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Salinity Adaptability and Tolerance of Hatchery Reared Comet Goldfish *Carassius auratus* (Linnaeus 1758)

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ABSTRACT

A study was carried out in the laboratory on adaptability and tolerance of hatchery reared Comet goldfish, *Carassius auratus* (Linnaeus 1758) to varied salinity regimes, to provide baseline data and information on possibility of its culture in brackish water or marine environment. A total of two hundred and twenty life juvenile of goldfish, aged eight months used in this study were raised in and purchased from a reputable fish farm in Lagos, Nigeria. Biometric data on total length (T) and body weight (BW) measurements were recorded in the fisheries laboratory of Lagos State University. Goldfish of 17 to 25 cm total length, weighing between 70 and 145 g body weight were subjected to 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 parts per thousand (‰) salinities in the laboratory. There was a significant decrease in total length and body weight measurements with increased salinity. Mean growth rate (MGR) of 39.196, 34.783, 34.555, 20.889, 15.852 and 10.645 g day^{-1} were observed in 0, 1, 2, 3, 4 and 5 ‰, respectively, while the specific growth rates (SGR) were 0.012, 0.011, 0.008, 0.008, 0.005 and 0.005 g day^{-1}, respectively. No death (0% mortality) was recorded in 0, 1, 2 and 3 ‰. The most adaptable salinity was 0 ‰; the fish however exhibited high level of tolerance between 1 and 5‰ salinities. The baseline data from this study indicate that gold fish, *Carassius auratus* will adapt and tolerate culture systems of fresh and low brackish water environments of 0 to 5 ‰ salinities.

Key words: *Systema*, salinity, euryhaline, salinometer, comet

INTRODUCTION

Goldfish belongs to Family Cyprinidae. It is an exotic fish species. It was first described and named in *systema Naturae* (1758) as *Cyprinus auratus*. Matsui (1972) claimed that a mission in 1832 established a new genus *Carassius* for goldfish and thus separated *Cyprinus* and *Carassius*. Natural mutation of the crucian carp gave rise to Goldfish. It was first reared in China in 1000, Europe in 1611 and America in 1876 AD. Of the cyprinids cultured by man, goldfish remains the most prominent and commonly used as ornamental and kept as expendable pet at home, offices and pubhc places such as hotels, parks and tourist centres etc. Its aesthetic nature is as a result of its beautiful yellowish orange (golden) color. Over the centuries goldfish has evolved into several varieties such as Oranda, Lion head, Comet, Hibuna, Shubunkin and Black moor to mention a few (Matsui, 1972). Adaptability and tolerance of fish including goldfish to physical and chemical

changes in water vary greatly. Most fish are adapted and only survive in the freshwater; however some have great adaptations for seawater. Some are describes as euryhaline having developed certain adaptive features that make them suitable in brackish water. Adaptation of freshwater fishes to temperature, pressure and current have been described by Nikolsky (1963), Matsui (1972), Olaniyan (1975), Boyd and Lichtkoppler (1979), Hunner and Dupree (1984) and Boyd (1990). They described ecological factors such as salinity, dissolved oxygen, temperature and pH as some limiting factors in the aquatic habitats. Knowledge of salinity tolerance of fish according to Oldfied (2004) could allow new captive species combinations. Knowledge of salinity preference could bring aquarists or fish hobbyists' one step closer to providing ideal artificial conditions. Schofield *et al.* (2006a, b) reported that goldfish is able tom persist in low salinity environments of <10 ppt for a long period of time and higher salinities for short period. Altinokand and Grizzle (2001) recorded highest specific rate and most efficient food conversion ratio and energy absorption efficiency for goldfish in freshwater. However, Wang *et al.* (1997) reported influence of salinity on food consumption, growth and energy conversion efficiency of common carp (*Cyprinus carpio*) fingerling. In their reports salinity tolerance of common carp was similar to that of gold fish, higher than that of silver carp and lower than those of *Tilapia zillii*. From the study of Luz *et al.* (2008), salinities up to 6 ‰ did not affect weight gain, standard growth and feed conversion rates, no stress. There was good adaptation in terms of metabolic resources even after 21 days of salinity exposure. Higher salinities produced significant muscle dehydration and adverse effects on growth, food intake and food conversion rate.

