Salinity intrusion affects early development of freshwater aquaculture species pabda, *Ompok pabda*

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ABSTRACT

Salinity intrusion in freshwater ecosystems of low-lying coastal areas poses a major threat to aquaculture and agricultural production. An experiment was conducted to observe the effects of salinity on early life development of the freshwater aquaculture species pabda, *Ompok pabda*. Fish embryos (n = 200) and fry (n = 100) were exposed to five different salinity concentrations viz., 0 (control), 2.5, 5.0, 7.5 and 10.0 ppt with three replications. The LC_{50} values were calculated by probit analysis. The 24 h LC_{50} values recorded for embryos was 15.07 ppt and hatching success decreased significantly as salinity concentration increased. The 48 h LC_{50} values recorded for larvae was 5.07 ppt and larval developmental rate was reduced in response to an increase in salinity concentration. Mostly larval deformities were found from 5.0 to 10.0 ppt salinity. The 72 h LC_{50} values of fry was denoted as 2.42 ppt and fry mortality was augmented significantly with exposure time and salinity concentration. Fry mostly survived at 0 (92.67 %) and 2.5 ppt (65.67 %) salinities after 24 h exposure, but none survived at 5.0 and 7.5 ppt salinities after 48 h. 100 % fry mortalities occurred at 10 ppt salinity after 24 h exposure. Thus, the present findings provide useful information on salinity effects on early life development of *Ompok pabda* and sensitivity for embryonic development. It is expected that current findings will be helpful to raise awareness of the sensitivity of salinity for freshwater aquaculture species.

1. Introduction

Salinity intrusion is considered a remarkable threat for freshwater ecosystems of low-lying coastal countries, such as Bangladesh. Climate change induced rising sea levels along with other natural phenomena such as storm surges and cyclones, which are likely to play a significant role in salinity intrusion (Rabbani et al., 2013; IPCC, 2019). In addition, the withdraw of freshwater for irrigation purposes and decreased river water flow during the dry season also contribute to incremental salinity in freshwater and brackish water areas of the coastal zone of Bangladesh. Moreover, coastal aquaculture operations, especially shrimp farming and salt cultivation, represent other forms of anthropogenic causes of salinity intrusion (Hossain et al., 2013). To fill a

shrimp culture pond, farmers fetch saltwater from adjacent ecosystems (like estuaries or the open sea) through canal systems, through which pond water is often discharged into the surrounding freshwater regions. Increasing water salinity has led to changes in the physical environment of coastal ecosystems which may have adverse effects on the aquatic flora and fauna. Over the last 4 decades water salinity level increased about 26 % in coastal area of Bangladesh (Alam et al., 2017). It is anticipated that in the near future the saltwater zone will be increased from 5 percent to 17 percent while freshwater zone will be reduced from 45 percent to 36 percent and brackish water zone will be reduced from 50 percent to 47 percent in Bangladesh (Rahman et al., 2015). Surveys have revealed that rice and fish production has significantly declined because of soil and water salinization in coastal region of Bangladesh

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(Ahmed and Diana, 2015).

Environmental parameter plays an important role in the aquatic ecosystem and any adverse environmental conditions may create stressful situation for aquatic organisms and their capacity for homeostasis may be hampered. Environmental salinity is an important factor affecting the survivability of aquatic organisms and any fluctuation of water salinity may affects different physiological processes in animals (Saravanan et al., 2018). For example, Jahan et al. (2019) revealed the salinity intrusion affects growth performance, hemato-biochemical parameters and altered erythrocytes structure of striped catfish, *Pangasianodon hypophthalmus*. Typically, egg fertilization, embryonic development, and larval growth of aquatic organisms are mostly dependent on water salinity range for specific aquatic environments (Boeuf and Payan, 2001). As a result of salinity intrusion and seasonal fluctuation of water salinity in coastal freshwater regions, many aquatic organisms including wild stock of commercially important fish species may be subjected to salinity stress. Eventually, some species may become extinct and or migrate from these areas due to loss of coping capacity with such extreme environments. It was evident that 12, 19 and 24 % inland freshwater and brackish water fishes become extinct, endangered and threatened, respectively due to salinity intrusion in the riverine system across the coastal zone of Bangladesh (Alam et al., 2017). However, the relationship between fish growth and water salinity is not clearly understood, as available information has shown differential response from species to species (Table 1). For instance, growth rate of common carp, *Cyprinus carpio* decreased with an increase in water salinity (Ghosh et al., 2019) while a change in salinity from 0 to 36 PSU did not affect the growth of tilapia, *Oreochromis spilurus* (Jonassen et al., 1997; Saravanan et al., 2018). Lower salinity increased the growth performance of striped catfish, *P. hypophthalmus* (Jahan et al., 2019). However, very limited virtual information is available regarding saltwater toxicity to freshwater fish species.

