



The Potential Impact of Sodium Chloride on the Behaviour of *Oreochromis niloticus*

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ABSTRACT

Background: This study investigates the behavioural effects of sodium chloride (NaCl) on *Oreochromis niloticus* (Nile Tilapia), a widely cultivated aquaculture species. Recognizing the common use of NaCl in fish farming for disease management and stress relief, the study explores whether low, sub-recommended concentrations of NaCl could influence fish behaviour under chronic exposure.

Methods: Experimental groups were exposed to 0.8 g/L (Low) and 1.6 g/L (High) NaCl for 10 and 60 days, while a control group remained in NaCl-free water. Six key behavioural parameters were monitored: Feeding, rheotaxis sensitivity, acoustic sensitivity, aggression, midline crossing and surfacing.

Result: The results revealed clear dose-dependent and time-dependent changes in behaviour across all parameters. Even at concentrations significantly lower than the standard therapeutic range of 4-8 g/L, NaCl caused measurable behavioural alterations. These findings suggest that NaCl, while conventionally deemed benign, may exert subtle yet significant effects on fish behaviour when used chronically at low levels. The study holds important implications for aquaculture practice and fish welfare. Behavioural indicators may serve as early-warning tools for physiological or toxicological stress, encouraging a more refined and cautious approach to salt application in aquaculture systems. The research challenges existing assumptions about the neutrality of salt treatments and emphasizes the need to re-evaluate routine input standards. This work is among the few to document behavioural impacts of low-dose NaCl exposure in a resilient species like tilapia, offering original insights into aquaculture toxicology and advocating for behaviour-based toxicity screening in future studies.

Key words: Behavior, NaCl, Tilapia.

INTRODUCTION

Sodium chloride (NaCl), often referred to as the “aspirin of aquaculture,” plays a vital role in fish farming due to its wide range of applications (El-Gawad *et al.*, 2016). It has been effectively used for treating fungal infections in fish and eggs, managing bacterial diseases (Fathollahi *et al.*, 2020) and controlling parasitic infections such as proliferative kidney disease caused by *Tetracapsuloides bryosalmonae* (Enevoa *et al.*, 2018). Additionally, NaCl supports critical processes such as fertilization, reproduction and early development, primarily by reducing stress and enhancing osmoregulatory function in aquatic animals (Burgdorf-Moisuk *et al.*, 2011).

In terms of survival, NaCl is essential for maintaining homeostasis in fish, particularly under stressful or fluctuating environmental conditions. NaCl baths at concentrations of 30.0-60.0 g/L have been shown to improve weight gain, relative growth rate and specific growth rate in *Oreochromis niloticus* (Elrahman *et al.*, 2016). Moreover, for safe transportation, concentrations ranging from 4.0-10.0 g/L for up to 5 hours are recommended for this species (Tavares-Dias, 2022), further emphasizing its practical relevance in aquaculture management.

Beyond physiological effects, NaCl can also influence fish behavior, which serves as a sensitive and immediate indicator of environmental stress. Behavioral adaptability is a crucial survival strategy in animals, complementing

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slower physiological adjustments (Salvanes *et al.*, 2013; Sewall, 2015; Tseng *et al.*, 2020). Fish, being ectothermic, are especially responsive to external changes, with factors like temperature, salinity and chemical exposure leading to notable alterations in behavior such as changes in swimming patterns, aggression and respiratory rates (Hansen *et al.*, 2016; Olusanya and van Zyll de Jong, 2018; Tong *et al.*, 2020; Alfonso *et al.*, 2021; Keen *et al.*, 2017). Sub-lethal effects have been well-documented in species like *Tilapia mossambica* and *Oreochromis niloticus*, highlighting behavior as a critical endpoint in toxicological

studies (Shrivastava *et al.*, 2011; Khalil and Emeash, 2018; Fattah *et al.*, 2020).

Oreochromis niloticus (Nile tilapia) is widely used in aquaculture due to its hardy nature, broad salinity tolerance and fast growth. Its economic value and adaptability make it a suitable model organism for investigating the physiological and behavioral effects of environmental factors such as salinity.

