The Effects of Water Exchange and Water Quality on Growth and Survival of *Clarias gariepinus* (Fingerlings) along the Mount Cameroon Region.

ABSTRACT

Clarias gariepinus has huge economic and nutritive value in Cameroon but yet it is not widely cultivated. The purpose of this study was to test the effect of water quality and water exchange (which are some factors that affect fish growth) on the growth and survival of this species along the Mt Cameroon region.

An experimental setup was used in the lab of the University of Buea campus to emulate conditions in real life and the length and weight of the fish were measured and plotted against time.The results showed that water exchange has an effect on the growth and survival of *Clarias sp.* along this region while water quality has no significant impact on the fish growth.

This study confirms that *Clarias gariepinus* can be cultivated along the Mt Cameroon region successfully and probably in other regions of the country as long as the fish farms are designed to have water exchange and the water quality is closely monitored.

1: INTRODUCTION

Due to the unsustainable exploitation of global fish stock, there will soon be a collapse in fisheries. Mindful of this, alternative sources of protein from the sea is being sought through aquaculture (Jennings *et al* 2001). The National Act of Aquaculture in 1980, defines aquaculture as the propagation and rearing of aquatic species in controlled or selected environment including but not limited to ocean ranching.

In 2002, world fish supply was 133.6 million tones of which 24 million tones came from inland aquaculture , 16.4 million tons from marine aquaculture and the rest from catches. But in 2006, production increased to 143.6 million tones, 31.6 million tones from inland aquaculture and 20.1 million tones from marine aquaculture (FAO 2009).

Africa comes second in inland aquaculture after Asia with a 23.5% of world total inland production showing the fast growth of aquaculture in Africa (FAO 2009), and still comes second only to Asia in the demand for fish in their diet with 17.4% of animal protein coming from fish (Brummett et *al* 2008).

The colonial masters in Africa in the 1940s and 1950s saw aquaculture as a viable means of food production and invested to support its development. Research stations were built across the continent to investigate species such as: *Oreochromis sp., Clarias gariepinus, Cyprinus carpio, Heterotis niloticus and Sarotherodon sp*. (Brummett et *al* 2008). *Clarias gariepinus* is particularly abundant in Central and West Africa where it dominates inland fisheries and traditional cuisine.

Cameroon belonging to the Central African states, saw the light of aquaculture in 1948 with the production of tilapia (*Oreochromis niloticus*) followed by catfish (*Clarias gariepinus*). Later in 1969, the common carp (*Cyprinus carpio*) was introduced and by 1990 the aquaculture industry had grown with new species like the herbivorous carp (*Ctenopharyngodon idella*), (FAO 2004-2009). Presently, the most cultivated fish species in Cameroon is the *Oreochromis niloticus* (Brummett et *al* 2007). In Cameroon, aquaculture has also seen an increase in productivity as *Oreochromis niloticus* production increased from 40 tones in 2000 to 210 tones in 2003 while the catfish increased from 10 tones in 2000 to 114 tones in 2003 (MINEPIA).

Due to the economic and nutritional value of *C. gariepinus* in Cameroon in recent years, a research to evaluate the possibilities of cultivating this species along the Mount Cameroon region was necessary since Foumban in the Western region is the only area in Cameroon where *C. gariepinus* is being cultivated. This experimental setup was at the University of Buea life science laboratory. The lab was chosen because the fish will be safe and protected from humans and other external disturbances and the experimental setup was designed to suit the present designs used in most fish farms in Cameroon. The treatments chosen were also the ones that will most likely affect the fish growth or survival and were easy to measure (Temperature, DO, pH and Nitrate) as compared to the other factors like turbidity, phosphates etc which were either too complex for me to measure or has less impact on the fish growth.

2: FISH FARMS IN CAMEROON

After the creation of the 10 provinces in Cameroon in 1992 (presently called regions), the principal regions that were involved in aquacultural production were; Adamawa, Centre, Littoral, North West, Western and the Eastern regions as shown in fig 1 below (MINEPIA 2003). These fish farms were involved in the mix production of tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*). The Western region of Cameroon is the only region that produces catfish (*Clarias gariepinus*), tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio).*

This experiment is a laboratory trial carried out at the University of Buea Science Laboratory 1 to investigate if *Clarias gariepinus* can be cultivated in the Mount Cameroon region. To do this, 100 *Clarias* fingerlings (six weeks old and of weight between 2.91g to 12.68g) were bought from IRAD (Institute of Agricultural Research for Development) in Foumban, Western region of Cameroon and transport to Buea, the South West Region (About 600km) where the experiment was set up.