Pabda is commonly known as butter catfish (*Ompok pabda*), an Indian freshwater aquaculture species with high market demand due to its soft meat texture, good taste and high nutritional value. In the last decade, attention has been drawn to reduction in abundance of *O. pabda* and has consequently been enlisted as an endangered species in Bangladesh, India and Pakistan and on global scale as near threatened (CAMP, 1998; IUCN, 2014). Again this species (*O. pabda*) might be in critical condition due to salinity intrusion in the low-lying coastal

system of Bangladesh. Dasgupta et al. (2016) revealed that maximum salinity tolerance level of *O. pabda* is 5 ppt. Fish assemblages from freshwater origins can be partially or completely altered due to the salinization of rivers and river fed wetlands being recorded in the globes (Wedderburn et al., 2008; Hoagstrom, 2009; Beatty et al., 2011). In this context, the main objectives of the present study were to evaluate the sensitivity of the freshwater fish species *O. pabda* to increased salinity levels and to assess its ability to resist to water salinization induced by salinity intrusion.

2. Material and methods

2.1. Test animals and stock solution

The experiment was performed in the Aquaculture laboratory at Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh, and experimental animals *Ompok pabda* (fertilized eggs, 3 days old fry) were provided by a reputed finfish hatchery (*Chanchal Matsha Hatchery*). The fertilized eggs and fry were transported to the laboratory under oxygenated condition in plastic bags filled with freshwater from the hatchery. During collection time, the physical and chemical parameters of the water were recorded: dissolved oxygen ($\geq$7.5 ppm), pH (ranged between 7.61–8.2) and salinity (0.0 ppt) The collected embryos were more or less at the gastrula stage, confirmed by a clear perivitelline space, germinal disc and blastomere formation (Islam et al., 2018) and fry (age > 72 h) were in post-larval stage, characterized by the complete absorption of their yolk sacs.

A stock solution of saline water (30 ppt) was prepared by mixing brine with dechlorinated tap water. Natural brine with a salinity of 130 ppt was obtained from a government fish hatchery under the Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh on request. Prior to the preparation of desired concentrations of saltwater, both brine and dechlorinated tap water were subjected to filtration by using 65 μm filter papers to remove debris and other unwanted suspended solids. Test water of different salinity 2.5, 5.0, 7.5 and 10.0 ppt were prepared by the addition of required amounts of dechlorinated tap water to the stock solution. This range of salinity was selected using expert judgement, in order to understand the effects of environmental water salinity due to its intrusion on different ontogenetic stages of the freshwater fish species *O. pabda*.

Table 1
Previous studies conducted the effect of salinity on developmental stages in different fish species.

Test Species	Parameters	Life stage	Dilution water	Test duration	Test water	Water salinity range (ppt)	Effects	References
Cyprinus carpio	ATPase activity, survival and growth		Dechlorinated tap water	14 days	Rock salt	0 to 7.5 ppt	Fish showed a great adaptation to all salinities in presence of cortisol	Saravanan et al., 2018
Lepomis gibbosus	Mortality		Deionized tap water	96 h	Sea Water and NaCl		–	Venâncio et al. 2019
Carassius auratus	Growth, food intake, metabolic adaptation		–	21 days	Marine salt	0 to 10 ppt	Significant muscle dehydration, significant increases in circulating cortisol, adverse effects on growth, food intake and food conversion rate.	Luz et al. 2008
Gadus morhua	Growth, plasma ions, cortisol and immune parameters	Juvenile	Ground water	187 days	Sea water	6.0 to 32 ppt	Limited or no effects on stress and immune-related parameters, no indications of ion regulatory disturbances at salinities as low as 6‰	Árnason et al. 2013
Cyprinus carpio	Food consumption, growth and energy conversion efficiency	Fingerlings	Tap water	92 days	Sea water	0.5 to 14.5 ppt	SGR reduced with increase, in salinity, FCR diminished with an increase in salinity, highest feed digestibility in low water salinity	Wang et al. 1997
Oreochromis mossambicus	Metabolic rate, expression of metabolic and osmoregulatory genes in the gill	Adult male	–	48 h	Fresh and sea water	-0.2 psu and-	Energetic costs of osmoregulation are higher in sea water than in fresh water	Zikos et al. 2014

