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Salinity tolerance and survival of an Indian major carp, *Cirrhinus mrigala* (mrigal): Feasibility assessment for rearing in inland saline water

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ABSTRACT

An experimental trial was conducted in triplicate to determine the effect of different salinity levels 0 (SA0), 2(SA2), 4(SA4), 6(SA6), 8(SA8) and 10 (SA10) ppt on survival, behaviour, and morphological changes in mrigal, *Cirrhinus mrigala* fingerlings during short-term rearing in inland saline water in glass aquaria for 10 days. Healthy fingerlings (average length-11.18 cm, average weight-11.05 g) of mrigal, procured from the Instructional cum Research Farm, College of Fisheries, were conditioned for one week at 0 ppt (freshwater) in FRP pools and conditioned fingerlings were gradually acclimated to varying salinities by raising the salinity by 1 ppt hourly and then stocked into glass aquaria of respective salinity levels @ 10 fingerlings aquarium^{-1}. Predetermined salinity levels and the water level were maintained in all the treatments and fish were fed with pelleted feed (crude protein 26.12%) @ 0.5% of fish body weight, once a day, as sustenance ration throughout the experimental period. The results indicated that all the water quality parameters, except temperature, varied significantly ($P \leq 0.05$) across treatments. Furthermore, no fish mortality occurred up to 6 ppt salinity during the experiment. In contrast, survival rates were 93.33% and 86.67% at 8 and 10 ppt salinity, respectively at the termination of the experiment. Normal swimming and feeding (feed intake) behaviour were recorded up to 6 ppt, whereas no adverse morphological changes were observed in fish during the tolerance test in all the treatments. From the above results, it can be concluded that mrigal, *C. mrigala* can tolerate salinity up to 6 ppt during short term (10 days) rearing in inland saline water.

Key words: *Mrigal, Salinity tolerance, Survival, Behaviour, Inland saline water*

Introduction

Aquaculture is a significant economic activity and it is regarded as one of the world's fastest growing food production sectors, contributing significantly to livelihood, employment, and revenue generation. With a total fish production of 14.16 million metric tons, India ranked second in the world for aquaculture production in 2019–20 and contributes around 7.58 % of the world's fish production (Annual Report, 2020-21, Dept. of Fisheries, GoI). Aquaculture has a vast potential for sustainably utilizing a wide variety of inland water resources in the country including inland saline areas. Among all freshwater species farmed in India, carps make up around 87 % of the total freshwater aquaculture production (Paul and Giri, 2015).

Globally, there is a significant threat to inland and coastal ecosystems from soil salinization (Herbert *et al*., 2015), particularly in semiarid and

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arid regions with low rainfall and high evapotranspiration rates. This has not only affected agricultural productivity but also negatively impacted the socio-economic well-being of farming communities (Singh *et al*., 2017; Ansal and Singh, 2019). It is estimated that 6.74 million hectares (mha) of land in India are affected by soil salinity, of which around 1.2 mha are situated in the non-coastal Indo-Gangetic plains of northern India, which is not suitable for agriculture (Singh and Ansal, 2021). The development of viable, sustainable and suitable aquaculture technologies in such salt-affected areas will allow these untapped natural resources to be converted into productive resources and increase the farmers' incomes (Kumar *et al*., 2017). Developing inland saline aquaculture is challenging because the chemistry of inland saline water differs from brackish/seawater. It can be overcome by modifying the chemistry or by selecting the species that are tolerant of differences (Allan *et al*., 2009).

Various physico-chemical properties of water influence primary and secondary production, thereby influencing fish production. Salinity is one of the major abiotic/physical factors influencing the survival, growth and metabolism of aquatic animals (Mubarik *et al*., 2015) and any fluctuation in water salinity beyond the tolerance level may results in to poor growth, health and mortality in fish (Gholampoor *et al*., 2011; Kumar *et al*. 2018; Singh *et al*, 2018). As aquaculture activity in Punjab is primarily based on freshwater carps, therefore, for its expansion as well as diversification in salt affected area, it is imperative to know the maximum salinity tolerance limit of important and widely cultivable freshwater fish species, such as mrigal, in inland saline water.

Many studies have been done to evaluate the effect of acute and chronic salinity stress on the salinity tolerance limit, survival and behavioral changes in fishes like rohu/Jayanti rohu (Kumar *et al*., 2018; Murmu *et al*., 2020), catla (Hoque *et al*., 2020), common carp (Mangat and Hundal, 2014; Singh *et al*., 2018), mrigal (Baliarsingh *et al*., 2018; Hoque *et al*., 2020) in artificial/inland saline water but comprehensive studies with respect to salinity tolerance, survival and behavioral responses (swimming, feed intake) in mrigal in inland saline water are scanty. Hence, the present study is designed to evaluate the salinity tolerance limit as well as behavioural and morphological changes in freshwater carp, *C. mrigala* (mrigal) during short term rearing in inland saline water at different salinity levels.

