A SEMINAR PAPER ON

Impact of Salinity on Biological Performance of Some Selected Farmed Fishes in Bangladesh

Course Title: Seminar

Course Code: FBE 598

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Term: Summer'18

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Submission Date: 8th May 2018

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ON

Impact of Salinity on Biological Performance of Some Selected Farmed Fishes in Bangladesh[1]

By

Abu Bakar Siddique[2]

ABSTRACT

In the coastal areas, fishes those are available only in the freshwater are going to be endangered and may be extinct due to salinity intrusion though salinity brings some conveniences for shrimp cultivation. This seminar paper is to review the impact of salinity on biological performance of some selected farmed fishes (Climbing Perce, Silver barb, Rohu and Nile Tilapia) in Bangladesh. As this paper is a review paper so, all information are collected from secondary sources like various relevant books and journals and internet browsing. *Anabas testudineus* fingerlings can adapt to gradual increase of salinity. Normal growth was observed at salinity regimes of 0-6ppt. Specific growth rate (SGR) of *A. testudineus* decreased as the salinity increased. The highest SGR was recorded at 0ppt salinity and lowest SGR was recorded at 15ppt salinity. In case of Silver barb, the salinity tolerance limit was up to 10ppt and 100% mortality was observed at 16ppt with a median lethal concentration (LC_{50}) of 12.90ppt. Up to 12ppt Silver barb exhibited no significant abnormalities in behavior compared to the control 0ppt, whereas in 14 and 16 ppt, fish showed signs of agitated behaviors, respiratory distress and abnormal nervous behaviors with high mortality. Average daily weight gain (ADG) and SGR of *Labeo rohita* decreased as the salinity increased. The highest SGR was recorded at 0ppt salinity and lowest SGR was recorded at 8ppt salinity and maximum ADG was found at 2ppt salinity. *L. rohita exhibited* normal responses at 0 to 4ppt salinity levels. But at 12ppt salinity death was recorded from very first day and death all within 2 days. Feed conversion ratio (FCR) of Nile Tilapia increased with salinity increasing and the best FCR value was found at 2.08 ppt salinity. Due to higher salinity gill morphology of Nile Tilapia was affected.

Keywords: Salinity intrusion, Climbing Perce, Silver barb, Rohu, Nile Tilapia, Specific growth rate (SGR), Average daily weight gain (ADG), Feed conversion ratio (FCR).

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CHAPTER 1

INTRODUCTION

Bangladesh is the land of river, approximately contains about 700 rivers, and is blessed with an extensive biodiversity of fish and fisheries resources. Once the people of the country familiar as "Machhe Bhaate Bangali", the 'fish and rice' loving people as it is the land of an abundant and extraordinary combination of fish resource. With the touch of modernization and many other natural and human interferes the fisheries resources of Bangladesh have lost its abundance and many fish species became vulnerable or endangered. Salinity intrusion is a growing problem in the coastal areas everywhere the globe and Bangladesh is the one of the worst victim. This problem has become a great threat to the fish and fisheries resource of Bangladesh. The problem turns into aggravated especially in the dry season when rainfall is inadequate and incapable of lowering the concentration of salinity on surface water and leaching out salt from soil. Climate change associated hazards like sea level rise, cyclone and storm surge have been causative to the problem in many fold. Bangladesh, a low-lying deltaic land, is predominantly vulnerable to sea level rise and its associated hazards. Any increase in sea level may intrude much longer distance in inland as the geography of the coastal zone in Bangladesh is relatively low-lying (Karim and Maimura 2008).

A considerable area of coastal land in Bangladesh has already eroded. SAARC Meteorological Research Council (SMRC) found that the trend of sea level rise in Hiron point, Char Ganga and Cox's Bazar, three tidal stations of Bangladesh, is 4.0mm/year, 6.0mm/year and 7.8mm/year correspondingly (Rahman and Alam 2003). GW (2004) reported that the rise in the sea level is not indistinguishable in every geographical location. The rise may be estimated a little more in some regions than to others depending on some factors and these are not limited to some climate independent factors like land subsiding and climate dependent factors like thermal extension. However, the climate reliant on factor seems to be more influential.

Therefore, the impact of sea level rise also varies depending on geographic location as well as socio-economic factors like population thickness, living option, poor infrastructure, insufficient policy and incompetent technology. Apart from land erosion, sea level rise is likely to put gravest threat by land desertification through salinity intrusion. Irrigated water claim is extremely affected by salinity interruption in surface water (Shahid 2011) and salt buildup in the root zone of soil affects plant growth in coastal soil (Yadav et al. 2009). Besides compelling agricultural production, salinity bounds the freshwater accessibility for drinking purpose and fish production.

Salt water is heavier than freshwater when the two are at same temperatures. Mixing procedures of saltwater and freshwater are so complex; nor are they consistent and circulation is the primary mechanism responsible for estuarine mixing (Figure 1.1), but at minimum four (tides, winds, waves, and river runoff) other forces affect the process. Tides, winds, waves, and freshwater invasion all factors influence the mixing process, but they vary and differ in their effects from season to season, even day to day.

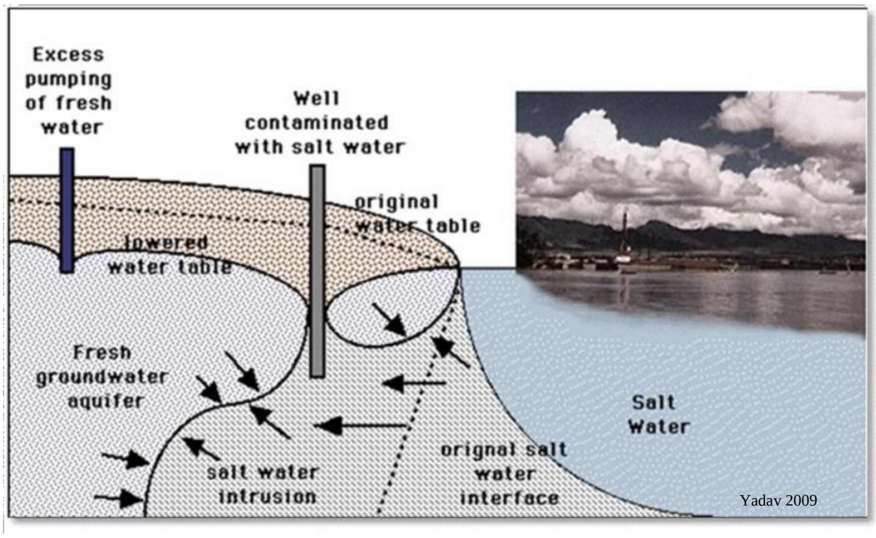

Figure 1.1 Sources of salinity intrusion in coastal areas.

