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Anthropization, Salinity and Oxidative Stress in Animals in the Coastal Zone †

Abhipsa Bal [1,2] and Biswaranjan Paital [1,*]

1 Redox Regulation Laboratory, Department of Zoology, College of Basic Science and Humanities, Odisha University of Agriculture and Technology, Bhubaneswar 751003, India; abhipsa.hope@gmail.com
2 Zoology Section, Department of Education in Science and Mathematics, Regional Institute of Education, Bhubaneswar 751022, India
* Correspondence: biswaranjanpaital@gmail.com; Tel.: +91-674-2397029
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Abstract: In coastal and abiding zones, ground water continuously faces a very slight but alarmingly increasing trend in salinity due to several reasons such as the excess loss or use of it, with the constant dissolution of salts from the Earth's surface and heat-trapping pollution from human activities, rising sea levels and finally, high flooding. Many recent studies have indicated that even a slight elevation in ground water salinity may affect freshwater inhabitants, highlighting the importance of research on the effects of low salinity stress on coastal zone freshwater inhabitants. Along with abiotic factors such as salinity, dissolved oxygen, pH, and alkalinity, anthropogenic factors also cause a lot of stress on the inhabitants in coastal zones. Climatic factors also play an important role in influencing the life of coastal water inhabitants. For example, statistics such as those obtained by correlation and discriminant function analysis indicate that sublethal salinity acts as a strong modulator in the physiology of inhabiting fish in fresh as well as coastal water. Parameters such as increase in body weight, feed intake and irregularities in morphometry increase under higher salinities, which are confirmed by a decline in the growth of fishes. Similarly, blood physiology aspects, such as a significant loss in hemoglobin content, the RBC count and eosinophils, are coupled with amelioration in neutrophil count at the higher salinities of 6 and 9 ppt in few freshwater organisms. Normal histoarchitecture is also lost in most fish under high salinity conditions and higher anthropogenic loads. The generation of tissue damage in terms of oxidative stress is prominent under high fluctuations in abiotic factors including higher salinity or under high anthropogenic loads. Hence, a loss in compromised normal physiology due to the toxic effects of low- or high-salinity saline water or in fresh inhabitants including hardy fishes under changing climatic conditions are evident. This raises concerns about maintaining water quality in coastal and allied zones globally in the coming decades.

Keywords: coastal water; environmental effect; global climate change; water salinity; hardy fish; multiple biological factors

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1. Introduction

Water is an essential component of the ecosystem which anchors life on the Earth and integrates people from varied cultural, societal and economic backgrounds. However, in the context of a sustainable environment, the frequent anthropogenic activities that have been remarkably burdening the ecosystem are emerging as a major concern worldwide [1]. These issues of global concern have currently received prior attention among researchers worldwide as they affect the sustainability of the planet and its inhabitants. Anthropogenic activities have put global water security at risk by negatively affecting the aquatic as well as the terrestrial ecosystem in various ways [1].

Climatic changes and human activities have induced shifts in salinity levels in marine and coastal freshwater ecosystems and have immeasurably affected species diversity in the respective ecotones. Anthropogenic factors have subsequently inundated the geomorphology of coastal wetlands, estuaries, etc. The amount of dissolved salts in water can have a significant impact on the survival of aquatic organisms in the context of varied salinity preferences which are species-specific [2]. The major factor in the decline in species richness in the areas is the oxidative stress caused due to the overproduction of reactive oxygen species (ROS) in response to the shifts in the optimal salinity level [1,2].

The recurring anthropogenically induced climatic disturbances have caused havoc in the biodiversity of the aquatic ecosystem in a specific manner by releasing toxic substances/xenobiotic compounds and further altering hydrological parameters [1]. The source of anthropogenic activities largely includes the use of plastics ranging from nano- to macro-sized plastics in day-to-day life, rapid urbanization and industrialization, residual wastes generated from waste water treatment plants, construction and works, wastes generated from discarded electronic devices, transportation, biocides and fertilizer-based agriculture, etc. The proliferation of injudicious human activities can lead to the depletion of natural resources, habitat loss and a rippling effect throughout the ecosystem [2]. The optimal values of different hydrological parameters such as pH, alkalinity, dissolved oxygen, salinity, turbidity, conductivity, total dissolved solids, biological oxygen demand (BOD), chemical oxygen demand (COD), etc., help in sustaining life under water [3]. Anthropogenic activities induce a paradigm shift in biotic and abiotic parameters and thus lead to disturbances in the dynamics of aquatic biota. Among the abiotic factors, salinity is one of the significant factors which help in maintaining a differential osmotic gradient concentration for the survival of organisms belonging to different aquatic habitats which include freshwater, groundwater and marine ecotones. A swift change in the salinity level can affect the availability of nutrients and physiological processes. Altered salinity induces transformations in biotopes and biocenosis, and causes cytotoxicity, abnormal growth, osmotic imbalance, infertility and/or reproductive disorders, and neurodegenerative disorders along with various morphological and cellular anomalies [4,5]. The increase/decrease in salinity levels of a biota may induce immediate effects on the oxidative stress (OS) physiology of its organisms or might exhibit the dysfunction of mitochondrial complex enzymes upon prolonged exposure (Figure 1).