Materials and Methods

The present study was conducted in laboratory condition, in triplicate, at the Instructional cum Research Farm, College of Fisheries (30°54′21.5" N and 75°48′04.7" E), Guru Angad Dev Veterinary and Animal Sciences University in Ludhiana, Punjab for a period of 10 days.

Procurement of inland saline (stock) water and preparation of experimental salinity levels

From the salt-affected and water-logged areas of the village Birawala in the district of Mansa, Punjab, inland saline water was collected and used as stock water. This stock water was continuously aerated for 5 days and filtered with clean muslin cloth and the filtered water was diluted with freshwater (borewell water; salinity 0 ppt) for the preparation of different salinity levels *viz.* 2, 4, 6, 8 and 10 ppt and were designated as SA2, SA4, SA6, SA8 and SA10 treatments, whereas water with 0 ppt salinity (fresh water/bore well water) served as control (SA0).

Experimental setup

The experiment was carried out in glass aquaria (50 l), in triplicate, at different salinity (0, 2, 4, 6, 8 and 10 ppt) levels for 10 days. Healthy fingerlings (Av. length-11.18 cm, av. weight-11.05 g) of mrigal, *C. mrigala*, procured from the Instructional cum Research Farm, College of Fisheries, were conditioned for one week at 0 ppt (fresh water) in FRP pools under indoor condition prior to the conduct of experiment. For salinity tolerance test, conditioned fingerlings were gradually acclimated to varying salinities (2-10 ppt) by raising the salinity by 1 ppt hourly and then stocked into glass aquaria of respective salinity levels @ 10 fingerlings aquarium^{-1}. In order to maintain the acceptable oxygen level in water, all the experimental aquariums were continuously aerated by an air pump.

Throughout the study, salinity was monitored on daily basis and maintained according to the salinity of respective treatment. Fish excretory material and unutilized feed were siphoned out daily from each aquarium and water level in each tank was maintained at uniform level throughout the experiment. All the experimental aquariums were arranged following the completely randomized design (CRD) method.

Fish feed preparation and feeding

For the feeding of experimental fish, feed pellets (crude protein 26.12 %) were prepared using locally available ingredients *viz.* rice bran (49%), mustard meal (49%), vitamin-mineral mixture (1.5%) and common salt (0.5%). The proximate composition (crude protein, ether extract, ash, crude fiber and nitrogen free extract) of feed ingredients and formulated feed pellet (Table 1) was estimated as per standard methods (AOAC, 2005). During the experimental trial, fish were fed with pelleted feed @ 0.5% of fish body weight, once a day, as maintenance ration.

Observations recorded

All the physico-chemical parameters of water including temperature, pH, salinity, electric conductivity (EC), total alkalinity (TA), total hardness (TH), ammonical nitrogen (NH_3-N), nitrate-nitrogen (NO_3-N), orthophosphate (O-PO_4) and ionic composition like Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-} of the inland saline water (stock water) and water samples from each experimental aquaria were analyzed using standard method (APHA, 2005).

Fish survival, fish behavior with respect to swimming activity (active, less active), feed consumption/intake (normal, reduced appetite) and morphological changes (physical deformities) in fish were monitored on daily basis and were used for the assessment of salinity stress on the fish. The swimming response was determined by observing the swimming patterns of fish in the water column, and the feeding response was determined by observing the amount of leftover feed on the tank's bottom (Lawson and Alake, 2011). At the termination of the experiment, survival rate was calculated using the following formula:

$$\text{Survival (\%)} = \frac{\text{Total number of fish survived after 10 days}}{\text{Total number of fish stocked}} \times 100$$

Statistical analysis

Data were analyzed using one way ANOVA and Duncan's multiple range tests using statistical package SPSS 20.0 to study the significant differences ($P \leq 0.05$) among different treatments with respect to water quality parameters and survival (%) of fish.

Results and Discussion

The mean physico- chemical parameters of inland saline water (stock water) including temperature, pH, salinity, EC, TA, TH, NH_3-N, NO_3-N and O-PO_4 and ionic composition in terms of cations i.e. Na^+, K^+, Ca^{2+}, Mg^{2+} and anions i.e. Cl^- and SO_4^{2-} are presented in Table 2.

With respect to the ionic composition of stock water, among the cations, the relative abundance of Na^+ was higher than other cations ($Na^+ > Mg^{2+} > Ca^{2+} > K^+$), whereas among the anions, Cl^{-1} was the most abundant followed by SO_4^{2-}. Therefore, it can be con-

Table 1. Proximate composition (DM basis) of different feed ingredients and experimental feed

Ingredients/feed	Crude Protein (%)	Ether Extract (%)	Crude Fiber (%)	Ash (%)	Nitrogen Free Extract (%)
Rice Bran*	13.26	1.46	14.89	11.43	58.96
Mustard Meal*	39.21	2.09	11.16	7.83	39.71
Fish feed pellets	26.12	1.64	12.92	9.37	49.95

*Solvent extracted

Table 2. Water quality parameters of inland saline water (stock water):

