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Salinity Tolerance and Preference of Hatchery Reared Nile Tilapia, *Oreochromis niloticus* (Linneaus 1758).

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Abstract: A study was conducted in fisheries laboratory of Department of Fisheries, Lagos State University, Nigeria on salinity tolerance and preference of hatchery reared Nile tilapia, *Oreochromis niloticus*, (Linneaus, 1758). Tilapias are important candidate species for aquaculture and are increasingly cultured in polyculture system with shrimp. Thus creating a demand for Tilapia genotypes well suited to elevated salinities. *O. niloticus* is a member of the Family Cichlidae and one of most cultured fish species in Nigeria. It is known for its high prolific rate of breeding and multiplication. Six hundred and sixty (660) fingerlings of the fish measuring between 53-140 mm TL and weighing 8.96 to 21.56 g BW were subjected to salinity regimes of 0-10‰ for 28 days. All the fish survived in 0-7‰, and 100% death was recorded in 9 and 10‰. Different levels of behavioural responses to threat and feeding were observed among the fish. Salinities 0-7‰ were tolerated by the fish, however the most preferred salinity was 1‰. The present study as demonstrated in the laboratory therefore, suggests the possibility of culturing Nile tilapia, *O. niloticus* in both fresh and low brackish water environments and as added data to the existed reviews on this economically valued fish species. The salinity regimes well that were tolerated and preferred for optimal survival, growth and behavioural performances of *O. niloticus* are therefore investigated.

Key words: Aquaculture, artisanal, brackish, cichlidae, ionic concentration, osmo-regulation, survival

INTRODUCTION

A species Nile Tilapia, *Oreochromis niloticus* belongs to family Cichlidae. This species which dominates freshwater fish culture is one of the least salt tolerant tilapia (Mostofa-Kamal and Mair, 2005). It is an economically importance fish species as food and bait in both capture and artisanal fisheries and one of the most prolific species of the cichlids. Other related species include: *Tilapia zillii*, *Tilapia melanopleura* and *Sarotherodon galililae*.

Salinity as one of the limiting factors in the life history of Tilapia and non related species has attracted attentions of several researchers. Effects of salinity on other water quality parameters and life history of fishes have been variously reviewed. Effects of salinity was widely reported on oxygen, pH, temperature and specific gravity by Nikolsky (1963); on gametes and fertilization period of the fish by Holliday (1965) and Rockwell (1956); on metamorphosis, early development and hatching of teleosts by Heuts (1947), Kinne (1964), Holliday and Jones (1967); on behavioural response by Baggerman (1959, 1960). Others include Vant Hoff (1903), Lee *et al*. (1981), Watanabe *et al* (1985a, b), McGeachin *et al*. (1987), Hopkin *et al*. (1989), Prunet and Bornancin (1989), Villegas (1990), Suresh and Lin (1992), Avella *et al*. (1993), Linkongwe *et al*. (1996) and Deguara and Agius (1997). The reviews although appeared old, but are still relevant in this study.

The recent reviews include that of Baroiller *et al*. (2000), Sandra *et al*. (2000), Garcia -Ulloa *et al*. (2001), Lutz (2001), Nugon (2003), Lawson (2004), Lemarie (2004), Mostofa-Kamal and Mair (2005), Kabir Chowdhury *et al*. (2006), Ridha (2006, 2008); Yao *et al*. (2008), Breves *et al*. (2010), Schofield *et al*. (2010) and Lawson and Alake (2011). The rapid growth of tilapia, their resistance to poor water quality, ability to grow under sub-optimal nutritional conditions, and high fecundity, all make them well suited for aquaculture. Linkongwe (1996) suggested high growth rates of juvenile of *O. niloticus* in waters with temp of 28-32ºC at 0-8 g/L salinity. The ontogeny salinity tolerance in *O. aureus*, *O. niloticus* and *O. mossambicus* spawned, hatched and reared in freshwater was reported in Watanabe *et al*. (1985a, b). The ontogenetic changes in salinity tolerance were determined to be more closely related to body size than chronological age (Villegas, 1990). Effects of salinity on survival, growth and reproduction was determined by Schofield *et al*. (2010) in *O. niloticus* from Mississippi to assist in predicting their

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potential spread to estuarine and coastal region. According to Baroiller *et al*. (2000), *O. niloticus* does not tolerate salinities above 20 ppt and might not be suitable for culture in full strength seawater (37-40 ppt).