Further, salinity not only interrupts the osmotic balance but also leads to a disruption of the organelle membranes of aquatic invertebrates as well as those of vertebrates [6,7]. This review aims to assemble and analyze the ecotoxicological impact of human activities driving the rise in salinity and its effect on the oxidative regulation pathway. The assessment of the information in the present review will be helpful for understanding and mitigating the harmful effects of anthropogenic factors and climatic changes on aquatic life in a very precise manner.

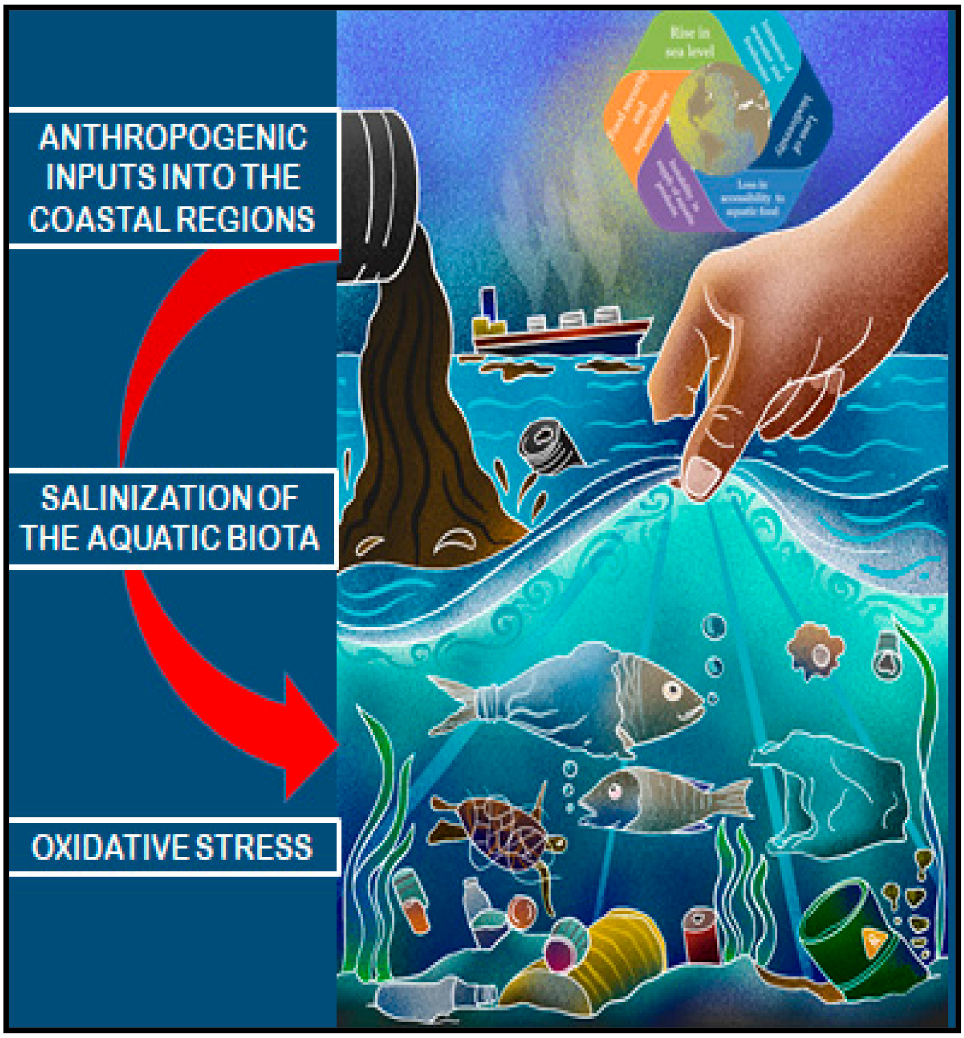

Figure 1. The anthropogenic inputs have intensified the physicochemical parameters as well as the disturbances in climatic changes. Climatic change- and anthropogenic factor-mediated salinity fluctuations have threatened the oxidative health status of aquatic organisms in coastal areas.