Parameters	Mean value	Parameters	Mean value
Salinity (ppt)	15.0 ± 0.00	O-PO_4^{-3}(mg l^{-1})	0.038±0.02
Temperature (°C)	29.13±0.28	Na^+(mg l^{-1})	1063.34±9.10
pH	8.86 ±0.04	K^+(mg l^{-1})	64.42±1.08
EC (mS cm^{-1})	18.96 ±0.41	Ca^{2+}($CaCO_3$ mg l^{-1})	248.57 ±3.05
TA ($CaCO_3$ mg l^{-1})	396.64 ±4.16	Mg^{2+} ($CaCO_3$ mg l^{-1})	599.38 ±3.70
TH ($CaCO_3$ mg l^{-1})	2296.78 ±3.46	Cl^- (mg l^{-1})	3107.23±11.87
NH_3-N (mg l^{-1})	0.089 ±0.002	SO_4^{2-} (mg l^{-1})	152.13±3.83
NO_3-N (mg l^{-1})	0.007±0.001	*Values are Mean ± SE	

cluded that Na^+ and Cl^- were the most dominant cation and anion, respectively in the inland saline (stock) water. Similar trends were also recorded by Sharma *et al*. (2017), Singh *et al*. (2018) and Kumar *et al*. (2018) in inland saline water collected from different salt affected locations of Punjab.

The physico-chemical properties of water of different treatments (SA0-SA10) are presented in Table 3. The values of all the water quality parameters, except temperature, varied significantly ($P \leq 0.05$) among different treatments. Further, except temperature and DO, all the parameters increased progressively with the increase in salinity; the highest and lowest values were recorded in 10 ppt (SA10) and control (SA0), respectively. This increment can be attributed to the increasing concentration of ions with increase in salinity levels.

According to Ertan *et al*. (2015), water quality influences fish metabolism, feed intake, and survival rates. Depending on the species, fish grow best at a certain temperature range and any significant variation beyond the preferred range adversely affects the fish survival and growth (Buttner *et al*., 1993). Even though carp can grow well at temperatures from 18 – 37 ºC (Jhingran, 1991), but the better temperature range for growth is 25-32 ºC (Boyd, 1998). Similarly, the temperature of different treatments stayed within the permissible range for carps in the present study as well. The D.O. is the most important abiotic factor in aquaculture (Boyd, 1998), affecting fish growth and survival both in natural (Taylor and Miller, 2001) and cultured environments (Piper, 1982) and should be greater than 5 mg l^{-1} for good survival and optimum productivity for carps (Swingle, 1967; Boyd, 1998), while the optimal pH range for carps is 6.5 to 9.0 (Boyd and Pillai, 1984; Jhingran, 1991; Boyd and Tucker, 1998). In the present investigation, the pH and DO remained well within the optimum range for carps thus depicted that there was no detrimental effect of varying salinity on the pH and DO of water. The above findings are in agreement with Singh *et al*. (2020) who also reported these parameters with in optimum limits for carps at different salinities.

With increasing salinity levels, water EC, TA, and TH increased owing to variation in ionic composition of water and their respective capacities for conducting electric current in different treatments (Sharma *et al*., 2017; Purnamawati *et al*., 2019). Further, the optimum range of TH for aquafarming is 50-300 mg l^{-1} and above optimum limit, it has an adverse effect on ability of gills to bind ions and homeostatic equilibrium in fish (Purnamawati *et al*., 2019) thus affecting survival and growth of fish (Bhatnagar *et al*., 2004), which was evident in the present study in higher salinity treatments. Ammonia is a major problem in high density fish culture systems and in a culture system where fish are fed

Table 3. Mean physico-chemical parameters and ionic composition of water in different treatments (SA0-SA10) during salinity tolerance test

