**International Journal of Agriculture, Forestry and Fisheries**
2015; 3(5): 195-201
Published online October 22, 2015 (http://www.openscienceonline.com/journal/ijaff)

# Rural Cage Aquaculture in Ox-bow Lakes of Zambezi Plains

Boniface Nyika[1], Grant Simuchimba[2]

[1]Department of Fisheries, Ministry of Agriculture & Livestock, Zambezi District, Zambia
[2]Zoology and Aquatic Sciences, Copperbelt University, Kitwe, Zambia

## Email address

grant.simuchimba@gmail.com (G. Simuchimba), bonifacenyika@yahoo.com (B. Nyika)

## To cite this article

Boniface Nyika, Grant Simuchimba. Rural Cage Aquaculture in Ox-bow Lakes of Zambezi Plains. *International Journal of Agriculture, Forestry and Fisheries*. Vol. 3, No. 5, 2015, pp. 195-201.

## Abstract

The experiment was conducted in Zambezi district in Chiwano ox-bow Lake to investigate the performance of cage aquaculture in the ox-bow lakes of Zambezi plains during the cold dry season for five months. A fish cage of 4m long by 2m wide and 2m deep was constructed and put in Chiwano ox-bow Lake. Oreochromis andersonii an indigenous cichlid species in the Zambezi River was stocked in the cage made out of local materials that included bamboos and timber. The cage was stocked with 1,800 fingerlings, at the stocking rate of 120fish/$m^3$. Feed was formulated using locally available ingredients that included; fish waste, maize bran and cassava meal. In the first two months, the fish was fed 5% of the total biomass by 3 times per day and 3% of the total biomass by 3 times a day in the last three months. The fish was fed by hand through broadcasting the feed on the water surface in the cage. Physico-chemical parameters of the water such as dissolved oxygen, temperature, pH and ammonia were measured using chemical kits. The mortalities were observed and recorded daily from the time of stocking the fish. Thirty (30) fish were sampled randomly and returned to the cage every month and their standard lengths and weights recorded for five months. The results showed high survival rate of 84.3% and positive specific growth rate of 6.74%. The water quality in the lake had an average pH value of 7.5, average temperatures were above 20°C, the dissolved oxygen (DO) averaged at about 5.3ppm and ammonium nitrogen averaged at 0.013mg.$dm^{-3}$. It was concluded that though the performance of cage aquaculture in the ox-bow Lakes of Zambezi plains through the cold dry season was low, the growth rate of the fish was positive.

## Keywords

Rural Cage Aquaculture, *Oreochromis andersonii*, Tilapia, Zambezi Plains, Ox-Bow Lake

## 1. Introduction

There is an increasing popularity of fish cage aquaculture world-wide especially in Europe and Asia where cage culture is a major contributor to the total aquaculture production. According to [7], investment necessary to produce a unit of fish meat in cage aquaculture is 30-40 percent of that invested in a conventional fish pond system, and the construction of cages is quick and simple as compared to that of ponds. Maguswi in [8] indicated that cage aquaculture was an emerging activity in Zambia, and there were less than ten successful examples that were documented of which none of them was at subsistence level. According to the [5], 537.26 tons of fish was produced from cages in 2011, all from commercial fish farmers from Lake Kariba in southern province who produced 532.42 tons and the remaining 4.84 tons from small-scale fish farmers in the province. Reference [8] stated that despite having been introduced in some of the countries over the past 20 years, cage culture was still practiced by a handful of successful operators in sub-Saharan Africa. Though fish cage aquaculture has not been done in most parts of Zambia, the country has abundant water resources, favorable weather conditions, abundant labor and high market demand for fish products ([13]; [16]).