2.2. Embryo- larval development toxicity test

2.2.1. Assessment of hatching success

The fertilized eggs of butter catfish *O. pabda* were divided into two groups. A portion of embryos at the morula stage were used to conduct mortality tests with diluted of saltwater. Twenty (20) μL of the suspensions with about 200 embryos were incubated in 25-mL petri dish filled with 10 ml of test solution of various salinities (three replicates) including a freshwater control (Table 2). After 24 h of incubation, embryonic development of all replicates was fixed by adding a drop of 40 % formaldehyde to the petri dishes. The criteria used to determine the lethal concentration (LC_{50}) was percentage hatching success of embryos. One hundred hatched larvae were observed under a microscope (Zeiss LSM, 880). Successful hatching rate was counted, taking into consideration the existence of a yolk sac and the same morphology as the reference larval stage (Sarma et al., 2012), whereas unhatched and dead embryos were recorded as undeveloped embryos.

2.2.2. Assessment of larval development

In the meantime, another portion of the embryos were also incubated in 25 mL petri dishes by following the same procedure of mortality test. But in this case, embryo-larval development was fixed at the moment of complete absorption of the yolk sac in 80 % of the larvae in control groups. Fully developed larvae with no abnormalities were counted (Sarma et al., 2012) and abnormal and dead larvae were also counted for the calculation of LC_{50}. Mortality was checked every 24 h and dead embryos or larvae were discarded. Organisms were not fed during this period. Toxicity assays were performed at 25 °C with a normal day-light photoperiod.

2.3. Fry mortality bioassay

The fish fries were obtained from the same pool of gametes, were used for the mortality test and exposed to salinity for 72 h. The experimental design was completely randomized, with five various salinity concentrations (0.0, 2.5, 5.0, 7.5 and 10.0 ppt) and four replicates for each concentration. In the experiment, 2000 fries were used and distributed indiscriminately into 20 experimental units. Each experimental unit consisted of a beaker with volume of 1 L. During the test, animals were fed with egg custard every day, as recommended by Chakrabarti et al. (2009). Mortality was observed at 24 h, 48 h and 72 h after stocking into the experimental units which was used to calculate lethal concentration (LC_{50}).

2.4. Water quality analysis

Water physio-chemical parameters were assessed separately for each treatment to establish whether they were maintained at recommended levels for the biology of the butter catfish. At the beginning and end of the experiments, water temperature, dissolved oxygen (DO) and pH were determined by digital thermometer and multimeter DR 600, respectively whereas alkalinity, total ammonia, and nitrite were determined by Dr 6000 spectrophotometer.

2.5. Data analysis

A probit regression (PreProbit software; Sakuma, 1998) was used to calculate LC_x using data from the toxicity test. This method established the relationship between the salinity levels and the probits of observed cumulative responses. Statistical analysis was performed using SPSS software version 20.0 for data obtained from all bioassay. The differences among treatments compared to the control were determined with the help of a one-way ANOVA followed by a Tukey's test (Zar, 1996). The confidence level was fixed at 95 % ($p < 0.05$). The relationship between the salinity concentration and responses (percentage of undeveloped embryos, malformed larvae and fry mortality) was subjected to Spearman non-parametric correlations and confidence level was at both 95 % ($p < 0.05$) and 99 % ($p < 0.01$).