Parameters	Treatments*					
	SA0	SA2	SA4	SA6	SA8	SA10
Temperature (ºC)	$29.90^{a}\pm0.14$	$29.77^{a}\pm0.20$	$29.92^{a}\pm0.17$	$29.94^{a}\pm0.15$	$29.90^{a}\pm0.17$	$30.06^{a}\pm0.08$
pH	$7.82^{f}\pm0.019$	$7.98^{e}\pm0.012$	$8.12^{d}\pm0.035$	$8.22^{c}\pm0.022$	$8.40^{b}\pm0.009$	$8.54^{a}\pm0.027$
DO (mg l^{-1})	$7.06^{a}\pm0.02$	$6.87^{b}\pm0.04$	$6.90^{b}\pm0.03$	$6.97^{ab}\pm0.01$	$6.87^{b}\pm0.03$	$6.90^{b}\pm0.06$
Conductivity (mS cm^{-1})	$0.59^{f}\pm0.02$	$3.0^{e}\pm0.04$	$7.06^{d}\pm0.04$	$9.94^{c}\pm0.05$	$11.23^{b}\pm0.17$	$12.88^{a}\pm0.19$
Alkalinity(mg l^{-1})	$274.33^{f}\pm2.91$	$299.33^{e}\pm3.38$	$332.67^{d}\pm3.48$	$378.00^{c}\pm2.08$	$411.00^{b}\pm4.36$	$424.00^{a}\pm4.93$
Hardness(mg l^{-1})	$291.33^{f}\pm2.03$	$394.00^{e}\pm3.46$	$541.00^{d}\pm2.52$	$850.00^{c}\pm3.61$	$1008.67^{b}\pm6.01$	$1228.33^{a}\pm4.98$
Ammonia (mg l^{-1})	$0.019^{e}\pm0.002$	$0.021^{e}\pm0.001$	$0.025^{cd}\pm0.002$	$0.029^{bc}\pm0.002$	$0.032^{ab}\pm0.002$	$0.036^{a}\pm0.003$
Nitrate (mg l^{-1})	$0.014^{c}\pm0.001$	$0.015^{c}\pm0.002$	$0.016^{ab}\pm0.002$	$0.017^{ab}\pm0.001$	$0.019^{a}\pm0.001$	$0.020^{a}\pm0.002$
Orthophosphate (mg l^{-1})	$0.008^{d}\pm0.000$	$0.009^{bc}\pm0.001$	$0.011^{b}\pm0.001$	$0.011^{b}\pm0.001$	$0.012^{b}\pm0.001$	$0.015^{a}\pm0.002$
Na^+ (mg l^{-1})	$52.07^{f}\pm1.25$	$159.85^{e}\pm3.01$	$326.07^{d}\pm3.48$	$548.05^{c}\pm2.92$	$633.70^{b}\pm2.42$	$794.09^{a}\pm4.45$
K^+ (mg l^{-1})	$6.82^{f}\pm0.55$	$11.77^{e}\pm0.64$	$15.92^{d}\pm0.29$	$30.15^{c}\pm1.28$	$46.69^{b}\pm0.54$	$55.89^{a}\pm0.65$
Cl^-(mg l^{-1})	$59.64^{f}\pm1.63$	$251.87^{e}\pm1.70$	$549.55^{d}\pm3.72$	$987.28^{c}\pm2.84$	$1153.95^{b}\pm2.80$	$1252.73^{a}\pm2.33$
Ca^{2+} (mg l^{-1})	$47.59^{f}\pm1.42$	$71.99^{e}\pm1.56$	$109.33^{d}\pm1.72$	$125.45^{c}\pm2.01$	$139.62^{b}\pm1.73$	$183.82^{a}\pm1.59$
Mg^{2+} (mg l^{-1})	$62.24^{f}\pm1.22$	$91.29^{e}\pm1.36$	$173.80^{d}\pm2.84$	$219.81^{c}\pm0.31$	$260.50^{b}\pm3.20$	$276.15^{a}\pm0.67$
SO_4^{2-} (mg l^{-1})	$11.12^{f}\pm0.02$	$61.09^{e}\pm0.99$	$82.00^{d}\pm1.51$	$95.82^{c}\pm1.74$	$105.92^{b}\pm1.97$	$121.22^{a}\pm1.84$

*SA0 = 0 ppt, SA2= 2ppt, SA4 = 4 ppt, SA6 = 6ppt, SA8= 8 ppt, SA10= 10ppt

Values are Mean ± SE, Values with same superscripts (a,b,c…..f) in a row do not differ significantly ($P \leq 0.05$)

with high protein feed, as it is toxic to fish at high concentrations (Buttner *et al*., 1993). According to Wurts (2000), pH and salinity have positive correlation with ammonia and in the present study as well, it has been observed that concentration of ammoniacal-nitrogen varied significantly (P≤0.05) at higher salinity levels, though it was within permissible limit (≤0.05 mg l^{-1}) for carps (Jhingran, 1991; Ayyappan, 2011). Furthermore, significant (P≤0.05) differences were also observed in the cations and anions concentration among different treatments and showed an increasing trend (P≤0.05) with increase in salinity levels. Moreover, alike stock water, amongst different cations, Na^+ was the most prevailing cations (Na^+>Mg^{2+}>Ca^{2+}>K^+), whereas among the anions, Cl^{-1} was the most abundant followed by SO_4^{2-} in the treatments having salinity level of 2-10 ppt. The conclusion of the current study can be supported by the similar findings with respect to ionic concentration at different salinities (Sharma *et al*., 2017; Chitra *et al*., 2017; Singh *et al*., 2018; Bhatt *et al*., 2018; Kumar *et al*., 2018; Singh *et al*. 2020).

Survival of fish

Survival of fish was recorded on daily basis during the tolerance test and is presented in Figure 1 and 2. During the salinity tolerance test (10 days), no mortality of fish was recorded up to 6 ppt salinity levels at any day indicating that mrigal, a stenohaline freshwater fish, can tolerate salinity levels up to 6 ppt under short term salinity stress in inland saline water. At 8 ppt salinity, 96.67 and 93.33 % survival was observed on 9th and 10th day, while survival% reduced from 100 % on 7th day to 86.67% on 10th day at 10 ppt salinity. Hence, fish survival depicted an inverse relationship with salinity beyond 6 ppt.