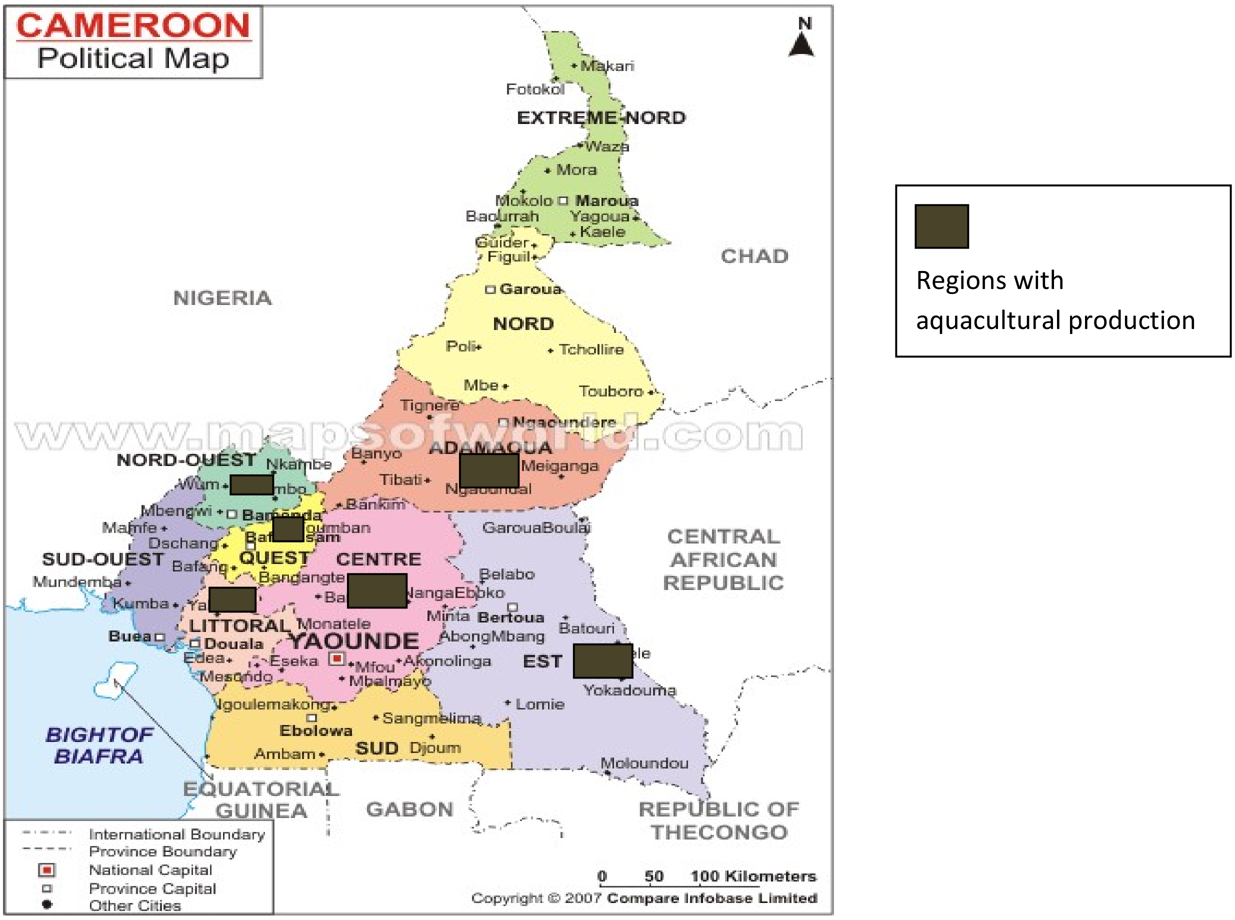


Fig 1: Map of Cameroon showing the regions of aquacultural production.

3: JUSTIFICATION TO PROJECT:

Aquaculture has a long history as far back as thousands of years where by plants, fishes, molluscs and crustaceans have been cultivated by humans for which most of the cultivated fish species are for commercial purpose rather than consumption purpose (Kaiser *et al* 2005).

Clarias gariepinus is a warm-blooded omnivorous fish (Durborow et al 1997) with a crude protein level of 40%. It performs better with respect to growth rate and feed conversion ratio than other *Clarias* sp. (*Clarias focus, Clarias barachus*). It has a wide range of prey to feed on, insects and crustaceans being top of its list (Van Weerd 1995). *C. gariepinus* constitutes a high source of protein and it is an ideal diet fish food (Osibona et al 2006), hence they are ranked high in most consumer preference lists in most African countries (Huisman et al 1987). *Oreochromis niloticus* is also a culturable species in Cameroon but the main reasons why *C. gariepinus* was preferable for this experiment are; as compared to *Oreochromis niloticus*, they grow fast to about 10g in 7-8 weeks, perform well in both monoculture and polyculture (Huisman et al 1987) and sells high in the markets. In Cameroon, *C. gariepinus* sells for 1400 FCFA/kg as compared to *Oreochromis niloticus* that sells for 1000 FCFA/kg (MINEPIA 2003) and grows more than twice the size of *Oreochromis niloticus* when matured (Huisman et al 1987). It grows to about 59 kg in weight and 1.7 m in length (Skelton 1993),

Due to its economic value and resistance, it was important to deduce the optimal conditions for cultivating *C. gariepinus* in the Mount Cameroon region.