3. Results

3.1. Effects of salinities on hatching success of O. pabda

With increasing salinity concentration, the embryonic developmental success decreased and the incubation periods of *O. pabda* increased. The mortality rate of embryos increased significantly ($p < 0.05$) and the hatching success decreased significantly ($p < 0.05$) with increasing salinity concentration. The percentage of embryos hatching success is presented in Fig. 1. After 24 h LC_{50} values for undeveloped embryos of *O. pabda* was 15.07 ppt and regression values $R^2 = 0.887$ (Table 4). The log values of unhatched embryos in response to dose are presented in Fig. 3. A few mortalities of embryos were observed in the control (0 ppt) salinity but did not exceed the threshold and the mortality in other concentrations was dose-dependent, highest at 10 ppt.
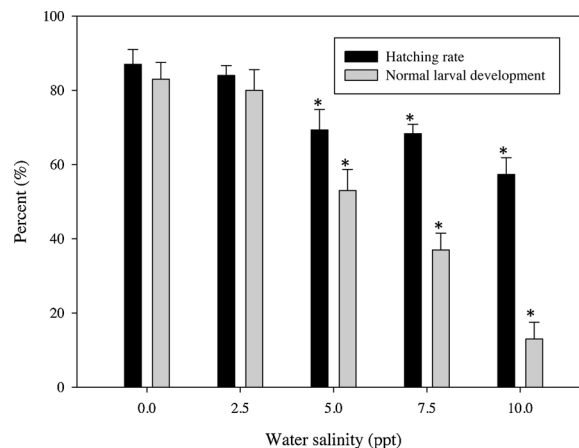

Fig. 1. Percentage (%) of total hatching rate and normal larval development of *Ompok pabda* were recorded at different salinity concentration (0.0, 2.5, 5.0, 7.5 and 10.0 ppt) (n = 200). An asterisk (*) indicates statistical difference at $p < 0.05$ when comparing with control.

Table 2

Toxicity bioassay tests and short-term exposures to water salinity (before and after) in different developmental stages of *Ompok pabda*.

Test species	Bioassay	Endpoints	Dilution water	Test water	Water salinity (ppt)	Test condition
Ompok pabda	Embryo-larval development	*LC_{50} Undeveloped embryos	Dechlorinated tap water	Brine	0.0, 2.5, 5.0, 7.5 and 10.0	Normal day light, 25 °C, 24 h
		*LC_{50} Abnormal larvae	Dechlorinated tap water	Brine	0.0, 2.5, 5.0, 7.5 and 10.0	Normal day light, 25 °C, 48 h
	Fry	*LC_{50} Mortality	Dechlorinated tap water	Brine	0.0, 2.5, 5.0, 7.5 and 10.0	Normal day light, 25 °C, 72 h

'*' Water salinity causing 50 % of mortality (LC_{50}) or any other effect (EC_{50}).
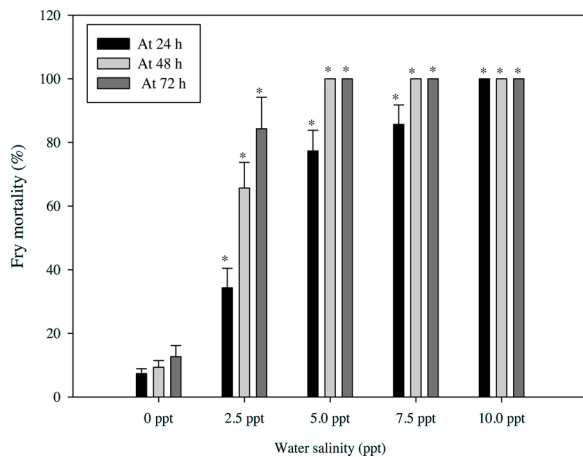
Fig. 2. Fry mortality rate (%) of *Ompok pabda* was recorded at 24 h, 48 h and 72 h exposures in 0.0, 2.5, 5.0, 7.5 and 10.0 ppt salinity (n = 100). An asterisk (*) indicates statistical difference at *p* < 0.05 when comparing with control.
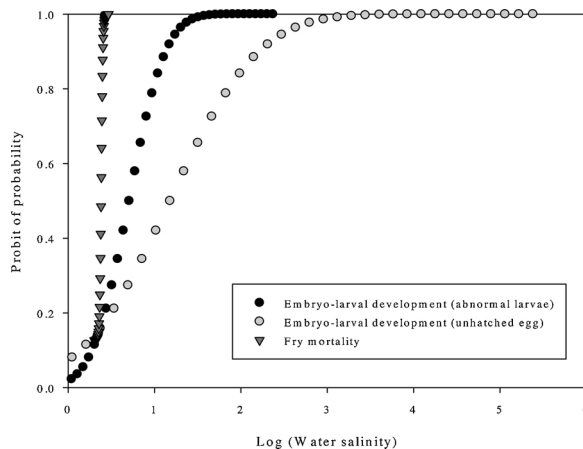

Fig. 3. Linear transformation and the relationship of probit of log salinity (ppt) concentration used to determine LC_{50} in different developmental stages of *Ompok pabda.*

3.2. Effects of salinities on larval development of O. pabda

Larval toxicity assay revealed that, the rate of larvae abnormalities was significantly (p < 0.05) increased in response to increase in salinity concentrations after 48 h of exposure. The value of LC_{50}, 48 h exposures for *O. pabda* larvae was recorded 5.07 ppt and regression value was $R^2 = 0.889$ (Table 4). The linear regression of percentage of larval abnormalities and salinity concentration is shown in Fig. 3. Highest larval deformities were recorded from 5.0 to 10.0 ppt.