The present study aims to evaluate the behavioral effects of sodium chloride exposure in *Oreochromis niloticus*, with a focus on understanding how varying concentrations may alter fish activity, stress response and adaptability. These findings are expected to contribute significantly to the development of behavioral biomarkers for stress in aquaculture settings and support sustainable fish health management practices.

MATERIALS AND METHODS

Collection and maintenance of experimental fishes

The fish utilized were tilapia, *Oreochromis niloticus* (with mean weight of 14.5 ± 2.54 g), acquired from a commercial fish farm. These fish were carefully examined for any signs of pathogenic infection and transferred into a 500 L of capacity tank for 15 days. Prior to the transfer, the acclimation tanks were cleaned with 0.1% KMnO_4 to eliminate any fungal or dermal infections. During this acclimation period the fish were fed with commercial ration and water changes were performed three times per week to ensure optimal conditions. The original day-night light cycle remained uninterrupted and temperature between the range 25 to 30°C. Throughout the acclimatization period, the tank remained aerated and fish mortality remained below 10%.

Experimental design

The study was conducted in the Department of Zoology at Mar Thoma College for Women, Perumbavoor, during January-February 2025. In the present study, healthy *Oreochromis niloticus* were used. After 15 days acclimatization, in the stocking tank, fish used for study was transferred to 20 litre circular plastic troughs (6 fish/ trough) and closed with circular nets. The troughs containing equal volumes of water were employed, with consistent maintenance of water quality, temperature and aeration across the tanks. Experimental groups, namely, L (0.8 g/L of sodium chloride) and H (1.6 g/L of sodium chloride), along with control groups were maintained for 10 and 60 days each as triplicate sets. The dose selected was much below the recommended safe limits prescribed for usage. Fish of similar size and weight (20.16 ± 4.26 g and mean length of 9.44 ± 0.91 cm) were selected. They were provided with the same quantity of food at regular intervals. After acclimatization, the behavioral assessment of tilapia was carried out for 5 days continuously during the days of exposure:

5-10 days (10-day period)

55-60 days (60-day period)

For 3 sections (2 hour each):

Morning (6-8 am)

Noon and (11 am- 1 pm)

Evening (4-6 pm)

Behaviours were noted visually by using a note book for recording behavior, a stop watch and video camera (Altmann, 1974) according to predetermined criteria (Stephan *et al.*, 2004; Hale *et al.*, 2006; Ferey and Miller, 1972; Scott *et al.*, 2003). Recorded values were averaged and subjected to statistical analysis.

The behaviours included:

Food response

Time taken to complete the feed provided (seconds).

Rheo sensitivity

Rheological disturbances were created by moving a glass rod in water and fish movement was observed. The time taken to create an abnormal swimming pattern or imbalance (sec) was noted.

Acoustic sensitivity

As for acoustic responses, fish movement on tapping the tank surface with a pencil was done. The time taken (sec) for which the response lasted was noted.

Aggressiveness

Fish orienting itself and swimming towards another fish, nips, chases and defensive acts (fish responding to an aggressive act by other fish)- agonistic behaviour. The number of aggressive encounters during the observation hours was noted.

Surfacing behavior

Mean frequency of the fish rise to surface to gulp air (average of the number per 1 minute).

Number of midline crossing

The aquarium was divided by a midline externally and the numbers of midline crossing from fish through 1 minute were detected for each aquarium. During each observation period, it was repeated thrice and the average number taken.

One-way ANOVA was performed using R software to ascertain the effect of the different doses on various behaviours. Normality and homogeneity of variance were assessed formally using Shapiro-wilk and Levene's tests, respectively. Follow up analyses were performed using Dunnett's multiple comparisons between control and the treatment concentrations/durations (Hothorn *et al.*, 2008).

RESULTS AND DISCUSSION

Fig 1 shows that the feeding rate of *O. niloticus*. The feeding rate was higher in the NaCl-exposed groups compared to the control. Both the L and H groups required less time to complete feeding at both 10-day and 60-day exposure durations. The control group consistently took the longest

time to complete feeding at both time points. The low concentration (L) group fed faster than the control but slower than the high-concentration group. The High concentration (H) group exhibited the fastest feeding behavior, completing the feed in approximately 15 seconds by day 60-almost one-fourth of the initial control value.