Several reviews either supporting or contradicting the presence of Nile Tilapia, *O. niloticus* in fresh and brackish water systems made it imperative for us to work on its salinity tolerance and preference. The present study may support, compliment or contradict some reviews on the culture of this commercially important fish species.

MATERIALS AND METHODS

Six hundred and sixty (660) of *O. niloticus* were obtained from a reputable fish hatchery in Badagry area of Lagos, Nigeria. In the laboratory, biometric data on total length (TL) and body weight (BW) measurements were recorded for individuals. TL to the nearest 1 mm and BW to the nearest 0.01 g. Their sizes ranged between 53 and 140 mm and weighed between 8.96 and 21.56 g. They were acclimatized in the laboratory for a period of 72 h in acclimatization tanks of 60x36x36 cm each.

Salinity levels were obtained by mixing de-chlorinated tap water to artificial sea water following the method of Vant Hoff (1903). Confirmation was carried out using an optical refractometer (to the nearest 1‰) and by titration. Ten millilitres of each aliquot was titrated against 27.09 g/L $AgNO_3$ using $K_2Cr_2O_7$ as an indicator.

Water parameter at the period of this study were pH (7.3 to 7.6), DO (6-9 mg/L), Unionised Ammonia Nitrogen (FAN) level was 0.02±0.0 mg/L. Replacement of water was done daily by siphoning the bottom of the containers and adding 70% clean water. In this study freshwater (salinity = 0.0‰) was represented by de-chlorinated tap water in the Control tank.

Each aliquot contained 13 L mixture. Twenty (20) fingerlings of *O. niloticus* were transferred into each of the eleven glass tanks from acclimatization tank and in triplicates for period of 28 days. The fish were fed with fish feed meal of 50% Crude protein (CP) at 5% of total body weight. The daily number of survivors and deaths in each tank was recorded. The weekly mean total length and body weight of fish were also recorded.

The following statistical analyses were carried out:

The Mean growth rate (MGR) =

$$\frac{W_2 - W_1 \times 100(g/day)}{0.5(W_2 - W_1)} \quad (1)$$

The Specific growth rate (SGR) =

$$\frac{LogW_2 - LogW_1 \times 100(g/day)}{Number\ of\ days} \quad (2)$$

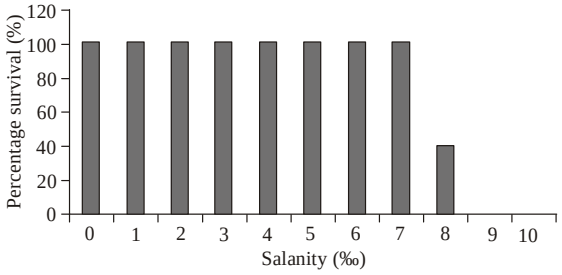

Fig. 1: Percentage survival of *O. niloticus* in varied salinities

The Percentage difference in body weight (W) =

$$\frac{W_2 - W_1 \times 100\%}{W_1} \quad (3)$$

The Percentage difference in total length (L) =

$$\frac{L_2 - L_1 \times 100\%}{L_1} \quad (4)$$

where,
W_1 = Initial body weight of fish (g)
W_2 = Final body weight of fish (g)
t = duration of experiment (t = 28 days),
0.5 = constant
L_2 = Final total length of fish (mm)
L_1 = Initial total length of fish (mm)

In this study, the tolerance levels were the salinity regimes where 50% of fish survived the period of experimentation, while the preference level was the salinity with record of highest number of survivors, very high appetitive behaviours and best growth performance in terms of MGR, SGR, BW and TL. Feeding response was determined by the absence or presence and quantity of leftovers in the bottom of the glass tanks, while threat response by erratic, aggressive or normal behavioural patterns displayed by the fish when touched with a glass rod were used as baseline for data collection. Experimental period was 28 days.

RESULTS

Effects of salinity on the survival of *O. niloticus*: Percentages of the survivors of *O. niloticus* in varied salinities are presented in Fig. 1. In this study, 100% survival rate was recorded in 0 to 7‰, 40% in 8‰ and all deaths (i.e., 100% mortality rate) in 9 and 10‰.