3.3. Effects of salinities on fry mortality

The fry mortalities were recorded in treatment groups after 24, 48 and 72 h of exposure. The rate of fry mortality increased significantly (p < 0.05) with exposure time along with the increased salinity concentration (Fig. 2). After 72 h, LC_{50} values for fry mortality was 2.42 ppt and linear regression value was $R^2 = 0.882$ (Table 4). The log values of fry mortalities in response to concentration are showed in Fig. 3. Highest numbers of fry survived those survived were recorded at 0 ppt (92.67 %) and 2.5 ppt (65.67 %) after 24 h of exposure. Only 22.67 and 14.33 % were endured at 5.0 and 7.5 ppt, respectively. None was viable at 5.0 and 7.5 ppt after 48 h exposure. Occurrences of mortalities increased with exposure time and salinity concentration and none survived (100 % mortalities) at 10.0 ppt of salinity after 24 h exposure.

3.4. Water quality parameters

Water physio-chemical parameters play an important role on embryonic and larval development. Various types of water quality parameters such as temperature, dissolved oxygen, pH, Alkalinity, ammonia and nitrite were measured during the study (Table 3). Total

Table 4
Lethal concentration of water salinity (ppt) calculated in different developmental stages of *Ompok pabda,* determined by probit regression analysis.

Developmental stage and quality	Lethal concentration (ppt)			R^2 (Probit regression)
	LC_{10}	LC_{50}	LC_{90}	
Embryo development - unhatched egg	1.38	15.07	–	0.887
Embryo-larval development - abnormal larvae	1.44	5.07	13.54	0.889
Fry mortality	2.31	2.42	2.53	0.882

Table 3
Water quality parameters in embryo-larval development and fry stage of *Ompok pabda* during toxicity bioassay test (mean ± SE).

Parameters	Water salinity				
	0 ppt	2.5 ppt	5.0 ppt	7.5 ppt	10.0 ppt
Embryo-larval development bioassay					
Water temperature (C)	24.6 ± 0.4	24.5 ± 0.2	25.1 ± 0.3	25.07 ± 0.2	25.3 ± 0.4
Dissolved oxygen (mg/L)	7.2 ± 0.3	6.9 ± 0.8	7.1 ± 0.5	6.9 ± 0.2	6.9 ± 0.4
pH	7.6 ± 0.3	7.9 ± 0.3	7.9 ± 0.5	7.5 ± 0.2	8.0 ± 0.2
Alkalinity (mg/L)	23.1 ± 0.7	21.6 ± 0.4	23.5 ± 0.6	22.8 ± 0.4	23.6 ± 0.4
Total ammonia (mg/L)	0.21 ± 0.04	0.33 ± 0.07	0.31 ± 0.04	0.22 ± 0.04	0.35 ± 0.04
Nitrite (mg/L)	0.0343 ± 0.0031	0.0433 ± 0.0042	0.0363 ± 0.0007	0.0295 ± 0.0004	0.0391 ± 0.0002
Fry mortality bioassay					
Water temperature (C)	25.24 ± 0.31	25.07 ± 0.10	25.40 ± 0.61	24.73 ± 0.43	25.07 ± 0.50
Dissolved oxygen (mg/L)	7.33 ± 0.83	7.92 ± 0.19	7.38 ± 0.45	7.78 ± 0.40	7.95 ± 0.55
pH	6.88 ± 0.23	7.69 ± 0.42	7.22 ± 0.13	8.08 ± 0.16	7.20 ± 0.07
Alkalinity (mg/L)	23.68 ± 0.75	24.58 ± 0.42	22.78 ± 0.62	23.57 ± 0.42	22.60 ± 0.43
Total ammonia (mg/L)	0.36 ± 0.11	0.21 ± 0.08	0.45 ± 0.09	0.31 ± 0.02	0.48 ± 0.04
Nitrite (mg/L)	0.0210 ± 0.002	0.0323 ± 0.0042	0.0417 ± 0.0038	0.0428 ± 0.0038	0.0278 ± 0.0062

ammonia and pH slightly increased both in embryo-larval development and fry mortality in case of salinity toxicity, but were not significantly different. Water temperature and dissolved oxygen were almost uniform during the study period. Total alkalinity and nitrate had no distinct changes over the periods.