Goldfish has been described as hardy to an extent of tolerating drastic changes in both physical and chemical qualities of water by Matsui (1972) it is general described as purely freshwater fish. However, of recent, its culture in brackish water and marine environment had received very little attention. Therefore, for this reason, this study is directed at investigating the salinity adaptability and tolerance of goldfish under laboratory condition. The data obtained from the study can provide information and serve as a baseline data for goldfish culture in freshwater, brackish water and marine environment. However, if successful, the saltwater may be more physiologically appropriate for its culture than freshwater.

MATERIALS AND METHODS

A total of two hundred and twenty life juvenile of Goldfish, *Carassius auratus* of 17 to 25 cm long, weighing 70 and 145 g body weight were raised and purchased from a reputable fish hatchery in Lagos, Nigeria. The fish were acclimatized in glass tanks (size: 60×36×36 cm) in the Fisheries laboratory of the Lagos State University, Lagos, Nigeria for period of 72 h. The study was conducted and carried out in triplicates between March 1997 and February 1998.

Different levels of salinities such as 1, 2, 3,4,5,6,7,8,9 and 10 ‰ were prepared from fresh and sea waters by simple dilution method (Lawson, 2004). Chloride free freshwater from the university's borehole was used as a control experiment. The salinities were confirmed with Salinometer and by titration. Ten milhliter of each aliquot was titrated against 27.09 g L^{-1} $AgNO_3$ using K_2CrO_7 as an indicator.

Twenty juveniles of comet goldfish were abruptly transferred acchmatized tanks into each glass tank containing 20 L aliquot and labeled according to its salinity.

The fish were fed with feed meal of 45% crude protein at 5% of the body weight under the laboratory condition of 23-29°C. The tanks were aerated continuously and the food residues and feacal products were siphoned daily.

The survival and responses of the fish to swimming (i.e., erratic, very active or normal), threat (i.e., weak, moderate or normal when touched with a glass rod) and feeding (i.e., very high, high, moderate, low or poor appetite) were used as baseline for data collection. Response to swimming was a measure of the swimming patterns of the fish in water column, while the feeding response was by the visual assessment of the quantity of the leftover on the bottom of the tank. Number of deaths was recorded daily.

The final mean total length and body weight of the fish were also recorded.

The following statistical analyses were carried out:

$$\text{The percentage body weight gain/loss} = \frac{W_2\text{-}W_1}{W_1} \times 100\% \quad (1)$$

$$\text{The percentage gain/loss in total length} = \frac{L_2 \times L_1}{L_1} \times 100\% \quad (2)$$

$$\text{The mean growth rate (MGR) was determined as: MGR} = \frac{W_2 - W_1 \times 100(\text{g day}^{-1})}{0.5\ (W_2 - W_1)} \quad (3)$$

$$\text{The specific growth rate (SGR) was determines as: SGR} = \frac{\text{Log}W_2 - \text{Log}\ W_1 \times 100(\text{g day}^{-1})}{\text{No. of days}} \quad (4)$$

Where:

W_1 = Initial weight of the fish
W_2 = Final weight of the fish
t = No. of days used for experiment
0.5 = Constant
L_2 = Final total length of fish
L_1 = Initial total length of fish

The tolerance level was based on the ability of the 50% of the juveniles to survive the first 7 days in the aliquots, while the most adaptable level was the salinity at which the best growth rates in terms of MGR, SGR, BW and TL were recorded. Experimental period was 14 days.

RESULTS

Effects of salinity on the survival of *C. auratus*: The tolerance level of the fish was based on the survival rate of at least 50% of the tested specimens in varied salinities for the first 7 days. The percentages of the survivors in varies salinities are presented in Fig. 1. There were 100% survivors between 0 and 30‰ salinities throughout the experimental period. Survival was 60 and 40%, respectively for 4 and 5‰ salinities.

The survivorship curves of *C. auratus* in varied salinities are presented in Fig. 2. One hundred percent survivors were recorded between 0 and 3‰ salinities throughout the period of experiment, in 4‰ (Between day 1 and 4) and in 5, 6 and 7‰ (From day 1 to 3). There were various levels of survival and mortality from the days 6 to 14 between salinities 6 and 10‰.