Survivorship curves for *O. niloticus*: Figure 2 presents the survivorship curves for *O. niloticus* in varied salinities. All fingerlings survived 0 to 7‰ salinities. In 8‰ it was 60% in 8‰ from day 8 to 20 and 40% between

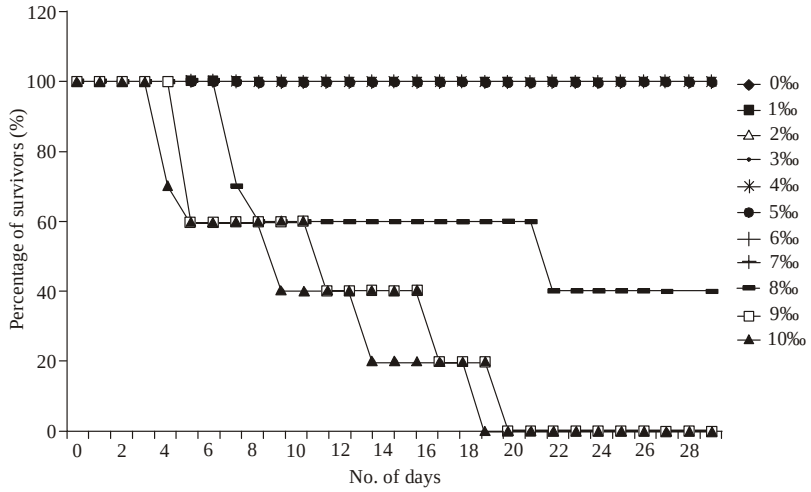

Fig. 2: The survivorship curves of *O. niloticus* in varied salinities

Table 1: Summary of the percentage changes in total length (mm) and body weight (g) of *O. niloticus* in varied salinities (‰)

	Total length of fish (mm)			Body weight of fish (g)		
Salinity level in ‰	Final mean length (T_2)	Initial mean length (T_1)	Increase or decrease in mean lenght (T) (%)	Final mean weight (W_2)	Initial mean weight (W_1)	Increase or decrease in mean weight (W) (%)
0	100	77	29.87	16.61	13.1	26.79
1	102	81	25.93	13.91	10.61	31.06
2	112	92	21.74	21.22	15.23	39.38
3	104.5	88	18.75	15.77	13.19	19.61
4	115	100	15	14.12	12.04	17.28
5	97	84.5	14.79	12.94	11.23	15.18
6	104	93.5	11.23	14.81	13.37	10.81
7	95.5	87	9.77	13.77	12.8	7.54
8	64.5	89	-27.53	10.91	12.16	-10.28
9	80	93	-13.98	13.62	14.42	-5.55
10	76	93	-18.28	13.9	15.27	-9.05

day 21 and 28). At 9‰ survival rate was 100% from day 1 to 4. However, it dropped to 60, 40, and 20% on the 5th, 11th, and 16th day respectively. In 10‰, survival rate was 100% (from day 1 to 3); 60% (day 5 to 8); 40% (from day 9 to 12). Mortality rate was 100% from day 18 to 28.

Effects of salinity on the growth rates of *O. niloticus*: Table 1 presents the percentage differences in total length and body weight measurements of *O. niloticus* in varied salinities. In over all, the growth rate decreased with increased salinity.

Total length (TL): In this study there was decreased in TL of fish as salinity increased. There was increase of 29.87 and 9.77% in TL of fish reared in 0 and 7‰ respectively. Loss in size as result of various levels of death was observed in 8‰ (-27.53%), 9‰ (-13.98%) and 10‰ (-18.28%).

Body weight (BW): Body weight gains were observed in salinities 0 to 7‰. There was 39.38% increase in weight of fish in 2‰ salinity and weight loss of -10.28, -5.55 and -9.05% due to various degrees of mortality was recorded in 8, 9, and 10‰.

Mean (MGR) and Specific (SGR) growth rate of *O. niloticus*: The relationships between the mean (MGR) and specific (SGR) growth rates in varied salinities are presented in Fig. 3. Increased MGR and SGR values were recorded in 0-7‰, however degrees of reduction in the values differed between 8-10‰. The highest value of 32.898 g/day in MGR was recorded in 2‰, while the greatest loss of -17.342 due to death was recorded in 8‰. The SGR values were 0.513 and -0.169 g/day were reported for 8 and 2‰, respectively.

Effect of salinity on threat response of *O. niloticus*: The summary of daily response of *O. niloticus* to threat in varied salinity regimes is presented in Table 2. The fish exhibited a normal response to threat between 0 and 5‰, various levels of response (i.e., restlessness or hyper-activeness or erratic behaviour) were displayed between 6 and 8‰.