(Source: Yadav et al. 2009)

Different kinds of climate change induced factors as well as anthropogenic factors influence the salinity intrusion in freshwater of coastal areas of Bangladesh.

The major factors affecting salinity intrusion are: Anthropogenic factors of salinity intrusion; Low flow condition of river by barrage in upstream neighboring country, Salinity intrusion due to faulty management of coastal polders. Climate change induced factors; Sea level rise, Cyclone and storm surge, Back water effect, Precipitation etc.

In the coastal areas, fishes those are available only in the freshwater are going to be endangered and may be extinct due to salinity intrusion though salinity brings some conveniences for shrimp cultivation. The salinity intrusion problem becomes exacerbated particularly in the dry season when rainfall is inadequate and incapable of lowering the concentration of salinity on surface water and leaching out salt from soil. Coastal agriculture experiences a yield reduction or in some cases devastation due to tidal inundation and salinity. Climate change associated hazards like sea level rise, cyclone and storm surge have been contributing to aggravate the problem. Salinity of soil is increasing day by day by natural occurrences as well as Anthropogenic factors (SRDI 2009).

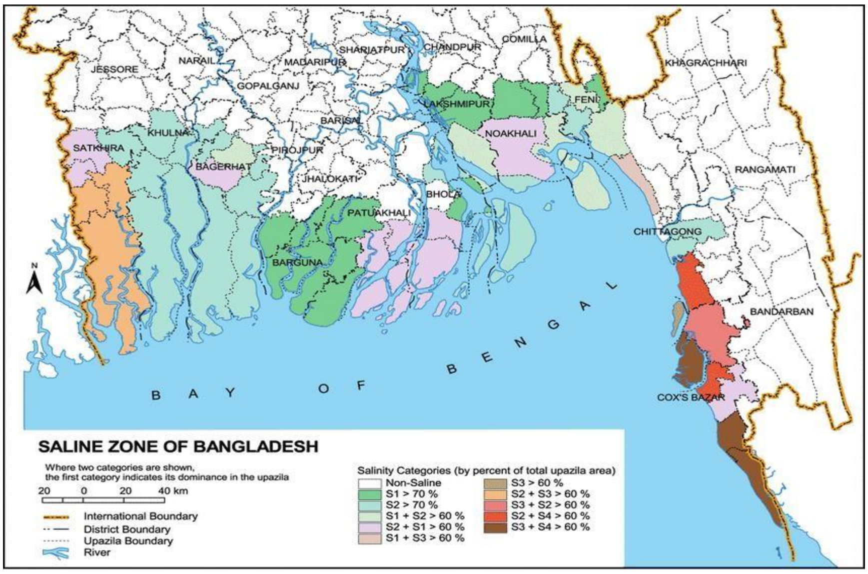

Figure 1.2 Soil salinity map of Bangladesh.

(Source: SRDI 2009)

Fish responses to stress are controlled by Hypothalamus-Pituitary-Adrenal (HPA) axis. The hypothalamus releases a hormone called corticotrophin releasing factor, or CRF. CRF travels through a localized blood circulation circuit to the pituitary, which hangs down right at the base of the brain. The pituitary releases a secondary hormone called adrenocorticotropic hormone, or ACTH. ACTH has two actions, primarily on the adrenal/inter-renal tissues. Initially, within seconds, specialized cells in the adrenal release a third hormone called epinephrine (formally known as adrenalin) in response to ACTH.

In this seminar paper to review the impact of salinity on biological performance of some selected farmed fishes in Bangladesh. These fishes are Climbing Perce (*Anabas testudineus*), Silver Barb (*Barbonymus gonionotus*), Rohu (*Labeo rohita*), and Nile Tilapia (*Oreochromis niloticus*). The impact of salinity on those fishes are described in review and findings.

1.1 Objective

To review the impact of salinity on biological performance of some selected farmed fishes in Bangladesh which are Climbing perch (*Anabas testudineus*), Silver barb (*Barbonymus gonionotus*), Rohu (*Labeo rohita*), and Nile Tilapia (*Oreochromis niloticus*).

CHAPTER 2

MATERIALS AND METHODS

This seminar paper is completely a review paper. Therefore, all the information were collected from secondary sources such as various relevant books and journals, which were available in the library of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU). For collecting recent information, internet browsing was also be practiced. Valuable suggestion & information were taken from my honorable major professor, course instructors and other resources personnel to enrich this paper. After collecting necessary information, it has compiled and arranged chronologically for better understanding and amplification.

CHAPTER 3

REVIEW OF FINDINGS

This chapter is the gathering of information of some past conducted researches which are relevant to this study. As salinity intrusion in freshwater due to climate change, is a great thought of the time; researchers around the world thinking about it and conducting innovative studies to visualize the further probable impacts of salinity intrusion on freshwater species including fish and adaptation measures to cope with it. The related research findings are discussed in brief in this section to make a connection or analyze comparisons between past studies and the present research.

3.1 Impact of Salinity on Climbing Perch

3.1.1 Effects of salinity on the survival rate of Climbing Perch.

Dubey *et al.* (2014) observed the 96h median lethal salinity (MLS_{96} h) level of *Amblypharyngodon mola* and *Pethia ticto* after exposing to saline water (0-10ppt) in direct transfer method. The 96-h median lethal salinity for *A. mola* was found to be 6.20ppt whereas for *P. ticto* it was 6.12ppt. Faizul and Christimus (2013) conducted a study on salinity tolerance of (*Anabas testudineus*) and noticed that fry can tolerate salinity up to 10ppt. Bianco and Nordlie (2008) observed that the upper salinity tolerance limit of the major primary cyprinids fish (*A. testudineus*) was 11ppt.

According to Nahar, F. (2015) *A. testudineus* fingerlings showed 100% survival rate between 0 to 9ppt salinities, 60% survival rate in 12ppt salinities, 20% survival rate in 15ppt salinities and all death (100% mortality) in 18 and 21ppt salinities (Figure 3.1).

