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Full Length Research Paper

The effects of salinity on growth of goldfish, *Carassius auratus* and crucian carp, *Carassius carassius*

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The effects of four different salinities (SW, 50% SW, 100% SW and 150% SW) on specific growth rate, weight gain, food intake and survival of goldfish and crucian carp were investigated for 20 days. Both species were respectively adapted to water source, which has salinity of 8 ppt in the experimental unit for one month and then transferred to SW (8 ppt), 50% SW (12 ppt), 100% SW (16 ppt) and 150% SW (20 ppt) experimental treatments. Four goldfish fish and three crucian carp fish were placed in each aquarium. They were fed with commercial feed (Tetra Pond) to satiation twice a day and individually weighed at weekly interval. The final weight of the goldfish reared in the SW (938 ± 486 mg) and 50% SW (723 ± 269 mg) was significantly larger than that of fish reared in the 100% SW (475 ± 114 mg) and 150% SW (106 ± 318 mg). The specific growth rate was the highest in the SW (SGR: 0.53 ± 0.270% day-1) and the lowest in the 150% SW (SGR: 0.06 ± 0.195% day-1). Food intake was higher in the first three treatment groups (10.33 ± 0.572; 10.86 ± 0.917; 10.17 ± 0.767 g, respectively) than in the 150% SW (7.75 ± 1.612 g). Survival was not significantly different in the four salinity treatments (81.20 ± 23.94 ton 100.00 ± 0.00%). The final weight of the crucian carp breeding in the SW (860 ± 220 mg) and 50% SW (848 ± 394 mg) were significantly higher than the other two treatment groups. It was the worst in the 150% SW (-15 ± 903 mg). Specific growth rate was higher in the SW (SGR: 0.22 ± 0.040% day-1) and 50% SW (SGR: 0.30 ± 0.103% day-1) than the other two treatment groups. It was the lowest in the 150% SW (-0.06 ± 0.300% day-1). Food intake was higher in the first three treatment groups (8.70 ± 1.352; 7.25 ± 0.540; 7.06 ± 0.647 g, respectively) than in the 150% SW (5.60 ± 1.875 g). Survival was significantly influenced in the 150% SW (83.33 ± 19.24%). In conclusion, both species can be transferred to brackish water having not more than 8 ppt salinity. The maximum salinity tolerances of goldfish and crucian carp were 20 ppt. These findings are important in aquarium fish industry.

Key words: Goldfish, crucian carp, salinity, growth, survival.

INTRODUCTION

Growth is controlled by environmental factors such as temperature, photoperiod and salinity in fish (Fry, 1971). There are various studies on the effects of these factors on growth (Clarke et al., 1981; Wang et al., 1997; Swanson, 1998; Altinok and Grizzle, 2001; Imsland et al., 2001; Moustakas et al., 2004; Wuenschel et al., 2004; Engstrom-Ost et al., 2005; Resley et al., 2006; Imsland et al., 2008; Kangombe and Brown, 2008; Kearney et al., 2008; Luz et al., 2008; Overton et al., 2008; Arjona et al., 2009). Nowadays, it is known that salinity affects fish growth rate but how it influences it is not totally understood. There is an accepted hypothesis of how salinity affects energy budget in fish. If salinity is too high or too low in the external environment than fish body fluid (depending on fresh water or marine fish), fish spends more energy to regulate osmotic balance. Therefore, less energy remains for growth in these environments because of the use of too much energy for active ion transport. It is recently cited that fish uses roughly 10% of total energy for osmoregulation (Boeuf and Payan, 2001). Salinity affects fish hormonal activity as well. Four hormones (gonadothropin hormone, cortisol, insulin-like growth factor 1 and thyroid hormones) take a role in osmotic regulation (McCormick, 2001).Salinity is defined as the total concentrations of all ions in water. It is not just the concentration of sodium chloride in water.

Table 1. Some water quality parameters of water source.