Each fish species has an ideal salinity tolerance

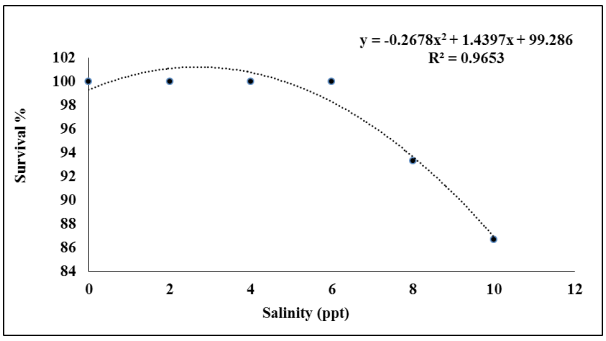

Fig. 1. Survival (%) of mrigal, *C. mrigala* with respect to changes in salinity at the termination of the experiment

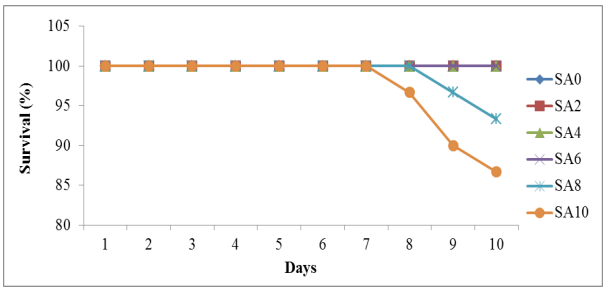

Fig. 2. Survival (%) of mrigal, *C. mrigala* during the experimental period in different treatments

range (Martinez-Porchas *et al*., 2009) that depends on its physiological condition, which is a result of the multifaceted interactions between its nervous system, metabolism, and physiology (Sharma *et al*., 2017) and any alteration in salinity can bring osmotic stress in aquatic animals, including fish, by interfering with physiological homeostasis and normal biological processes and also hasten oxidative damage (Kültz, 2015; Abdel-Tawwab and Monier, 2018) which affects the survival, metabolism, and distribution of fish species (Suresh and Lin, 1992; Ranjbar and Nejad, 2020).

Many studies demonstrated the effect of brackish water/artificial saline water of different salinities on the survival of freshwater carps and recorded varied salinity tolerance limit viz. 4 and 8 ppt for mrigal (Baliarsingh *et al*., 2018; Hoque *et al*., 2020), 6 ppt for common carp (Mangat and Hundal, 2014, Singh *et al*., 2019), 6 ppt for rohu (Tarer, 2000; Islam *et al*., 2014) and < 5 ppt for catla (Hoque *et al*., 2020) but studies pertaining to use of inland saline water is limited. In reference to the salinity tolerance of freshwater carps in inland saline water, Singh *et al*. (2020) documented that amur carp can tolerate salinity up to 5 ppt (100% survival) during long term rearing, while koi carp, rohu and common carp can tolerate salinity up to 12, 10 and 10 ppt, respectively (100% survival) during short term (10 days) rearing (Sharma, 2017; Kumar *et al*., 2018; Singh *et al*., 2018). Among freshwater catfish, Kumar *et al*. (2017) reported that *Pangasianodon hypophthalmus* can tolerate the salinity up to 15 ppt in inland saline water. The variances between findings may be attributable to the experimental variables in regard to species, fish size, genetic variability, water quality parameters including salinity, saline water composition, and salinity stress duration (Ansal *et al*., 2016; Singh *et al*., 2018; Purnamawati *et al*., 2019) and adapting ability of fish to ever-changing environmental condi-

tions (Koedijk *et al*., 2012).

It has been shown that salinity stress primarily affects gills of freshwater fish, which are essential for both osmoregulation and nitrogenous waste excretion (Nikolsky and Birkett, 1963). Further, a larger osmotic gradient between fish body fluid and culture environment might result in a greater consumption of energy for osmoregulation process (Arjona *et al.*, 2009), affecting growth and survival of fish. In rainbow trout, Ranjbar and Nejad (2020) found that increasing salinity activated the hormonal pathways, particularly thyroid and cortisol hormones, to adapt to osmotic stress. In the present investigation, 100% survival up to 6 ppt salinity implies that the fish were very capable of regulating their body physiology with in this limit (Singh *et al*., 2019) and decrease in survival at higher salinities (>6 ppt) may be corroborated to increase in osmotic maintenance requirement of fish at higher salinity levels (Kilambi and Zdinak, 1980) causing osmoregulatory stress, a detrimental effect of salinity exposure for stenohaline freshwater fish.

Effect of salinity on behavior and morphological changes in fish

During salinity tolerance test, swimming response of fish was normal and fish were active up to 6 ppt salinity (Table 4). At 8 and 10 ppt salinity, fish showed gradual departure from normal swimming behaviour and less activity of fish was recorded on 10th and 9th day, respectively. Further, similar trend was also recorded in feeding behaviour of fish with respect to feed intake in the present study where reduced appetite response was observed on 9th and 8th day at 8 and 10 ppt salinity, respectively.