4: AIM OF PROJECT

C. gariepinus is being cultivated in the Western region of Cameroon only making the national distribution very limited and very costly since the demand market is high and the supply is low. In order to avoid this, other fish farms need to be created hence the aim of this work which was to investigate the best conditions for cultivating *C. gariepinus* in the Mount Cameroon region.

The experiment will have two setups;

Water exchange rate**:** This is important in fish farming since fish growth is affected by water quality, and since *Clarias gariepinus* are poor swimmers, it is important to know if a flowing pond or a static pond will be good for its cultivation.

Water quality: This is usually difficult to measure since we have a lot of water quality parameters (pH, DO, temperature, hardness of water, suspended solids, nitrates, nitrites, ammonia etc). Choosing the suitable parameter to investigate is usually not easy. For this experiment, the parameters chosen were temperature, pH and ammonia. These 3 parameters will easily affect the fish growth and can easily be analyzed. Also they are the parameters that can easily change from normal to fatal for the fish growth in a short period of time.

The hypotheses for the experiments are;

Hypothesis 1: *Clarias gariepinus* will reduce their growth and metabolic rate under severe water quality conditions so that they can get adapted to the change. If they don't then they will easily be killed by the sudden and severe environment change.

Hypothesis 2: Higher water exchange rate will favor the growth and survival of *Clarias gariepinus*. Higher water exchange rate will increase fish productivity and also allow a higher stocking density which will increase income hence compensating for the cost.

5: MATERIALS /METHODS

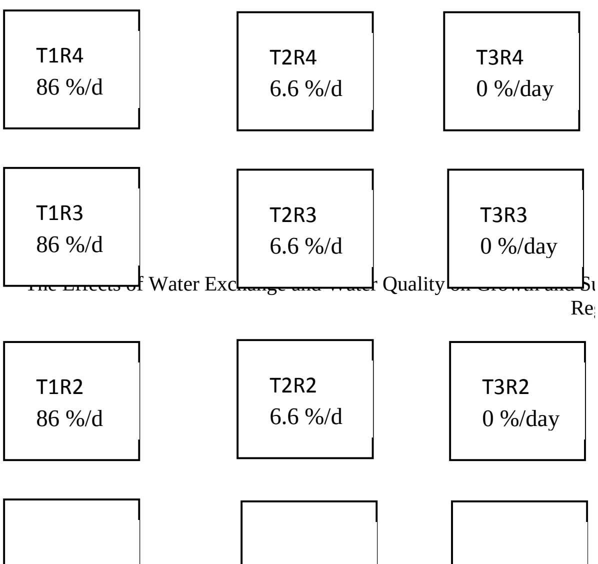
Two experimental setups were used, the first measuring the water quality (pH, ammonia and Temperature) effect on *Clarias gariepinus* fingerlings growth and survival and the second setup was to measure the effect of water exchange on the growth of the fish. The same fish food (dried shrimps) was used for the entire experiment at a dosage of 5% body weight of the fish per day as in Ogundiran et al 2009. Feeding rate affects cannibalism, growth and survival. Therefore, feeding rate was strictly maintained (because ammonia and nitrite levels will increase with increase feeding and they are toxic to fish (Al-Hafedh et *al* 2003). The number of fish left was counted and the weight and length of the fish was measured on a 5 days interval to evaluate treatment effects on growth and survival of *Clarias gariepinus.*

Chlorine (Cl) is a chemical used to disinfect most public water supplier and the concentration of Cl in the water used was 0.5 mg/l. At this concentration the water is not good for fish culture. Cl is also toxic at low ph, especially in combination with ammonia (U.S. EPA 1976). To reduce the Cl concentration in water, it was exposed for 48 hours for dechlorination before being used in the experiments. During the process of data collection, all the fish were measured (Length from tip of mouth to the tail fin and weight) and the average taken. If a fish happened to die, its entire measurement was removed from subsequent calculation so it does not affect the results.

5.1*: Experimental setup for water exchange*

12 shallow plastic tanks were used in this setup as recommended in Haylor 1992. The size of the plastic tanks was 31 cm wide x 44 cm long x 23 cm high. The plastic tanks were filled with 1kg of ceramic stones to simulate a rough bottom and filled with 15 litres of water. An outlet was fixed at that 15 L mark (13 cm high) to drain out excess water. Water was used from a 200 litre drum to simulate the various exchange rates by siphoning. The plastic tanks were covered with nets to avoid insects from flying into the tanks and introduction of any foreign objects. The siphoning tube were also covered at the far end in the drum to avoid dirt from blocking the tubes. The tubes were attached to weights so it sinks to the bottom of the drum for the siphoning to be effective.

