

Inland Saline Aquaculture- Prospectus and Challenges

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SUMMARY

The world's freshwater supplies are dwindling, and land and groundwater salinization are increasing. In the coming decades, saline water will replace freshwater as the main resource for agriculture and aquaculture. Because the inland saline water in India lacks potassium ions, it must first be fortified with K⁺ in the culture medium or supplemented with minerals through feed before being used for further aquaculture techniques. Increasing salt levels endanger animal survival by causing oxidative stress in aquatic creatures and negatively affecting metabolism and the immune system. The culture of shrimp is commonly practised in India's inland saline regions. It is evidence that the superiority of the world's population is animated in a country. So, it would be more environmentally favourable to embrace low saline tolerance species culture as opposed to shrimp farming in low-saline environments. It will result in the best possible use of unused water in inland saline zones. Also, it is advised that inland saline water be used for the culture of freshwater fish using appropriate production methods that do not harm the ecosystem. Recent research has shown that aquatic organisms are more likely to survive under salinity stress with a longer acclimatisation period.

INTRODUCTION

Salinity is a significant issue in many parts of the world and is expected to get significantly worse over the next 30-50 years. The majority of the focus has been on the terrestrial environment, particularly the disappearance of agriculturally productive land. Aquatic ecosystems in rivers, streams, and especially wetlands may experience unexpected changes as a result of increased salinity. Almost 953 mha of fertile land worldwide are restricted in production due to an elevated congregation of salts in the rootzone soil. The largest area pretentious by salinity and sodicity is in Australia, followed by Asia. The majority of saline-affected soils and brackish groundwater sources are restricted to arid and semiarid localities, where they are the primary causes of the decline in freshwater supplies (Dheeran et al., 2025). Over 673 million of acres of ground in India have been defaced by the saline and sodicity issuance. Freshwater sources have been decadent as an upshot of secondary salinization initiated on by the induction of irrigation in arid areas, as saline levels have expanded across with ground water levels. In coastal Andhra Pradesh and other locations, large-scale shrimp farming using coastal water left around 2.1 million acres of land unsuitable for agriculture. Similar to this, the groundwater in the country's north-western states is between 30 and 84% salinized or brackish and unusable for irrigation. Many thousand acres of productive land have been made unusable for farming due to the use of irrigation water of poor quality.

Land degradation brought on by salinity is becoming a significant obstacle to the food and nutritional security of emerging nations. A number of factors, most notably the growing population, are anticipated to lead to a rise in the demand for water. Making the greatest use of the available resources has become vital due to the apparent rising population strain in growing nations. The growing population puts pressure on the responsible and sensible use of all resources to create protein-rich food that will feed people and end malnutrition. The inland saline area is one resource that is underutilised, but not all resources are used to their full potential. According to the soil map of the world, sodicity affects 953 mha, or around 8% of the land surface. According to earlier reports, salt-affected soils cover 42.3% of Australia's land area, 21.0% of Asia's, 7.6% of South America's, 4.6% of Europe's, 3.5% of Africa's, 0.9% of North America's, and finally 0.7% of Central America's land area. Australia has the greatest area in a salty environment in the world, which equates to nearly one-third of the entire continent's surface area. Similar to this, around 25% of India's subsurface water areas are becoming sodicity. When these water resources are used continuously for longer periods of time to irrigate field crops, large-scale salinization occurs, which degrades freshwater in numerous locations of the country. With increased irrigation in dry and semi-arid areas without appropriate drainage, the salinity issue is getting worse. In practically all of the regions served by canals, a large portion of the nation is already saturated with water and salinized. Across India, the water table is elevating at a pace of 30-100 cm/year in a number of irrigation districts. Depending on the

topographical position, hydrological and climatic circumstances, drainage accessibility, land utilization, and cultural practises, the problem's nature and severity vary from place to locality. Given the scarcity of such land and the saline water beneath it, inland saline aquaculture appears to be particularly promising (Dheeran et al., 2025a). According to water management experts, the best long-term solution to deal with water scarcity, is to increase the productivity of existing water resources, or to harvest more food with less water. According to this viewpoint, using salinized water and fish farming in low-salinity areas will be a practical choice for sustainable food production that makes use of underutilised water resources. To lessen the growing burden on freshwater resources and produce fish in dry and semi-arid areas, low-salinity aquaculture practises for freshwater fishes are preferable. This article covers deteriorated land uses in inland saline areas, inland saline area characteristics, species tolerance to salt and how that affects physiology, a detailed picture of salinity-related issues and prospects around the world, and its mitigation techniques.