Parameter	Value
EC (mmhos/cm)	842.2
Hardness (mg/l $CaCO_3$)	732.5
Alkalinity (mg/l $CaCO_3$)	600.0
Bicarbonat (mg/l)	348.9
Calcium (mg/l)	89.8
Magnesium (mg/l)	12.4
Ammonia (mg/l)	0.22
Nitrite (mg/l)	0.007

Several other ions contribute to salinity (such as calcium, magnesium, sodium, potassium, bicarbonate, chloride and sulfate). They vary in different waters. Salinity is generally reported in milligrams per liter (equivalent to parts per million, ppm) in freshwaters. Even it is recorded in grams per liter (equivalent to parts per thousand, ppt) in brackish and seawater (Boyd and Tucker, 1998).

Goldfish (*Carassius auratus*) is a freshwater fish in the family *Cyprinidae* of the order *Cypriniformes*. It is one of the earliest bred fish and the most commonly retained ornamental fish. Its origin is central Asia, China and Japan. Wildform of goldfish is the Prussian carp (*Carassius gibelio*). They have about 300 varieties in distinct size, body shape, fin and tail configuration and coloration.

Crucian carp (*Carassius carassius*) is found in the same genus. It lives in both fresh and brackish water. Several characteristics differentiate it from goldfish. Its snout is rounded while that of goldfish is pointed. Its color is shining golden-green.

The aim of this study was to assess the influence of salinity on growth performance of goldfish and crucian carp as stenohaline fresh water fish.

In this study, both fish were exposed to four salinity treatments (SW, 50% SW, 100% SW and 150% SW) for 20 days to evaluate weight gain, specific growth rate, food intake and survival of goldfish and crucian carp in each treatment.

MATERIALS AND METHODS

Goldfish (8.99 ± 0.93 g and 81.54 ± 4.18 mm) were provided commercially and crucian carp (14.31 ± 4.47 g and 106.94 ± 12.78 mm) were caughted from the Big Meandros River in Aydin, Turkey. Four different salinity treatments (SW, 50% SW, 100% SW and 150% SW) were tested for goldfish and crucian carp. There were four replicates for each salinity treatment. Water quality parameters of water source are given in Table 1. Laboratory condition was climatized for 24 h a day for arrangement of water temperature.

Animals were acclimated to laboratory conditions for about one month before the experiment started. The fish were not fed for 24 h before they were transferred to experimental aquarium. Goldfish (n = 64, 8.78 ± 0.76 g bw) and crucian carp (n = 64, 14.31 ± 4.47 g bw) were separately placed in the 5-L aquarium. Salinity was gradually raised by 2 ppt per day until desired salinity levels were reached. The osmolarity of each salinity treatment was measured by osmometer (Model 3250 Advenced Instruments, Inc). Water was changed every morning at the rate of 75% with water that had similar salinities, and aquariums were also cleaned at this time. They were fed *ad libitum* with feed (Tetra Pond) twice a day for 20 days in four different salinity conditions. All fish were individually weighed in each aquarium on days 0, 7, 14 and 21. Daily feed intake was determined for each replicate. Parameters of fish growth performance (specific growth rate, weight gain and food intake) and survival were calculated (Hargreaves and Kucuk, 2001; Kangombe and Brown, 2008):

Specific growth rate (SGR) (% day^{-1}) = $[(\log_e W_f - \log_e W_i) / \text{day}] \times 100$

Weight gain (WG) (g) = $W_f - W_i$

Food intake (FI) (g) = total feed consumption

Survival (S) (%) = $((N_f - N_i)/N_i) \times 100)$

Where, W_i and W_f are the initial and final mean body weights and N_f, N_i are the number of harvested and stocked fish. Differeces in mean values of SGR, WG, FI and S among four treatments were analyzed by SSPS (9.0) with p<0.05.

RESULTS

Water osmolarity, temperature and pH values in the SW, 50% SW, 100% SW and 150% SW for goldfish and crucian carp are given in Tables 2 and 3. Osmolality was significantly different among the four salinity treatments for each species. Water temperature and pH were constant among treatments for both species.