To measure the effect of water exchange on the growth and survival of *Clarias gariepinus* fingerlings, 3 different exchange rates were set up with 4 replicates each. The exchange rates were; 0 %/day, 6.6 %/day and 86 %/day. Each tank contained 3 *Clarias gariepinus* fingerlings randomly selected. The results obtained were used to plot a regression curve with exchange rate (%) against average growth rate (g/wk). Dissolved oxygen was being observed using a VWR DO200 Oxygen meter. Fig 2 below shows the experimental layout.



T- treatment

R- Replicates

Fig 2: Diagrammatic representation of experimental setup for water exchange.

Assumption

Since the tank designs had poor removal of ammonia, we assumed that the ammonia accumulation in each treatment was the same and that the only reason for low ammonia in any treatment was due to high water exchange rate.

5.2*: Experimental setup for Water quality*:

Water quality determines to an extent the success or failure of a fish farm. Water quality parameters usually tested are suspended solids, temperature, pH, dissolve metal, dissolved oxygen hardness of water and ammonia-nitrogen (Sawnn 1992). Of these parameters, pH, temperature and Ammonia were measured because they were considered vital for *Clarias* survival.

18 shallow buckets (28cm diameter X 26cm height) were used for the water quality experiment (as recommended in Haylor 1992) and each bucket was filled with 5 liters of water containing 3 randomly selected *Clarias gariepinus* fingerlings. All the replicates were covered with mosquitoe nets to avoid the fingerlings from jumping out and also to avoid insects from flying in. 75% of the water in each bucket was changed every 3 days to avoid nutrients accumulating. Since the treatments were not flow through systems, aerators were used to supply oxygen to the buckets to ensure that dissolved oxygen do not influence the results. Measurements of fish

weight and length were taken every 5 days and the results obtained were analyzed using Linear Mixed Model.

5.2.1*: pH*

pH can be defined as the negative logarithm of H^+ (hydrogen ion) concentration. Fishes can die when exposed to extreme or rapidly changing pH. pH can be altered by adding alum or acids like hydrochloric acid to reduce pH, or basis like sodium hydroxide to increase the pH (Tucker et al 2008). In the pH treatments, pH was slowly altered to avoid any unnecessary harm to the fish. The pH treatment included 2 sub treatments with three replicates each. The first sub treatment had decreasing pH, this was achieved by adding 11 % concentration of HCl (HCl was chosen since the reduction in pH can be controlled as compared to alum). The pH was dropped by 1 unit after readings have been taken. The second sub treatment involved pH increase which was achieved by adding 1M concentration of NaOH solution to the treatment. The pH was monitored on a daily basis using a pH pen (PH-03(I)-RoHS).

5.2.2*: Temperature*

Dissolved Oxygen (DO) is the measures of gaseous oxygen (O_2) dissolved in an aqueous solution and it greatly depends on temperature as the higher the temperature, the lower the dissolved oxygen and vise versa. DO can be measured in a number of ways, but the best method will depend on the number of tanks, accuracy, cost of measurement and time. The most commonly used techniques are the titration-based drop count and the oxygen meter (Hargreaves et al 2002). Sub treatment 1 of the temperature treatment had 1 aquarium heater in each tank that raised and maintained the water temperature at 30^{o}C (this helped to reduce the dissolved oxygen in the sub treatment). No aerators were used in this sub treatment. Sub treatment 2, involving a normal DO level of 4ppm to 5ppm which is favorable for fish growth (Sawnn 1992) was achieved by using aerators and the water temperature fluctuated between 23^{o}C and 25^{o}C (room temperature). The DO level was monitored using an oxygen meter. This particular treatment is complex since it involved temperature and DO. The importance of the treatment though was to find out how these two parameters will affect the fish growth since our world is seeing a lot of temperature changes due to global warming which in effect affects the amount of DO.

5.2.3: *Ammonia*

Nitrates are produced when the ammonia produced by the fish is broken down by bacteria in the presence of oxygen (Sawnn 1992). If this ammonia is not broken down, it becomes very toxic to the fish. To estimate the tolerance level of ammonia toxicity by the fish, 2 sub treatments were used; sub treatment 2, had an ammonia concentration less than 0.2 mg/L all through the experiment and this was maintained by changing the water every 3 days. Sub treatment 1 on the other hand had an increasing ammonia concentration. This was achieved by keeping the water unchanged all through the experiment. The ammonia concentration was measured using LaMotte salt water aquaculture kit.