Fig 2 clearly shows that the control groups very sensitive to acoustic stimuli. But the L and H treatment groups gets restored soon after responding to an acoustic stimuli. When the control fishes remain sensitive for 33 sec to an acoustic response, L and H treatment groups are sensitive only for 32sec and 19 sec respectively. In the case of the 60-day period also a similar trend is noted (23 sec, 20 sec and 14 sec for control, L and H respectively).

Similar is the results obtained for rheo sensitivity (Fig 3). If 23 sec and 18 sec was the time taken to create an abnormal swimming pattern or imbalance in the fish in the 10-day period for control L and H groups respectively as against the control where 26 sec was used. 10 sec, 8 sec

and 3 sec was taken during the 60-day period for Control, L and H respectively.

The frequency of aggressive behavior (Fig 4) noted in the control group was (1) lower than both the L and H groups (3) both in the 10-day period and 60-day period (3, 7, 10 for Control, L and H respectively). In case of surfacing behavior (Fig 6), higher frequency is observed in the L and H treatment groups when compared with the controls both in the 10-day period and 60-day period (1, 2, 3 and 1, 3, 6 for Control, L and H of 10-day and 60-day respectively). The number of midline line crossings (Fig 5) also followed a similar trend as the surfacing behavior. In the 10-day period, 2, 5, 7 midline crossings were noted in Control, L and H respectively and in the 60-day period, 7, 9, 18 midline crossings were noted in control, L and H respectively.

The frequency of aggressive behavior (Fig 4) noted in the control group was (1) lower than both the L and H groups (3) both in the 10-day period and 60-day period (3, 5, 9 for Control, L and H respectively).

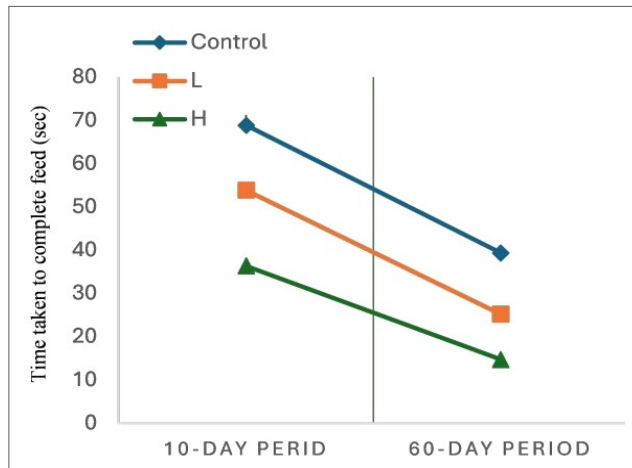


Fig 1: Showing the dose specific response of NaCl on the time taken to complete feeding.

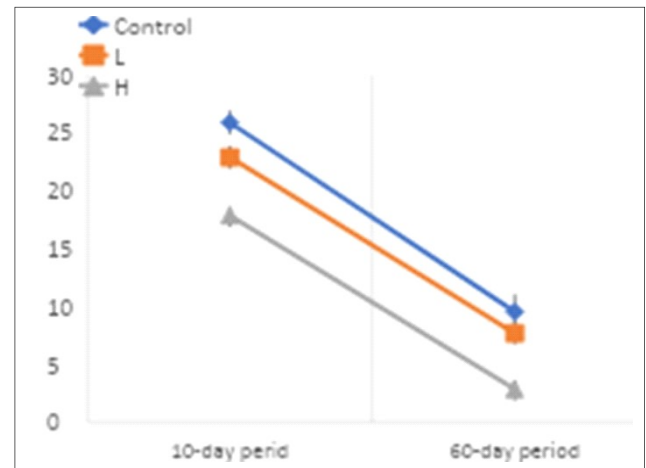


Fig 3: Showing the dose specific response of NaCl on rheo response.