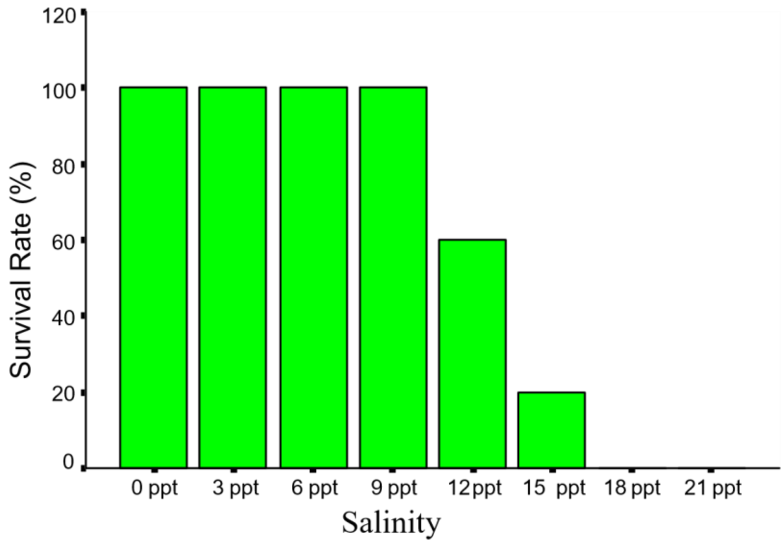

Figure 3.1 Survival rate of *A. testudineus* in different salinities.
(Source: Nahar, F. 2015)

During 60 day rearing period all fingerlings survived in 0 to 9ppt salinities. In 12ppt salinity survival rate was 85% at 15 days rearing period and then decreased up to 60% at 60 days rearing period. At 15ppt salinity survival rate was 75% at 15 days rearing period and then decreased up to 20% at 60 days rearing period. At 18ppt salinity survival rate was 100% up to 2 days and then dropped into 20% at 3rd day and 0% (100% mortality) at 4th day. In 21 ppt salinity 100% survival was recorded at 1st day but 0% (100% mortality) at next day (Table 3.1).

Table 3.1 Fortnightly survival rate (%) of *A. testudineus* fingerlings at different salinity (ppt) level in 60 day rearing period. Individual letters denote significantly different

Salinity	Survival Rate (%)			
(ppt)	15 day	30 day	45 day	60 day
0	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}
3	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}
6	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}
9	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}
12	85.0 ± 5.0^{ab}	80.0 ± 0.0^{bc}	67.5 ± 2.5^{bcd}	60.0 ± 10.0^{cde}
15	75.0 ± 5.0^{bcd}	55.0 ± 5.0^{de}	40.0 ± 10.0^{ef}	20.0 ± 5.0^{f}

(Source: Nahar, F. 2015)

3.1.2 Effects of Salinity on the Specific Growth Rate of Climbing Perch.

Specific growth rate (SGR) decreased as the salinity increased. The highest SGR was recorded at 0ppt salinity and lowest SGR was recorded at 15ppt salinity (Figure 3.2).

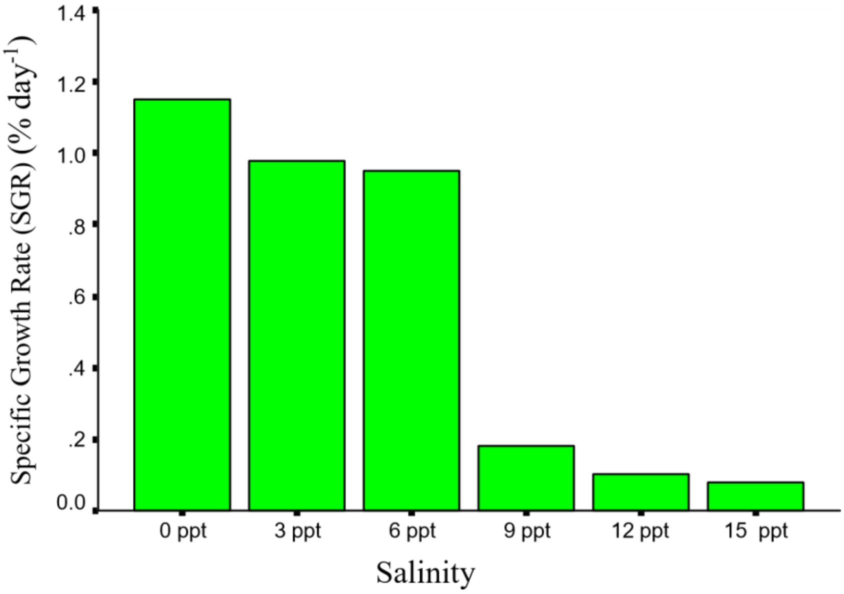

Figure 3.2 Specific growth rate (SGR) of *A. testudineus* at different salinities.

(Source: Nahar, F. 2015)

There was higher SGR was found in *A. testudineus* fingerlings reared at 0ppt salinity at 60 day (1.16 ± 0.05^{a}) than that of other days while similar SGR was observed at the same salinity at 15, 30 and 45 day rearing period which was significant. Moreover, Significantly higher SGR was observed in *A. testudineus* fingerlings reared at 3ppt and 6ppt salinity at 60 day than that of other days while similar SGR was found at the respective salinity at 15, 30 and 45 day rearing period. Besides, significantly lower SGR was detected in *A. testudineus* fingerlings reared at 9ppt salinity at 15 and 30 day (0.17 ± 0.01^{cd}) than that of other days while similar SGR was observed at the same salinity at 45 and 60 day rearing period. Significantly lower SGR was detected in *A. testudineus* fingerlings reared at 12ppt salinity at 30 and 45 day (0.08 ± 0.01^{cd}) than that of other days while similar SGR was found at the same salinity at 15 and 60 day rearing period. Similarly significantly lower SGR was detected in *A. testudineus* fingerlings reared at 15ppt salinity at 30 day (0.07 ± 0.03^{d}) than that of other days while similar SGR was observed at the same salinity at 15, 45 and 60 day rearing period (Table 3.2).

Table 3.2 Fortnightly Specific growth rate (SGR) of *A. testudineus* fingerlings at 60 day rearing period. Individual letters denote significantly different

Salinity (ppt)	Specific Growth Rate (SGR) (% day^{-1})			
	15 day	30 day	45 day	60 day
0	1.14 ± 0.02^{a}	1.14 ± 0.02^{a}	1.14 ± 0.05^{a}	1.16 ± 0.05^{a}
3	0.97 ± 0.01^{b}	0.99 ± 0.01^{b}	0.96 ± 0.02^{b}	0.99 ± 0.00^{b}
6	0.96 ± 0.02^{b}	0.94 ± 0.03^{b}	0.93 ± 0.01^{b}	0.96 ± 0.01^{b}
9	0.17 ± 0.01^{cd}	0.17 ± 0.01^{cd}	0.18 ± 0.01^{c}	0.18 ± 0.01^{c}
12	0.12 ± 0.01^{cd}	0.08 ± 0.01^{cd}	0.08 ± 0.01^{d}	0.11 ± 0.01^{cd}
15	0.07 ± 0.01^{d}	0.07 ± 0.03^{d}	0.08 ± 0.00^{d}	0.09 ± 0.00^{cd}

(Source: Nahar, F. 2014)

3.2 Impact of Salinity on Silver Barb (*Barbonymus gonionotus)*

3.2.1 Effect of Salinity on Behavioral Stress Responses in Silver Barb

Aysel and Ayhan (2010) observed various behavioral anomalies in Nile tilapia, *Oreochromis niloticus* when exposed to the saline water. Behavioral stress responses of fish such as opercula activity, convulsions, equilibrium status, hyperactivity, swimming etc. were observed. According to Evans (2010) a longer exposure time to the salinity gradient could result in different behavioral responses like *Barbonymus gonionotus* modified their physiology.