Goldfish growth performance is demonstrated in Table 4. Specific growth rates were 0.53, 0.34 and 0.27% day^{-1} in the salinities of SW, 50% SW and 100% SW, respectively. There were no significant differences among them. Fish growth was strongly influenced in the 150% SW as seen in SGR (0.06% day^{-1}) and WG (Figure 1). Weight gain was 938 ± 486 mg in the SW and reduced by 23, 34 and 78% in the 50% SW, 100% SW and 150% SW, respectively (723 ± 269; 475 ± 114; 105 ± 318 mg). Food intake showed identical results as SGR and WG. It was 10.33 ± 0.572, 10.86 ± 0.917, 10.17 ± 0.767 g in the SW, 50% SW, 100% SW, respectively. It significantly decreased by 21% in the 150% SW. Even though survival did not show any significant differences among salinity treatments, mortality was 6.25% in the 50% SW and 8.80% in the 150% SW. Fish in the 150% SW had less appetite and pale color. Therefore, they had some injuries on their bodies and mortality increased.

Growth performance of crucian carp is given in Table 4. Growth was affected by increasing salinity as seen in goldfish. Weight gain was high in the SW (860 ± 220 mg) and in the 50% SW (848 ± 394 mg). It decreased by 66% in the 100% SW and 105% in the 150% SW as seen in Figure 2. SGR was high in the first two treatments (0.22 and 0.30% day^{-1}) but, SGR was suprisingly influenced in

Table 2. Water osmolality, temperature and pH of goldfish in the four salinity treatments (mean±SD).

Parameter	Salinity			
	SW	50% SW	100% SW	150% SW
Osmolarity (mOsm/l)	24.75±0.96[a]	139.75±14.41[b]	273.75±4.57[c]	400.50±2.89[d]
Temperature (°C)	26.32±0.49[a]	26.67±0.61[a]	26.1±0.48[a]	26.27±0.51[a]
pH	7.92±0.16[a]	8.06±0.20[a]	8.05±0.18[a]	8.09±0.21[a]

Table 3. Water osmolality, temperature and pH of crucian carp in the four salinity treatments (mean±SD).

Parameter	Salinity			
	SW	50% SW	100% SW	150% SW
Osmolarity (mOsm/l)	24.50±1.00[a]	149.00±0.82[b]	275.75±1.26[c]	401.50±0.58[d]
Temperature (°C)	26.46±0.51[a]	26.62±0.57[a]	26.28±0.48[a]	26.30±0.49[a]
pH	8.00±0.21[a]	8.08±0.20[a]	8.07±0.18[a]	8.16±0.20[a]

Table 4. The effect of salinity on weight gain (WG), specific growth rate (SGR), food intake and survival of goldfish and crucian carp in the four salinity treatments (mean±SD).

Salinity	WG (mg)	SGR (% day^{-1})	Food intake (g)	Survival (%)
Goldfish				
SW	938±486[a]	0.53±0.270[a]	10.33±0.572[a]	100.00±00.00[a]
50% SW	723±269[a]	0.34±0.095[ab]	10.86±0.917[a]	93.75±12.50[a]
100% SW	475±114[ab]	0.27±0.074[ab]	10.17±0.767[a]	100.00±00.00[a]
150% SW	106±318[b]	0.06±0.195[b]	7.75±1.612[b]	81.25±23.94[a]
Crucian carp				
SW	860±220[a]	0.22±0.040[a]	8.70±1.352[a]	100.00±0.00[a]
50% SW	848±394[a]	0.30±0.103[a]	7.25±0.540[ab]	100.00±0.00[a]
100% SW	290±127[ab]	0.08±0.035[ab]	7.06±0.647[ab]	100.00±0.00[a]
150% SW	-15±903[b]	-0.06±0.300[b]	5.60±1.875[b]	83.33±19.24[b]

the 150% SW (0.06% day^{-1}). Survival was only affected in the 150% SW (83.33 ± 19.24%).