Few studies have documented the change in swimming behaviour of fish due to change in salinity level (Sharma, 2017; Kumar *et al.,* 2018; Singh *et al*., 2018). Kumar *et al.* (2018) demonstrated active swimming behaviour of rohu up to 4 ppt salinity, whereas fish became less active/sluggish at intermediate (6 ppt) and higher salinities (8-10 ppt) during short term exposure in inland saline water, whereas Singh *et al.* (2018) revealed active swimming behaviour of common carp up to 8 ppt but fish become less active at 10 ppt after 8 days of salinity exposure during salinity tolerance test in inland saline water. With reference to feeding response (feed intake), Mangat and Hundal (2014) demonstrated high/moderate appetite behaviour between 0-6 ppt in common carp, whereas in rohu, very high appetite behaviour was recorded up to 4 ppt salinity but sequentially reduced at ≥ 6 ppt (Islam *et al*., 2014). Further, during salinity tolerance test conducted in inland saline water, Kumar *et al.* (2018) reported normal feeding of rohu up to 6 ppt, while low appetite was observed at 8 and 10 ppt on 9th and termination day (10th) of the experiment. In contrast, Singh *et al.* (2018) documented normal feeding behavior of common carp in inland saline water for 10 consecutive days during salinity tolerance test. Due to increased metabolic rate, fish become restless at higher salinities, which mean fish are approaching the limits of their tolerance for salinity (Islam *et al*., 2014; Singh *et al*., 2019). Furthermore, no adverse morphological changes in fish were observed during tolerance testing in any treatment. Scales and fins were intact and no excess mucus secretion was observed at any salinity level throughout the experiment.

Table 4. Swimming activity, feeding response and morphological changes in mrigal, *C. mrigala* during the salinity tolerance test

Behavior	Days	Treatments					
		SA0	SA2	SA4	SA6	SA8	SA10
Swimming Activity*	**1-7**	AT	AT	AT	AT	AT	AT
	8	AT	AT	AT	AT	AT	LAT
	9	AT	AT	AT	AT	LAT	LAT
	10	AT	AT	AT	AT	LAT	LAT
Feeding Behavior**	**1-7**	NOR	NOR	NOR	NOR	NOR	NOR
	8	NOR	NOR	NOR	NOR	NOR	ReAp
	9	NOR	NOR	NOR	NOR	ReAp	ReAp
	10	NOR	NOR	NOR	NOR	ReAp	ReAp
Morphological Changes***	**1-10**	N	N	N	N	N	N

* Swimming Activity: AT = Active, LAT = Less Active; **Feeding response: NOR= Normal Appetite, ReAp = Reduced Appetite; ***Morphological changes: N= No

From the above results, it can be concluded that mrigal, *C. mrigala* can tolerate salinity up to 6 ppt during short term (10 days) rearing in inland saline water without any detrimental effect on survival %, behavioral and morphological characteristics of fish.

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Conflict of Interest

Authors declare no conflict of interest among the authors.

References

Abdel-Tawwab, M. and Monier, M.N. 2018. Stimulatory effect of dietary taurine on growth performance, digestive enzymes activity, antioxidant capacity, and tolerance of common carp, *Cyprinus carpio* L., fry to salinity stress. *Fish Physiology and Biochemistry*. 44(2): 639-649.

Allan, G.L., Fielder, D.S., Fitzsimmons, K.M., Appelbaum, S.L., Blaustein, J. and Raizada, S. 2009. Inland saline aquaculture. In: Burnell, G. and Allan, G. (Eds.), *New Technologies in Aquaculture: Improving Production Efficiency, Quality and Environmental Management,* (pp. 1119-1147). Wood head Publishing Limited and CRC Press LCC, ISBN 978-1-84569-384-8.

Annual Report, 2020-21. Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India.

Ansal, M.D. and Singh, P. 2019. Development of inland saline-water aquaculture in Punjab, India. Global Aquaculture Advocate. https://www.aquaculturealliance. org/advocate/development-inland-saline-water-aquaculturepunjab-india/?headlessPrint= AAAAAPIA9c8r7gs82oW.

Ansal, M.D., Dhawan, A., Singh, G. and Kaur, K. 2016. Species selection for enhancing productivity of freshwater carps in Inland Saline Water of Punjab-A Field Study. *Indian Journal of Ecology*. 43(1): 45-49.

AOAC, 2005. *Official Methods of Analysis.* 18th edition, Association of official analytical chemists, Washington DC, USA.

APHA. 2005. *Standard Methods for the Examination of Water and Waste Water*. 21st Edition, American Public Health Association, Washington DC, USA.

Arjona, F. J., Vargas-Chacoff, L., Ruiz-Jarabo, I., Gonçalves, O., Páscoa, I., del Río, M. P. M. and Mancera, J. M. 2009. Tertiary stress responses in Senegalese sole (*Solea senegalensis* Kaup, 1858) to osmotic challenge: Implications for osmoregulation, energy metabolism and growth. *Aquaculture*. 287(3-4): 419-426.

Ayyappan, S., Moza, U., Gopalakrishnan, A., Meenakumari, B., Jena, J. K. and Pandey, A. K. (Eds.). 2011. *Handbook of Fisheries and Aquaculture*. (pp 1116). Directorate of Information and Publication, ICAR, New Delhi.