McCormick (2009) observed that saltwater adaptation in salmonids generally occurs prior to saltwater exposure when endogenous hormones mediate rapid morphological, physiological and behavioral changes. Soares *et al.* (2006) stated that the progressive decrease in the opercular frequency led to swimming close to the water surface in order to increase the oxygen intake in the water surface. Magil and Sayes (2004) reported that the ability of fish to tolerate or show behavioral adaptation to such conditions is essential as the physiological challenge presented by fluctuating salinities may compromise survival and fitness of the inhabiting individuals. Tanck *et al.* (2000) observed that stress disturbs the fine internal balance, homeostasis, and has further detrimental effects on behavior, growth, reproduction, immune function and disease tolerance.

Effects of sub-lethal and lethal concentrations of salinity on behavioral stress responses on silver barb were observed Amin F. B. et al. (2014). The fish exhibited a normal behavioral activity without mortality when exposed to 0ppt (control). At sub-lethal concentration of salinity (12ppt) a low stress responses were noticed like aggression, stunned posture, erratic swimming etc. Stress responses like impatience or agitated activeness or erratic movement observed at lethal concentrations (14ppt and 16ppt) (Table 3.3-3.5). At the beginning of experiment (up to 3 hours) the fish showed frequent movement from surface to bottom, then aggression and sometime showed jumping activity at the lethal concentrations of salinity.

Table 3.3 Agitated behaviors after exposure 72h on different salinity

Clinical signs	**Salinity (ppt)**			
	0	**12**	**14**	**16**
Aggression	0	1	1	5
Jumping	0	0	3	5
Stunned posture	0	2	3	3
FSBM	0	0	2	4
Erratic swimming	0	1	3	3

Frequent surface to bottom movements (FSBM); none (0), very weak (1), weak (2), moderate (3), strong (4), very strong (5). (Source: Amin F. B. 2014)

Table 3.4 Respiratory distress after exposure 72h on different salinity

Clinical signs	**Salinity (ppt)**			
	0	**12**	**14**	**16**
Opercula movement	0	0	2	4
Air gulping	0	0	4	5
VPES	0	0	3	5
EMS	0	0	3	5

Vertical posture with exposed snouts (VPES), excessive mucus secretion (EMS), none (0), very weak (1), weak (2), moderate (3), strong (4),very strong (5). (Source: Amin F. B. 2014)

Table 3.5 Abnormal nervous behavior after exposure 72h on different salinity

Clinical signs	Salinity (ppt)			
	0	**12**	**14**	**16**
SSM	0	1	2	4
State of motionless	0	2	4	4
Sudden darts	0	0	3	5
DP	0	0	4	3
Death	0	0	3	5

Sluggish and swirling movements (SSM), Different postures (DP), none (0), very weak (1), weak(2), moderate (3), strong (4), very strong (5). (Source: Amin F. B. 2014)

3.2.2 Effects of Salinity on Blood Glucose

Fazio *et al.* (2013) studied the effects of salinity levels on hematological and biochemical parameters of the widely cultured silver barb, *Barbonymus gonionotus*. Semra *et al.* (2013) found that in Tilapia (*Oreochromis aureus*) plasma sodium chloride increased in parallel with salinity rise. Glucose and potassium were not altered significantly. Muscle water content decreased when salinity concentration was elevated.

The silver barb selected for the present study showed variations in the blood glucose level when exposed to 6.5ppt and 9.68ppt, at different time intervals. The glucose levels at both treatments were found to be increased within an hour and highest about from 6-12h. Then glucose level gradually decreased and got back to its original states within 24h (Figure 3.3).

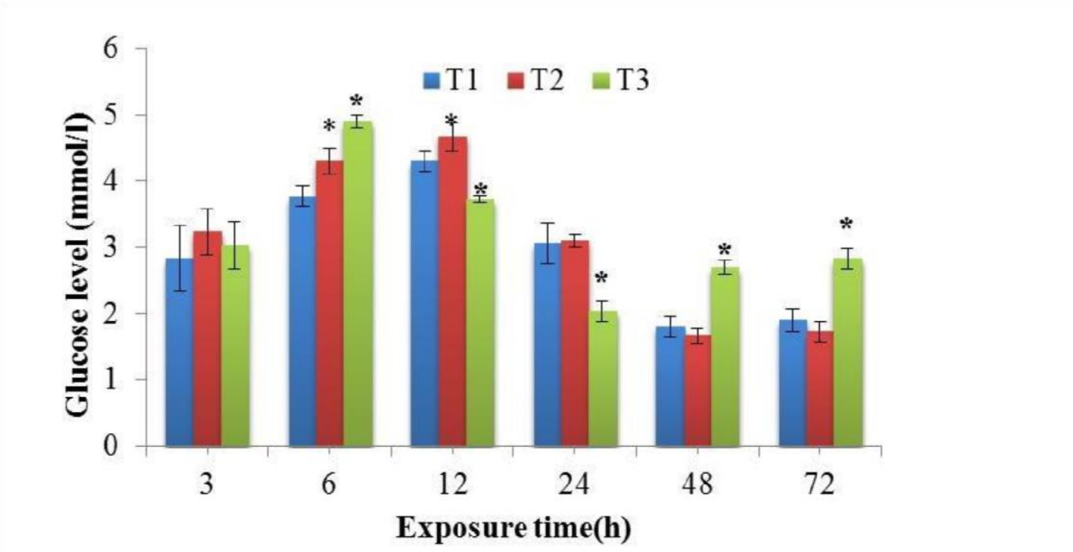

Figure 3.3 Effects of salinity on blood glucose levels at different time intervals in silver barb. Asterisk (*) indicates significant difference at $P<0.05$ (T1= control, T2=6.45, T3=9.68).
(Source: Stosik et al. 2001)

3.2.3 Effects of salinity on red blood cell (RBC)

Gabriel *et al.* (2011) investigated the effects of acclimation to captivity on blood composition of Nile tilapia *O. niloticus & B. gonionotus*. Results from this study therefore suggest that sex and size have some degree of influence on the blood characteristics of *B. gonionotus*. Anyanwu *et al.* (2007) conducted an experiment to study on the effect of changes in salinity on *Sarotherodon melanotheron* and observed that the WBC and THMB decrease which may indicates a weakened defense (immunosuppression) and also noticed a delay clotting in the event of an injury to the fish.

