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EFFECTS OF PERIODIC SALINITY VARIATION ON THE EXPRESSION OF SOME PHENOTYPIC TRAITS IN STRIPPED DWARF CATFISH (*Mystus vittatus*)

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ABSTRACT

Salinity fluctuations are known to have direct or indirect influence on phenotypes and thereby, evolve the subsequent life history traits in aquatic animals especially in fish. The present study was carried out to investigate whether periodic salinity fluctuations can influence the expression of some phenotypic traits (e.g. survival, standard length, tail length, body area, and body colour) in stripped dwarf catfish (*Mystus vittatus*). Ninety medium sized stripped dwarf catfish were collected and reared up to three months dividing into two treatments such as control treatment (CT) and salinity treatment (ST). The CT fish were reared at 0 ppt during the experimental period, while ST fish were reared at 10 ppt in first month, 0 ppt in second month and 10 ppt again in third month. There were significant effects of salinity on survival and the overall body colour of stripped dwarf catfish during the experiment. The results showed a significant difference in the tail length between the two treatments in which the average of tail length with the ST throughout the experimental period was significantly smaller than the CT. The study also found that the ST fish were significantly less bright and highly fade in appearance compared to the CT fish. The overall results have revealed an important role of periodic salinity fluctuation on the expression of some phenotypic traits in stripped dwarf catfish and thereby, underpinned the evolution of different phenotypic traits in many animals and also their plasticity as result of environmental stress in nature.

Keywords: Catfish, salinity stress, fish phenotypes, fish colour.

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INTRODUCTION

Over the recent decades, salinity intrusion has been considered one of the major problems in most of the countries around the world (Shi and Jiao, 2014). From the big countries like China (Xue *et al.,* 1993), United States (Rice *et al.,* 2012), Russia (Magritsky *et al.,* 2017), Brazil (Melo *et al.,* 2014) and India (Sankaran *et al.,* 2012) to the very small islands like Maldives (Sovacool, 2012), Nauru (Alberti *et al.,* 2017) and the Gulf Islands (Klassen and Allen, 2017), their coastal areas are severely affected by the unwanted increase of salinity. Therefore, all countries around the world are very concerned and anxious about this issue. On the other hand, several studies indicated that sea-level rise (Rice *et al.,* 2012), changes in stream and wind flows (Ross *et al.,* 2015), seasonal variability (Li *et al.,* 2017), extended droughts and lower rainfalls (Nielsen and Brock, 2009; Dasgupta *et al.,* 2015), frequent storm surges/cyclones (Riddin and Adams, 2010), brackish water shrimp/fish cultivation (Tho *et al.,* 2008; Nicholls *et al.,* 2018) and irrigation with saline water (Clarke *et al.,* 2015) are the major causes for the salinity intrusion and its subsequent increase in most of the areas.

Salinity intrusion, both in short-term and long-term, has direct and/or indirect impacts not only on aquatic resources but also on territorial resources inhabiting adjacent to the coastal areas. For instances, salinity intrusion may adversely reduce the water and soil qualities (Arslan and Demir, 2013; Ahmed and Askri, 2016), decline biodiversity (Amores *et al.,* 2013), damage habitats and food resources (Love *et al.,* 2008; Garner *et al.,* 2015), decrease the overall crop and other biological productions (Alam *et al.,* 2017; Nhung *et al.,* 2019), alter daily life cycle and physiological activities (Komoroske *et al.,* 2016), create hazards to the normal health conditions (Chakraborty *et al.,* 2019), and cause the outbreak of different diseases (Ramasamy and Surendran, 2011).

Bangladesh is situated in South Asia (total area: 1,47,570 km^2) which has a 710 km long coastal belt (CZPo, 2005). Its coastal land zone covering approximately 32% (47,150 km^2) of the total area which is blessed with hundreds of ponds, rivers, estuaries, floodplains, lakes, mangroves, and aquaculture farms (Shamsuzzaman *et al.,* 2017; DoF, 2018). Unfortunately, sea level rise (Nishat and Mukherjee, 2013), elevated temperature (Miah *et al.,* 2015), low rainfall (Islam *et al.,*

2019), salinity increase (Alam *et al.,* 2017), seasonal variability (Hossain *et al.,* 2012), frequent heavy storms, cyclones, tidal surges (Biswas *et al.,* 2018; Haque *et al.,* 2018), floods with saline water (Kulp and Strauss, 2019), and unplanned shrimp aquaculture (Azad *et al.,* 2009) are mostly blamed for affecting these coastal fisheries resources in Bangladesh. All these factors cause a common problem known as 'salinity intrusion or rising', which brings a great challenge to every single life inhabiting there. Among various species, fish are most vulnerable as they tend to live in water that is affected at first and converted moderately to high salinity very easily during any event of climate change.

Environmental factors are crucial for an individual as they can influence the subsequent life history traits. Water salinity, among different factors, is considered as one of the most important water qulaity parameters for fishes as they can play a crucial role in shaping different traits by influencing their physiology, behaviour, and other traits (Küçük, 2013).