DISCUSSION

Aquaculturists are trying to find the optimum salinity conditions for each species so that fish production will increase and brackish water areas will be used more efficiently. Several studies indicate that oligohaline water (<5 ppt) for fresh water fish (Wang et al., 1997; Altinok and Grizzle, 2001; Fashina-Bombata and Busar, 2003; Luz et al., 2008; Kangombe and Brown, 2008; Overton et al., 2008) and isosmotic water (10 to 15 ppt) for marine fish (Imsland et al., 2001; Rubio et al., 2005; Resley et al., 2006; Arjona et al., 2008; Imsland et al., 2008) cause more rapid growth. In isosmotic water, food uptake and growth rate increases. Fish converts more feed to energy and uses less energy for standard metabolic rate, including osmoregulation. A lot of the remaining energy is saved for growth. Most of the studies have been conducted to estimate the effect of salinity on growth of food fish (Wang et al., 1997; Kangombe and Brown, 2008; Overton et al., 2008; Arjona et al., 2009; Imsland et al., 2001; Rubio et al., 2005; Resley et al., 2006; Arjona et al., 2008; Imsland et al., 2008). A few studies have been carried out on aquarium fish (Altınok and Grizzle, 2001; Luz et al., 2008). This study was carried on the goldfish, a commonly reared ornamental fish.

Fresh water fish generally grow well in both fresh water and low salinity environments. If salinity level increases more, growth rate starts declining. Luz et al. (2008) indicated that high growth rate was observed in goldfish adapted to 0 to 2 ppt at about 1.2% day^{-1}. Although, growth rate was low in 0.4% day^{-1} and 0.2 % day^{-1} at 8 and 10 ppt, respectively. Wang et al. (1997) found that SGR was high in common carp at 0 to 2.5 ppt. It began to decrease at ≥4.5 ppt. Overton et al. (2008) observed that

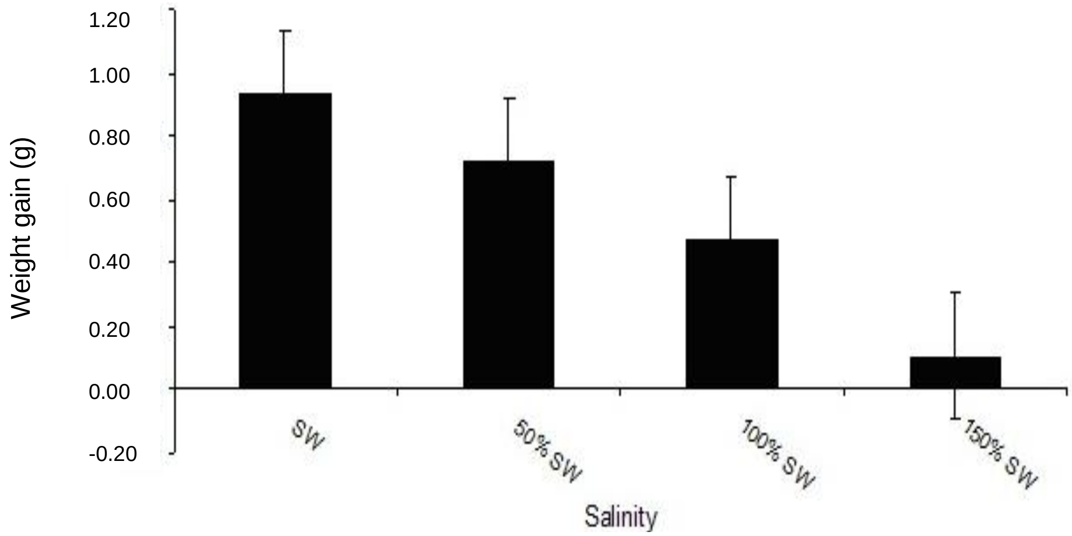

Figure 1. Weight gain (WG) of goldfish at four salinity treatments.