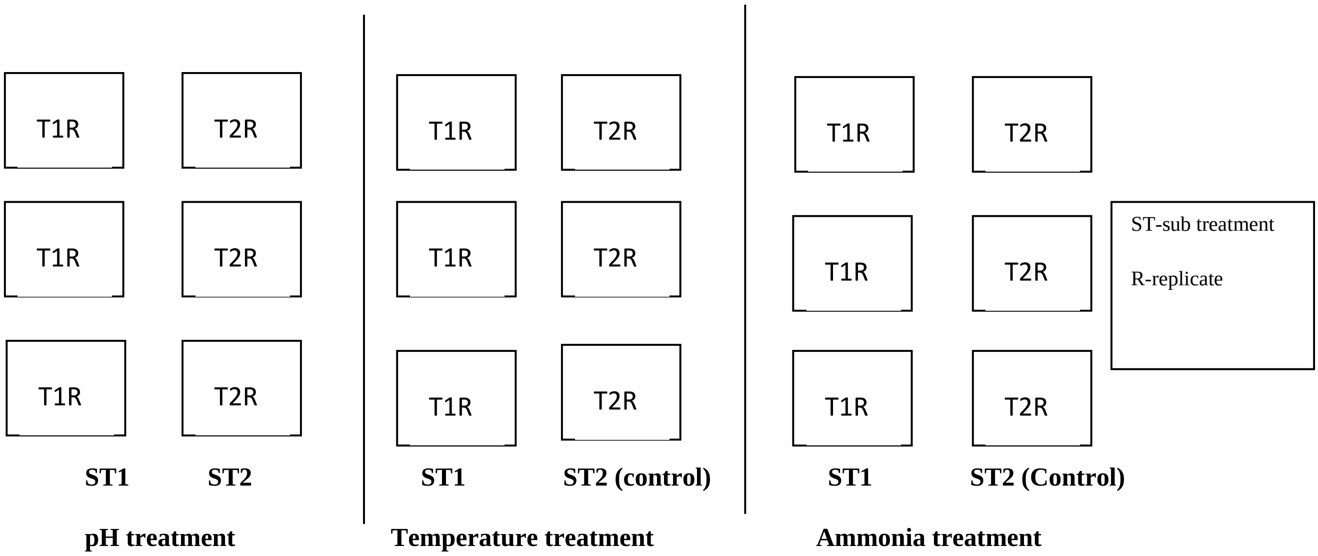
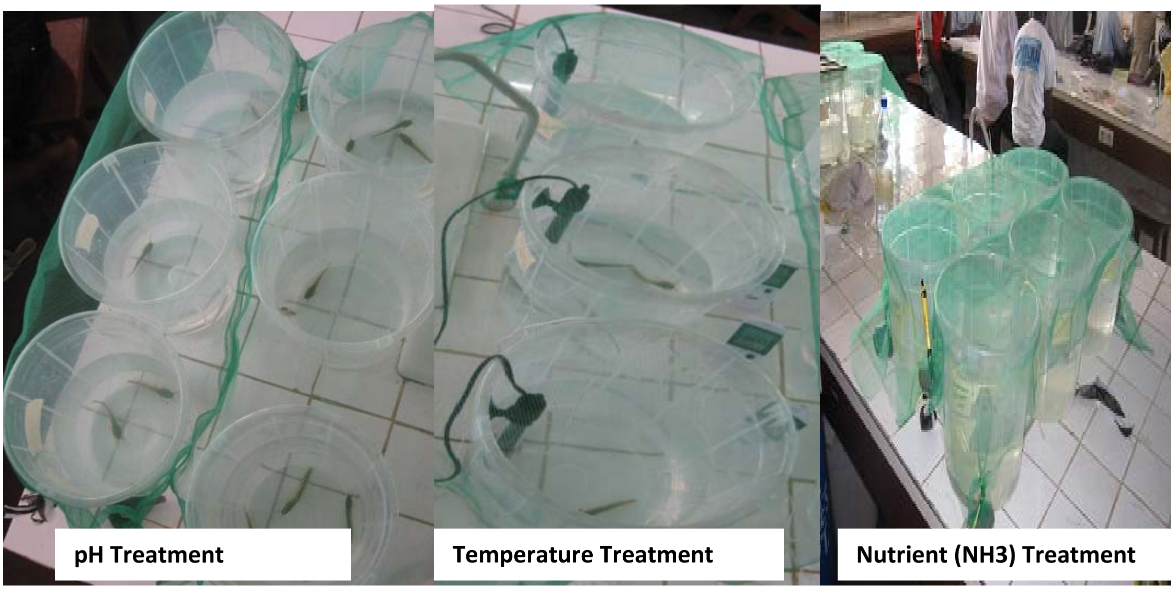


Fig 3: Diagrammatic representation of water quality experimental setup.



Experimental setup for water quality

5.3: Analysis of growth

The growth rate was analyzed using the following formula as in Adewolu et *al* 2008.

$$\text{Specific Growth Rate} = \frac{\log w_2 - \log w_1}{t_2 - t_1}$$

w_2 = final weight

w_1 = initial weight

t_2-t_1 = time difference in days

Data for fish weight obtained from the experiment was subjected to statistical analysis of variance (ANOVA). Significant difference in mean was evaluated using the Linear Mixed Model and a One Way T Test used for the statistical analysis of variance within treatments in SPSS version 17.0. Treatments were considered significant at ($p<0.05$).