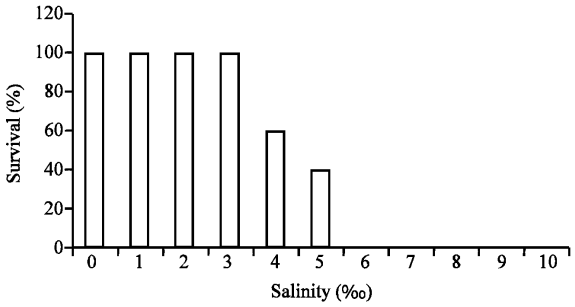

Fig. 1: Percentage Survival of *Carassius auritus* in varied salinities

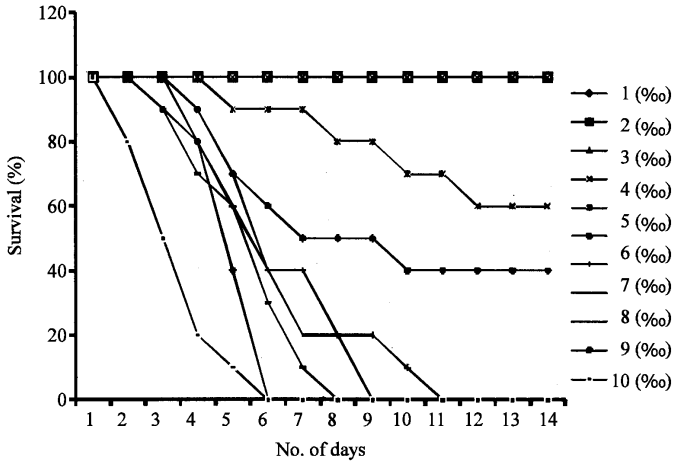

Fig. 2: The survivorship curves of *Carassius auratus* in varied salinities

Table 1: Summary of the Percentages gain /loss in total length and body weight of juvenile *Carassius auratus* in varied salinities.

Salinity level parts per thousand (‰)	Final mean total length (L_2)	Initial mean total length (L_1)	% gain or loss in total length (L)	Final mean body weight (W_2)	Initial mean body weight (W_1)	% gain or loss in body weight (W)
0	31	21	47.62	119	80	48.75
1	24	17	41.1	135	95	42.1
2	26	20	30	112	79	41.8
3	29.5	23	19.6	131	94	39.4
4	27	23	17.4	157	113	38.05
5	24.4	21	16.2	143	105	36.2
6	0	25	-100*	0	141	-100*
7	0	20	-100*	0	76	-100*
8	0	25	-100*	0	140	-100*
9	0	23	-100*	0	136	-100*
10	0	22	-100*	0	114	-100*

*100% mortality

Effects of salinity on the growth of *C. auratus*: The percentages gain or loss in total length and body weight measurements of *C. auratus* in varied salinities are given in Table 1.

Total length: The initial mean total length of the fish ranged between 17.0 and 25.0 cm. There was general decreased in length with increased salinity. The highest total length gain of 47.62% was recorded in control tank. Appreciable gains in lengths were observed between 1 and 5‰. However, there was no length gain between 6 and 10‰ salinities.

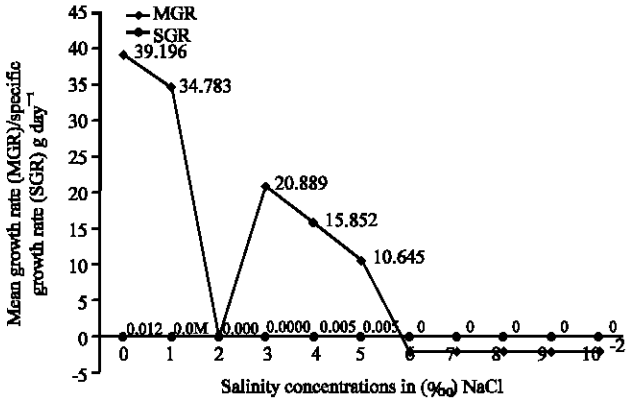

Fig. 3: Frequency polygon of relationship between mean growth rate (MGR) and specific growth rate (SGR) of *Carassius auratus* in varied salinities

Body weight: Initial mean body weight of the fish varied between 76 and 141 g. Generally, appreciable decrease in weight was recorded with increased salinity, the highest increase of 48.75% was observed in 0‰. The least gain of 36.20 g in weight was recorded for 5‰ salinity. There was no gain in body weight between 6 and 10‰ salinities.

