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Review

Some artificially applied stressors have a positive effect on fish fitness

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Introduction

Fish are exposed to various local and global environmental stressors, such as pollutants and acute changes in temperature, and the chances of succumbing to infectious diseases may be increased as a result [1-4]. Accordingly, the stress induced by environmental stimuli in fish is thought to influence their fitness. The objective of this brief review is to summarize knowledge concerning stress in fish and the effects of some artificially applied stressors on their fitness.

Generalized stress response in fish

It is known that exposure of fish to stressors (environmental stimuli) may result in a series of biochemical and physiological changes. These changes are mediated by the neuroendocrine system at the organismal level. In addition to this neuroendocrine stress response, there is a cellular stress response following exposure to stressful situations. These stress responses affect general health, disease resistance, the immune system, growth, and reproduction [1-5]. The stress response to exogenous or endogenous stimuli in fish has been subdivided into primary, secondary, and tertiary responses. The primary response represents the perception of an altered state and initiates a neuroendocrine response. This initial response includes the rapid release of stress-related hormones such as cortisol and catecholamines into the blood circulation. Cortisol and adrenaline are known to activate many metabolic pathways. The secondary stress response is composed of the various biochemical and physiological adjustments associated with stress and these are mediated by several stress hormones. The production of glucose from glycogen in response to stress assists the animal by providing energy substrates to tissues in order to cope with increased energy demand. The tertiary stress response represents whole organism and population level changes associated with stress. Long term exposure to a stressor can lead to decreased performance, such as decreased growth, disease resistance and reproductive success. The stress response at the cellular level is the induction of family of stress proteins called heat shock proteins (HSPs), which are highly conserved cellular proteins in animals and plants observed so far. Extensive studies on model species have revealed three major families of HSPs: HSP 90, HSP70, and low molecular weight HSPs. In the unstressed cell, there is a constitutive production of these proteins (known as a heat shock cognate; HSC), which are essential in various aspects of protein metabolism [1,2,4,6,7].

Effect of stressors on the fitness of fish
-Physiological stressors-

Growth in fish is regulated to a major extent by growth-related factors, such as liver-derived insulin-like growth factor (IGF)-1 in response to pituitary-secreted growth hormone (GH) binding to the GH receptor (GHR). The GH-IGF-1 axis in fish has a critical role in regulating both growth and development [1, 8, 9]. The changes in mRNA expression levels of *gh*, *ghr*, and *igf1* genes in response to acute physiological stress derived from physical disturbance (handling) have been described in fish [10]. The *ghr* mRNA levels in pituitary, liver, and muscle decreased gradually in response to the stressor. After exposure to stress, hepatic *igf1* expression transiently increased, then decreased 16 h post-stress. However, the pituitary *gh* mRNA level did not change in response to the stressor. These observations indicate that expression of *gh*, *ghr*, and *igf1* responded differently to stress. Therefore, an acute physiological stress could mainly down-regulate the expressions of growth-related genes in coho salmon *in vivo*. This observation also suggests that a relationship between the neuroendocrine stress response and growth-related factors exists in fish.

-Thermal and chemical stressors-

Temperature can induce numerous changes in biological functions. The redox state in response to a severe acute stress resulting from heat shock in fish was measured. Plasma lipid peroxides levels in fish gradually increased after heat shock treatment. Plasma glutathione (GSH) levels temporarily decreased, but they returned to basal levels by 17.5 h post-stress. Expression levels of hepatic GSH and HSP 70 gradually increased after heat shock treatment [11]. Oxytetracycline (OTC), belonging to the tetracycline antibiotic family, has been used for many kinds of bacterial diseases in cultured fish, but high doses of OTC are known to cause side effects in fish and can have negative effects on their environment. The total GSH (tGSH) levels in the liver of OTC-fed fish were 4-fold higher than those in control fish; and double the control levels in muscle and stomach. Plasma tGSH levels in OTC-fed fish were also higher than those in control fish. Expression levels of HSP 70 in liver, muscle, and stomach decreased following OTC administration [12]. Thermal stress and tetracycline antibiotics are known to enhance reactive oxygen species (ROS) production in the tissues [13-15]. Hence, these phenomena concerning the changing patterns of multiple stress- and redox-related biomarkers suggest that thermal and chemical stressors can affect the redox state and induce oxidative stress in fish.

Conclusions and future directions

Recently, the possibilities of using positive stress (eustress or good stress) and avoiding negative stress (distress or bad stress) for animals and plants has been discussed [16-18]. When the organism is exposed to stimuli that induce distress, a functional physiological state is no longer maintained. However, when the organism is exposed to stimuli that induce eustress, it enters a qualitatively different physiological state, but still maintains homeostasis [16]. Oxidative stress has become a common theme in relation to the impacts of climate change. It is known that severe oxidative stress due to ROS leads to oxidative damage *in vivo*. However, a moderate level of oxidative stress could modulate cellular functions and have positive effects on animal health [19,20]. Accordingly, manipulation of appropriate stress treatment, such as mild physiological or thermal treatment, osmotic stress, chemical stress, rearing density and light condition, could be employed to control and improve the health and production of fish as a eustress [9-12,21-23]. Further studies should reveal the relationships between stress management, oxidative stress, growth-related factors, and fitness of cultured fish.

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