Stripped dwarf catfish (*Mystus vittatus*) is native to fresh and brackish waters of Bangladesh, India, and other South Asian countries (Shafi and Quddus, 2001). Their colour may vary with age which is generally gray to shining golden having five pale blue to deep black stripes on each side of the body (BdFISH, 2010). Their maximum length could be 11.7 cm (Rahman, 1989 and 2005). Because of its excellent taste, high nutrient value, and availability throughout the year, stripped dwarf catfish stands out as one of the most valued fish species in South Asian countries (Hussain, 1999; Rao *et al.,* 1999). Studies have already showed the distribution and habitat (Shafi and Quddus, 2001; Gupta, 2014), feeding and breeding biology (Shafi and Quddus, 2001; Gupta, 2014) and morphology of *M. Vittatus* (Rahman, 1989 and 2005; Shafi and Quddus, 2001). Although some studies have been carried out with *M. vittatus* to explore their different trait development under various environments, the influences of salinity on the expression of phenotypic traits have not clearly been exposed yet. Therefore, this study has been conducted to explore whether salinity fluctuation can affect some phenotypic traits (e.g. length, body area and colour patterns) of *M. vittatus.*

MATERIALS AND METHODS

Fish collection and acclimatization: The experiment was conducted in the Wet Laboratory of Fisheries and Marine Resource Technology (FMRT) Discipline, Khulna University, Khulna, Bangladesh. Two hundred (200) juvenile stripped dwarf catfish (*M. vittatus*) were collected for stock from a local farmer of Khulna and were transported immediately in oxygenated containers to the assigned Wet Laboratory. They were kept in a large tank (100 litres) and the conditioning period was two days.

Experimental design: Ninety (90) fish of almost the same size (mean±SE of standard length in cm: 8.09±0.09 and $F_{1,88}$=0.24, P=0.62 and Cohen's d=0.10) were sorted out from the stock to assign randomly into two treatments as the following, T_1 (0 ppt- hereafter control treatment or 'CT') and T_2 (10ppt- hereafter salinity treatment or 'ST') during this experiment. Each treatment had three replications, which possessed 15 juveniles in a glass aquarium (50cm×29cm×30cm). The highest salinity tolerance of this species was determined through a pre-experimental trial after estimating the median lethal salinity ($MLS\text{-}50_{96h}$), which was 12 ppt. The salinity was gradually increased (±1ppt/day) to avoid any stress. The whole experimental design is briefly illustrated in Fig. 1.

Water management and feeding: The aquariums were cleaned up prior to stocking of fish and fitted with continuous aeration. All aquariums were covered to avoid fish escaping and evaporation. The fish were fed with live food (insects' eggs, larvae, and flesh of small shrimps) including a small amount of commercial supplementary fish feed (Progoti Feed Ltd. Bangladesh labeling with 31% protein, 5% fat, 12% moisture and 4% fibre) twice daily (0800 and 1500h). The fish were fed until the satiation (*ad libitum*) to avoid the feeding effect. About 30% of the water was removed by siphoning every morning before the feeding to clean the faces and uneaten food. the aquarium walls were also cleaned three times a week from Dirt attached. Optimum water quality was maintained throughout the experimental period. Salinity was recorded daily after siphoning by using the refractometer (RHS-28ATC, maker-Japan, China, USA) and the desired level was adjusted by adding brine solution or freshwater. Water temperature of all aquariums were maintained at ±30°C.

Phenotype analysis: The photograph of every individual (placed on a graph paper) was captured by using a digital camera (Canon DS126621), and some phenotypic traits such as standard length, tail length, body area and overall fish colour were measured every month following the methods of Rahman *et al.* (2013, 2019). Fish mortality was also monitored and recorded every day. All raw images were used by the ImageJ (v1.50) software for the measurement of these selected phenotypic traits. The previously described raw images were also carefully observed to detect the overall fish colour (i.e. how many fish were fade, dark or bright) after each treatment (Fig 2). Before taking the image (described above), the body colour of individual fish was carefully observed and recorded. Then the captured image of individual fish along with its code was observed again very carefully to confirm its recorded body colour. Finally, they were categorized into three colour groups based on their body colour such as (1) natural (Fig. 2a), (2) dark (Fig. 2b) and (3) fade- pale in colour (Fig. 2c).