The mean and specific growth rates of *C. auratus*: The frequency polygons of relationship between the mean and specific growth rates of *C. auratus* in varied salinities are presented in Fig. 3. There was general decrease in MGR with increased salinity, SGR value of 0.008 g day^{-1} was recorded for 2 and 3‰ while 0.005 g day^{-1} was observed in 4 and 5%. The highest MGR and SGR values of 39.196 and 0.012 g day^{-1}, respectively were recorded in 0‰. However, between 6 and 10‰ salinities both MGR and SGR values were -2.00 and 0.00 g day^{-1}, respectively.

Effects of salinity on the behavioural patterns of *C. auratus*: The behavioural patterns were based on their responses to swimming, food and threat.

Swimming response: The summary of the daily swimming response of goldfish, *C. auratus* in varied salinities is presented in Table 2. Fish introduced abruptly into salinities 0 to 3‰ were very active throughout the experimental period. They were actively swimming within the first three days; thereafter they were less active, this was accompanied by sign of stress.

At 7‰ the fish were very active in days 1 and 2. The erratic behaviour set in from day 5 to 8; from salinities 8 to 10‰, fish did not exhibit normal swimming after day 2. Those in tank 10‰ exhibited great sign of shock with erratic swimming immediately they were transferred; thereafter they became unconscious and died.

Feeding response: Table 3 shows the summary of the daily feeding response of *C. auratus* in varied salinities. Between 0 and 3‰, the feeding behaviour was normal with fish exhibiting very high appetitive behaviour in days 1 and 2. The fish exhibited different levels of response to feeding in 4 to 9‰ salinities.

Threat response: Table 4 is a summary of daily threat response of goldfish, *C. auratus* in varied salinities. The response of the fish to threat between 0 to 3‰ salinities was exhibited normally

Table 2: Summary of daily swimming response of *C. auratus* in varied salinities

Day	0‰	1‰	2‰	3‰	4‰	5‰	6‰	7‰	8‰	9‰	10‰
1	VA	VA	VA	VA	VA	VA	VA	VA	N	N	E
2	VA	VA	VA	VA	VA	VA	VA	VA	N	N	E
3	VA	VA	VA	VA	VA	VA	VA	N	E	E	E
4	VA	VA	VA	VA	N	N	N	N	E	E	E
5	VA	VA	VA	VA	N	N	N	E	E	E	E
6	VA	VA	VA	VA	N	N	E	E	E	D	D
7	VA	VA	VA	VA	N	N	E	E	E	D	D
8	VA	VA	VA	VA	N	N	E	E	E	D	D
9	VA	VA	VA	VA	N	N	E	D	D	D	D
10	VA	VA	VA	VA	N	N	E	D	D	D	D
11	VA	VA	VA	VA	N	N	D	D	D	D	D
12	VA	VA	VA	VA	N	N	D	D	D	D	D
13	VA	VA	VA	VA	N	E	D	D	D	D	D
14	VA	VA	VA	VA	N	E	D	D	D	D	D

