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Towards a physiological response of fishes under variable environmental conditions: An approach through neural network

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A B S T R A C T

Present study aims to explore the effectiveness of environmental factors as predictive markers for assessing their impact on stress and endocrine physiology in selected five ecologically important fish species of Sundarban mangrove estuarine area, India. Our goal was to develop a realistic integrated conceptual model to analyze and envisage the consequence of fluctuating environmental parameters on the stress physiology of these fishes and their adaptive responses to thrive in such environment. Fishes were collected monthly throughout the year from 3 different study sites and various anti-oxidant (enzymatic and non-enzymatic) and detoxification enzymes were measured. Levels of the stress hormone cortisol and reproductive hormone 17β-estradiol were also measured as indicators of stress accumulation and reproductive status of the selected fish species. The study sites showed variations in physical factors such as pH, dissolved oxygen, temperature and salinity, which may be related to environmental fluctuation and/or pollution level. Such panel of multiple enzyme and hormone biomarkers in fish might be a useful tool to develop an assessment model. This study demonstrated a sharp indication of variation in the antioxidant enzyme profiles depending on the physical environment but the changes is exclusively site as well as species specific. To justify our assumptions cluster and non-metric multidimensional scaling (NMDS) analysis have been done to investigate the ordination of physiological parameters and water quality parameters; if it varies for each species or not. Levels of superoxide dismutase (SOD), catalase (CAT), glutathione S-transferase (GST), glutathione peroxidise (GPx), malondialdehyde (MDA) and glutathione (GSH) showed variations depending on the physical environment but the changes is exclusively site as well as species specific. Finally, the prediction model and NMDS scaling confirmed MDA, GST and GSH as decisive factor to envisage steroid hormone, whereas organic carbon, temperature, ammonia and alkalinity as the major contributor of its prediction.

1. Introduction

Developing a basis of mechanistic understanding of how different environmental conditions can modulate organismal function, in turn, might ultimately help in linking causality with predictability of response (Livingstone et al., 2000; Marigómez and Baybay-Villacorta, 2003; Moore et al., 1994). However, the necessary physiological data for environment impact on sentinel aquatic animals, specially fish that should permit a more comprehensive understanding of possible causal links between animal and ecosystem health is often limited or fragmentary, both spatially and temporally (Rice, 2003).

Various physico-chemical and biological factors may directly or indirectly affect water quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Moses, 1983). All aquatic organisms including fish have tolerable limits of water quality parameters in which they perform optimally. A sharp drop or an increase of that might affect their body functions (Davenport, 1993) and cause severe stress. Each water quality parameter interacts with and influences other parameters, sometimes in complex ways (Boyd, 1990). The connection between water quality factors and their effect on fish growth rate, health and reproduction is also complicated (Barman et al., 2005). Even low