Zambezi is one of the districts in Zambia which has abundant water resources. Despite the district having a lot of water, the fishing industry is not fully exploited and this has led to high fish prices in the district because most of the fish consumed come from the neighboring Lukulu district of Western province. On the west bank of Zambezi River in the district, fish farming through ponds is almost impossible because of the dominant sand soils and flooding during the rainy season, especially on flood plains. Introducing fish cage aquaculture in ox-bow lakes present on the Zambezi plains using locally available cheap materials will encourage the locals, including fishermen, to begin small scale fish cage farming and utilize the abundant water resources around them in order to meet the high fish demand currently prevailing on the market. The major problem to the slow development is the level of adoption of cage aquaculture which demands a lot of capital for its establishment and also the flooding during the rainy season. According to [7] the other constraints in African cage aquaculture include unavailability of locally produced high quality extruded feeds at competitive prices in most of the countries, lack of economies of scale in cage culture production costs, lack of experts in cage culture to offer training to would be cage farmers, lack of understanding and commitment by governments to the development of aquaculture in some countries and lack of expertise in disease identification and management. Although expensive modern systems of cage aquaculture are increasingly common, there is a diversity of cage farming systems in Asia covering a spectrum of traditional to modern practices involving a wide variety of species, environments, investments and inputs [7]. Apart from the natural small water bodies dotted along major rivers such as the Zambezi River in form of ox-bow lakes, Zambia has about 1,082 small water bodies that were constructed throughout the country by the government covering a total area of 5,410 hectares [15].

The performance of cage aquaculture is affected by some physio-chemical parameters present in the water body. According to [11] and [9] warm water fish species such as tilapia are affected by low oxygen levels, low temperatures, daily fluctuation of pH in a water body, and high levels of ammonia in cages. The main objective of the study was to determine the performance of a rural small scale fish cage made of locally available materials, in ox-bow lakes on the Zambezi plains, through the cold dry season when there is no flooding.

## 2. Material and Method

### 2.1. Study Area

Zambezi district is in the North Western Province between 13°00'–14°15'S and 22°00'–23°45'E. According to [6] and [22], the district is on the north and west bounded by Angola, on the south by Kalabo and Mongu districts, and on the east by Kabompo District. West of the Zambezi district is an area of flat watershed plains and in the east the sand country is gently undulating. Reference [6] further states that the western plains lie at 914m above sea level while the eastern plains are around 1,070m. The specific study location (Chiwano Ox-bow Lake) lies 3km south of Zambezi district town Centre and 500m from Zambezi Boarding School and the nearby Mshona village. This selected ox-bow lake is 100m by 850m long giving the average area of about 8.5 hectares. The lake has an average depth of 4.9m and water flows in from the river in the rain season and the flow is vice versa in the dry season. This research was an experiment designed to determine the performance of rural cage aquaculture in ox-bow lakes on Zambezi plains in Zambezi district.

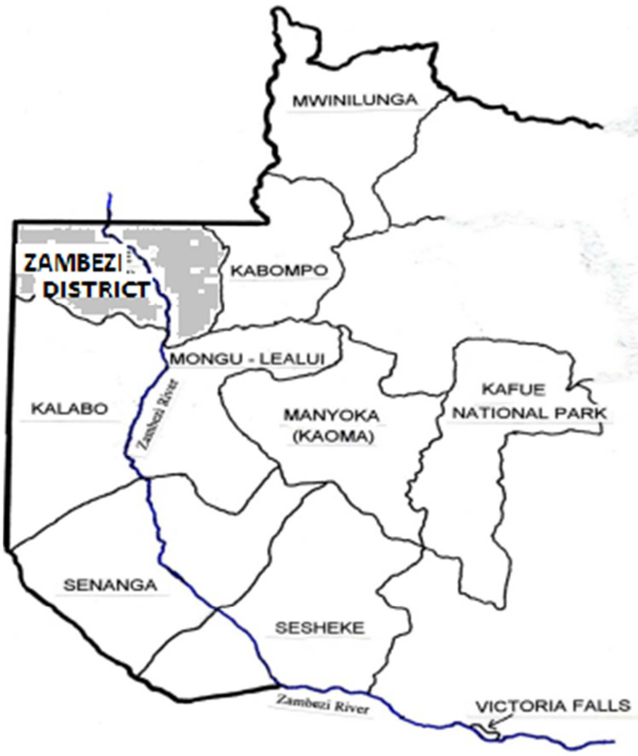


*Fig. 1. Map showing the Zambezi River passing through Zambezi district (Balovale) [6].*

### 2.2. Fish Cage Specifications and Materials

A fish cage of 4m long by 2m wide and 2m deep was constructed and put in Chiwano ox-bow Lake. The following were the dimensions of the fish cage:

A 4m x 2m x 2m cage was constructed using bamboos as predator protection and timber as cage collar, fastened by nails, and bolts and nuts.

A 40% meshed net shed bag was used inside the cage as net bag.

A chicken wire mesh was used as jump net as well as anti-theft cover on top of the cage where a door with lock and key were fixed.