Red blood cells, or erythrocyte, are the most important compound among all blood cells which act as the carrier of the oxygen through which oxygen reach different body tissues via blood in vertebrates. Figure 3.4 shows the mean values of the red blood cell (RBCs) count recorded from exposing silver barb to different sub-lethal concentrations of salinity for a period of 72h. The results showed that up to 24h exposures, the number of RBC (cells x $10^6/mm^3$) undergone a significant decrease ($P<0.05$) in both treatments compared to control. However, fish exposed to longer period for 72h at 6.45ppt, had almost similar number of RBC as found in the control.

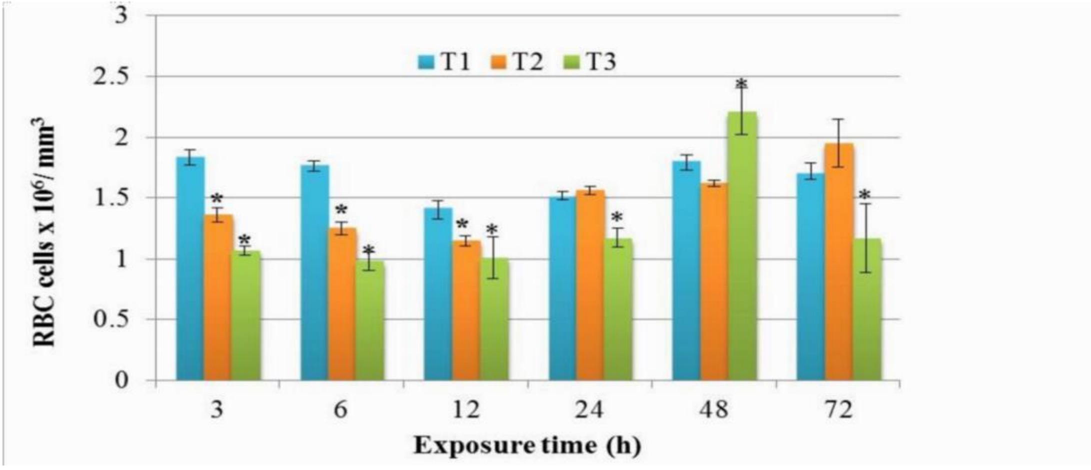

Figure 3.4 Effects of sub-lethal exposure of salinity on blood RBC levels at different time intervals in silver barb. Asterisk (*****) indicates significant difference at P<0.05. (T1= control, T2=6.45ppt and T3=9.65ppt). (Source: Stosik et al. 2001)

3.2.4 Effects of salinity on white blood cell (WBC)

Stosik *et al.* (2001) observed salinity increase up to 45ppt showed a significant reduction in the number of WBC and THMB of sick as blood WBC are the major cell components involved in immune responses and fish THMB also participate in defense mechanisms by means of their phagocytic ability.

WBC of the blood acts as defensive element against the external and unwanted intrusive element. Results of white blood cell (WBCs) count (cell x 10^4/mm^3) in blood of silver barb which exposed to different sub-lethal concentrations of salinity for a period of 72h are shown in Figure 3.5. There were gradual significant elevations (P<0.05) of number of WBC in both treatments as compared with the control.

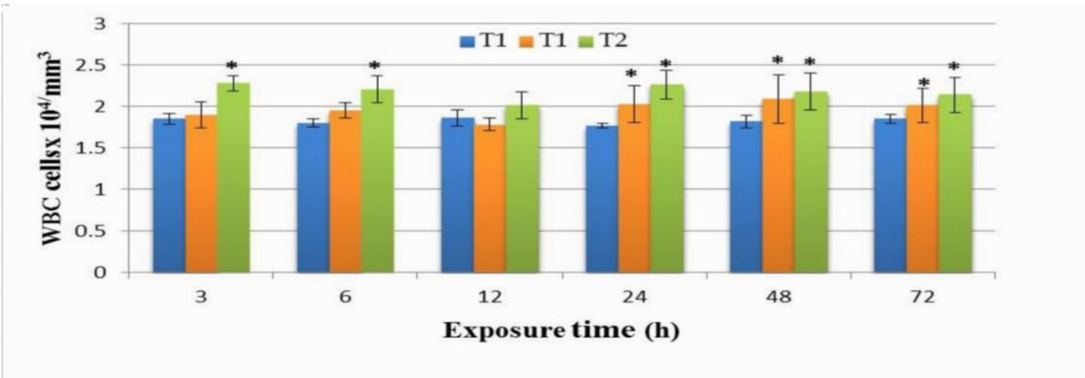

Figure 3.5 Effects of sub-lethal exposure of salinity on WBC levels at different time intervals in silver barb. Asterisk (*****) indicates significantly different at P<0.05. (T1= control, T2=6.45ppt and T3=9.65ppt). (Source: Stosik et al. 2001)

3.2.5 Morphological Changes of Gill Due to Salinity

Uliano *et al.* (2010) studied acute effects of different salinities on routine metabolism, spontaneous activity and excretion of ammonia and urea studied in two freshwater fish: gambusia, *Gambusia affinis* and zebrafish, *Danio rerio*, acclimated to 27°C. Imsland *et al.* (2008) determined that the fish homeostatic system is continuously affected by the changes of the level of salinity, temperature, pH, oxygen concentration as well as anthropogenic substances in the surrounding water. Augley (2008) found that mean weight of *Pleuronectes platessa* decreased at all three (25, 30 and 35ppt) salinities and significant differences in mean weight change were found between the highest and lowest salinities, fish at the lowest salinity showed slow weight loss than fish kept at either of the higher salinities.

Evans *et al.* (2005) observed salinity stress in freshwater fish affects primarily gills, as the major organ involved both in osmoregulation and waste nitrogen excretion. In this experiment the morphological changes in gill of salinity treated fish were observed. As gill lamellae are the primary receptor of water as well as the ionic movement in water, it will be affected by any change in osmotic balance. In the present study at sub-lethal concentration of 12ppt (T2), no significant change of gill morphology was observed except an appearance of ruptured lamellae with slight slime secretion. But in the lethal concentration of 14ppt (T3), significant changes were observed compared to the fish in control (T1) such as ruptured and broken lamellae, curved and broken gill filament etc. (Figure 3.6 and 3.7).