4. Discussion

Salinity intrusion in coastal areas, not only leads to permanent changes in the soil and water characteristics, but also changes the reproductive cycle of native fish including commercially important aquaculture species. Already, problems with climate change and salinity intrusion is driving the development of new aquaculture practices, for example, the development of an aquaculture system of salinity tolerant species. The present study exhibited the toxicity bioassay of different salinity concentrations on the hatching success, embryo-larval development and fry mortality of *Ompok pabda*. It is very crucial to know the effects of environmental parameters on large scale seeds production, and larval rearing of fish species in the hatchery system or wild environment (Gong et al., 2018). The hatching success remarkably decreased with increasing salinity concentration. For instance, embryos exposed to control (0 ppt) revealed a hatching performance of 87 %, but 57.33 % hatching success was recorded at the highest salinity concentration (10 ppt). Our study is with agreement of Farhana et al. (2019), who found decremented hatching success with increasing salinity stress in freshwater zebrafish, *Danio rerio* embryos after 96 h of exposure. Sampaio et al. (2007) demonstrated the successful fertilization of climbing perch, *Anabas testudineus* below 5 ppt salinity and the results were similar to our study. Certain freshwater fish species can hatch in low salinity levels such as silver carp, *Hypophthalmuchthys molitrix* (Gao, 1965), and yundu, *Heterobranchus longifilis* (Bombata and Busari, 2003) and similar findings were reported by Nadirah et al. (2014). They also found 97.3 % hatching success of climbing perch, *A. testudineus* at 3 ppt salinity concentration. Several researchers believed that fish embryos are more active under 10 ppt salinity (Bush and Weis, 1983; Pissetti et al., 2003).

Earlier studies showed almost similar verdicts on the reduction of hatching success of *O. pabda* due to salinity toxicity. For example, hatching success was reduced significantly in peipsi whitefish, *Coregonus lavaretus* (Albert et al., 2004); Black bream, *Acanthopagrus butcheri* (Haddy and Pankhurst, 2000); puffer fish, *Takifugu obscures* (Yang and Chen, 2006) and peipsi whitefish, *C. lavaretus* (Cingi et al., 2010) after exposure to different salinity concentrations. Comparable results were also found in snake head fish, *Channa striatus* (Amornsakun et al., 2011); green catfish, *Mystus nemurus* (Amornsakun, 1999a); climbing perch, *Anabas testudineus* and siamese gourami, *Trichogaster pectoralis* (Amornsakun et al., 2004a, 2004b).

Toxic effects hinder the development, as well as reducing the hatchability of embryos. Generally, it may occur due to the inhibition of the tetraspanin cd63 gene which may cause deficit exudation of proteolytic enzymes essential for the regulation of chorion (Michael et al., 2011). Usually, the chorion is digested by the proteolytic hatching enzyme secreted from hatching gland cells of an embryo during the normal hatching process of fish embryos. Protease structure and function might be disrupted due to toxicants that block the pore canals of the chorions, resulting in oxygen shortages for the development of embryos (Fan and Shi, 2002). Embryos and larval sensitivity to toxicants usually depend on the species (Ansari and Ansari, 2012; Arufe et al., 2010). In the present study, LC_{50} values at 24 h embryos exposure to salinity was 15.07 ppt, almost three folds higher than salinity LC_{50} for zebrafish (*D. rerio*) embryo at 5.6 ppt (Ord, 2019) and milkfish (*Chanos chanos*) at 10 ppt (Walsh et al., 1991). Again, our record was lower than salinity LC_{50} for killfish (*Fundulus heteroclitus*) at 40 ppt (Saeed et al., 2015) maintaining that different species maintain different tolerances for salinity depending on their habitat.