Baliarsingh, M.M., Panigrahi, J.K. and Patra, A.K. 2018. Effect of salinity on growth of *Cirrhinus cirrhosus* in captivity. *Indian Journal of Applied Research.* 8(5): 24-26.

Bhatnagar, A., Jana, S.N., Garg, S.K., Patra, B.C., Singh, G. and Barman, U.K. 2004. Water quality management in aquaculture. *Course Manual of summer school on development of sustainable aquaculture technology in fresh and saline waters, CCS Haryana Agricultural, Hisar (India)*. 3: 203-210.

Bhatt, D., Kaur, V.I., Ansal, M.D. and Kumar, P. 2018. Salinity tolerance of freshwater shubunkin gold fish, *Carassius auratus* (Linn.): Suitability for rearing in inland saline water. *Indian Journal of Ecology*. 45(4): 876-880.

Boyd, C. E. 1998. Water Quality for Pond Aquaculture. Research and development Series No. 43. pp 37. International Centre for Aquaculture and Aquatic Environment, Auburn University, Alabama.

Boyd, C.E. and Pillai, V.K. 1984. Water Quality Management in Aquaculture. CMFRI, Special Publication No. 22. (pp 1-96). Central Marine Fisheries Research Institute, Cochin.

Boyd, C.E., and Tucker, C.S. 1998. *Pond Aquaculture Water Quality Management.* Kluwer Academic Publishers, Boston, London.

Buttner, J.K., Soderberg, R.W. and Terlizzi, D E. 1993. An Introduction to Water Chemistry in Freshwater Aquaculture. Northeastern Regional Aquaculture Center Fact Sheet No. 170. University of Massachusetts, North Dartmouth, MA. On-line publication.

Chitra, V., Muralidhar, M., Saraswathy, R., Dayal, J.S., Lalitha, N., Thulasi, D. and Nagavel, A. 2017. Mineral availability from commercial mineral mixtures for supplementation in aquaculture pond waters of varying salinity. *International Journal of Fisheries and Aquatic Studies.* 5(4): 430-434.

Ertan, E., Agrah, N. and Tarkan, A.S. 2015. The effects of salinity, temperature and feed ratio on growth performance of European sea bass (*Dicentrarchus labrax* L., 1758) in the water obtained through reverse osmosis system and a natural river. *Pakistan Journal of Zoology*. 47: 625-633.

Gholampoor, T.E., Imanpoor, M.R., Shabanpoor, B. and Hosseini, S.A. 2011. The study of growth performance, body composition and some blood parameters of *Rutilus frisii kutum* (Kamenskii, 1901) fingerlings at different salinities. *Journal of Agricultural*

Science and Technology. 13(6) : 869-876.

Herbert, E.R., Boon, P., Burgin, A.J., Neubauer, S.C., Franklin, R.B., Ardón, M. and Gell, P. 2015. A global perspective on wetland salinization: ecological consequences of a growing threat to freshwater wetlands. *Ecosphere. 6*(10): 1-43.

Hoque, F., Adhikari, S., Hussan, A., Mahanty, D., Pal, K. and Pillai, B.R. 2020. Effect of water salinity levels on growth performance and survival of *Catla catla*, genetically improved *Labeo rohita* (Jayanti rohu) and *Cirrhinus mrigala. International Journal of Oceanography & Aquaculture*. 4 (2): 00190. https://doi.org/10.23880/ijoac-16000190

Islam, M., Ahsan, D.A., Mandal, S.C. and Hossain, A. 2014. Effects of salinity changes on growth performance and survival of rohu fingerlings, *Labeo rohita* (Hamilton, 1822). *Journal of Coastal Development*. 17(1): 1000379. DOI: 10.4172/1410-5217.1000379

Jhingran, V.G. 1991. *Fish and Fisheries of India.* 5th Edn., Hindustan publishing Corporation, New Delhi.

Kilambi, R.V. and Zdinak, A. 1980. The effects of acclimation on the salinity tolerance of grass carp, *Ctenopharyngodon idella* (Cuv. and Val.). *Journal of Fish Biology*. 16(2): 171-175.

Koedijk, R., Imsland, A.K., Folkvord, A., Stefansson, S. O., Jonassen, T. M. and Foss, A. 2012. Larval rearing environment influences the physiological adaptation in juvenile Atlantic cod, *Gadus morhua*. *Aquaculture International*. 20(3): 467-479.

Kültz, D. 2015. Physiological mechanisms used by fish to cope with salinity stress. *The Journal of Experimental Biology*. 218(12) : 1907-1914.

Kumar, A., Harikrishna, V., Reddy, A.K., Chadha, N.K. and Babitha, A.M. 2017. Salinity tolerance of *Pangasianodon hypophthalmus* in inland saline water: effect on growth, survival and haematological parameters. *Ecology, Environment and Conservation*. 23: 475-482.

Kumar, M.U., Ansal, M.D. and Kaur, V.I. 2018. Salinity tolerance and survival of freshwater carp, *Labeo rohita* Ham.(rohu) in inland saline water. *Indian Journal of Ecology*. 45(4) : 872-875.