Six empty 200L steel drums were used as floaters of the cage.

The cage was stocked with 1,800 fingerlings of Oreochromis andersonii, at the stocking rate of 100fish/$m^3$.

The study was conducted from April to August 2012 in Chiwano ox-bow lake of Zambezi district. Physico-chemical parameters of the water such as dissolved oxygen, temperature, pH and ammonia were measured using chemical kits. The fish was fed with a locally formulated feed crumbles of maize bran, waste fish and cassava meal as binder. In the first two months, the fish was fed 5% of the total biomass by 3 times per day and 3% of the total biomass by 3 times a day in the last three months. The fish was fed by hand through broadcasting the feed on the water surface in the cage. The mortalities were observed and recorded daily from the time of arrival of the fish. Thirty fish were sampled randomly and returned to the cage every month and their standard lengths and weights recorded for five months.

*Table 1. Cage Construction Costs using locally available materials.*

| Item | Description | Quantity | Unit cost (ZMW)[a] | Item amount(ZMW)[a] |
|---|---|---|---|---|
| Cage collar | Timber | 50 m | 5 | 250 |
| Predator protection | Bamboos | 25 | 2.5 | 62.5 |
| Nails | 5” | 2½ kg | 24 | 60 |
| | 4” | ½ kg | 12 | 12 |
| | 2½” | 5 kg | 20 | 100 |
| | 1½” | ½ kg | 12 | 12 |
| Bolts and nuts | Fastening the cage | 12 | 5 | 60 |
| Net bag | 40% meshed net | 1 | 500 | 500 |
| Jump net | Chicken wire mesh | 1 x 8m | 15 | 120 |
| Floats | 200l Steel drums | 6 | 100 | 600 |
| Sinkers | Lead sinkers | 20 | 5 | 100 |
| Rope | | 2 x 50m | 150 | 300 |
| Anchors | Stones | | | - |
| Labour | Skilled and unskilled | Lump sum | | 1, 000 |
| Total | | | | 3, 176.5 |

[a]Zambia kwacha (K1 = US$6)

### 2.2.1. Fish Species

The fish species stocked in the experimental cage was *Oreochromis andersonii* (commonly known as three spotted bream in English and Inkenzhi in Lunda language) collected from National Aquaculture Research and Development Centre in Mwekera, Kitwe as 5g fingerlings. The fish is indigenous in Zambezi River and it has a good growth rate in ponds.

### 2.2.2. Feed

The locally formulated feed crumbles which the locals could afford was made using fish waste (34%), Maize bran (65%) and Cassava meal (1%) as binder.

*Monitoring and sampling:* The fish was monitored day and night by the local people who supported the project and fisheries officers from Zambezi district. The fish was sampled monthly for five months and the following parameters were recorded: mortalities, weight and total length.

### 2.2.3. Growth Rate

The growth rate was determined in terms of weight (g) and length (cm). The growth rate of *O. andersonii* was calculated from the following formulae:

$$\text{Growth rate (g/day)} = (W_1 - W_0) / (t_1 - t_0)$$

Where,
$W_1$ = weight (g) at time $t_1$
$W_0$ = weight (g) at time $t_0$
$t_1$ = Date of last sampling
$t_0$ = Date of previous sampling
Growth rate (cm/day) = $(L_1 - L_0) / (t_1 - t_0)$
Where,
$L_1$ = length (cm) at time $t_1$
$L_0$ = length (cm) at time $t_0$
$t_1$ = Date of last sampling
$t_0$ = Date of previous sampling

### 2.2.4. Survival Rate

The survival rate was calculated by using the following formula:

$$\text{Survival rate} = N_1/N_0 \times 100\%$$

Where,
$N_1$ = total number of live *O. andersonii*
$N_0$ = total number of *O. andersonii* stocked

### 2.2.5. Food Conversion Ratio

The food conversion ratio (FCR) was calculated using the following formula:

$$FCR = \text{Total feed}/ [((N_0 + N_1)/_2) \times (W_1 - W_0)]$$

Where,
$N_1$ = total number of *O. andersonii* at time $t_1$
$N_0$ = total number of *O. andersonii* at time $t_0$
$W_1$ = weight (g) of *O. andersonii* at time $t_1$
$W_0$ = weight (g) of *O. andersonii* at time $t_0$