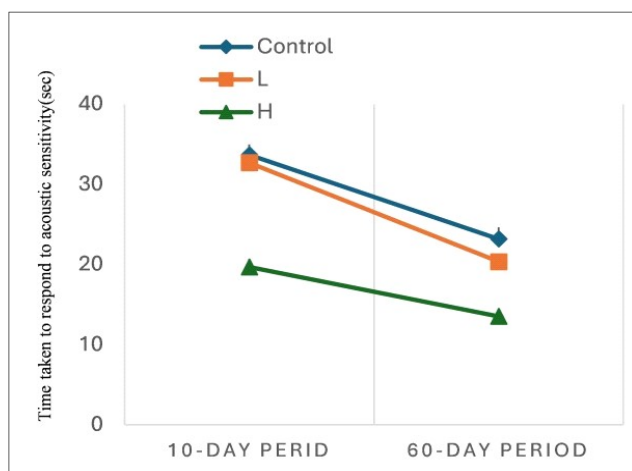


Fig 2: Showing the dose specific response of NaCl on acoustic sensitivity.

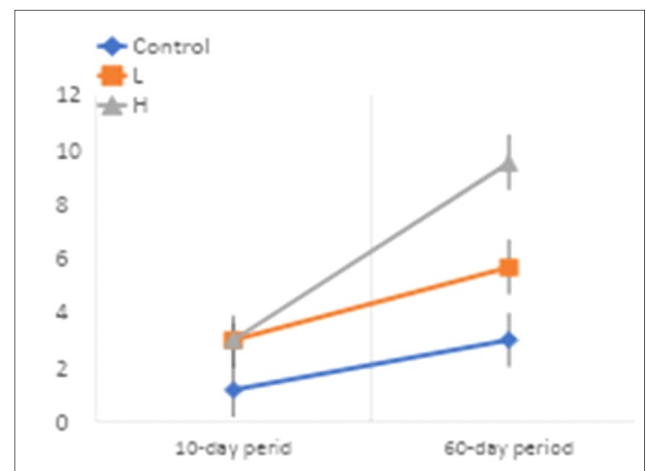


Fig 4: Showing the dose specific response of NaCl on aggressive behaviour.

The number of midline crossings (Fig 5) recorded over the 10-day period were 2, 5 and 7 in the control, L and H groups respectively, while after 60 days, the corresponding values increased to 7, 9 and 18 respectively.

In case of surfacing behavior (Fig 6), a similar trend as the midline line crossings was noted. Higher frequency is observed in the L and H treatment groups when compared with the controls both in the 10-day period and 60-day period (1, 2, 3 and 1, 3, 6 for Control, L and H of 10-day and 60-day respectively).

Across all six behavioral parameters-feeding, rheotaxis sensitivity (Rheo), acoustic sensitivity, aggression, Midline Crossing and Surfacing-there is a consistent dose-dependent and time-dependent effect observed when comparing low (L) and high (H) treatments against the control. At 10 days, significant reductions were seen in feeding particularly at higher doses. Conversely, aggression, midline crossings and surfacing showed a notable increase, especially in high-dose groups, suggesting stress-

induced hyperactivity or anxiety-like responses. In case of acoustic and rheotaxis sensitivity, across all groups it seem to be higher in the control than both L and H groups. All p-values for these significant changes were well below 0.001, confirming strong statistical relevance (Table 1).

By 60 days, most behavioral alterations intensified. Feeding continued to decline significantly over time, with the highest suppression observed at 60 days in the high-dose group (-27.25). Rheo sensitivity and acoustic sensitivity fell further, for H dose compared to L and control. Aggression also rises dramatically for both doses at 60 days, indicating progressive behavioral dysregulation. Midline crossings increased sharply, peaking at 60 days for the high group (+10.17), further reinforcing the pattern of hyperactivity. Surfacing showed minimal changes at lower doses but became strongly elevated at high doses by 60 days. Overall, the data suggest that chronic exposure amplifies behavioral disruptions in a dose-dependent manner (Table 2).