VA: Very active; N: Low active; E: Erratic swimming; D: Death

Table 3: Summary of daily feeding response of *C. auratus* in varied salinities

Day	0‰	1‰	2‰	3‰	4‰	5‰	6‰	7‰	8‰	9‰	10‰
1	VHA	VHA	VHA	VHA	VHA	VA	HA	HA	MA	LA	NA
2	VHA	VHA	VHA	VHA	VHA	VA	HA	HA	MA	LA	NA
3	VHA	VHA	VHA	VHA	VA	VA	MA	MA	NA	NA	NA
4	VHA	VHA	VHA	VHA	HA	HA	MA	MA	LA	NA	NA
5	VHA	VHA	VHA	VHA	HA	HA	MA	MA	LA	NA	NA
6	VHA	VHA	VHA	VHA	HA	MA	MA	LA	LA	D	D
7	VHA	VHA	VHA	VHA	MA	MA	LA	NA	NA	D	D
8	VHA	VHA	VHA	VHA	MA	MA	LA	NA	NA	D	D
9	VHA	VHA	VHA	VHA	MA	MA	LA	D	D	D	D
10	VHA	VHA	VHA	VHA	MA	MA	LA	D	D	D	D
11	VHA	VHA	VHA	VHA	MA	MA	D	D	D	D	D
12	VHA	VHA	VHA	VHA	MA	MA	D	D	D	D	D
13	VHA	VHA	VHA	HA	MA	LA	D	D	D	D	D
14	VHA	VHA	VHA	HA	MA	LA	D	D	D	D	D

VHA: Very high appetite; HA: High appetite; MA: Moderate appetite; LA: Low appetite; NA: No appetite; D: Death

throughout the duration of the experiment. At 4 and 5‰, the response was also normal between day 1 and 7, however it was moderate from day 8 to 14. There were various levels of response to threat between 6 and 10‰.

Effects of salinity on pigmentation of *C. auratus*: Table 5 describes changes in the body pigment that were observed in comet goldfish, *C. auratus* in varied salinities. The fish showed no observable departure from the normal body pigmentation of gold colour between salinities 0 and 3‰ throughout the experiment. The normal gold colour was maintained in 4 and 5‰ from day 1 to 4, thereafter, a change to bleached yellow colour was observed. There was a restoration to normal gold between days 9 and 14. However, between 6 to 10‰ salinities body laceration and bleached yellow coloration was observed among the individual fish.

Table 4: Summary of daily threat response of *C. auratus* in varied salinities

Day	0‰	1‰	2‰	3‰	4‰	5‰	6‰	7‰	8‰	9‰	10‰
1	R	R	R	R	R	R	MR	MR	MR	WR	WR
2	R	R	R	R	R	R	MR	MR	MR	WR	WR
3	R	R	R	R	R	R	MR	MR	MR	WR	WR
4	R	R	R	R	R	R	WR	WR	MR	WR	WR
5	R	R	R	R	R	R	WR	WR	MR	WR	WR
6	R	R	R	R	R	R	WR	WR	MR	D	D
7	R	R	R	R	R	R	WR	WR	MR	D	D
8	R	R	R	R	MR	MR	WR	WR	D	D	D
9	R	R	R	R	MR	MR	WR	D	D	D	D
10	R	R	R	R	MR	MR	WR	D	D	D	D
11	R	R	R	R	MR	MR	D	D	D	D	D
12	R	R	R	R	MR	MR	D	D	D	D	D
13	R	R	R	R	MR	MR	D	D	D	D	D
14	R	R	R	R	MR	MR	D	D	D	D	D

R: Normal response; MR: Moderate response; WR: Weak response; D: Death

Table 5: Summary showing changes observed in the body pigments of *C. auratus* in varied salinities

Day	0‰	1‰	2‰	3‰	4‰	5‰	6‰	7‰	8‰	9‰	10‰
1	G	G	G	G	G	G	LY	LY	LY	LY	LY
2	G	G	G	G	G	G	LY	LY	LY	LY	LY
3	G	G	G	G	G	G	LY	LY	LY	LY	LY
4	G	G	G	G	G	G	LY	LY	LY	LY	LY
5	G	G	G	G	Y	Y	LY	LY	LY	LY	LY
6	G	G	G	G	Y	Y	LY	LY	LY	D	D
7	G	G	G	G	Y	Y	LY	LY	LY	D	D
8	G	G	G	G	Y	Y	LY	LY	D	D	D
9	G	G	G	G	G	G	LY	D	D	D	D
10	G	G	G	G	G	G	LY	D	D	D	D
11	G	G	G	G	G	G	D	D	D	D	D
12	G	G	G	G	G	G	D	D	D	D	D
13	G	G	G	G	G	G	D	D	D	D	D
14	G	G	G	G	G	G	D	D	D	D	D