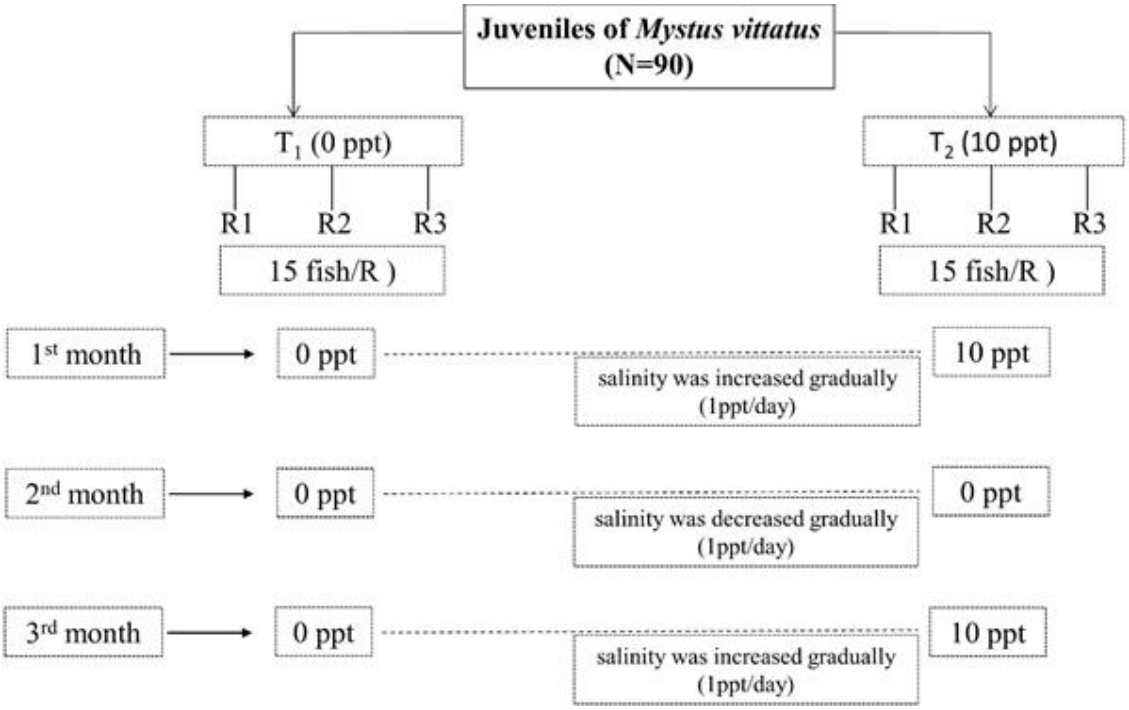

Figure 1. The overall design of the experiment. Ninety juveniles of *Mystus vittatus* were randomly assigned into two salinity treatments: T1 (0ppt) and T2 (10ppt). T1 fish were reared constantly at 0 ppt, while T2 fish were reared at different salnities during the experimental period. T2 fish were kept at 10 ppt, 0 ppt and 10 ppt in first 20 days of each month, while salinity was increased or decreased gradually (±1ppt/day) to avoid any salinity stress by the rest 10 days of each month. Here, N- total sample size and R- replication.

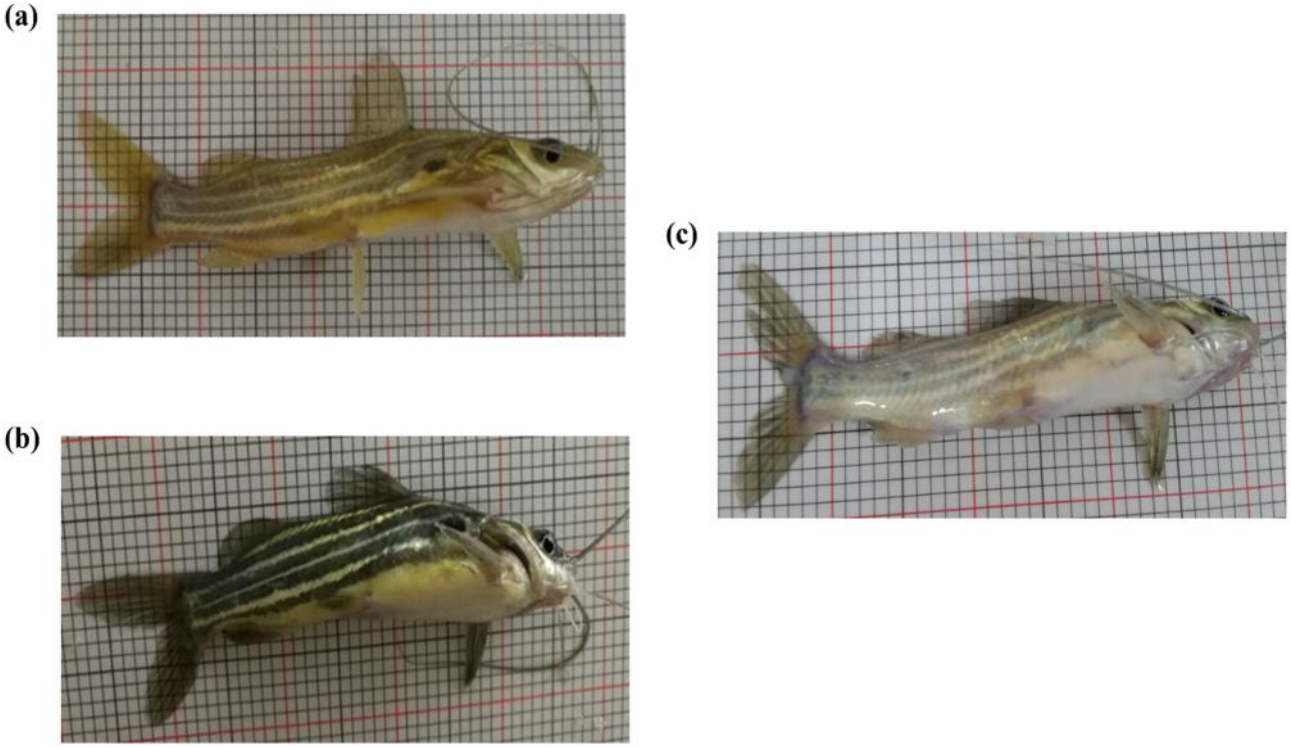

Figure 2. Types of observed body colour of experimental *Mystus vittatus*, where (a) natural body colour, (b) dark body colour and (c) fade or pale body colour.