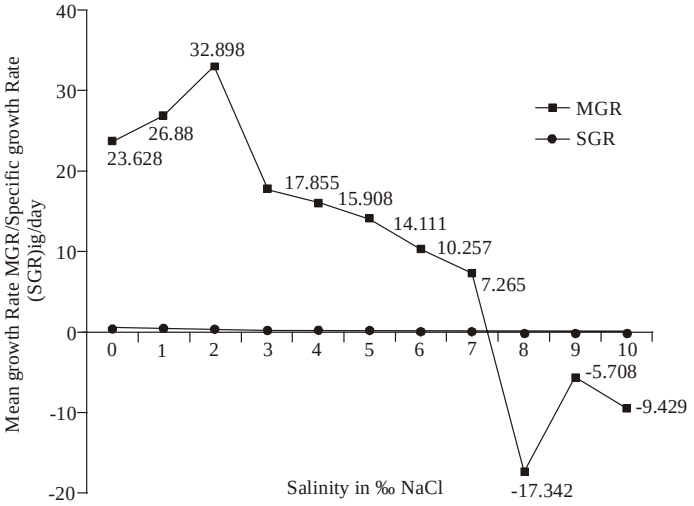

Fig.3: Frequency polygons of relationships between (i) the Mean Growth Rate (MGR), and (ii) Specific Growth Rate (SGR) of *O. niloticus* in varied salinities

Table 2: Summary of daily threat response of *O. niloticus* in varied salinity regimes

	Salinity concentration in part -per-thousand (‰)										
Day	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
1	N	N	N	N	N	N	N	H	H	H	D
2	N	N	N	N	N	N	N	H	H	H	D
3	N	N	N	N	N	N	N	H	H	H	D
4	N	N	N	N	N	N	N	H	H	H	D
5	N	N	N	N	N	N	N	H	H	H	D
6	N	N	N	N	N	N	N	H	H	H	D
7	N	N	N	N	N	N	N	H	H	H	D
8	N	N	N	N	N	N	M	M	M	D	D
9	N	N	N	N	N	N	M	M	M	D	D
10	N	N	N	N	N	N	M	M	M	D	D
11	N	N	N	N	N	N	M	M	M	D	D
12	N	N	N	N	N	N	M	M	M	D	D
13	N	N	N	N	N	N	M	M	M	D	D
14	N	N	N	N	N	N	M	M	M	D	D
15	N	N	N	N	N	N	N	N	M	D	D
16	N	N	N	N	N	N	N	N	M	D	D
17	N	N	N	N	N	N	N	N	M	D	D
18	N	N	N	N	N	N	N	N	M	D	D
19	N	N	N	N	N	N	N	N	M	D	D
20	N	N	N	N	N	N	N	N	M	D	D
21	N	N	N	N	N	N	N	N	M	D	D
22	N	N	N	N	N	N	N	H	M	D	D
23	N	N	N	N	N	N	N	H	M	D	D
24	N	N	N	N	N	N	N	H	M	D	D
25	N	N	N	N	N	N	N	H	M	D	D
26	N	N	N	N	N	N	N	H	M	D	D
27	N	N	N	N	N	N	N	H	M	D	D
28	N	N	N	N	N	N	N	H	M	D	D

N = Normal response; M = Moderate response; H = Hyperactive; D = Death

Effects of salinity on feeding response of *O. niloticus*: In this study, fish showed very high appetitive behaviour to food between 0 and 5‰ salinities (Table 3). Different levels of response to feeding (i.e., very high, high, moderate and low appetite) were displayed between 6 and 8‰ within the period.

DISCUSSION

Investigations from this study showed that Nile Tilapia, *Oreochromis niloticus* tolerated between 0 to 7‰ salinity regime. In these regimes all there was no death, high growth performances in terms of TL, BW, SGR and

Table 3: Summary of daily feeding response of *O. niloticus* in varied salinity regimes