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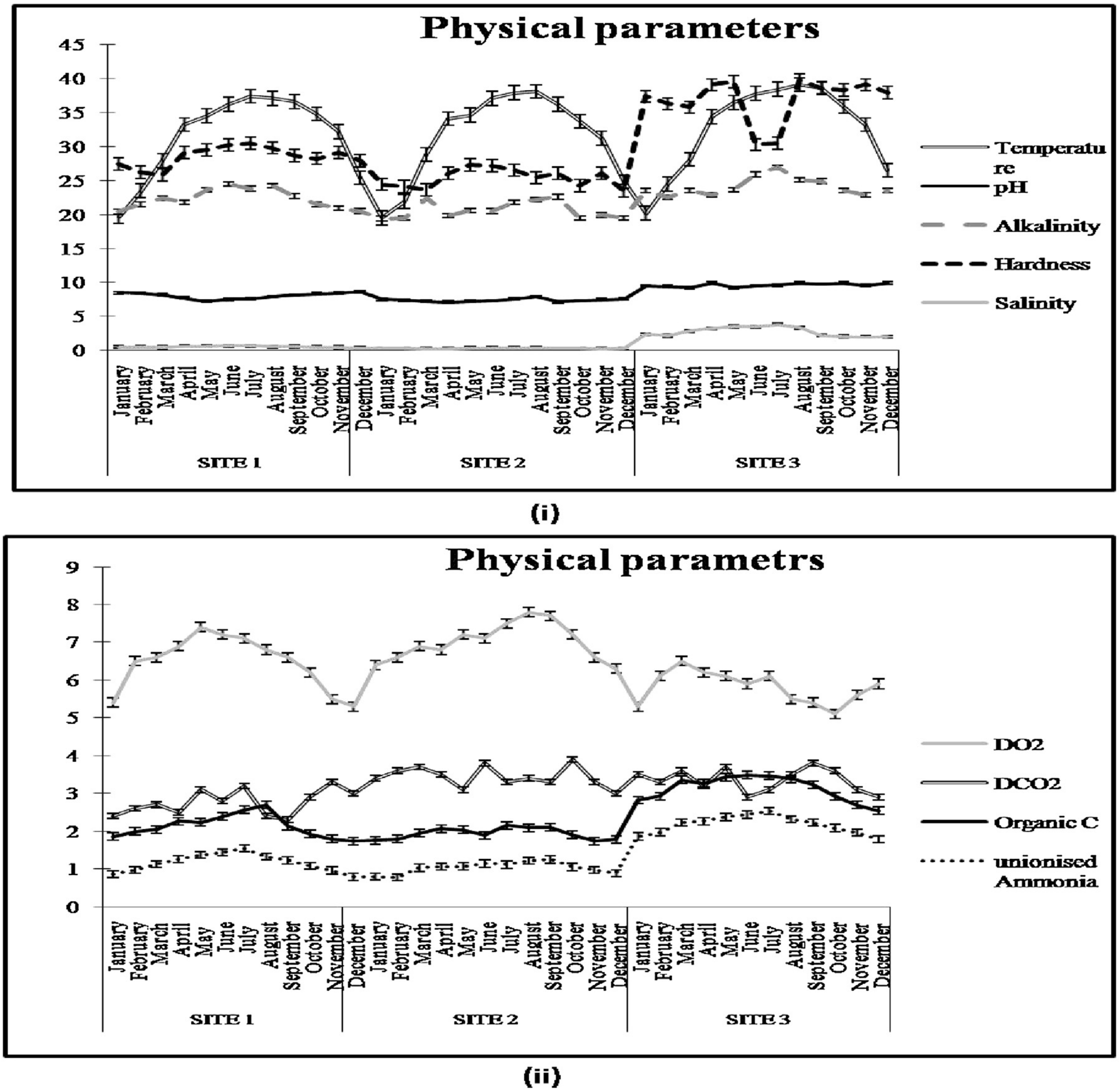

Fig. 1. Mean value of water quality parameters (i) temperature, pH, alkalinity, hardness and salinity (ii) DO_2, DCO_2, organic carbon and ammonia during an annual cycle in three different sites.

level of stress due to change in environmental parameters might have adverse long-term consequences like reduced growth rates, mortality due to infection and reduction in reproductive potential (Kjellan et al., 2015).

Anthropogenic eutrophication of water bodies associated with urbanization and agricultural and industrial development is the main factor contributing to increased toxic substances (Cazenave et al., 2006; Guzmán-Guillén et al., 2013). The production and persistence of toxic elements depends on the complex interaction of many environmental factors (sunlight, temperature, pH, dissolved oxygen, turbidity, turbulence) (Van Apeldoorn et al., 2007; Posch et al., 2012). It is well established fact that environment has great impact on xenobiotic transfer in fish. Xenobiotic toxic elements have been reported to affect the health and even cause mortality of fish species (Scott and Sloman, 2004). For this reason, investigations into the effects of unpredicted changes in physical factors and xenobiotic toxicity in fish have become increasingly important in biomonitoring studies. The liver is among the most affected organs against xenobiotic toxicity. Liver is the target site for xenotoxic elements that are dissolved in the water. The actions of such toxicity in fish liver involve increased generation of reactive oxygen species (ROS) which randomly attack cell components, including proteins, lipids and nucleic acids (Cazenave et al., 2006; Prieto et al., 2006). An imbalance between the generation and removal of ROS in this tissues results in oxidative stress and extensive cellular damage (Winston and Di Giulio, 1991; Hellou et al., 2012). Oxidative stress is defined as a situation when steady-state reactive oxygen species (ROS) concentration is transiently or chronically enhanced, disturbing cellular metabolism and its regulation and damaging cellular constituents (Lushchak, 2014). Examinations of oxidative stress biomarkers in fish liver tissues might be widely used in biomonitoring studies of ecological risk assessment. The activation of oxidative manifestations leads to response of antioxidants, activation of genes encoding antioxidant enzymes and elevation in the concentration of ROS scavengers. Antioxidant enzyme activities can be used to detect early responses in fish to different xenobiotics and toxicants (Pavlović et al., 2010; Hellou et al., 2012; Guzmán-Guillén et al., 2013). There is little or scanty data regarding changes in liver and gill antioxidant enzyme activities after the exposure of fish to the toxic aquatic environment. Moreover, considerable gaps still are remaining on response of physical factor fluctuation to oxidative stress, particularly in aquatic animals.

Estuaries are nursery ground and habitat of many shell and fin fishes (Ray and Straskraba, 2001). Estuaries are regarded to be the