The present study suggests that the feeding rate is positively influenced by both the concentration and duration of sodium chloride exposure. Enhanced osmoregulatory demands at higher salinities would require the breakdown of energy-dense nutrients (Bœuf and Payan, 2001). This heightened energy requirement for osmoregulation, following environmental stress, which happens to be increased salinity levels due to NaCl exposure in the present study, triggers changes in physiological processes aimed at maintaining energy balance, to optimize food digestion and nutrient absorption (Psochiou *et al.*, 2007, Gheisvandi *et al.*, 2015).

Both the acoustic and rheo response reveals that the NaCl treatment, facilitates stress management. The acoustic and rheo sensitivity data of the NaCl exposed group in comparison with control group reveals two things. The NaCl treatment, is seen to decrease the period of neural sensitivity of the exposed fish to sound; the greater the concentration of NaCl and greater the duration for which the fish is exposed, the lesser responsive is the fish to a sound stimuli. This finding is supported by the study of Fournet *et al.* (2019) which showed that for every one unit increase in salinity the probability of toadfish acoustic occurrence decreases by 16%.

The swimming pattern of control fish remained under equilibrium from longer duration when compared to NaCl exposed groups. In other words, swimming equilibrium was lost earlier by fish exposed to H concentration of NaCl than those in L group and Control for both 10 and 60 days period. This shows that sensitivity of the NaCl exposed fish again decreases and points the NaCl exposure for increased periods and for increased concentrations in the studied range which is way below recommended safe limits (4-10 g/L) lowers the coping mechanism of the organism. Studies of Stoessel *et al.* (2019) on Murray hardyhead suggests that the probability of loss of equilibrium increases with increasing salinity.

Aggression, surfacing and midline crossings exhibited a clear dose-dependent response. Lorenz *et al.* (2015)

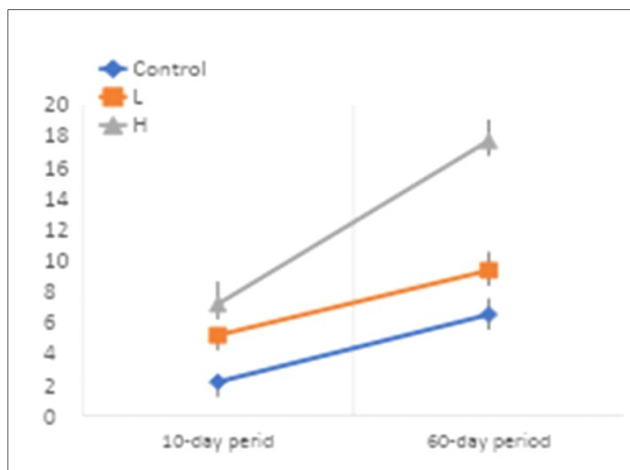


Fig 5: Showing the dose specific response of NaCl on midline crossing.

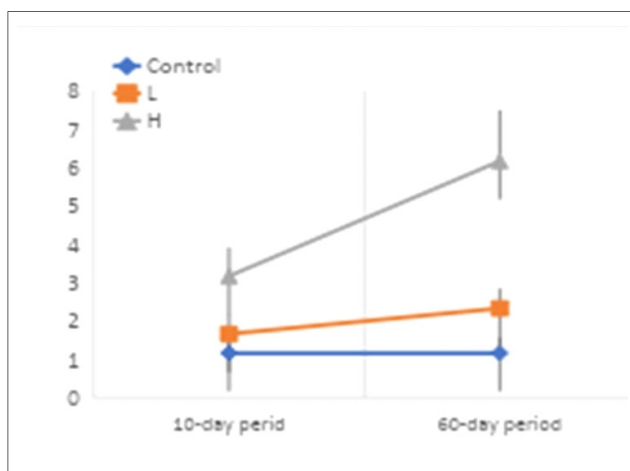


Fig 6: Showing the dose specific response of NaCl on surfacing behaviour.

Table 1: Dunnett's multiple comparison between treatments at 10 days.

Parameter	L	H	Std. error	t value
Feeding	-14.9167	-31.5	0.9371	-15.92*
Acoustic sensitivity	-1.75	-15.3333	0.6095	-25.156*
Rheo sensitivity	-4.5	-9	0.563	-7.994*
Aggression	1.3333	2.25	0.2531	5.267*
Midline crossing	2.6667	4.75	0.3888	6.858*
Surfacing	0.25	1.5	0.2125	7.06*

Significance level* p = 0.001.