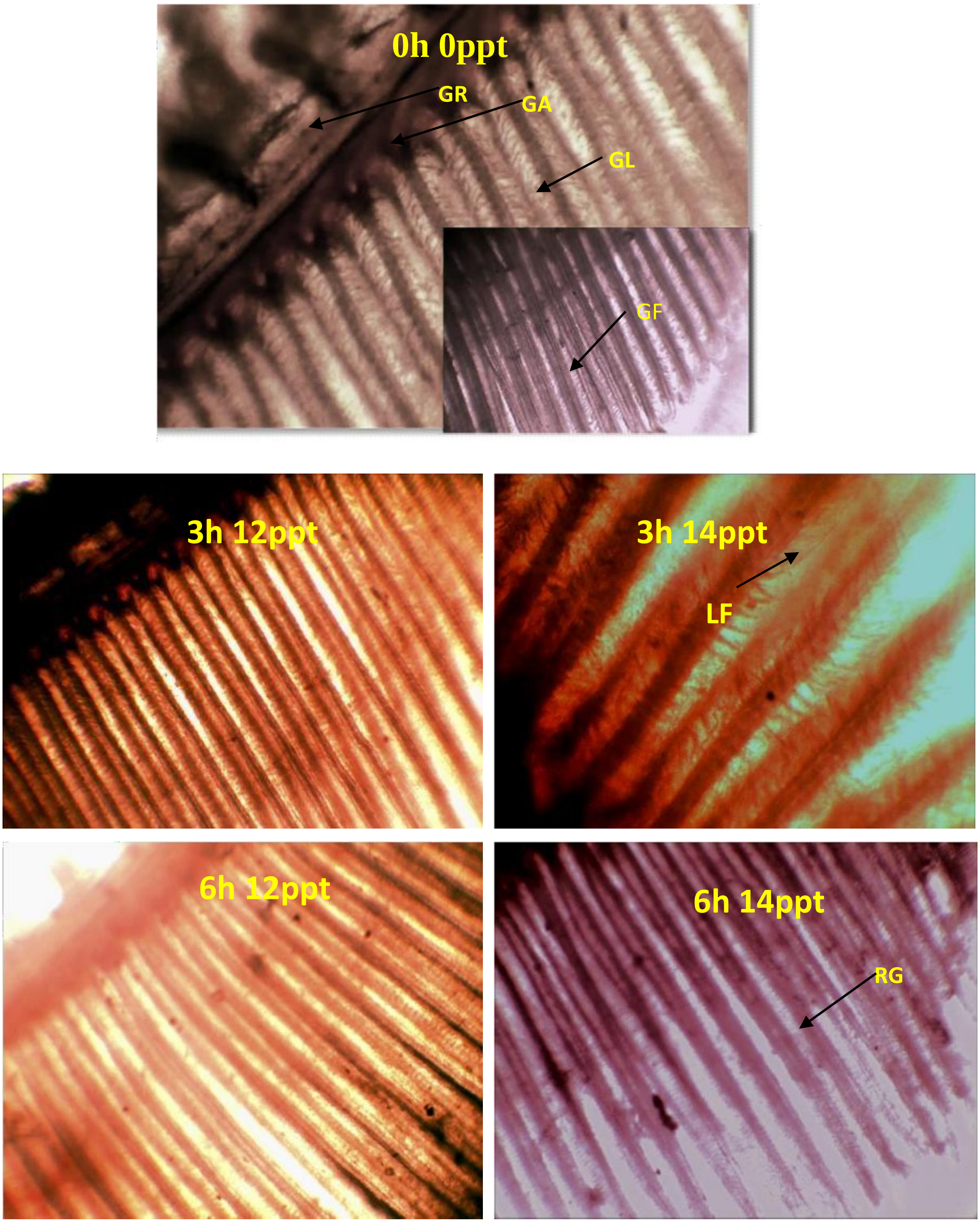

Figure 3.6 Microscopic view of gill morphology at different salinity levels at different time intervals (0, 3 and 6h); Arrows are indicating gill lamellae (GL), gill raker (GR), gill arch (GA), gill filament (GF) and, ruptured gill (RG), lamellar fusion (LF).

(Source: Evans et al. 2005)

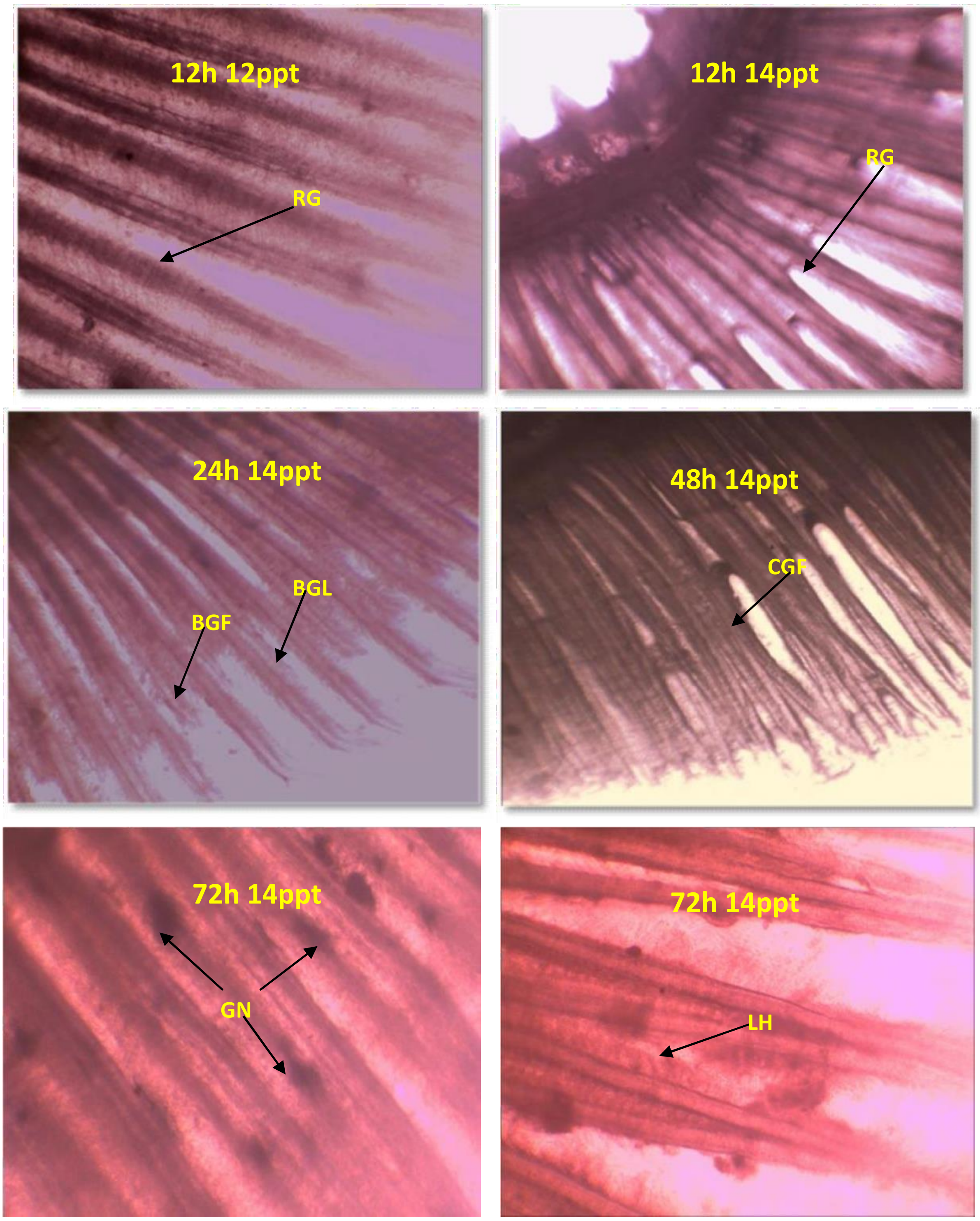

Figure 3.7 Microscopic view of gill morphology at different salinity levels at different time intervals (12, 24, 48 and 72h); Arrows are indicating broken gill lamellae (BGL), broken gill filament (BGF), curved gill filament (CGF), gill necrosis (GN), lamellar hyperplasia (LH).