In our study, several larval abnormalities were recorded due to exposure to different salinity concentrations. Normal larval developments were reduced, and abnormality increased significantly (p < 0.05) with increasing salinity concentration (Figs. 1 and 3). Fridman et al. (2012a, b) also addressed the higher mortality, slower development, and higher rate of abnormalities in *O. niloticus* larvae with increasing salinity concentration in the environment. Jomori et al. (2012) also revealed similar results for catfish, *Clarias gariepinus*. Perez-Robles et al. (2014) reported the highest percentage of larval abnormality of bullseye puffer, *Sphoeroides annulatus* at 5 ppt salinity. Doroshev and Aronovich (1974) also showed the higher incidence of larval abnormality of navaga, *Eleginus nava*; polar cod, *Boreofadus saida* and Aractic flounder, *Liopsetta glacialis* in low salinities.

In the experiment, we also observed fry mortality rates were significantly higher with increase in salinity concentrations Fig. 2. The 72 h LC_{50} of fry mortality of *O. pabda* was recorded at 2.42 ppt, which is six times inferior to those of the 72 h LC_{50} for Thai silver barb, *Barbodes gonionotu* (Akther et al., 2009). Similar results also found for *Cirrhinus mrigala* and *Cyprinus carpio* fry at 3.54 and 8.13 ppt respectively (Kasim, 1983). Lethal toxicity for salinity in several freshwater species such as Yellow perch larvae, *Perca flavescens* (Wilkerson et al., 1992), Silver barb fry, *Barbonymus gonionotus* (Siddique, 2018), Bighead carp fry, *Aristichthys nobilis*, (Garcia et al., 1999) were also showed the homogenous results. It appears that the early life development of many freshwater species has wide range of salinity tolerance and that some species enjoys similarity in salinity requirement for their early life development. Whilst the salinity tolerance of *O. pabda* fry was 2.42 ppt (this study), *F. heteroclitus* (Dorfman, 1977) was as high as 23 ppt. Therefore, in a climate change scenario of freshwater salinization, O. pabda is likely to be more affected than many other species of freshwater origin.

Considering the LC_{50} of different life stages of *O. pabda* recorded in this study, it is obvious that salinity is important in its hatchability. However, as development continues, salinity requirement must be significantly lowered to enhance successful fertilization, embryos & larval development, growth, survival and reproduction in the end. Similar results were also reported for *Chirostoma humboldtianum* and *Chirostoma riojai* (Hernandez-Rubio and Figueroa-Lucero, 2013); rohu fingerlings, *Labeo rohita* (Islam et al., 2014); snake head fish, *C. striatus* (Amornsakun et al., 2017); and Nile tilapia, *Oreochromis niloticus* (Fridman et al., 2012a). However, it is important to identify a salinity threshold for freshwater fish species. LC_{50} values for *O. niloticus* were found at 17.2 ppt salinity (Watanabe et al., 1985). Survival and developmental rates of *Clarias gariepinus* can also be severely affected with increasing water salinity (Britz and Hecht, 1989). They also mentioned no fry can survive at 10 ppt salinity and 0–2 ppt salinity was the best for fry of this fish to grow, which is similar to our findings. It has become alarming in the recent years that global warming, rise in sea level and saltwater intrusion has induced rapidly in coastal aquaculture areas. However, our long-term sustainability of aquaculture must be dependent on efficient uses of natural resources. Early life stage of teleost fishes is usually the most crucial period due to their poorly developed regulatory systems such as gills and livers, where functional changes occur rapidly (Ozoh, 1979).

5. Conclusion

The present study reported the salinity toxicity bioassay of *Ompok pabda*. Salinity strikingly affects the hatching rate, embryo development and fry survivability at higher concentrations. The results of this study suggest that the salinity in aquatic environments have an antagonistic effect on the embryonic and larval development of *O. pabda* those might create problems to the farmers of the coastal Bangladesh during nursing period. Our study also suggests that *O. pabda* could also be a model species for evaluating the developmental toxicity in the saline environment. However, this study addressed only the exposure of salinity of *O. pabda* fish during early developmental stages. Therefore, for potential persistence of toxic effects in the long term, we recommend further evaluation of the same endpoints in juvenile or adult *O. pabda* to

determine whether the effects of salinity toxicity are transitory or permanent.

Author contributions

Md Rushna Alam conceived, designed and performed the experiments and collected data. Sadia Sharmin, SM Majharul Islam and Md Ariful Alam drafted the manuscript. Friday Ojie Ehiguese and Shib Nath Pattadar were assisted in data analysis and edited the manuscript. Md Shahjahan assisted in the experimental design and edited the manuscript. All authors reviewed and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

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