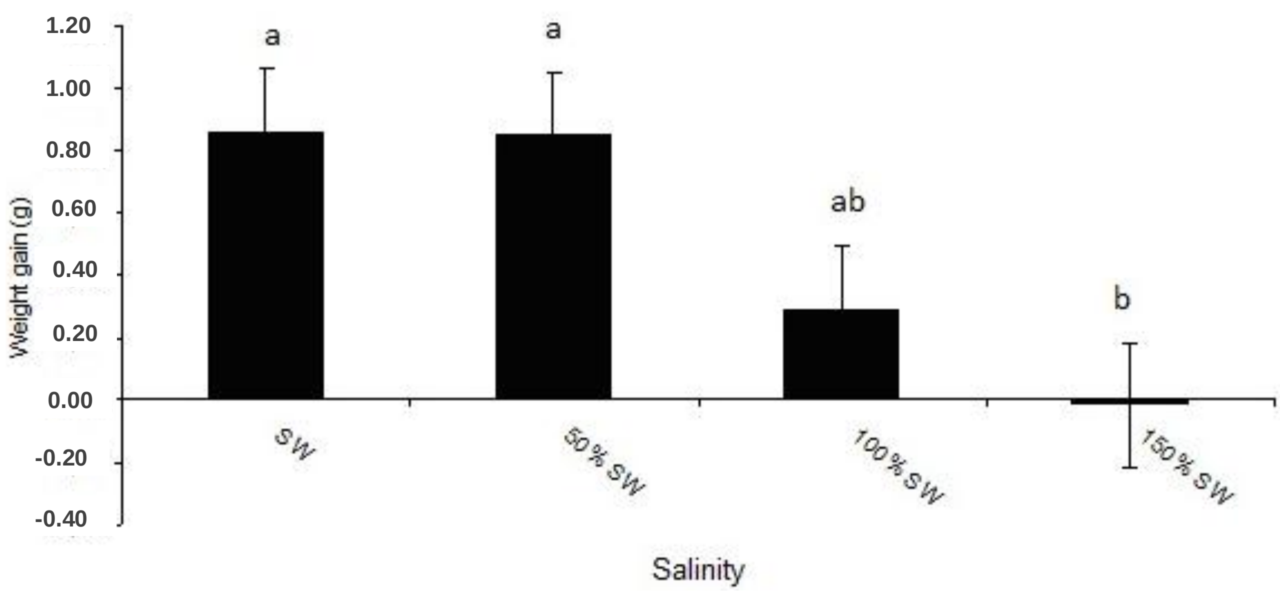

Figure 2. Weight gain (WG) of crucian carp at four salinity treatments.

Eurasian perch had higher growth rate at 0 to 8 ppt and it began to reduce at 10 ppt. Altinok and Grizzle (2001) indicated that ≥9 ppt of salinity negatively affected goldfish growth. In this study, growth of goldfish was higher (0.53 and 0.34% day^{-1}) in the SW (8 ppt) and 50% SW (12 ppt) when compared with fish reared in the 150% SW (20 ppt) (0.06% day^{-1}). Although, growth of crucian carp was not high enough (0.22% day^{-1}, 0.30 % day^{-1}) in the SW (8 ppt) and 50% SW (12 pp), it was too low in the 100% SW (16 ppt) (0.08% day^{-1}) and became negative in the 150% SW (20 ppt) (-0.06% day^{-1}). The water source used in this experiment is abundant for monovalent and divalent ions because of high alkalinity, hardness, bicarbonate and electrical conductivity values. Wurts (1998) showed that high calcium concentration makes fish to hold salt in their body in fresh water. Fish may have high salt in the blood and do not spend more energy to regulate osmotic balance. Thus, they may grow rapidly and tolerate high salinity (20 ppt).

High salinity is one of the stress-causing factors for both fresh water and marine fish. It affects fish in three dimensions. In the primary response, sympathetic nervous system is stimulated for release of catecholamines and plasma cortisol. In the secondary response, these hormones activate the release of glucose into the blood for energy production for heart rate, gill blood flow

Table 5. The optimum salinity and salinity tolerance of some fresh water fish.