Statistical analyses: All statistical analyses were done by using the 'RStudio' version 1.0.143 (R Development Core Team, 2020). The descriptive statistics were measured by using the 'psych' package. The Shapiro-Wilk test was followed for normality, while the Levene's test was performed for homogeneity of variance by using the 'car' package. First, all the traits (except the categorical variables- overall fish colour) were tested to check their normal distribution and then the appropriate transformations were applied to yield normal distributions for non-normal distributed traits.

The survival rate of individual fish in each treatment was calculated with the Kaplan-Meier model using the 'survival' package. In the model, the entire experimental period (120 days) was included as 'time' data, status of each fish (0= alive and 1= dead) as 'event' and treatment as 'predictor' variable. Finally, the Cox proportional hazards model was applied using the 'survival' package to find out the significance of treatment effect on fish survival.

All the data were first sorted and divided into three groups for the analysis in 1) control treatment, 2) salinity treatment, and 3) control versus salinity treatment. First, the regression model was applied using the 'car' package to see whether standard length, tail length, and body area increased with the increase of rearing month. Then the one-way analyses of variance (ANOVA) were performed by using the 'car' package to explore the phenotypic variation (except fish colour) between different treatments throughout the experimental period. The Cohen's *d* was calculated for each ANOVA model using the 'sjstats' package to quantify the magnitude of the effect (Cohen, 1988). The Pearson's chi-squared test was followed by using the 'gmodels' and 'rcompanion' packages in order to explore the variation in body colour. Cramer's V based on adjusting chi-square significance was also calculated by using the 'vcd' package to find out the association between colour patterns as a percentage of their maximum possible variation. The mosaic plot was made to depict the status of different fish colour throughout the experiment between different treatment groups using 'vcdExtra' package. All the graphs were prepared by using the 'ggplot2' package of R.

RESULTS

Fish survival: The survival analysis showed that fish reared in ST showed significantly reduced survival rate (87%) than that of CT (98%, N=90, $P<0.05$, Fig. 3).

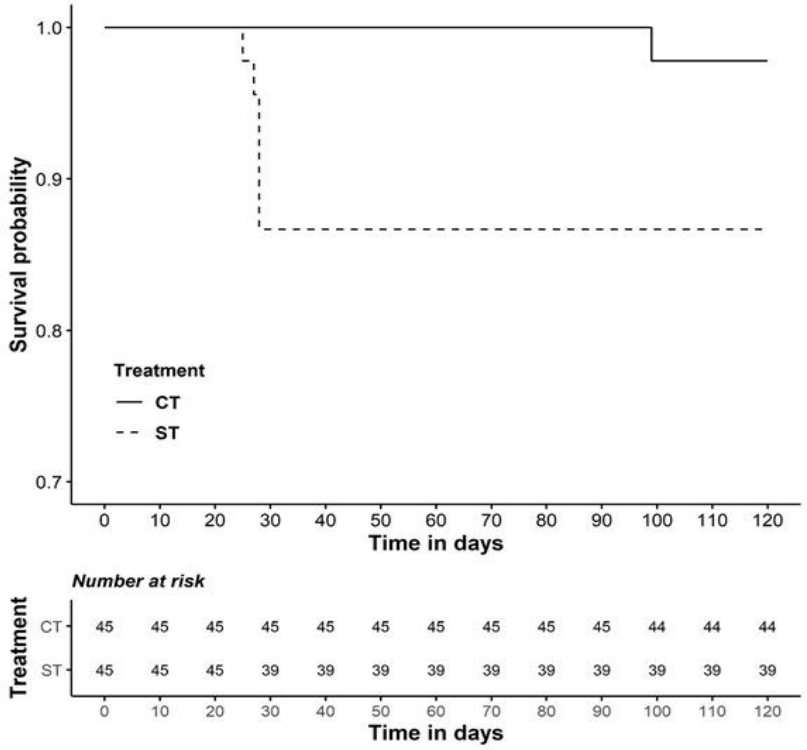

Figure 3: Variation in survival rate of experimental *Mystus vittaus* reared in control treatment (CT) and salinity treatment (ST) during different months. The survival probability was estimated by the Kaplan-Meier method. The number of fish in risk at different time points (days) is displayed on the graph. The lines represent survival curves of the two treatments.

Standard length

Control treatment: The regression model showed that the standard length of CT fish increased with the increase of rearing period ($F_{3,176}$=5.42, P<0.01, R^2=0.07, Fig. 4a). The ANOVA model revealed that the standard length increased significantly after one month ($F_{1,88}$=7.31, P<0.01, Cohen's d=0.57, Fig. 4a), while it did not increase significantly in the second ($F_{1,88}$=0.54, P=0.46, Cohen's d=0.15) and third month ($F_{1,88}$=0.06, P=0.81, Cohen's d=0.05, Table 1).

Salinity treatment: It was found that the standard length of ST fish increased with the increase of rearing months ($F_{3,176}$=2.85, P<0.05, R^2=0.03, Fig. 4b). The results showed that the standard length increased significantly after two months ($F_{1,88}$=2.60, P<0.05, Cohen's d=0.32, Fig. 4b), whereas there was significantly no variation found between the initial and one-month old size ($F_{1,88}$=2.59, P=0.11, Cohen's d=0.34, Fig. 4b). The outcomes also revealed no significant variations between the first and the second month ($F_{1,88}$=0.73, P=0.39, Cohen's d=0.18), and the second and the third month ($F_{1,88}$=0.02, P=0.88, Cohen's d=0.03, Table 1).