G: Golden/normal body colouration; Y: Light yellow; LY: Lacerated bodies with bleached yellow colouration; D: Death

DISCUSSION

A number of reports in the literature describing salinity characteristics in various fish species have shown that many fresh water teleosts grow poorly or die at salinity greater than 5‰, except for the catfish, which have been cultured in brackish water or a controlled environment between 11 and 13‰. Salinity tolerance of Comet goldfish, *C. auratus* was best exhibited by the juvenile at levels ranging between 0 and 5‰ while the adaptable salinities ranged between 0 and 3‰. However, salinity 0‰ was the most adapted and tolerated. 100% survival recorded between 0 and 3‰ salinities could be attributed to the ability of the fish to develop osmo-regulatory adaptations, which enabled the species to regulate osmotic pressure of its body fluid (Nikolsky, 1963). The 60 and 40% survival rates were observed in salinities 4 and 5‰ indicated that the fish was drifting away from their tolerance limit and the fish can still regulate their body fluid in order to restore the osmotic pressure to normal within these salinities. High mortality rate of 100% recorded in 6 to 10‰ was as a result of stress, which occurred due to the inability of the fish to maintain osmotic balance between the salt concentration of its body fluid and that of its environment (i.e. 6-10‰).

The salinity adaptation and tolerance may also be attributed to an increase in the thyroid tissue activity to produce thyroid hormone (Baggerman, 1957, 1960).

Appreciable increase in the total length and body weight between 0 and 5‰ was an indication that the fish can still tolerate and maintain growth within these environments. However, high percentage loss in growth within 6 and 10‰ showed the fish had moved away from their tolerance levels and there was a breakdown in the osmo-regulatory system of the fish.

The best growth rates (MGR = 39.196 g day^{-1} and SGR = 0.012 g day^{-1}) which were recorded in 0‰ showed it to be most adaptable salinity, this was in agreement with Matsui (1972) reported goldfish to be pure freshwater fish.

The erratic swimming behavior of the fish among the fish might probably due to the inability of the fish to cope with abrupt change in environmental condition occasioned by the sudden increase in salinity. Ability of the fish to maintain active swimming in salinities 0-10‰ indicates that their tolerance levels had not been exceeded.

Very high appetitive behavior of the fish between 0 and 3‰ is an indication that the fish were still within the tolerance limit. However, the high, moderate and low appetitive behavior showed that the fish were gradually drifting away from their limit and no sign of appetite displayed especially among fish in 9 and 10‰ suggested osmo-regulatory breakdown of the fish in these respective salinities.

Normal and moderate response of the fish to threat between 0 and 3‰ are indications that the fish were within the adaptable and tolerance limits. Weak response showed the fish had moved away for these limits and there was a breakdown of osmotic pressure within the fish (Olaniyan, 1975).

Maintenance of normal body gold color at levels between 0 and 3‰ showed that the fish were still able to maintain their body metabolism. The departure of the colour from the gold to light yellow in 4 and 5‰ indicates gradual breakdown of metabolic activities. The inability of the fish to carry out normal physiological activities between 6 and 10‰ culminated in the bleaching of the body pigments and laceration of the fish.

The major findings in this study is that Comet goldfish, *Carassius auratus* though a freshwater fish species has tendency to survive, adapt and tolerance to grow fast in a low brackish water environment of 1-5‰ salinities. This is finding is in support of Schofield et al (2006a, b) who stated in his study that the ability of the goldfish to withstand low levels of salinity indicates that it may be able to invade estuarine areas periodically, especially during periods of high rainfall. Therefore, the species may be capable of using estuarine regions to gain access to new river systems and expand its distribution. Although the goldfish is capable of survival at low ($\leq$10 ppt) salinities for an extended period of time, these conditions may be stressful to the fish. Published reports indicate that holding goldfish at low salinities causes changes in the distribution and density of mitochondria-rich (chloride) cells, evokes increases in blood cortisol, increases oxygen consumption by 54 to 64%, increases urea-N excretion and decreases specific growth rate and feed-conversion ratio. These sub-lethal effects may ultimately limit establishment of the species in brackish waters or marine environment.

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