6: RESULTS

6.1 Survival of *Clarias gariepinus*

A total of 90 *Clarias* fingerlings were used, 42 were lost during experimental procedure. The survival rate was 53.33%. The major cause of these loses were cannibalism, death by treatment, desiccation and some unknown causes. Each fish that died during the experiment was removed and the cause of death noted. The result is represented in the table 1 below.

Table 1: Showing total mortality during the entire experiment and the cause of death.

Death factor	**pH treatment**	**Temperature treatment**	**Ammonia treatment**	**Water exchange**	**percentage**
Cannibalism	8	5	6	0	45.2%
Death by treatment	6	0	7	0	30.9%
Desiccation	2	0	0	5	16.7%
unknown	2	0	0	1	7.1%

6.2 Significant growth rate of *Clarias gariepinus*

The significance difference between the sub treatments in each experiment was calculated to investigate if the different treatments actually affect the fish growth. The results in table 2 below shows that no significant growth difference occurred in any of the experiments except for the water exchange experiment which had a significance of 0.007. This signified that water exchange rate can affect the growth and survival of *Clarias sp* as compared to pH, Temperature and Nitrates.

Table 2: Showing results of significance level between sub treatments.

Treatment	**df**	**F**	**Significance between sub treatment**
pH	1	0.994	0.337
Temperature	1	0.083	0.776
Ammonia	1	2.3	0.150
Water exchange	2	5.451	**0.007**

6.3: Growth rate in pH treatments

Both pH sub treatment had decrease in weight due to their treatment as can be seen in fig 4a and 4b. There was a slight decrease in weight between pH of 8.60 and 7.82 since this was during the quarantine period. From pH of 7.82 to 6.03 and downward (decreasing pH), there was constant weight lost up to pH of 4.41 were the fish could not survive (fig 4a). On the other hand when pH was increased, growth rate was decreased till a pH of 10.42 where they all died. The best growth rate was registered between pH of 8.04 to 9.36. There was a sharp drop in weight from 8.48 to 8.06 because this was the quarantine period (fig 4b).

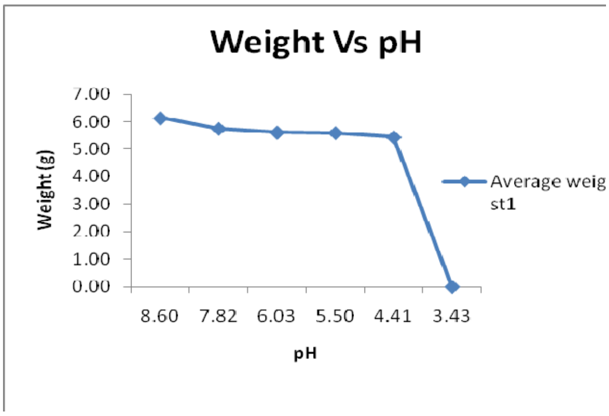


Fig 4a: Weight change with decreasing pH

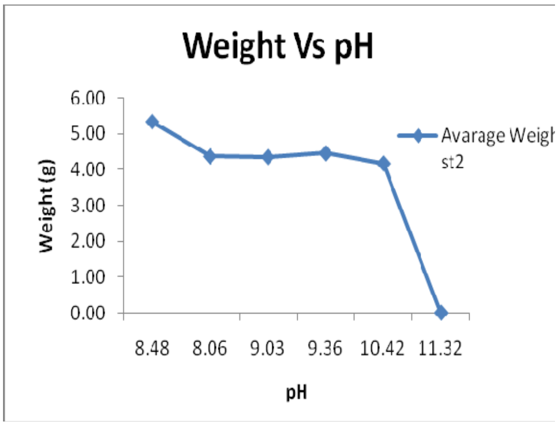


Fig 4b: Weight change with increasing pH

6.4: Growth rate in Temperature/DO treatments

This treatment was used to evaluate the combine effect of temperature and DO on the growth and survival of *Clarias sp*. From Table 3a below we witnessed that the fish had a fast increase in growth but then started slowing down as DO was decreasing. On the other hand, Table 3b shows a steady growth due to the stable DO level. Hence, low DO which is caused by high temperatures reduces the growth rate of *Clarias sp* while to optimize their growth they need average DO of between 4 to 6 ppm.

Table 3a and 3b: Showing how temperature/ DO affect the growth of *C. gariepinus*.