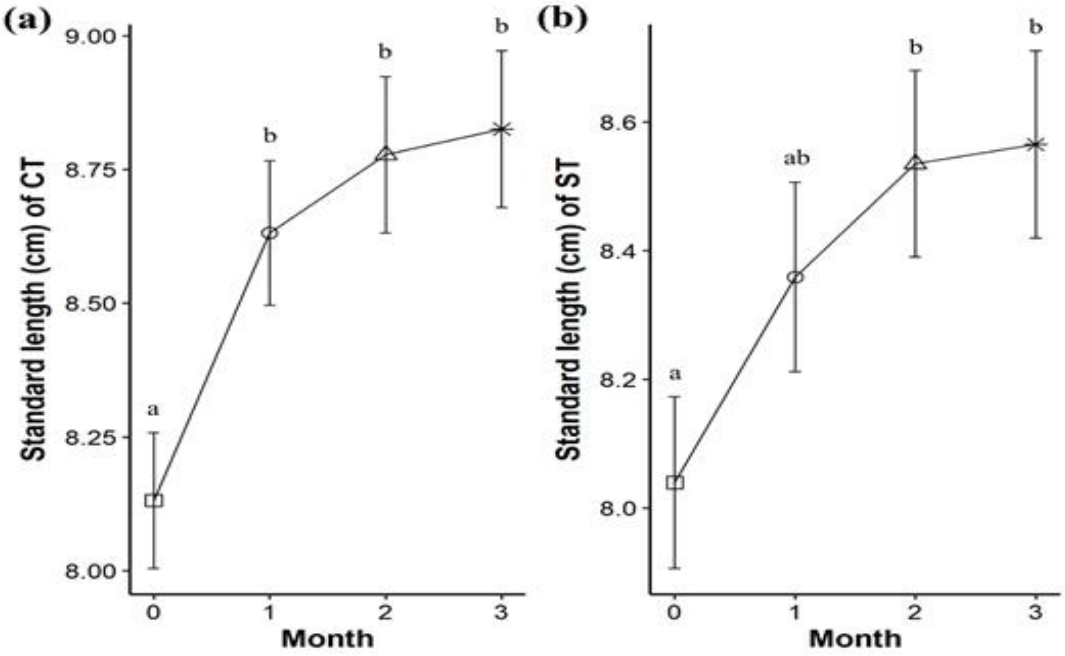

Figure 4: Variation in standard length (cm) of experimental *Mystus vittaus* reared in (a) control treatment (CT) and (b) salinity treatments (ST) during different months. Values are given as mean ± standard error (SE). Different letters of 'ab' denote significant variations in standard length between two months. The analysis was done using 95% confidence level.

Control treatment vs. salinity treatment: The comparison of standard length in each month revealed no significant variation between CT and ST fish reared in different months (Table 1).

Tail length

Control treatment: It was revealed that tail length increased with the increase of rearing period ($F_{2,132}$=4.04, P<0.05, R^2=0.04, Fig. 5a). The findings showed that the tail length of first month fish became significantly larger at the end of the experiment ($F_{1,88}$=2.76, P<0.05, Cohen's d=0.38, Fig. 5a). However, no significant variation was found between the first and second month ($F_{1,88}$=1.97, P=0.12, Cohen's d=0.07), and the second and third month ($F_{1,88}$=0.79, P=0.71, Cohen's d=0.06, Table 1).

Salinity treatment: The outcomes of regression model revealed that tail length increased with the increase of rearing month ($F_{2,132}$=3.45, P<0.05, R^2=0.04, Fig. 5b). The subsequent ANOVA model revealed significant variation of tail length between the first and third month reared fish ($F_{1,88}$=2.4, P<0.05, Cohen's d=0.36), whereas no significant variation was found between the first and second month ($F_{1,88}$=2.11, P=0.09, Cohen's d=0.06), and the second and third month ($F_{1,88}$=0.29, P=0.95, Cohen's d=0.04, Table 1).

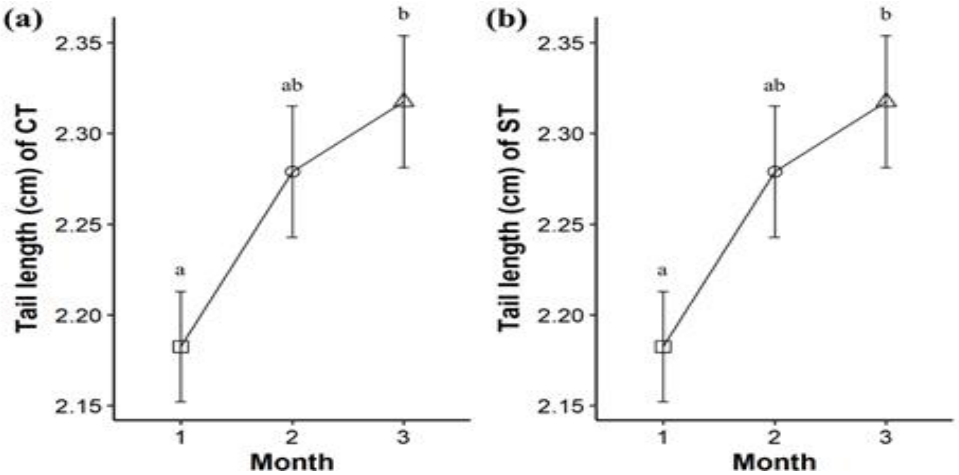

Figure 5: Variation in tail length (cm) of experimental *Mystus vittaus* reared in (a) control treatment (CT) and (b) salinity treatments (ST) during different months. Values are shown as mean ± standard error (SE). Different letters of 'ab' denote significant variation in tail length between two months. The analysis was done using 95% confidence level.