Characteristics of inland saline water

Alkali soils and saline soils are the two main categories for saline-affected soils in India. Salt-sodic soils can also exist in some particular contexts. Saline-sodic soils are typically included in the sodicity soil category since their treatment will be more alike to that of sodicity soils. The sole difference in management for their restoration is that matching soil requires additional water for the leaching of dissolved salts prior to amendment implementation. In comparison to other cations, sodium is present in larger concentrations in the soil suspension and on the interchange complex in sodicity soils. The physical circumstances, mess-up in nutrient availability, and restraint of biological activity owing to elevated pH, surpassing 10.0 in grievous cases, and interchangeable sodium percentage of up to 90 percent have a negative impact on the performance of common crops on sodic soils. The preponderance of sodium carbonates and bicarbonates in salt solutions are competent of alkaline hydrolysis, overloading the absorbing compound with sodium. Alkali/sodic soils can be restored in a major way by methods that aim to dissolve CaCO_3 . These soils are lacking in accessible N, Ca, Zn, and organic matter. Certain micronutrients cause issues due to toxicity or deficiency. The main causes of alkali soil formation in the nation include irrigation with groundwater that contains excessive levels of carbonate and bicarbonate ions, an increase in source water due to the installation of canal irrigation, and saline-laden runoff from nearby areas and undrained regions. The canal-irrigated, arid, and semiarid places are home to many inland saline plains. These soils are renowned by the plenty of neutral dissolved salts. As a salt, sodium chloride predominates. Increased soil salinity is generally correlated by elevated water table, often within 2 m of the surface. Since subsoil water is typically saline, irrigation with it has a significant negative impact on crop output. These soils generally have worthy physical characteristics but inadequate natural drainage. Saline soil emergence is typically associated to a rise in water table initiated on by the use of irrigation and defective drainage. In order to increase inland saline aquaculture production while maintaining environmental sustainability, these deteriorated sites that are inappropriate for agricultural development can be utilised (Dheeran et al., 2025b).

Scope of inland saline aquaculture

Aquaculture in inland saltwater includes a variety of species, systems, and water characteristics. These production systems have virtually limitless advantages for enhancing aquaculture production. Use/reuse of inland salt waters is a crucial source for producing increased-quality seafood using underutilised resources in saline affected area by rising demands for potable water and marine coastal regions. The regulation and sustainability of these food production systems would further rise with the incorporation of aquaculture with traditional systems, halophytic, or even seaweed farming. We are quickly gaining the information necessary to transform these systems into successful farming endeavours through rudimentary and applied research into realistic administration strategies for these systems. Priority research areas include practical aggregation of aquaculture waste for plant crop manufacturing and additional study of the physiological stresses associated with raising more beneficial species in inland salt settings. Following the 2008 food and fuel crises, there will unavoidably be another water crisis, climate change effects on conventional crops, fertiliser shortages, and other effects of growing people fighting for finite resources. Inland saline aquaculture (ISA) is sure to be a common significant instrument for boosting sustainable aquaculture production, which is what the world needs most right now.

Use of poor-quality water for aquaculture

With a 42% contribution of the world's water resources, India is home to 17% of the world's population. Agriculture uses around 85% of India's freshwater resources, with the remaining 15% going to home and

industrial uses. Groundwater quantity and quality are the most crucial elements in high productivity. The locale where water is deficient are typically enclosed by poor-quality groundwater supplies. In India, areas of the dry and semi-arid states of Rajasthan, Haryana, Delhi, Punjab, and Uttar Pradesh have the highest concentration of saline and brackish groundwater. The use of brackishwater for irrigation in agriculture is rising as a result of the shortage of better-quality water and rising pumping costs. In bounteous sections of the country, places that were formerly concealed by better-quality aquifers are enhancing contaminated and inadequate for agricultural development as a result of broad groundwater pumping. Fitness of soil, animals, people, and the environment is vigorously threatened by the indiscriminate utilization of fewer-quality waters in the nonappearance of effective soil water crop livestock executive techniques. Increased usage of poor water quality leads to the buildup of sodicity, and toxicity issues in soils, which not only lower crop yield but frequently cause areas to become unusable for farming. The aquaculture sector can increase aquaculture production in salt-affected areas by making use of these resources.