Table 2: Dunnett's multiple comparison between treatments at 60 days.

Parameter	L	H	Std. error	t value
Feeding	-15.75	-27.25	0.5876	-26.8*
Acoustic sensitivity	-3.5	-9.9167	0.4946	-20.05*
Rheo sensitivity	-1.5833	-5.9167	0.3684	-4.298*
Aggression	1	5.6667	0.3536	16.028*
Midline crossing	2.8333	10.1667	0.5028	5.635*
Surfacing	0.08333	2.91667	0.31881	9.149*

Significance level* p = 0.001.

reported that aggression levels in fish may increase with rising salinity. According to Fondriest Environmental (2013), higher NaCl concentrations and prolonged exposure reduce dissolved oxygen levels, which may explain the increased surfacing behavior observed in the exposed fish as they attempt to gulp atmospheric air. The resulting oxygen deficiency could also trigger heightened aggression and midline crossings due to competition for limited oxygen resources, reflecting restlessness and stress.

Surfacing behavior and midline crossings could be indicative of respiratory or adaptive stress caused due to the increase in the level of sodium chloride. Fish in high salinity can elevate energy expenditure and induce metabolic stress, ultimately affecting growth, reproduction and overall fitness (Hochachka and Somero, 2002). As salinity increases, dissolved oxygen levels decrease exponentially, leading to significant impacts on fish metabolism, fish behavior, including swimming speed, foraging and habitat selection, (Fondriest Environmental, 2013; Wootton, 1990; Wu, 2002). Insufficient oxygen, particularly in hypoxic conditions, can induce stress, negatively impacting fish health and performance (Marium *et al.*, 2023). Similarly, Huang *et al.* (2021) observed that exposure to deltamethrin and cadmium induced prolonged hyperactivity in zebrafish, linked to metabolic and physiological disturbances such as altered oxygen consumption and ventilation.

NaCl is widely used in aquaculture as a prophylactic for disease management and moderate salinity (8-10 ppt) has been shown to support survival, growth and physiological homeostasis in many cultured species like *Pangasianodon hypophthalmus* (Lingam *et al.*, 2025) and improved rohu (Jayanti) (Murmu *et al.*, 2020). The present study emphasizes that even NaCl treatment within safe usage limits can still affect fish behavior and physiology.

CONCLUSION

Behavioral changes in apparently healthy fish might indicate a nonspecific response to stressors. However, these changes can still provide a valuable, quick and non-invasive way to predict and assess potential economic losses from disease before mortality occurs.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University, Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish or preparation of the manuscript.

REFERENCES

- Altmann, J. (1974). Observational study of behavior: Sampling methods. *Behaviour*. **49**(3): 227-267.