Control treatment vs. salinity treatment: The comparison of tail length between CT and ST after first month of the experiment revealed that CT fish had significantly larger tail than their counter group ($F_{1,88}$=13.29, P<0.01, Cohen's d=0.77, Fig. 6). In the second month, although both CT and ST fish were kept in the same condition (0 ppt), CT possessed significantly larger tail than ST ($F_{1,88}$=10.16, P<0.01, Cohen's d=0.67, Fig. 6). At the end of the experiment (third month), it was also revealed that CT fish had significantly larger tail than ST fish ($F_{1,88}$=13.09, P<0.001, Cohen's d=0.76, Fig. 6, Table 1).

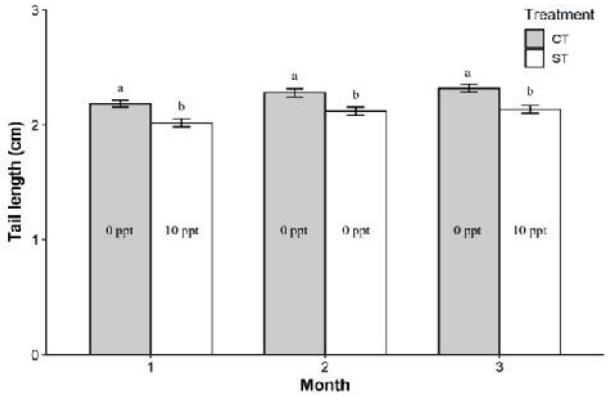

Figure 6: The variation in tail length (cm) of *Mystus vittaus* among different treatments throughout the experimental periods. Here, CT indicates the control treatment, while ST denotes the salinity treatment. The salinity level of both treatments during each month is depicted within the respective treatment bar. Different letters of 'ab' indicate significant variation between CT and ST during each month. The analysis was done using 95% confidence level.

Body area

Control treatment: The results showed no significant increase of body area with the increase of rearing period ($F_{2,132}$=0.19, P=0.82, R^2=0.01, Table 1).

Salinity treatment: The regression model found no significant increase of body area in ST fish with the increase of experimental months ($F_{2,132}$=0.69, P=0.50, R^2=0.005, Table 1).

Control treatment vs. salinity treatment: The comparison of body area between CT and ST fish showed no significant variation at any month (Table 1).

Fish body colour

Bright colour: The Pearson's Chi-squared test showed that CT fish reared in the second month had significantly more bright coloured fish than those of the first month fish (χ^2=7.2, P<0.01, Cramer's V=0.2, Fig. 7). At the end of the experiment, the results showed no significant variation between CT fish reared in the second and third month (χ^2=0.05, P=0.83, Cramer's V=0.24, Fig. 7). Meanwhile, the findings revealed no significant difference in bright colouration between ST fish kept in the first and second month (χ^2=1.23, P=0.27, Cramer's V=0.19, Fig. 7), while they had significantly higher number of bright coloured fish during the second month than those of the third month (χ^2=4.46, P<0.05, Cramer's V=0.22, Fig. 7). The comparison between two treatments found significantly higher number of bright coloured fish in CT than those of ST after the first (χ^2=3.73, P<0.05, Cramer's V=0.23, Fig. 7), second (χ^2=10.37, P<0.01, Cramer's V=0.27) and third month (χ^2=21.62, P<0.001, Cramer's V=0.28).

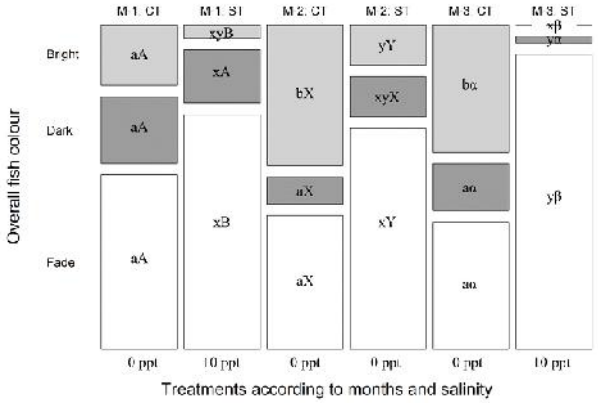

Figure 7: Mosaic plot showing body colour variation of *Mystus vittaus* among different treatments throughout the experimental periods. Here, 'M' indicates month and the numeric number in M denotes the rank of month. CT is the control treatment, while ST is the salinity treatment. The salinity level of both treatments during each month is shown across the x-axis. Different letters of 'ab' indicate significant variation among CT, while different letters of 'xy' indicate significant variation among ST during the experimental periods. Different letters of 'AB' indicate significant variation between CT and ST in the first month, differences in 'XY' indicates significant variation between CT and ST in the second month and differences in 'αβ' indicate significant variation between CT and ST in the third month.