Species tolerance to inland saline water

The fundamental criteria for selecting fish species that are appropriate for large-scale, inland saline aquaculture are often the same for any aquaculture industry. The chosen species must have established hatchery procedures, increased market demand, disease resistant, strong, salt-tolerant, fast-growing, and popular with consumers. The characteristics of readily accessible water sources must be matched with the water quality criteria for a species' best performance. It's possible that this is the only requirement unique to fish production in inland saltwaters (Dheeran et al., 2025c). Several fish species have been examined to see if they are suited for inland saltwater settings, including marine, estuarine, diadromous, and freshwater euryhaline species. The species that are undergoing testing for commercial production in inland saltwater are listed below.

Species	Tolerable salinity (‰)
<i>Labeo rohita</i>	12
<i>Ctenopharyngodon idella</i>	25
<i>Hypophthalmichthys molitrix</i>	10
<i>Cyprinus carpio</i>	12
<i>Oreochromis niloticus</i>	20
<i>Channa punctata</i>	13
<i>Heteropneustes fossilis</i>	9
<i>Clarias magur</i>	8
<i>Pangasius hypophthalmus</i>	15
<i>Carassius auratus</i>	10
Cray fish	6-8
<i>Macrobrachium rosenbergii</i>	12-15
<i>Penaeus monodon</i>	23-25
<i>Penaeus japonicus</i>	35
<i>Scylla serrata</i>	28-34
<i>Artemia</i>	>200
<i>Dunaliella salina</i>	>200

<i>Isochrysis. Tetraselmis, Chaetoceras</i>	30
<i>Spirulina platensis</i>	30
<i>Gracilaria</i> spp.	30
<i>Ulva</i> spp.	30
<i>Caulerpa</i> spp.	30

Effect of saline on physiology

An important environmental component that affects seawater fish's growth, development, and reproduction is salinity. Through the function of their osmoregulatory organs, such as their gills, kidneys, and intestines, teleost's manage plasma ion homeostasis. As a result of its role in ion transport, the basolateral Na⁺/K⁺-ATPase (NKA) pump creates the initial electrochemical gradient required for transmembrane proteins to exchange ions and water. Prior research has tended to concentrate on the physiological and biochemical elements of salt stress responses. Blood biochemical parameters are frequently measured in fish to identify health state and have also been used to diagnose diseases. Many investigations have proven that aquatic species' blood biochemical attributes are altered by the saline of their environment. Following saltwater challenges, blood ion levels are monitored and utilised as a tool for fish osmoregulatory capacity. The effects of salinity stress on euryhaline teleost's have also been documented, and these include adjustment in large-scale protein compound, altered activity of vital enzymes like Na⁺/K⁺-ATPase, and the growth or disappearance of specialised cells like pavement cells, ionocytes, and mitochondria-rich cells that are either seawater/ freshwater-type. Also, there has been a lot of interest in the link between fish immune response and salt stress. According to recent research, the increased production of reactive oxygen species, which can cause oxidative stress and negatively impact immunological function is closely linked to stress reactions to salinity fluctuations. In addition to their involvement in digestion, fish's intestines also play a part in osmotic and ionic balance through intestinal water uptake. The intestine microbial composition may be differently impacted by the presence of ambient water as a component contributing to host life activities. Intestinal microbiota in both humans and animals has garnered a lot of attention since it is thought to have a significant role in a variety of processes, including metabolism, performance, and health status. The activity of intestinal microbes has been found to be strongly correlated with the growth of cultured euryhaline aquatic species, such as *Oreochromis niloticus* and *Litopenaeus vannamei*. However, little is known about how the intestinal microbiota of host species react to environmental changes, such as alterations in water salinity under aquaculture conditions.