(Source: Evans et al. 2005)

3.3 Impact of Salinity on Rohu Fish

3.3.1 Effects of salinity on specific growth rate and average daily gain

Islam et al. (2014), also recorded significant difference in *Labeo rohita* and *Cirrhinus mrigala* in tolerance of salinity and found *L. rohita* (Rohu) more tolerant towards salinity up to 7ppt which supports the present findings. Specific growth rate (SGR) (% day^{-1}) decreased as the salinity increased. The highest SGR was recorded at 0ppt salinity and lowest SGR was recorded at 8ppt salinity (Figure 3.9). The average daily gain (ADG) of *L. rohita* was similarly decreased like SGR as the salinity increased. Maximum ADG was found at 2ppt salinity and then it was decreased (Figure 3.10).

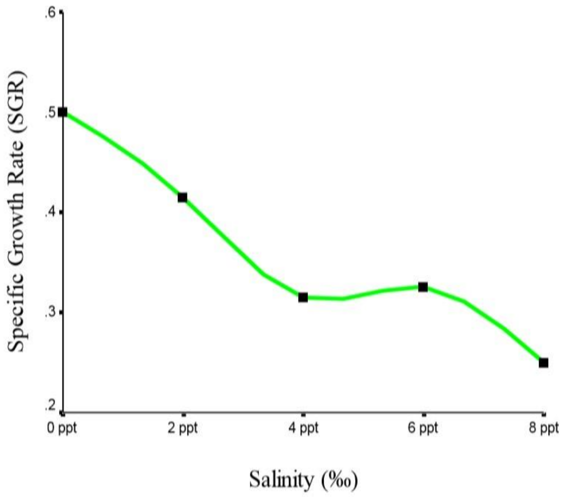

Figure 3.8 Specific growth rate (SGR) of *L. rohita* in different salinities.
(Source: Islam et al. 2014)

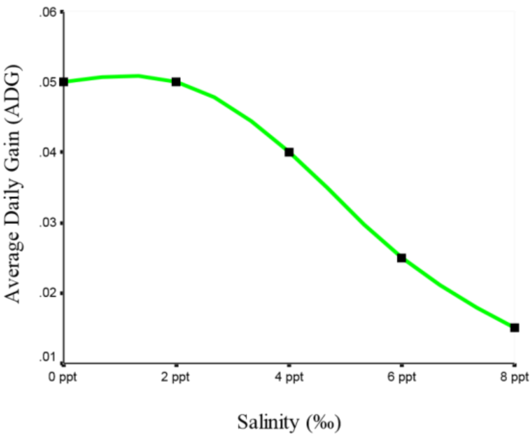

Figure 3.9 Average daily gain (ADG) of *L. rohita* in different salinities.
(Source: Islam et al. 2014)

3.3.2 Effect of salinity on threat response of Rohu

Aysel and Ayhan (2010) observed various behavioral anomalies (threat response, feeding response, swimming etc.) in *Oreochromis niloticus & L. rohita* when exposed to the saline water. The fish exhibited a normal response to treat between 0 to 4ppt salinity levels (Table 6). At 8ppt salinity first 15 days showed moderate response and next 15 days showed hyper activeness. At 12ppt salinity death was recorded from very first day and all death within 2 days.

Table 3.6 Threat response of *L. rohita* in different salinity regimes at different duration

Day	Salinity concentration (ppt)			
	0	**4**	**8**	**12**
01	N	N	M	D
03	N	N	M	D
06	N	N	M	D
09	N	N	M	D
12	N	N	M	D
15	N	N	M	D
18	N	N	H	D
21	N	N	H	D
24	N	N	H	D
27	N	N	H	D
30	N	N	D	D

N= Normal Response, M= Moderate Response, H= Hyperactive, D= Death

(Source: Aysel et al. 2010)

3.3.3 Effect of salinity on feeding response of Rohu

Fish showed very high appetitive behavior to food between 0 to 4ppt salinities (Table 7). Different level of response to feeding, very high appetite, moderate appetite, low appetite and death were displayed between 6 to 12ppt salinity levels.

Table 3.7 Summary of daily feeding response of *L. rohita* in different salinity regimes at different duration

Day	Salinity concentration in (ppt)			
	0	4	8	12
01	VHA	VHA	HA	LA
03	VHA	VHA	HA	D
06	VHA	VHA	HA	D
09	VHA	VHA	HA	D
12	VHA	VHA	HA	D
15	VHA	VHA	MA	D
18	VHA	VHA	MA	D
21	VHA	VHA	MA	D
24	VHA	VHA	MA	D
27	VHA	VHA	MA	D
30	VHA	VHA	MA	D

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

(Source: Aysel et al. 2010)

3.4 Impact of Salinity on Nile Tilapia

Akinrotimi *et al.* (2011) studied the effects of different salinity levels on some blood parameters of *Tilapia guineensis*. Adult and juvenile sizes were sampled from the wild of salinity 15ppt and transferred to the laboratory where they were exposed to different salinities level of 15ppt, 10, 5 and 0ppt for a period of 7 days. Lawson and Anetekhai (2011) studied salinity tolerance on both hatchery reared and natural Nile Tilapia, *Oreochromis niloticus* species and observed that both the fish species did not show any remarkable stressful sign up to 4ppt indicated that fish remain unaffected physiologically up to 4-5ppt. However, hyper-activity, jumping, frequent surface bottom movements, erratic swimming noted after exposing in higher salinity indicated that the fish were approaching their tolerance limit.

Semra *et al.* (2013) found that in Tilapia (*Oreochromis aureus*) plasma sodium chloride increased in parallel with salinity rise. Glucose and potassium were not altered significantly.

Muscle water content decreased when salinity concentration was elevated. Akinrotimi *et al.* (2016) studied the effects of different salinity levels on some blood parameters of *Tilapia guineensis*.