	Salinity concentration in part -per-thousand (‰)										
Day	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
1	VHA	VHA	VHA	VHA	VHA	VHA	VHA	HA	LA	LA	LA
2	VHA	VHA	VHA	VHA	VHA	VHA	VHA	HA	LA	LA	LA
3	VHA	VHA	VHA	VHA	VHA	VHA	VHA	HA	LA	LA	LA
4	VHA	VHA	VHA	VHA	VHA	VHA	VHA	HA	LA	LA	LA
5	VHA	VHA	VHA	VHA	VHA	VHA	VHA	HA	LA	LA	LA
6	VHA	VHA	VHA	VHA	VHA	VHA	VHA	HA	LA	LA	LA
7	VHA	VHA	VHA	VHA	VHA	VHA	VHA	HA	LA	LA	LA
8	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
9	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
10	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
11	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
12	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
13	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
14	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
15	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
16	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
17	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
18	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
19	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
20	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
21	VHA	VHA	VHA	VHA	VHA	VHA	HA	MA	LA	D	D
22	VHA	VHA	VHA	VHA	VHA	VHA	MA	MA	LA	D	D
23	VHA	VHA	VHA	VHA	VHA	VHA	MA	MA	LA	D	D
24	VHA	VHA	VHA	VHA	VHA	VHA	MA	MA	LA	D	D
25	VHA	VHA	VHA	VHA	VHA	VHA	MA	MA	LA	D	D
26	VHA	VHA	VHA	VHA	VHA	VHA	MA	MA	LA	D	D
27	VHA	VHA	VHA	VHA	VHA	VHA	MA	MA	LA	D	D
28	VHA	VHA	VHA	VHA	VHA	VHA	MA	MA	LA	D	D

VHA = Very High Appetite; HA = High Appetite; MA = Moderate Appetite; LA = Low Appetite; D = Death

MGR were recorded. This is an indication that the fish were perfectly able to regulate their body physiology within this regime. 100% deaths recorded in 9 and 10‰ indicate that the fish developed osmo-regulatory failure. The mortality was due to stress, duress and less resistance of the fish to these salinities.

Survival rate of 100% between 0 and 7‰ shows the fish were able to withstand a wide salinity range, this according to Kurata (1959) and Holliday and Jones (1967) depends on the ability of the body fluids to function at least for short time in an abnormal range of internal osmotic and ionic concentrations. The fish can regulate the body fluid to restore level of osmotic pressure to near normal. Nugon (2003) reports on juveniles of *O. aureus*, *O. niloticus* and Florida red Tilapia showed they exhibited good survival (>81%) in salinity regimes up to 20 ppt, with moderate survival of *O. aureus* (54%) and Florida red tilapia (33%) at 35 ppt salinity. The Mississippi commercial tilapia survived salinity regimes up to 10 ppt but exhibited poor survival at 20 ppt (5%).

Increased size of the fish suggested that the fish were able to regulate osmotic pressure of the body fluid; this was in agreement with suggestions of Nikolsky (1963), the more the osmo-regulatory adaptation, the greater the difference between the compositions and pressures of the internal fluid of the organism and its external environment. Weight loss salinities presumes lost of water to the external medium, this equivalent to when a fish migrates from fresh to seawater or is abruptly transferred from freshwater to higher salinities. The migration of fish from fresh to seawater will normally lead to increase osmotic concentration of fish's blood serum and change in ionic contents (Gordon, 1959; Miles and Smith, 1968).

The restlessness or hyper-activeness or erratic behaviour in high salinities indicates fast rate at which the fish were approaching their tolerance limits and loss of water to external medium from the fish.

The high appetitive behaviour displayed by the fish towards food is an indication that fish body metabolism can still be maintained or regulated in these salinities, while low appetite is an indication of near or total body metabolic break down. Such changes with increased salinity are indication that the salinities were near or outside the tolerance limits of the fish. Moderate and normal responses represented the near and far tolerance limits respectively. Fish move to preferred position in salinity gradient, to indicate salinity preferences in choice situation (Baggerman, 1959; McInerney, 1964). Hoar and Randal (1969) based the survival of fish on a combination of tissue tolerance and regulation. Higher osmo-regulatory cost at higher salinity could make fish to develop body lesions which covered 25% of their body surface. McGeachin *et al*. (1987) and Hopkin *et al*. (1989) observed external lesions and severe hemorrhages in internal organs in *O. aureus* in 100% seawater.

CONCLUSION

In this study, the significant effects of salinity on survival, behavioural responses and growth performance of *O.niloticus* were investigated in the laboratory. The salinity regimes of 0-7‰ were well tolerated by the fish, representing fresh to low brackish water environments, respectively, however, the most preferred salinity was 1‰. For aquacultural purpose, we suggest the culture of Nile Tilapia, *O.niloticus* in aquatic environment with salinities between 0-7‰. The present study therefore supports, compliments and contributes additional data to already existed reviews on the culture of this commercially important fish species.

This study also allows the coastal states to objectively evaluate risks associated with tilapia production in their coastal water sheds by quantifying the salinity tolerance of this commercially important fish.

Further experiments are in progress: (1) to establish the mechanisms which are involved in the regulation of a response in *O.niloticus* to salinity and (2) to produce a tilapia hybrid that has a combination of high salinity tolerance and fast growth performance.

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