2. Anthropogenic Activities, Levels of Salinity and Ecological Threat

The rapid development of industries to meet the daily demands of a rising population has resulted in the production of more human-generated wastes which include CO_2 emissions, undigested pharmaceutical compounds [8], nanoparticles from wastewater treatment plants, return flow from irrigated fields [9], organic and inorganic biodegradable nutrients, heavy metal accumulation, human pathogens [10], etc. Anthropogenic inputs have led to a transformation in the dynamics of rivers, lakes, estuaries, coastal wetlands, etc., through the deposition of sediments, a change in the velocity of water flow [4], a rise in sea levels due to climatic changes, an increase in risks of flood, changes in tidal patterns [11,12], shifts in physicochemical parameters of the aquatic ecosystem (e.g., pH, turbidity, salinity, etc.) [13], an increase in the toxicity and salinity levels of groundwater sources [14], etc.

The accelerated increase in sea levels due to climatic factors is linked to anthropogenic factors [12]. The rise in sea levels has threatened coastal estuaries, lagoons, wetlands and groundwater resources in the respective areas. From the above-cited literature, it is evident that, with the increase in the abundance of microplastics, heavy metals, xenobiotic compounds and other toxic substances in the sediment, the risk of those compounds entering the food chain is apparent [15]. The species richness, species diversity and habitat spatial structure of aquatic inhabitants have become vulnerable due to salinization. In addition, ocean acidification, heavy rainfall and fluctuations in temperature modulate the salinity levels of the aquatic community [16]. Thus, irrespective of the cause behind the salinization of the aquatic community, which may be due to natural or anthropogenic factors, the physiology of coastal water inhabitants is disturbed in general and oxidative stress physiology is disturbed in particular (Figure 2).

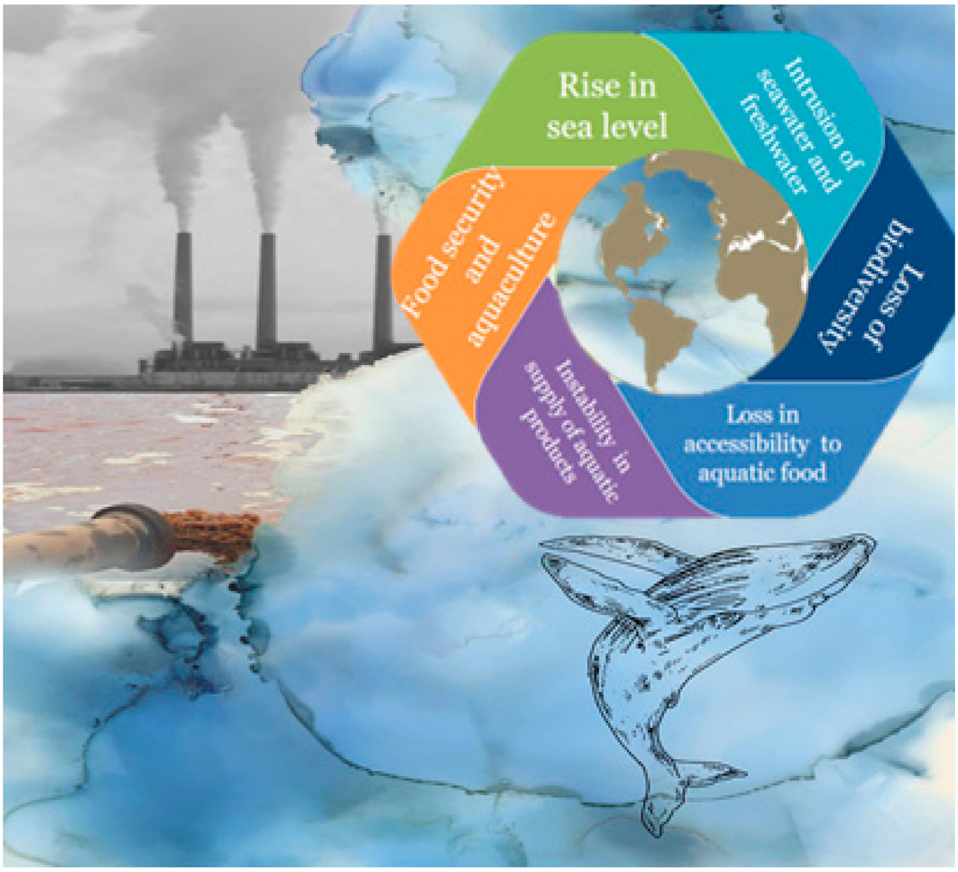

Figure 2. Human activities have led to a rise in sea levels and the intrusion of seawater into freshwater biota. The salinization of these ecotones has resulted in a loss of biodiversity and accessibility to aquatic food, and instability in the supply of aquatic products. Thus, this has indirectly threatened the sectors of food security and aquaculture.