Fish	Optimum ppt	Tolerance ppt	Reference
Goldfish	-	10	Du Jiayin (1986) cited in Wang et al. (1997)
	-	14	Pora (1939) cited in Ellory et al. (1973)
	1-3	-	Altinok and Grizzle (2001)
	-	5-10 (acute)	Schofield et al. (2006)
	-	10-15 (chronic)	
Black salty	-	15-20	Schofield et al.(2006)
Common carp	0.5-4.5	10.5	Wang et al. (1997)
	0.5-2.5	8.5	Du Jiayin (1986) cited in Wang et al.(1997)
Cutthroat trout	-	18-22	Wagner et al. (2001)
Rainbow trout	-	22	Eddy and Bath (1979)
	-	32	Gordon (1963)
Tilapia aureus	0-10	20-35	Nugon (2003)
Tilapia niloticus	0-10	20-35	Nugon (2003)
Tilapia mossambicus	-	56 (acclimated)	Uchida et al. (2000)
	17.5-20.0	27 (acute)	Assem et al. (1978) cited in Wang et al.(1997)
	-	42 (acclimated)	

and metabolic rate. In the tertiary response, those changes in blood physiology causes reduction in growth, survival and disease resistance. Wang et al. (1997) showed that food consumption rate decreased by increasing salinities in common carp. It began to reduce at salinity of 6.5 ppt. Even in marine fish, if salinity is too low (from 39 ppt to 15 ppt) in sole, it causes stress and fish decreases in feed intake and growth (Arjona et al., 2008). In this study, salinity increase resulted in reduction of food uptake. For goldfish, food intake was 10.17 to 10.86 g in the first three salinity treatments and it decreased to 7.75 g in the 150% SW (20 ppt). For crucian carp, it was 7.06 to 8.70 g in the first three treatments. It reduced by 5.6 g for fish adapted to 150% SW (20 ppt).

There is difference between fresh water fish and marine fish in prolonging the metabolism of their homoestasis in water (Boyd, 1990; Boyd and Tucker, 1998). Fresh water fish has more concentrated body fluids than the water they live. Their body fluids are called hypertonic as compared to fresh water. They deal with accumulation of water in their body and uptake of ions from water. Marine fish has more diluted body fluids than sea water. Their body fluids are called hypotonic as compared to sea water. They prevent water lose and accumulation of salt in their bodies. When fresh water fish is used to acclimatize salt water or marine fish is adapted to fresh water, fish consume a substantial energy for osmoregulation instead of more growth or they are unable to survive if salinity is higher than tolerant levels. Kangombe and Brown (2008) indicated that survival decreases with salinity in *Tilapia rendalli*. In this work, both species could tolerate salinity level from 8 to 20 ppt, but survival of both species decreased by 81.25 to 83.33% at 20 ppt (150% SW). Goldfish had necrotic injuries on the body. Crucian carp became too sensitive to any kind of noise during the experiment. It may be because of high salinity levels or its wildness. sodium, chloride, potassium, calcium, magnesium and bicarbonateions in water. Osmolarity increased by salinity rise in this experiment. The values found were 24, 139, 273, 400 mOsm/l in the SW (8 ppt), 50% SW (12 ppt), 100% SW (16 ppt) and 150% SW (20 ppt), respectively. Luz et al. (2008) also showed similar values of 3.33, 139.0, 250.3, 284.0 mOsm/l at 0, 4, 8, 10 ppt, respectively.

Recently, a new variety of goldfish has been developed (Schofield et al., 2006). It is called “black salty” and is used as live bait fish in brackish water and estuarine habitats. Although goldfish can tolerates 10 to 15 ppt, black salty can survive at 5 to 10 ppt for a long period of time and at high salinities (15 to 20 ppt) for a short period of time. Optimum and tolerance levels of salinity for some fresh water fish are given in Table 5. Even though, standard goldfish can tolerate 10 to 15 ppt salinity, this experiment showed that goldfish and crucian carp could survive in 20 ppt salinity. This may occur due to fish adaptation to SW (8 ppt) before the beginning of the experiment or enrichment of monovalent and divalent ions in water source.

In conlusion, the present findings demonstrate that environmental salinity affects the growth of goldfish, *Carassius auratus*, crucian carp and *Carassius carassius* for 30 days. Fish exposed to salinity higher than 8 ppt were slightly affected, but fish exposed to 20 ppt were strongly influenced. At 20 ppt of salinity, growth reduction may be explained by decrease in food intake-derived energy. The water used in this study is enriched with cations.

This may affect the experiment results in some ways. It is suggested that goldfish and crucian carp can be reared at salinities lower than 8 ppt and can tolerate 20 ppt salinity.

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