3.4.1 Effect of Salinity on Feed Conversion Ratio of Nile Tilapia

Sardella *et al.* (2004) conducted an experiment that specifically evaluated the tolerance of hybrid tilapia (*O. mossambicus* , *O. urolepis hornorum*) to hypersaline water found that the primary morphologic indicators of hypersaline stress, and the most sensitive of several endpoints tested, were ultra-structural changes in the gills. Weng *et al.* (2002) observed the effects of changes in salinity on Tilapia (*O. mossambicus*) and found that acclimation of fish from freshwater to sweater directly causes severe dehydration. Water salinity levels had significant effect on the daily weight gain, feed conversion rate (P = 0.0072) and survival of Nile tilapia. Regression analysis showed a quadratic behavior with better values for feed conversion rate 2.08 g L-1 of water salinity (Figure 3.10).

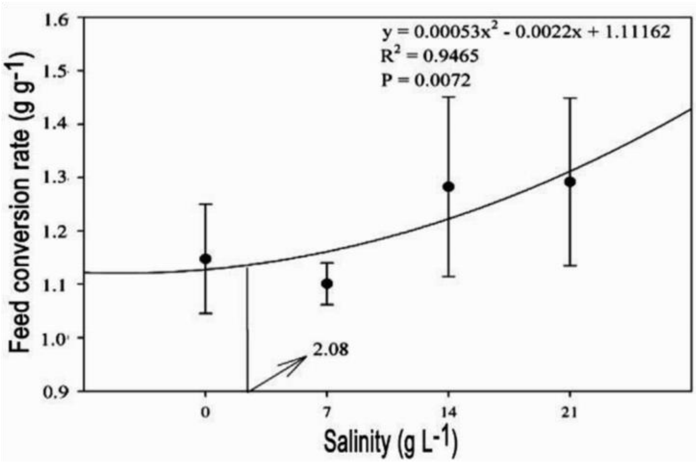

Figure 3.10 Effect of water salinity levels on feed conversion rate of Nile tilapia.

(Source: de Azevedo et al. 2015)

3.4.2 Effect of Different Salinities on Gill of Nile Tilapia

Regarding the histological analysis, Nile tilapia gills have the same pattern as in other teleosts. The filament is covered by a stratified epithelium in the interlamellar region in which there are epithelial cells, melanocytes, lymphocytes, macrophages, granulocytes and eosinophil's, as well as chloride cells. The structure of the gill arch and gill filaments shows mucosal cells. The secondary lamella is covered by a squamous epithelium that generally shows a thickness of one or two cell layers. Below the epithelium there are lamellar blood spaces that are bordered by pillar cells, which have a contractile function. In the outermost region of the secondary lamella, there is a blood vessel that has an internal covering of endothelium (Figure 3.11).

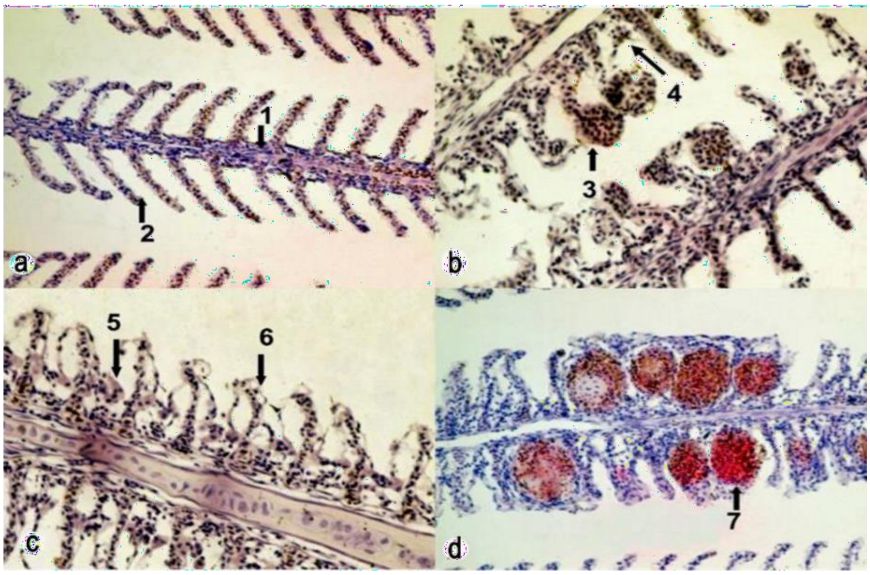

Figure 3.11 Histological sections of gills of *O. niloticus* specimens: a) Normal gill (1: primary lamella, 2: secondary lamella, H&E, 400x), b-d) Histopathological alterations. b and d) H&E 400x; c) H&E, 1000x; 3: telangiectasis; 4: aggregation of cells of the primary lamella; 5: hypertrophy of chloride cells; 6: intensive epithelial lifting; 7: lamellar aneurysms.

(Source: de Azevedo et al. 2015)

Change in salinities only affects *O. niloticus* survival at initial days before acclimatization, otherwise the fish can survive at salinities of up to 20ppt effectively.

After acclimatization, the chances of survival for *O. niloticus* were high with all the salinity levels tested. The mortalities observed were mainly attributed to stress as the salinity increases did not show effects after acclimatization. Stepwise acclimatization is an important process in ensuring survival rates during transfer of *O. niloticus* from low salinities to elevated salinities.

CHAPTER 4

CONCLUSIONS

In this paper we found that the significant effects of salinity on survival, behavioral responses and growth performance of *A. testudineus* were investigated. *A. testudineus* fingerlings can adapt to gradual increase of salinity. Normal growth was observed at salinity regimes of 0-6ppt. However, the most preferred salinity was 3ppt. For aquaculture purpose, the findings of this study suggest that *A. testudineus* fingerlings can be cultured in aquatic environment with salinities between 0-6ppt which confirm high production and better economic return.

We have found the effects of salinity on physiological and behavioral stress response in silver barb. The range finding test from 2ppt to 16ppt showed that the salinity tolerance limit of the fish was up to 10ppt and 100% mortality was observed at 16ppt with a median lethal concentration (LC_{50}) of 12.90ppt.

This research observation reveals that rohu fingerlings can adapt to gradual increase of salinity. Normal growth was observed at salinity regimes of 0-4ppt. However, the most preferred salinity was 2ppt. Therefore, adaptation with the changed climatic condition is the best policy to combat the global climate change.

Salinity tolerance on both hatchery reared and natural Nile Tilapia, *O. niloticus* species and observed that both the fish species did not show any remarkable stressful sign up to 4ppt indicated that fish remain unaffected physiologically up to 4-5ppt.In that aspect the finding of this study could be applicable in carp polyculture in saline water contaminated coastal ponds as rohu fish can be easily grown up to 4ppt salinity.

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