coordinating Programme. FAO, Manila.
30. Beveridge M C M (1984) Lake-based or land-based tilapia hatcheries? ICLARM News, 7: 10-11.
31. Beveridge M C M, M J Phillips, D C Macintosh (1997) Aquaculture and the environment: the supply and demand for environmental goods and services by Asian aquaculture and the implications for sustainability. Aquacult Res 28: 797-807.
32. Beveridge M C M, J F Muir (1997) Environmental impacts and sustainability of cage culture in Southeast Asian lakes and reservoirs. In: Ecological Aspects of Fish Production in SE-Asian Lakes and Reservoirs (van Densen, W., T. Saidin and M. Verdegem, Eds.). University of Wageningen.
33. Thomas Popma and Michael Masse (1999) Tilapia Life History and Biology. Southern Regional Aquaculture Center through Grant No. 94-38500-0045 from the United States Department of Agriculture, Cooperative States Research, Education, and Extension Service.
34. Costa-Pierce B A (1996) Environmental impacts of nutrients from aquaculture: towards the evolution of sustainable aquaculture systems. In: Aquaculture and Water Resource Management: (Biard, D.J., M.C.M. Beveridge, L.A Kelly and J.F. Muir, eds.) Blackwells, Oxford 1996: 81-113.
35. Kelly Addy, Linda Green, Elizabeth Herron (2005) Nitrogen and Water Quality. University of Rhode Island 2005:1-5.
36. Brix H, Lyngby J E (1983) The distribution of some metallic elements in eel grass (Zostera marina L.) and sediments in the Limfjord, Denmark. Estuarine Coastal and Shelf Science 16: 455-467.
37. Meays C L (2009) Water Quality Guidelines for Nitrogen (Nitrate, Nitrite, and Ammonia). Water Stewardship Division, Ministry of Environment, Province of British Columbia.
38. Hu B (1991) Technical development history of Chinese cage culture. In Chapter 8, Technical Development History on Chinese Freshwater Aquaculture, Beijing, Science and Technology Press 1991: 139-149.
39. Xu P, Yan X M (2006) Cage/pen culture in China's inland waters. Scientific Fish Farming. (In press).