Anthropogenic factors are also found to influence many other physiological events in both fresh water and saline water species. An increase in salinity is found to have an influence on the DNA and RNA content of cells [1]. A decrease in hemoglobin content, and alleviated RBC and eosinophil counts are found to be associated with the elevated count of neutrophils at higher salinities of 6 and 9 ppt in few freshwater organisms such as *Heteropneustes fossilis* [1,5,7]. Changing salinity in water is also related to the altered histoarchitecture in many aquatic organisms because the usual histoarchitecture in most freshwater or marine fishes is lost under saline or fresh water intrusion into their habitat, respectively. This fact is also found to be higher under the exposure of such organisms to altered salinity and anthropogenic loads. Higher anthropogenic loads are always conducive to the generation of tissue damage, which is due to the generation of higher reactive oxygen species-accumulated OS in aquatic animals. The generation of tissue damage in terms of OS is prominent under high fluctuations in abiotic factors including higher salinity or under high anthropogenic loads [1,5,7]; see Figures 1 and 2.

3. Salinization Induced Oxidative Stress Physiology in Aquatic Inhabitants

Higher/lower levels of salinity and the associated mediations in physiological disturbances in the inhabitants of coastal water ecosystems are significant. Freshwater species face hypersalinity-mediated OS (whereas marine species are more frequently exposed to hyposalinity-mediated OS (e.g., *Paralichthys olivaceus*). Osmoregulatory physiology plays a major role in the adaptation of an organism to salinity changes in the aquatic community. The energy incurred by the osmoconformers to adapt to salinity changes is lower than that incurred by osmoregulators [17]. However, only a handful of investigations have reported the regulation of OS in the aquatic biota of coastal water environments in response to salinity. The OS incurred by those species and their respective study of antioxidant profiles in invertebrates and vertebrates is precisely described.

3.1. Oxidative Stress Physiology in Aquatic Invertebrates

Salinity induction critically affects sperm quality in free spawning mussels, which perform external fertilization. The sperm is exposed to various stressors like UV radiation and salinity alterations once they are released into the aquatic environment. Studies in *Mytilus galloprovincialis* have reported OS, impaired DNA, and limited mitochondrial activity along with restricted sperm motility, causing a decline in the rate of fertilization [18]. An increase in salinity activates the oxidative stress physiology pathway by accelerating the antioxidant activities of superoxide dismutase (SOD) and catalase (CAT) in monogonot rotifer *Brachionus plicatilis* [19].

3.2. Oxidative Stress Physiology in Aquatic Vertebrates

Hyposalinity can cause oxidative damage and distress to the antioxidant profile of organisms. A decline in the physiological performance of *Paralichthys olivaceu* in coping with the hyposaline conditions has been revealed in the context of decreasing values of hematocrit and hematological parameters [20]. Furthermore, levels of antioxidant enzymes such as catalase increased in response to the oxidative damage caused in the liver cells. With the further intensification of a stressor, apoptotic factors were also reported in the species [21]. The maintenance of osmoregulatory physiology is also associated with antioxidant capacity as well as the oxidative health of species (*Xenopus laevis*) during salinity shifts. An accelerated amount of electron leakage during oxidative phosphorylation caused by the physiological adaptation and osmoregulatory responses that occur to maintain the survival of species often contributes to oxidative stress. Therefore, total antioxidant capacity is inversely proportional to plasma osmolality in hypersaline conditions [22].

Various investigations have recognized the source of anthropogenic factors in establishing a transformed hydrological community in terms of physicochemical parameters, species diversity indexes, etc. Conversely, very few investigations have reported the status of the oxidative health of aquatic inhabitants in response to the anthropogenically mediated salinization of water bodies in coastal areas.

4. Conclusions

The aim of this review was to accentuate the understanding of the oxidative stress physiology of aquatic populations induced by the anthropogenically mediated salinization of aquatic biota in the coastal regions. Anthropogenic factors have either led to an increase or decrease in salinity in different aquatic communities. These slight fluctuations in the optimal level of salinity affect the oxidative health of the inhabitants in these communities by accelerating the production of ROS, and causing an insufficient amount of antioxidant enzymes, limited mitochondrial respiration, etc. Moreover, OS also affects growth, development, physiological adaptations, performance, reproduction, etc. The OS incurred by the species is also associated with the apoptotic factors responsible for cell death. Thus, climate change, anthropogenic loads, abiotic factor stressors, alone or in combination, induce (oxidative) stress in aquatic organisms; therefore, their economic value is influenced.

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