### 2.2.6. Specific Growth Rate

The specific growth rate (SGR) of *O. andersonii* was calculated using the following formula:

$$SGR (\%day) = \ln (W_1 - W_0)/ (t_1 - t_0) \times 100$$

Where,
$W_1$ = weight (g) at time $t_1$
$W_0$ = weight (g) at time $t_0$
$t_1$ = Date of last sampling
$t_0$ = Date of previous sampling

## 3. Results and Discussion

In the experimental period the atmospheric mean maximum temperature was 31.1°C and the atmospheric mean minimum temperature was 0.6.5°C in Zambezi district (Zambia Meteorology Department, unpublished data). From the data collected the monthly average water temperature in the Ox-bow Lake (inside the fish cage) ranged from 19°C to 23°C (Fig 2).

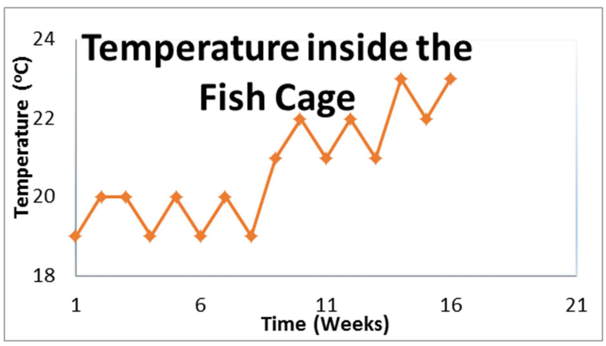


*Fig. 2. The weekly average temperatures (°C) during the five months period of the experiment.*

The water temperature recorded from Chiwano ox-bow lake at the time of the study (April – August) was the lowest in the year which was also comparable to the Zambezi district meteorological data. The temperature recorded was below 20°C during the first eight weeks of the study. In this period the fish was less active in feeding and metabolism was at its lowest as could be observed from the negative growth recorded in some months because of low temperatures [19]. The negative growth rates recorded in the second and third months may be as a result of lower temperatures which inhibits the growth of tropical fish whose optimal temperatures range between 25°C to 30°C ([11], [4], [14] and [3]). The water temperature from week eight (8) started rising quickly in response to the rise in the average monthly atmospheric temperature of August. The period chosen for the study provided important information on understanding the performance of cage aquaculture during the unfavourable water conditions of the year in Zambezi district during which the metabolism of *O. andersonii* is at its lowest level [19].

*pH*: The pH values were measured on a weekly basis with water sampled from within the fish cage in the ox-bow lake. The average weekly pH in the cage during the experiment ranged from 7.4 to 8.0 (Fig 3).

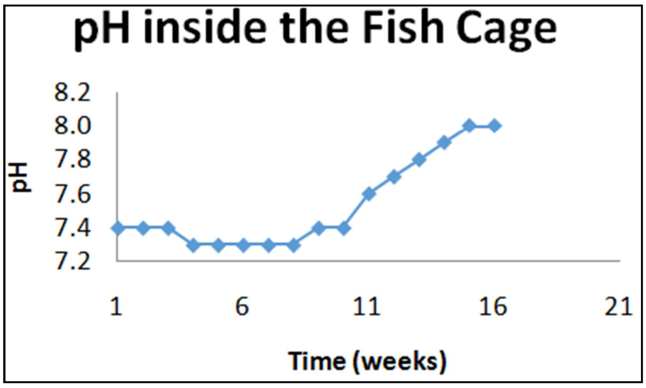


***Fig. 3.*** *The weekly average pH in the cage during the five months period of the experiment.*

The average weekly pH recorded for the first three weeks was about 7.4 and it reduced to about 7.3 in the five (5) weeks that followed. From the ninth week to the twelfth week the pH steadily increased for every week that passed. Reference [11] indicated that the desirable range for tilapia production is between 6.5 and 9. In this experiment, the pH ranged from 5.3 to 8.0 with an average of 7.2. For fresh water, including ox-bow lakes, the pH of the water would highly be dependent on the ground characteristics of the lake bottom. According to [10] the normal pH values, in some cases, can even range between 4 and 8.5. The observed pH in the ox-bow lakes indicated that the water was suitable for culturing fish in cages during the cold dry season of Zambia. In most cases, when the pH is outside the desirable range, fish growth is slowed, reproduction reduced and susceptibility to disease increased [11].