Strategies to manage sodicity

There are certain parallels constant supposing that each location's chemistry is very different. The Wakool region in Australia recorded the lowest levels of potassium in saline groundwater, where it was commenced at 5% of the application observed in saltwater with an equivalent saline. In saline groundwater, calcium levels were between 1.4-130 times greater than in seawater. With the exception of Alabama and Haryana, India, sulphate was likewise in relative excess everywhere else. There were certain areas with magnesium shortages, particularly in Australia. It should come as no surprise that a lot of research has been done on how to improve water chemistry inadequacies. gave an account of mineral sources that adequacy be used as supplies for main cations and abbreviated deficiencies in various water sources utilized for shrimp farming around the world. This ion has likely drawn the greatest attention due to its significance in physiology. Red sea bream lost balance and went dormant within three days of being transferred to salt groundwater. However, as long as K⁺ was given to the water, survival and performance were comparable to coastal seawater. Several species grown in saline groundwater, like *Argyrosomus japonicus*, *Scieanops ocellatus*, and *P. vannamei*, have also found potassium supplementation helpful. Inland saline water often has calcium abnormalities. Recent researchers found that adding calcium chloride to low-salinity groundwater increased red drum survival, growth, and feed efficiency. Although lowering the pH was useful, it was both costly and impractical. In comparison to seawater, common other sources of salt groundwater contain an increased amount of calcium. It has been decisive that the procreation of *Macrobrachium rosenbergii* larvae is distressed by the evidence that the saline of the groundwater in Haryana is rised than that of analogous saltwater in terms of calcium and magnesium. 2500 L/d of salty groundwater may be examined using a filter that holds roughly 0.5 m³ of ion exchange resin, which is enough to

strengthen a sizable *Macrobrachium* hatchery that can produce 1.5 million PLs annually. Ions are disoriented from ponds in flash flood after rains, through soil adsorption, and through water interchange, and remediation of rearing water can be extravagant. Because endemic soils contain clays that fix K^+ across neighbouring tetrahedral layers, pond sediments in particular adsorb K^+ . The effectiveness of treating a K^+ deficiency in salt groundwater by altering diet has been studied as a substitute or complementary strategy, but it has not been successful for finfish. However, *P. vannamei* raised in fewer-salinity groundwater showed an improvement in osmoregulatory capacity when diets were added with magnesium, potassium, phospholipids, and cholesterol. In saline groundwater, there are a variety of additional ionic compositional imbalances and potential pollutants. There will be a need for site-specific investigations for several of these ions. The superiority of research has concentrated on significant variations in single ions, but it is expected that chronic effects will become apparent as production from saline groundwater sources rises. Understanding these linkages will benefit from research into the physiological reactions of aquaculture species in low-salinity water and how to create artificial mixed-salt habitats. The probable for aquaculture employing salt groundwater has been negatively damaged by sub-optimal pH in added to ionic composition percentage. Acidic conditions can develop due to the application of acid-forming fertilisers on agricultural lands, the existence of acid sulphate soils, ferrollysis, and high quantities of dissolved carbon dioxide. Biochar can be applied to sediment and water to improve water quality and increase primary productivity. Preceding study also shows that applying biochar at a lower dose to water is preferable than applying it at a larger dose in sediment. Utilization of biochar in inland saline pond water can further enrich the system with potassium, which is lacking in the system and is essential for fish and crustacean osmoregulation. Such ground-breaking research may provide strategies for increasing the productivity of degraded soil and water through biochar made from agricultural crop waste, promoting their use for aquaculture and supporting the use of huge degraded land resources and saline ground water for aquaculture.

Advantages

Inland saline aquaculture is a promising technique to enhance consolidated use of freshwater in salt-affected areas all around the world. There are plenty of available water resources, early results with temperate fish are promising, and a commercial business using saline groundwater has been running successfully for a while. Saline water for fish culture in existing evaporation ponds and in specially developed indoor systems, intensive fish-farming facilities is the subject of several studies. Inland saline aquaculture requires water must be treated, confined, and possibly recycled on-site. Develops national environmental management policies for inland saline aquaculture. Reduce the amount of untreated nutrients released into the aquatic ecosystems. When growing algae for food and feed, saline ground waters may have an advantage over sea water. Several molluscan species, including non-endemic to inland saline water, such as Pacific oyster, Sydney rock oyster, tropical oysters, flat oyster, pearl oyster, silver-lipped oyster, black-lipped oyster, and winged oyster, may be suitable for culture in these waters. Create a database of inland saline water source characteristics.

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