Dark colour: The fish body colour analysis showed no significant difference in dark colouration between CT fish kept in the first and second month (χ^2=0.26, *P*=0.15, Cramer's V=0.24, Fig. 7), and the second and third experimental period (χ^2=0.41, *P*=0.52, Cramer's V=0.19). Similarly, the colour patterns of ST fish found no significant variation during the first and second month (χ^2=0.08, *P*=0.77, Cramer's V=0.22, Fig. 7), and the second and third experimental period (χ^2=2.48, *P*=0.12, Cramer's V=0.22). The comparison between CT and ST showed no significant variation after the first (χ^2=0.07, *P*=0.79, Cramer's V=0.23, Fig. 7) second (χ^2=0.11, *P*=0.74, Cramer's V=0.19), and third month (χ^2=3.43, *P*=0.06, Cramer's V=0.22),

Fade colour: The analysis showed no significant difference in fade colouration between CT fish kept in the first and second month (χ^2=1.11, *P*=0.29, Cramer's V=0.25, Fig. 7), and the second and third experimental period (χ^2=0.0, *P*=1.0, Cramer's V=0.24). Meanwhile, no significant variation was found between ST fish reared in the first and second month (χ^2=0.06, *P*=0.81, Cramer's V=0.22, Fig. 7), while a significantly higher number of fade fish was found during the third month than those ST reared in the second month (χ^2=8.99, *P*<0.01, Cramer's V=0.16, Fig. 7). The comparison between CT and ST revealed significantly higher number of fade fish was found in ST after the first month (χ^2=3.26, *P*<0.01, Cramer's V=0.19, Fig. 7), second month (χ^2=6.61, *P*<0.05, Cramer's V=0.19) and third month (χ^2=30.48, *P*<0.001, Cramer's V=0.14).

DISCUSSION

Water salinity is an influent factor on performance aquatic animals and has affect dissolved oxygen consumption (Tsuzuki *et al.,* 2008; Ern *et al.,* 2014), feed intake (Wang *et al.,* 1997; Darwis *et al.,* 2009) and its conversion efficiency (Arunachalam and Reddy, 1979; Kang'ombe and Brown, 2008), hormones regulation (Cooperman *et al.,* 2010; Peyghan *et al.,* 2013)**,** metabolism (Peterson-Curtis, 1997; Urbina and Glover, 2015), growth (Wang *et al.,* 1997; Bœuf and Payan, 2001; Sarma *et al.,* 2013)**,** and survival of fish (Sarma *et al.,* 2013; Sarma *et al.,* 2020).

In the current study, the findings of low survival rates with the fluctuated salinity, many previous studies illustrated, survival rates of some other freshwater catfishes decreased with an increasing of salinity such as *Clarias batrachus* (Sarma *et al.,* 2013), *Clarias gariepinus* (Britz and Hecht, 1989) and *Heterobranchus longifilis* (Fashina-Bombata and Busari, 2003). Also some other freshwater fish as *Channa punctata* (Dubey *et al.,* 2016), *Labeo rohita* and *Cyprinus carpio* (Mubarik *et al.,* 2019) whereas, their survival rates were reduced by increasing water salinity.

Sarma *et al.* (2013), after 90 days of experiment, found that the survival rates of *C. batrachus* were 96.7, 93.3 and 83.3% that were reared at 0, 4, and 8 ppt respectively. Britz and Hecht (1989) monitored that, larval growth of *C. gariepinus* at salinity levels 0, 2.5, 5.0, 7.5, and 10 ppt did not significantly differ, also their survival rates did not variance up to 5 ppt. But, there was significantly higher mortality at 7.5 ppt and all larvae died within 48 hours at 10 ppt. Fashina-Bombata and Busari (2003) tested the salinity tolerance at difference larval stages of *H. Longifilis*. They showed that the MLS_{96h} were 4.35, 8.00 and 8.70% for the post-yolksac larvae, fingerlings and post-fingerlings, respectively. Several studies, confirmed that the extreme salinity pushed the fish to cope with osmotic pressure (Plaut, 1998; Sterzelecki *et al.,* 2013) and made changes in physiological activities (Gonzalez, 2012; Komoroske *et al.,* 2016) which resulted in a lot of energy expenditure

for maintenance (Ern *et al.,* 2014; Vaz *et al.,* 2015; Urbina and Glover, 2015). For example, Sarma *et al.* (2013) revealed in *C. batrachus* significantly lower levels of blood glucose and glycogen in liver tissue at higher salinity, indicating higher rate of physiological activities to salinity stress. They also exposed reduced level of ATPase in liver and muscle of *C. batrachus* at higher salinity, indicating higher energy expenditure to cope the stress of high salinity (Sarma *et al.,* 2010). Moreover, De-Boeck *et al.* (2000) showed salt exposure could reduce food consumption up to 70% in *C. carpio* and their growth and survival rate were negatively affected. Thus, the length of experimental period with huge salinity stress might cause significantly higher mortality in 10 ppt than those fish in 0 ppt in the present study.