*DO*: The dissolve oxygen (DO) in water was measured on a weekly basis with water sampled from within the fish cage in the ox-bow lake. The average weekly DO in the cage during the experiment ranged from 5.3ppm to 5.4ppm (Fig 4).

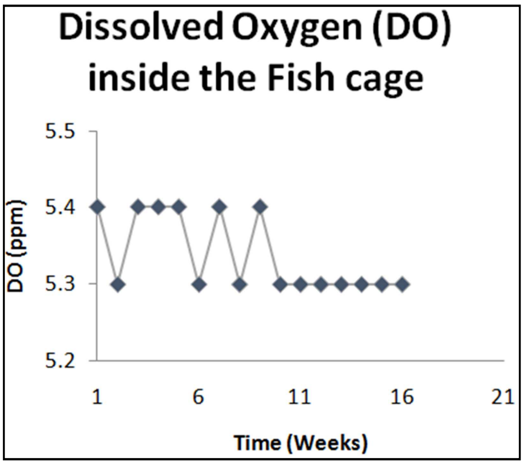


***Fig. 4.*** *The weekly average DO in the cage during the five months period of the experiment.*

The average dissolved oxygen (DO) recorded from the water inside the fish cage on a weekly basis ranged from 5.2ppm to 5.4ppm. Normally, tilapia can survive the routine dawn DO concentrations of less than 0.3 mg/l, considerably below the tolerance limits for most other cultured fish [18]. The DO was highest during the period when temperatures were at their lowest during this study. This is the period when most tropical fish, like *O. andersonii*, metabolism is at its lowest point. According to [10] a good water exchange can occur with a water velocity above 0.1 m/s due to the action of wind on the surface of the lake. This is normally sufficient to supply enough oxygen and to remove fish excrement. The concentration and availability of dissolved oxygen (DO) are critical to the health and survival of caged fish. The average DO observed in this ox-bow lake during the cold dry season was above the critical level of less than 2mg/l. In general fish species like tilapia need dissolved oxygen of 4mg/l DO (or ppm) or greater to maintain good health and feed conversion [11].

*Ammonium nitrogen*: The ammonium nitrogen ($N\text{-}NH_4$) in water was measured on a weekly basis with water sampled from within the fish cage in the ox-bow lake. The average weekly $N\text{-}NH_4$ values in the cage during the experiment ranged from $0.012mg.dm^{-3}$ to $0.014mg.dm^{-3}$ (Fig 5**Fig.** ).

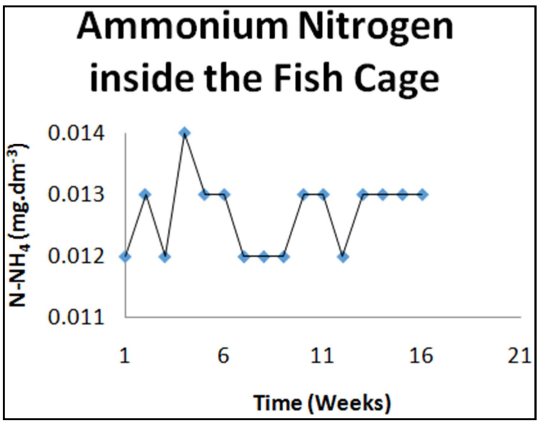


***Fig. 5.*** *The graph of weekly averages Ammonium Nitrogen in the cage during the five months period of the experiment.*

The ammonium nitrogen present in the ox-bow lake ranged from 0.012mg.dm$^{-3}$ to 0.014mg.dm$^{-3}$. Though the concentration could be seen to increase at a very slow pace every week, the highest level reached was lower than 0.5mg.dm$^{-3}$ the critical level for warm water fish such as tilapia [18]. The range in concentration observed in the ox-bow lake was within a limit that was not harmful to fish. According to [19], massive mortality of tilapia can occur within a few days when fish are suddenly transferred to water with un-ionized ammonia concentrations greater than 2 mg/l. The lake was free from nitrogenous waste that could generally come from manure runoff into the lake, inorganic fertiliser, plant decomposition and/or uneaten feed which is transferred into ammonia by bacteria. The level of ammonia toxicity depends also on species of fish, water temperature and pH [11].