Average Wt	Average DO
4.88	4.88
4.27	1.07
4.44	1.07
4.73	0.36
5.1	0.23
5.23	0.13

Table 3a: Growth rate with low DO (ppm) levels and temperature of 30 ^oC

Average Wt	Average DO
5.72	4.64
5.24	4.36
5.65	4.52
5.72	4.35
5.87	5.32
6.31	4.61

Table 3b: Treatment 2. Growth rate with DO (ppm) at room temperatue of 25 ^oC

6.5: Growth rate in nutrient treatments

The specific growth rate of *Clarias sp* was calculated to evaluate the effect of nutrients to the fish growth. There were steady growth with the treatment having acceptable concentration of nutrient while in table 4b, the fish could not survive at a certain concentration of nutrient considered to be the lethal dose. 0 represent no fish availability.

Table 4a and 4b: Effect of low Ammonia (Treatment 1) and increasing Ammonia (Treatment 2) on *Clarias gariepinus* growth and survival.

Date	Specific Growth Rate	NO_3^{2-}	NH_3
15-Feb	0	**5**	0.2
21-Feb	0.0041	**5**	0.2
26-Feb	-0.0007	**5**	0.2
03-Mar	-0.0171	**5**	0.2
08-Mar	0.0008	**5**	0.2
13-Mar	0.0019	**5**	0.2

Treatment 1

Date	Specific Growth Rate	Av. NO_3^{2-}	NH_3
15-Feb	0	**5**	0.2
21-Feb	-0.0124	**10**	0.5
26-Feb	-0.0205	**10**	0.7
03-Mar	0	0	0.90
08-Mar	0	0	0
13-Mar	0	0	0

Treatment 2

6.6: Growth rate in Water exchange experiment

Fig 5 below was used to evaluate the effect of water exchange to the growth and survival of *Clarias sp*. It is observed that the best growth rates were obtained in treatments 1 and 2 all having water exchange rates.

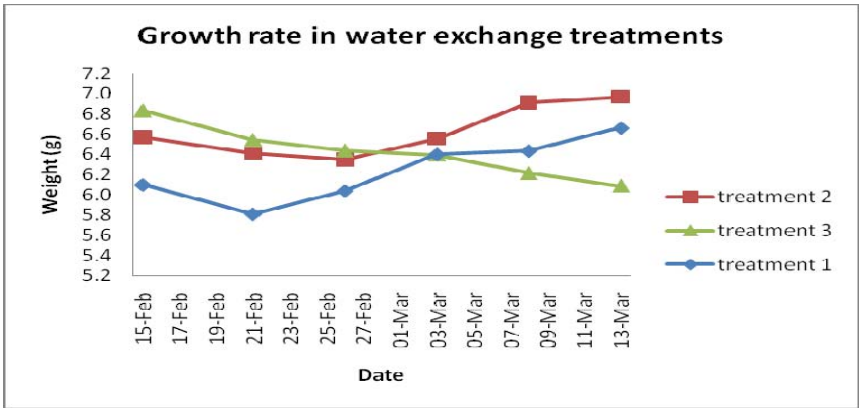


Fig 5: Difference in growth rate amongst the 3 different water exchange treatments.

7: DISCUSSION

7.1. Survivability of *Clarias gariepinus*

Cannibalism is a major problem with *Clarias gariepinus* (Brummett et al 2007) and it constituted 45.2% of the total mortality in my experiments. Cannibalism is influenced by the stocking density, food availability and size (Al-Hafedh et al 2003). The type of cannibalism practice was type 1 where the fish starts eating its prey from the tail upward (Hetcht and Appelbaum 1987) but in this case the entire body was not eaten, just the tail and the scales were eaten. Cannibalism was high in the water quality treatments and there was no cannibalism in the water exchange experiment, confirming that stocking density has an effect on cannibalism (Al-Hafedh et al 2003).

A total mortality of 30.9% was registered due to experimental treatment. According to the experiment, the minimum pH in which the fish could survive was 4.41 since beyond that, all the fishes died. The maximum pH for fish survival was 10.42. There was no mortality caused by treatments in the water exchange and DO treatments. The fish was able to survive with this range because of the high resistance rate and the ability to adapt to changing environment. This makes the species very special for aquaculture since if there happens to be any drastic change in its environment due to pollutants, it will take some time to affect them giving the farmer enough time to identify and react to the environmental change.

Desiccation was registered due to the fish jumping out of the buckets. This occurred only during the quarantine period (the first week of the experiment) and a percentage of 16.7% mortality was measured.

7.2. pH treatment

A look at the treatment effect on the fish growth showed no significant effect and there were slight signs of fish growth with time. When the combine effect of treatment and time were taken, there was no significant difference in growth of the fish in pH treatment with decreasing pH compared to the treatment with increasing pH. This can be explained by the undesirable increase in pH that affected the fish growth hence the growth rate decreased (Jacobsen 2005).

At pH of 5.5, the growth rate decreased greatly and the fish died at pH below 4.41 (fig 4a). On the other hand, fig 2b shows a drastic decrease in growth rate at pH above 9.36 and at a pH of 10.42. Previous studies have shown that a low and undesirable pH for fish growth lowers the liver activity (Jacobsen 2005) and during the experiment, pH levels became undesirable for fish survival in aquaculture ponds (Tucker et al 2008), hence lowering the liver's activity. The optimal growth rate was obtained at pH range of 7 to 9 also shown in other studies (Tucker et *al* 2008).