The standard length and body area of both treatments were not significantly affected by the fluctuations salinity. The findings of the previous works indicated that *M. vittatus* and some species of catfish are able to tolerate the variation salinity in their habitats without having significant effects on their growth performance. Britz and Hecht (1989) showed that the larvae of *C. gariepinus* could tolerate up to 10 ppt salinity without significant differences in growth performance. In another study, Dubey *et al.* (2016) showed the growth of *C. punctata* was not significantly affected up to 10 ppt, although a growth curve decreased with increasing salinity. Similarly, the growth performance of *Ctenopharyngodon idella* was not significantly impacted up to 10 ppt (Kilambi, 1980). The findings of these studies are consistent with the present study demonstrating that *M. vittaus* is a stenohaline freshwater fish. However, further studies should be carried out to explore the possible mechanisms of their hyper-osmotic tolerance.

In our study, the ST fish had a significantly smaller tail than those were reared at 0 ppt. There is difficult to interpret changes in tail length, as there is no consensus in the literature explaining what the reasons that lead to modulate the tail size as a result of the environmental stress. The tail is the main functional organ of fish for swimming and locomotion. A lot of studies showed that the development and growth of tail in different fish can be hampered because of the environmental stress such as temperature, light, diet restriction, etc. For example, Rahman *et al.* (2019) found significantly longer anal fin when *Heteropneustes fossilis* were reared in lighting condition with shelter facility than those kept in completely darker condition. Also, the tail spine length of five Daphnia taxa was found significantly shorter under food restricted conditions (Spaak and Boersma, 1997). Working with rainbow trout and striped bass, Taylor *et al.* (1996), Sisson and Sidell (1987) and Swank and Rome (2000) reported that tail beat frequency in trout and bass was lower (i.e. having lower swimming speed) when fish were acclimated to a higher temperature.

Table 1. ANOVA results showing the impacts of rearing period and salinity of different phenotypic traits in *Mystus vittatus*. Values are presented as mean ± standard error (SE). Here, CT indicates the control treatment, while ST denotes the salinity treatment. Different letters of 'ab' indicate significant variation among CT, different letters of 'xy' indicate significant variation among ST and different letters of 'AB' indicate significant variation between CT and ST during the experimental periods. The analysis was done using 95% confidence level.

Response	1st month		2nd month		3rd month	
	CT (0 ppt)	ST (10 ppt)	CT (0 ppt)	ST (0 ppt)	CT (0 ppt)	ST (10 ppt)
Standard length (cm)	8.63 ± 0.13^{ax}	8.36 ± 0.15^{Ax}	8.78 ± 0.15^{ax}	8.54 ± 0.14^{Ax}	8.83 ± 0.15^{ax}	8.57 ± 0.15^{Ax}
Tail length (cm)	2.18 ± 0.03^{ax}	2.02 ± 0.03^{Ay}	2.28 ± 0.04^{abx}	2.12 ± 0.03^{Aby}	2.32 ± 0.04^{bx}	2.13 ± 0.04^{By}
Body area (cm^2)	11.92 ± 0.36^{ax}	11.68 ± 0.35^{ax}	12.26 ± 0.40^{ax}	12.05 ± 0.34^{ax}	12.09 ± 0.38^{ax}	11.48 ± 0.36^{ax}

Thus, the shorter tail of ST fish in the present study might be because of the effect of salinity stress. However, the underlying physiological mechanisms of this phenomenon are still unknown, and therefore, further study should be taken to explore the possible reasons of salinity impacts of reduced tail development.

Evidences appeared that some fish can modulate their colour patterns to cope with salinity stress. For examples, Küçük (2013) found that *Carassius carassius* reared in 15 ppt showed less appetite and dull colour, while Lawson and Alake (2011) observed body laceration and bleached yellow colouration after 6 ppt rather than their normal golden colour among the individuals of *C. auratus.* As well as, the body colour of *Liza aurata* fry was changed from their normal colour when they were kept in higher salinity (Moghadam *et al.,* 2013). Moreover, Stymphalia minnow (*Pseudophoxinus stymphalicus*) showed abnormal swimming behaviour and their backside became darkened in colour after 12 h at 13.5 ppt (Bianco and Nordlie, 2008). The possible reasons of normal body colour changes due to environment al stress were explained by variations in physiological parameters such as melanophores (Kulczykowska *et al.,* 2018), plasma cortisol (Owen *et al.,* 2010), skin carotenoids concentration (Doolan *et al.,* 2008), glucose level (Van der Salm *et al.,* 2006) and

others (Iwama *et al.,* 1995; Suzuki *et al.,* 1995; Costa *et al.,* 2017). The findings of the present study manifested that most of the colour has faded when fish were reared at a high salinity, this may be due to, their physiological adaptation with the salinity induced stress condition, which is needed to investigate with further studies.

Conclusion: Among various ecological factors, salinity is one of the most specific factors to the aquatic environment. It can be concluded from the present investigation that periodic changes of salinity directly influence the expression of some phenotypic traits of economically important stripped dwarf catfish. The overall results alarmingly show that salinity intrusions not only reduce their survival significantly but also change the tail length and body colour. Although salinity changes did not show any significant variations in standard length and body area, other important traits such as reproductive performances (gamete quality, fertilization, hormones, etc.) and offspring fitness of this valuable fish species should be focused in future studies. Additional research should also be conducted to explore how fish can adapt with the predicted salinity fluctuations and what are their adaptive physiological mechanisms that fish can maintain to cope with the unprecedented changes.

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