***Table 2.*** *Highest, lowest and average water quality parameters.*

| Water parameters measured during experiment | Mean maximum | Mean minimum | Average |
|---|---|---|---|
| Water Temperature (°C) | 23 | 19 | 20.7 |
| pH | 8.0 | 7.3 | 7.5 |
| Dissolve Oxygen (ppm) | 5.4 | 5.3 | 5.3 |
| Ammonia Nitrogen (mg.dm-3) | 0.014 | 0.012 | 0.013 |

Growth: The initial number of O. andersonii stocked was 1,800 and the total biomass increased from 3,906g to 28,500g after five months. The fish grew from an average 6.97g at the time of stocking to an average 19g at termination of the experiment as can be seen from the tables (Table 3 and Table 4**Table** ) and figure (Fig 6) below. The average total length increased from 63.5mm at stocking to an average of 100mm after five months (Table 4 and Fig 7). The total feed administered to the fish in the cage in the five months was 55.5kg and the feed conversion was calculated to be 2.78 (Table 5). The survival rate of the fish was found to be 84.3% (Table 5) and the specific growth rate was calculated to be 1.67%/day (Table 5).

***Table 3.*** *Showing parameters for determining the performance of the fish in the fish cage at the beginning of the experiment.*

| No. | Description | Value |
|---|---|---|
| 1 | Number of fingerlings stocked or fish number (initial) | 1,800 |
| 2 | Biomass (initial) | 3,906 g |
| 3 | Average weight (initial) | 2.17 g |
| 4 | Biomass (end) | 28, 500 g |
| 5 | Average weight (end) | 19 g |
| 6 | Fish number (end) | 1,517 |
| 7 | Total feed administered | 55, 466 g |

Growth rate:
Weight and length

***Table 4.*** *Growth rate (weight and length) of fish in the fish cage for five month period of the experiment.*

| Description | Unit | Value |
|---|---|---|
| Weight(g) at time $t_0$ (initial) ($W_0$) | G | 6.97g |
| Weight(g) at time $t_1$ (final) ($W_1$) | G | 19g |
| Length(cm) at time $t_0$ (initial) ($L_0$) | Cm | 6.35cm |
| Length(cm) at time $t_1$ (final) ($L_1$) | Cm | 10cm |
| Day of last sampling (final) ($t_1$) | Number | 150 |
| Day of previous sampling (initial) ($t_0$) | Number | 1 |
| Growth rate (cm/day) | cm/day | 0.02cm/day |
| Growth rate (g/day) | g/day | 0.08g/day |

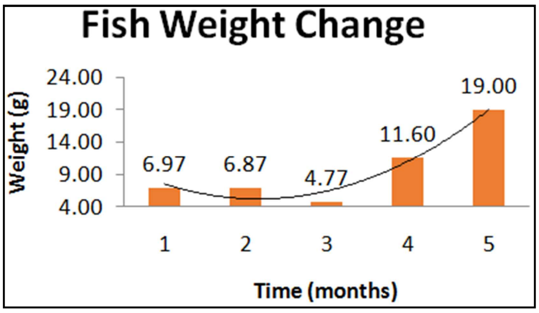


***Fig. 6.*** *The graph of weekly weight averages in the cage during the five months period of the experiment.*

Fish growth for both weight and length was negative in the first 3 months of rearing. The fish increased tremendously in both weight and length in the last two months. The overall specific growths was calculated as 0.08g/day and 0.02cm/day respectively for weight and length which was much lower than specific growth of 1.64 obtained by [17] for tilapia produced in small cages.

Cage culture offers several important advantages including the disruption of the breeding cycle of tilapia and therefore mixed-sex populations can be reared in cages without the problems of recruitment and stunting [12].

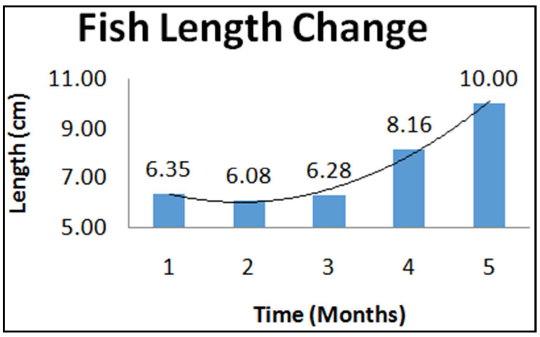


***Fig. 7.*** *The graph of weekly lengths averages in the cage during the five months period of the experiment.*

The increase of the growth rates in the 4th and 5th weeks could be due to the increase in temperatures among other factors. Preferred water temperature range for optimal growth is 25°C to 30°C. Growth diminishes significantly at temperatures below 20°C and death would occur below 10°C [12]. Cages stocked with 10gram fish at 2,500 per cubic meter will produce 25 to 30 gram fingerling in 5 to 6 weeks [12]. Generally, the growth of *O. andersonii* in the cage in this study was very slow and there was loss of weight in the second and third months of the experiment and then an increase in weight gain in the last two months of the experiment.