- Alfonso, S., Gesto, M. and Sadoul, B. (2021). Temperature increase and its effects on fish stress physiology in the context of global warming. *J. Fish. Biol.* **98**: 1496-1508. doi: 10.1111/jfb.14599.
- Bœuf, G. and Payan, P. (2001). How should salinity influence fish growth? Comparative Biochemistry and Physiology. *Toxicology and Pharmacology: CBP.* **130(4)**: 411-423.
- Burgdorf-Moisuk, A., Mitchell, M.A. and Watson, M. (2011). Clinical and physiologic effects of sodium chloride baths in goldfish (*Carassius auratus*). *Journal of Zoo and Wildlife Medicine.* **42(4)**: 586-592.
- El-Gawad, E.A.A., Shen, Z.G. and Wang, H.P. (2016). Efficacy of formalin, iodine and sodium chloride in improvement of egg hatching rate and fry survival prior to the onset of exogenous feeding in yellow perch. *Aquaculture Research.* **47(8)**: 2461-2469.
- Ebrahim, A.E.M., Goda, A.M.A.S., Rhman, G.A.A. and Ayyat, M.S. (2016). Effect of water salinity and NaCl supplementaion on growth performance, feed utilization, blood constituents and body composition of Nile tilapia, *Oreochromis niloticus*. *Zagazig Journal of Agricultural Research.* **43(3)**: 939-953.
- Enevova, V., Palikova, M., Blahova, J., Modra, H., Vojtek, L., Papezikova, I., Tichy, F., Mares, J., Navratil, S., Vecerek, V. and Svobodova, Z. (2018). Sodium chloride treatment effects on rainbow trout suffering from proliferative kidney disease caused by *Tetracapsuloides bryosalmonae*. *Diseases of Aquatic Organisms.* **131(1)**: 157-166.
- Frey, D.F. and Miller, R.J. (1972). The establishment of dominance relationships in the blue gourami [*Trichogaster trichopterus* (Pallus)]. *Behaviour.* **42(1)**: 8-62.
- Fathollahi, R., Khara, H., Pajand, Z. and Shenavar, S. (2020). Effects of sodium chloride and methylthionium chloride on *Persian sturgeon, Acipenser persicus* (Borodin, 1897): A histopathological and bacteriological study. *Caspian Journal of Environmental Sciences.* **19(1)**: 75-83. <https://doi.org/10.22124/cjes.2021.4308>.
- Fattah, A.F.A., Ahmed, F.A., Saleem, A.-S.Y., Mohammed, H.H., Youssef, M.I. and Said, E.N. (2020). Effect of the different stocking density on behavior, performance and welfare of the Nile tilapia (*Oreochromis niloticus*). *Egyptian Journal of Aquatic Biology and Fisheries.* **24(5)**: 539-560.
- Fondriest Environmental, Inc. (2013, November 19). Dissolved oxygen. Fundamentals of Environmental Measurements. Retrieved from <https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen>.
- Fournet, M.E.H., Stabenau, E. and Rice, A.N. (2019). Relationship between salinity and sonic fish advertisement behavior in a managed sub-tropical estuary: Making the case for an acoustic indicator species. *Ecological Indicators.* **106**: 105531.
- Gheisvandi, N., Hajimoradloo, A., Ghorbani, R. and Hoseinifar, S.H. (2015). The effects of gradual or abrupt changes in salinity on digestive enzymes activity of Caspian kutum, *Rutilus kutum* (Kamensky, 1901) larvae. *Journal of Applied Ichthyology.* **31(6)**: 1107-1112.
- Hansen, M.J., Morrell, L.J. and Ward, A.J.W. (2016). The effect of temporally variable environmental stimuli and group size on emergence behavior. *Behav. Ecol.* **27**: 939-945.
- Hochachka, P.W. and Somero, G.N. (2002). Biochemical Adaptation: Mechanism and Process in Physiological Evolution. Oxford University Press.
- Hothorn, T., Bretz, F., Westfall, P. (2008). Simultaneous inference in general parametric models. *Biom. J.* **50**: 346-363.
- Huang, Y., Mi, F., Wu, J., Lu, Y., Zhang, G. and Yu, T. (2021). Behavioral responses in zebrafish (*Danio rerio*) exposed to heavy metal and insecticide induced stress. *Indian Journal of Animal Research.* **55(12)**: 1439-1445. doi: 10.18805/IJAR.B-1390.
- Hale, M.E., Day, R.D., Thorsen, D.H. and Westneat, M.W. (2006). Pectoral fin coordination and gait transitions in steadily swimming juvenile reef fish. *Journal of Experimental Biology.* **209(18)**: 3708-3718.
- Keen, A.N., Klaiman, J.M., Shiels, H.A. and Gillis, T.E. (2017). Temperature induced cardiac remodelling in fish. *J. Exp. Biol.* **220**: 147-160.
- Khalil, F. and Emeash, H. (2018). Behavior and stereotypies of Nile tilapia (*Oreochromis niloticus*) in response to experimental infection with *Aeromonas hydrophila*. *Aquatic Sciences and Engineering.* **33(4)**: 124-130.
- Lingam, R.S.S., Babita Rani, A.M., Pothu Srinivas Rao, K., Paswan, V.K., Haridas, H., Dhillip Maniraj, N. and Suresh Babu, P.P. (2025). Impact of salinity on growth and physiological responses of striped catfish (*Pangasianodon hypophthalmus*) fingerlings. *Indian Journal of Animal Research.* **59(1)**: 168-172. doi: 10.18805/IJAR.B-5319.
- Lorenz, O.T., Riccobono, S.A. and Smith, P. (2015). Effects of salinity on the survival and aggression of the invasive Rio Grande cichlid (*Herichthys cyanoguttatus*). *Marine and Freshwater Behaviour and Physiology.* **49(1)**: 1-8.
- Marium, A., Chatha, A.M.M., Naz, S., Khan, M.F., Safdar, W., Ashraf, S. (2023). Effect of temperature, pH, salinity and dissolved oxygen on fishes. *Journal of Zoology and Systematics.* **1(2)**: 1-12.
- Murmu, K., Rasal, K. D., Rasal, A., Sahoo, L., Nandanpawar, P.C., Udit, U. K., Patnaik, M., Mahapatra, K.D. 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. doi: 10.18805/ijar.B-3801.
- Olusanya, H.O. and van Zyll de Jong, M. (2018). Assessing the vulnerability of freshwater fishes to climate change in Newfoundland and Labrador. *Plos One.* **13**: e0208182.
- Psochiou, E., Mamuris, Z., Panagiotaki, P., Kouretas, D. and Moutou, K.A. (2007). The response of digestive proteases to abrupt salinity decrease in the euryhaline sparid *Sparus aurata* L. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology.* **147(2)**: 156-163.
- Salvanes, A.G.V., Moberg, O., Ebbesson, L.O.E., Nilsen, T.O., Jensen, K.H. and Braithwaite, V.A. (2013). Environmental enrichment promotes neural plasticity and cognitive ability in fish. *Proc. Biol. Sci.* **280**: 20131331.
- Shrivastava, S., Thakur, U. and Shrivastava, L. (2011). Behavioural responses of Tilapia mossambica to water polluted with fly ash from coal: A laboratory study. *International Journal of Biology.* **3(1)**: 1-10.