7.2 Temperature

Treatment with normal DO had no significant effect on fish growth. The data also showed that there were no significant fish growth during the entire period in that treatment. The combine effect of treatment and time shows that there was no significant difference in growth between the treatment with the raised temperature and control, which in this case was the treatment with no temperature increase. This can be explained by the resistance level of the fish to survive even under extreme dissolve oxygen levels of 0.23 since they are breathers (Van Weerd 1995, Huisman et al 1987). According to Toko et al 2006, *Clarias gariepinus* has a normal growth rate even at oxygen concentration between 0.9 ppm to 1.2 ppm. This explains why there is no significant difference in growth between the two treatments.

There was a drop in weight during the first week, then an increase for the next 3 sampling dates. This was probably because the first week was the quarantine period so the fish were unstable and still struggling to adapt to the new environment. They resumed a normal increase in growth till they got to a DO level of 0.23ppm where growth rate started decreasing since at low DO, there is poor feed conversion as seen in early research (Primary Industries & Resources S. A. Factsheet 2001). Sub treatments 2 also had a decrease in growth rate during the quarantine period and then resume an increase in growth with favorable DO level ranging from 4.35ppm to 5.32ppm.

7.3 Ammonia

Clarias did not grow significantly in treatment with accumulated nutrient when compared with control treatment (water changed on a regular basis to avoid nutrient accumulation). The effect of ammonia is quick meaning fishes can still exhibit normal growth with small non lethal concentration. When the lethal concentration is reached, the fish dies instantaneously since they have no time to adapt.

The ammonia level was always below 0.2 mg/l for the control treatment (water changed on regular basis) which is favorable concentration for fish growth (Knepp et al 1973). Treatment with increasing nutrient on the other hand had a decrease in growth, but at week 3 of the experiment all the fish in the treatment died. The concentration of ammonia in treatment 1 was 0.9mg/l, which is toxic for fish culture. The ammonia concentration increased during the experiment since the fish excretes ammonia into water as waste. This un-ionized ammonia in the absence of oxygen and bacteria becomes very toxic to fish health (LaDon Sawnn, 1992).

7.4 Water exchange

A significant difference of 0.007 indicates that there was a significant growth difference between the treatments. Treatment 3 with no water exchange was considered as the control experiment and treatments 1 and 2 both having water exchange had significant growth rates when compared to the control. Treatment 1 with 86% water exchange per day had a higher significant growth rate than treatment 2 with only 6.6% water exchange indicating that ponds with high water exchange rate will tend to produce bigger fish.

Fig 5 shows the growth pattern in all 3 treatments and treatment 1 and 2 which all had water exchange showed a positive growth rate while treatment 3 with no water exchange had a negative growth. The negative growth rate can be explained by the poor water quality and lack of dissolved oxygen that will breakdown the ammonia release through excretion. Higher water exchange treatment had the best growth rate since from the second to the fourth week of measurement there was a steady increase in growth as compared to lower water exchange treatment. Also, on the final week of measurement growth still increased while treatment 2 showed a slight decrease in growth. This might be due the accumulation of ammonia. The ammonia concentration was higher in the nitrate/ammonia treatment than in the water exchange treatment because ammonia accumulation increases with increase in stocking density (LaDon Sawnn, 1992) and the stocking density for the water exchange was smaller as compared to that of the nitrate/ammonia treatment 2.

8 CONCLUSIONS

The results obtained from the experiment showed that individual water parameters have insignificant effect on the fish growth but when combined, they can significantly affect fish growth as seen in the water exchange rate treatments. Therefore, when cultivating *Clarias gariepinus* the major aspect to consider should be the water exchange rate as long as the other water parameters that can affect fish growth (Temperature, pH, Ammonia etc) are within the tolerance limits of the fish. With this information, the cultivation of *Clarias gariepinus* along the mount Cameroon region has the potential to become a success.

9: RECCOMENDATIONS

- More research should be done to determine the effect of stocking density to cannibalism since there was no cannibalism in tanks with low stocking densities (0.2 fingerlings L^{-1}) while the was a high rate of cannibalism in tanks with stocking density of 0.6 fingerlings L^{-1}.
- Two separate tanks were used for the experiment, so more research can be done to check if tank shapes affects growth and cannibalism.

- Series of water exchange rate can be tested to determine the best water exchange rate for *Clarias gariepinus* growth.
- Other water quality parameters such as hardness or water, suspended solid and toxicant can be studied to see if it affects the fish growth along this region.
- The experiment had a combine effect of temperature and dissolved oxygen on fish growth and survival. Individual experiments could be carried out for these parameters to evaluate their effect on the fish growth and survival.

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