Feed conversion ratio and Survival rate:

Feed conversion ratio (FCR) of 2.78 was much higher than the FCR of 1.38 obtained by [20] and FCR of 1.2 obtained by [2] for O. niloticus species. However, it was lower than FCR of 3.31 obtained by [22] for red tilapia. This high FCR could be attributed to the use of cheap homemade formulated fish feed. The fish was subjected to the home made feed of maize bran mixed with fish meal and cassava meal. The specific growth rate (SGR) of 1.67%/day was comparable to SGR of 1.69% obtained by [23] for O. niloticus fed with multi feed. The mortality encountered in this study was caused during stocking, and no mortality was observed during the progress of the experiment. The mean survival rate of 84.3% was higher than the 67% and 50% reported by [1] and by [20] for tilapia. These results show that during the hot dry season in Zambezi district the cage culture would perform much better.

***Table 5.*** *Feed Conversion ratio of fish in the fish cage for month period of the experiment.*

| Description | Unit | Value |
|---|---|---|
| Weight(g) at time $t_0$ (initial) ($W_0$) | g | 6.97g |
| Weight(g) at time $t_1$ (final) ($W_1$) | g | 19g |
| Total number of live fish ($N_1$) (final) | number | 1,800 |
| Total number of stocked fish ($N_0$) (initial) | number | 1,517 |
| Total feed administered | g | 55,466g |
| Feed Conversion Ratio (FCR) | ratio | 2.78 |
| Total number of live fish ($N_1$) | Number | 1,517 |
| Total number of stocked fish ($N_0$) | Number | 1,800 |
| Survival rate | % | 84.3% |

Specific Growth Rate:

***Table 6.*** *Specific Growth rate of fish in the fish cage for five month period of the experiment.*

| Description | Unit | Value |
|---|---|---|
| Weight(g) at time $t_0$ (initial) ($W_0$) | g | 6.97g |
| Weight(g) at time $t_1$ (final) ($W_1$) | g | 19g |
| Day of last sampling (final) ($t_1$) | number | 150 |
| Day of previous sampling (initial) ($t_0$) | number | 1 |
| Specific Growth Rate (SGR) | % /day | 1.67%/day |

## 4. Conclusion

The study showed that cage culture can support *O. andersonii* (tilapia) survival and minimal growth in ox-bow lakes of Zambezi plains during the cold dry season. This is evident through the high survival rate of 84.3% and low specific growth rate of 6.74%. The water quality in the lake was good with an average pH value of 7.5, the average temperatures was above 20°C, the DO average was 5.3ppm and ammonium nitrogen average was 0.013mg.dm$^{-3}$.

## Acknowledgements

I would like to acknowledge Mr. Edward Manda (Provincial Fisheries Officer) for encouraging and supporting me to undertake this program. Special acknowledgements go to my workmates in at Fisheries office in Zambezi district; Mr. Given Mtonga and Mr. Chofya Munyenyembe for their moral and technical support during the period of my study. The Kabwabwati Cooperative members for their hard work in the feeding and guarding of the cage in the period of the experiment.

## References

[1] Al-Ahmed, A. A., T. A. Al-Ahmed and M. Ridha. 1985. "Factors affecting production of tilapia fingerlings". *Kuwait Institute for Scientific Research, Report No. KISR1846, Kuwait.*

[2] Bailey, D. S., J.E. Rakocy, J. M. Martin, and R. C. Shultz. 2000. "Intensive production of tilapia fingerlings in a recirculating system". pp. 328-333. *In*: K. Fitzsimmons and J.C. Filho (eds.). *Proceedings from the Fifth International Symposium on Tilapia in Aquaculture*, Rio de Janeiro, Brazil.

[3] Bhujel, R.C. 2011. A Guidebook for culture of the Mouth Breeding Tilapias (Oreochromis Spp) in Zambia. FAO-RAP Lusaka, Zambia. 67 pp.