Lawson, E.O. and Alake, S.A. 2011. Salinity adaptability and tolerance of hatchery reared comet goldfish *Carassius auratus* (Linnaeus 1758). *International Journal of Zoological Research*. 7(1): 68-76.

Mangat, H.K. and Hundal, S.S. 2014. Salinity tolerance of laboratory reared fingerlings of common carp, *Cyprinus carpio* (Linn.) during different seasons. *International Journal of Advanced Research*. 2(11): 491-496.

Martínez-Porchas, M., Martínez-Córdova, L. R. and Ramos-Enriquez, R. 2009. Cortisol and glucose: reliable indicators of fish stress?. *Pan-American Journal of Aquatic Sciences*. 158-178.

Mubarik, S.M., Ismail, A., Hussain, S.M., Samiullah, F.J.K., Yaqub, S., Ahmad, S., Feroz, K., Khan, M.T., Nazli, S. and Ahma, B. 2015. Survival, growth and body composition of *Cyprinus carpio* under different levels of temperature and salinity. *International Journal of Biosciences*. *6*(10): 132-141.

Murmu, K., Rasal, K.D., Rasal, A., Sahoo, L., Nandanpawar, P.C., Udit, U.K. and Sundaray, J.K. 2020. Effect of salinity on survival, hematological and histological changes in genetically improved rohu (Jayanti), *Labeo rohita* (Hamilton, 1822). *Indian Journal of Animal Research*. 54(6): 673-678.

Nikolsky, G.V. and Birkett, L. 1963. *The Ecology of Fishes* (Vol. 352). London: Academic press.

Paul, B.N. and Giri, S.S. 2015. Fresh water aquaculture nutrition research in India. *Indian Journal of Animal Nutrition*. 32(2) : 113-125.

Piper, R.G. 1982. *Fish Hatchery Management.* US Department of the Interior, Fish and Wildlife Service.

Purnamawati, Nirmala, K., Affandi, R., Dewantoro, E. and Utami, D.A.S. 2019. Survival and growth response of snakehead fish *Channa striata* juvenile on various salinity levels of acid sulfate water. *AACL Bioflux*. 12(4) : 1467-1479.

Ranjbar, M. and Nejad, M.M. 2020. Effect of water salinity on enzymatic and hormonal indices of (*Oncorhynchus mykiss*) fingerlings. *International Aquatic Research*. 12(4): 309-314.

Sharma, M. 2017. Survival, growth, coloration and immune responses of fresh water ornamental fish koi carp, *Cyprinus carpio* (Linnaeus) in inland saline water. [M.F.Sc. Thesis, GADVASU, Punjab, India].

Sharma, M., Kaur, V.I. and Ansal, M.D. 2017. Physiological responses of freshwater ornamental fish koi carp, *Cyprinus carpio* (L.) in inland saline water: growth and haematological changes. *Indian Journal of Ecology*. 44(4): 864-868.

Singh, E., Bhatt, N., Priyadarshini, A., Surnar, S.R. and Reang, V. 2019. Survival and growth performance of *Cyprinus carpio* under different levels of salinity during summer season. *International Journal of Pure and Applied Bioscience.* 7 (3): 189-194.

Singh, G., Ansal, M.D. and Kaur, V.I. 2018. Salinity tolerance and survival of freshwater carp, *Cyprinus carpio* Linn. in inland saline water. *Indian Journal of Ecology*. 45 : 598-601.

Singh, P. and Ansal, M.D. 2021. Shrimp farming in Punjab and the future. *Smart Agripost-Fisheries.* 6(4): 6-11.

Singh, S., Jahan, I., Sharma, A. and Misra, V.K. 2017. Inland Saline Aquaculture – A hope for farmers. *International Journal of Global Science Research*. 4(2): 577-593.

Singh, S., Reddy, A.K., Harikrishna, V., Srivastava, P.P. and Lakra, W.S. 2020. Growth and osmoregulatory response of *Cyprinus carpio haematopterus* (Amur carp) reared in inland saline water. *Indian Journal of Animal Sciences*. 90(1): 120-124.

Suresh, A.V. and Lin, C.K. 1992. Tilapia culture in saline waters: A review. *Aquaculture*. 106(3-4): 201-226.

Swingle, H.S. 1967. Standardization of chemical analysis for waters and pond muds. *FAO Fisheries Report*. 4(4): 397-421.

Tarer, S.R. 2000. *The effect of salinity on the growth and tolerance of Labeo rohita and Cirrhinus mrigala* [M. Phil. Thesis, Department of Zoology and Fisheries, University of Agriculture], Faisalabad, Pakistan.

Taylor, J.C. and Miller, J.M. 2001. Physiological performance of juvenile southern flounder, *Paralichthys lethostigma* (Jordan and Gilbert, 1884), in chronic and episodic hypoxia. *Journal of Experimental Marine Biology and Ecology*. 258(2): 195-214.

Wurts, W.A. 2000. Sustainable aquaculture in the twenty-first century. *Reviews in Fisheries Science*. 8(2): 141-150.