- Stoessel, D.J., Fairbrother, P., Fanson, B.G., Raymond, S., Raadik, T.A., Nicol, M.D., Johnson, L. (2019). Salinity tolerance during early development of threatened Murray hardyhead (*Craterocephalus fluviatilis*) to guide environmental watering. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 30. 10.1002/aqc.3233.
- Sewall, K.B. (2015). Social Complexity as a driver of communication and cognition. *Integr. Comp. Biol.* **55**: 384-395. doi: 10.1093/icb/icv064.
- Stephen J. Walsh, Convener and asmund Bjordal convener. (2004). Fish behaviour in exploited ecosystem. *ICES Journal of Marine Science: Journal du Conseil* 2004. **61(7)**: 1030-1035. DOI: 10.1016/j.icesjms.2004.08.006(C).
- Tavares- Dias, M. (2022). Toxicity, physiological, histopathological, handling, growth and antiparasitic effects of the sodium chloride (salt) in the freshwater fish aquaculture. *Aquaculture Research*. **53**: 715-734. <https://doi.org/10.1111/are.15616>.
- Tong, S.-K., Lee, H.-L., Lee, Y.-C., Wu, L.-C., Tsou, Y.-L., Lu, S.-W., *et al.* (2020). Arginine vasopressin modulates ion and acid/base balance by regulating cell numbers of sodium chloride cotransporter and H⁺-ATPase rich ionocytes. *Int. J. Mol. Sci.* 21. doi: 10.3390/ijms21113957.
- Tseng, Y.-C., Yan, J.-J., Furukawa, F. and Hwang, P.-P. (2020). Did acidic stress resistance in vertebrates evolve as Na⁺/H⁺ exchanger-mediated ammonia excretion in fish? *Bioessays*. **42**: e1900161.
- Wootton, R.J. (1990). Ecology of teleost fishes. Springer Science and Business Media.
- Wu, R.S.S. (2002). Hypoxia: From molecular responses to ecosystem responses. Boca Raton, FL: CRC Press. **45(1-12)**: 35-45.