[4] Bocek, A. 2006. Water harvesting and aquaculture for rural development. International Center for Aquaculture and Aquatic Environments, Swingle Hall, Auburn University, Ulbama, USA.

[5] DOF, 2012. Fisheries Bulletin, Fisheries Statistics Management Unit (Data Centre). Chilanga, Zambia.

[6] Fanshawe D. B (2010). Vegetation Description of the Upper Zambezi Districts of Zambia. Biodiversity Foundation for Africa, Bulawayo.

[7] FAO, 2007, Cage aquaculture - Regional reviews and global overview, Fisheries Technical Paper, No. 498, FAO, Rome,

[8] Halwart, M., Soto, D., & Arthur, J. R. (Eds.). (2007). *Cage aquaculture: regional reviews and global overview* (Vol. 498). FAO.

[9] Kapetsky, J. M. (1994). A strategic assessment of warm-water fish farming potential in Africa (Vol. 27). FAO.

[10] Lekang O. (2009). Aquaculture Engineering. Blackwell Publishing, Oxford.

[11] Masser, M., 1997. Cage Culture, Site selection and water quality. Southern Region Aquaculture Center, Publication No. 161, Division of Agricultural Sciences and Natural Resources, Oklahoma State University.

[12] McGinty A. S. and Rakocy J. E. (1999). Cage Culture of Tilapia. Southern Regional Aquaculture Centre. SRAC Publication No. 281. USA.

[13] Mudenda, C. G., 2006. Economic perspective of aquaculture development strategy of Zambia. Consulant Report, Development Consultant, Lusaka, Zambia. Development Consultant. TCP/ZAM/3006.pp 99.

[14] Musuka, C. G. Likongwe, J.S., Kang'ombe, J., Jere, W.W.L., Mtethiwa, A.H., 2009. The Effect of Dietary Protein and Water Temperature on Performance of T. rendalli Juveniles Reared in Indoor Tanks. Department of Aquaculture and Fisheries Science, University of Malawi, Bunda College of Agriculture, Lilongwe, Malawi.

[15] Musuka, C.G and Musonda, F. F., 2013. Contribution of small water bodies and small-holder aquaculture towards poverty alleviation and enhancing household food security in Zambia.

[16] Musumali, M. M., Heck, S., Husken, S. M. C., Wishart, M., 2009. Fisheries in Zambia: an undervalued contributor to poverty reduction. The World Fish Center/The World Bank. Policy Brief 1913, pp 16.

[17] Ofori J. K., Dankwa H. R., Brummett R. and Abban E. K. (2009). Producing Tilapia in small cage in West Africa. Water Research Institute, Penang, Malasia.

[18] Popma T. And Masser M. (1999). Tilapia – Life History and Biology. Southern Regional Aquaculture Centre. SRAC Publication No. 283. USA.

[19] Popma, T. J., & Lovshin, L. L. (1996). *Worldwide prospects for commercial production of tilapia*. International Center for Aquaculture and Aquatic Environments.

[20] Ridha, M.T., and K.P. Lone. 1990. "Effect of oral administration of different levels of 17 methyltestosterone on the sex reversal, growth and food conversion efficiency of the tilapia *Oreochromis spilurus* (Günther) in brackish water". *Aquaculture and Fisheries Management* 21: 391-397. Rio de Janeiro, Brazil.

[21] Siraj, S. S., Z. Kamaruddin, M. K. Abd. Satar, and M. S. Kamarudin. 1988. "Effect of feeding frequency on growth, food conversion and survival of red tilapia (*Oreochromis mossambicus*/*O. niloticus*) hybrid fry". pp. 383-386. *In:* R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds.). *Proceeding of the Second International Symposium on Tilapia in Aquaculture.* Bangkok, Thailand and International Center for Living Aquatic Resources Management, Manila, Philippines.

[22] Wijkstrom U. N., & Larsson R., (1992). Fish Farmers in Rural Communities: Results of a Survey in Northwestern Province of Zambia. (ALCOM Field Document No.8). FAO.

[23] Yakubu A. F., Obi A., Oknji V. A., Ojiboye O. O., Adams T. E., Olaji E. D. and Nwogu N. A. (2012). Growth Performance of Nile Tilapia (Oreochromis niloticus) as Affected by Stocking Density and Feed types in Water Flow through System. World Journal of Fish and Marine Sciences. ISSN 2078-458.