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Welfare and stress in fish

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Abstract: *Moral philosophy is involved in developing a systematic approach to determine the sense of right and wrong and has been the major subject to define ethic in animal production. Traditionally, from a human-centered perspective, fish are simply objects for human consumption. Welfare is a complex conception of human consciousness about animal suffering. Stress is a consequence of low welfare and causes important changes in animal organisms but also in behavior and life quality. The main aspects of fish welfare approached on this study are: social subordination and stocking density; water quality (temperature and ammonia); transport of live fish; external indicators of welfare; pain perception and fear.*

Keywords: *fish welfare, pain perception, social subordination, stress, behaviour*

I. Introduction

Welfare is a complex conception of human consciousness about animal suffering. The sense of welfare on media and population is influenced by social, cultural and religious background. Moral philosophy is involved in developing a systematic approach to determine the sense of right and wrong and has been the major subject to define ethic in animal production. [1] Animal care in the production chain has become an increasing concern to livestock producers, research scientists, and the general public. Traditionally, from a human-centered perspective, fish are simply objects for human consumption. When the subject of fish welfare is raised in the aquaculture industry, there is often some hesitancy. However, there is a great need for more specific guidelines for health and welfare monitoring in fish species. Stress is the direct consequence of low welfare and causes many important changes in the fish organism, being responsible for the decrease of immune functions, reproductive problems and low growth rate. [2] Therefore, this paper aims to contribute to the current debate on welfare and stress in fish and provides a criterion for assessing fish welfare.

II. Welfare and Stress

Welfare is the human consciousness about animal suffering. Evidence demonstrated that fish have the same stress response and nociceptive capacity as mammals, which suggests a significant neurologic ability, perhaps a consciousness equivalent to those attributed to the higher vertebrates. This capacity proves to be sufficient to determine that fish can suffer and, as a consequence, a general sense that fish should be treated with the same consideration, care and protection that mammals and birds receive.[1] The main aspects of fish welfare approached on this study are: social subordination and stocking density, water quality: temperature and ammonia, transport of live fish, external indicators of welfare in fish as well as pain perceptionand fear.

There are many controversies about the concept of stress in the scientific community, but typically it is characterized as something negative to the organism, that decreases the homeostasis and the survival.[3] Koolhaas et.al. (2011) have recommended that the term "stress" should be restricted to situations where the environment exceeds the normal regulatory ability of the organism and to particular situations where the organism can not predict nor control this environmental demand.[4] The stress response in fish can be divided into three stages: the primary response involves neuroendocrine responses with increase of cortisol and catecholamine hormone. The secondary response includes hyperglycemia, arterial vasodilatation of the gills and increase of systolic volume of the cardiovascular system. The tertiary response is characterized by significant systemic changes with depression of immune function. At the end of this process, the adrenal gland produces hormones responsible for decreasing the inflammatory response. At this point, the organism is more susceptible to infections. The primary and the secondary responses are adaptive, where the organism tries to recover the homeostasis. The tertiary response occurs when the organism is not able to predict or control the changes and is incapable to adapt to the new conditions. Also, when the organism is expose to a long period of stress, osmoregulation disorder can occur as a consequence of alteration in the metabolism of minerals.[2]

2.1 Social subordination and stocking density

Social subordination occurs in most vertebrate species. The competition among the co-specifics can result in behavioral and physiological changes even in dominant and subordinate individuals. These changes may influence the health and survival of the animals. The most important modification of social subordination is the increase in plasma cortisol, which appears both in confined and free animals. Animals that lived in an environment with stable hierarchy were less exposed to stress than those which were in constantly changing

groups, because hierarchy establishment is stressful. When a new group is formed, cortisol levels increase both in dominant and subordinate individuals during the early stages of socialization, but usually returns to basal levels on dominant ones after few hours of hierarchical stabilization. These changes can be associated to environment, but also can vary depending on the organism. [2] Wedemeyer (1996) and Ellis et. al. (2001) defined three important concepts of animal density: (1) Carrying capacity: is the maximum number of fish that the particular environmental resources can support. It can be expressed as metabolic loading density kg/1/min or kg food/day/m³ or food/available O_2/1/minute. (2) Crowding: is the behavioral requirement of fish in physical space. It is expressed by weight of the fish per unit of water volume. (3) Loading density: is expressed in weight of the fish per unit of running water and is related to the space and the physiological requirements of the fish.[5,6] Some changes are correlated with the increase of population density: high mortality, parasitism, diseases, low corporal condition, low growth rate, and general health.[6]

2.2 Water quality: temperature and ammonia

Most fish species can not generate and retain enough endogenous temperature to maintain the corporal temperature different from the external environment. Temperature affects chemical reactions directly, which coordinates the function of proteins and biological membranes. Low temperatures tend to stabilize weak chemical reactions, influencing the biological membrane properties, and high temperatures destabilize the protein structures, resulting on protein denaturation depending on the temperature. Water temperature has direct effect on physiology, hematology and clinic biochemistry of fish and abrupt changes in temperature may have serious consequences in individual organisms. For example, the decrease in water temperature may interfere with the immune response. The simplest form to deal with thermal stress is avoiding the stressful temperatures. When an ectothermic organism experiences temperatures out of its optimum thermal zone, it can be interpreted as stressor, disturbing the homeostasis. Depending on the temperature or specie, the fish can initiate compensation mechanisms, or it will decline its performance until death. Acute exposition results in stress response, chronic exposition results in acclimatization response. It's important to mention that the chronic exposition to the population can induce changes in natural selection. Responses to thermal stress are: (1) increase of stress hormones (cortisol, adrenaline and noradrenaline); (2) changes in cardiovascular functions and metabolism; (3) performance modifications and (4) early response to cell stress by changes in production and genetic expression.[3]

Ammonia toxicity, expressed in total quantity of ammonia ($[NH3]^+$, $[NH^{+4}]$, mg N/L), is directly proportional to the increase of water pH, but it also varies with temperature, pressure and salinity.[7] The presence of any quantity of ammonia in water indicates water filtering insufficiency either because of high density or inadequate feed.[8] Ammonia is excreted mainly by gills. Stress stimulates the production of catabolic hormones, which lead to protein lyses, increasing the ammonia production. Stressed animals are more sensitive to environmental ammonia than non-stressed animals.[3] Some fish have strategies to protect themselves from ammonia peaks during feeding or from environmental ammonia.[7] Thus, fish that do not receive food by long periods of time are more sensible to ammonia than fed fish. Some species, like *Alcolapia grahami*, can excrete urea in some specific conditions when the environmental ammonia is high, but in these cases, the excretion of ammonia requires energy waste.[3] Israeli-Weinstein and Kimmel (1998) and Xu et. al. (2005) have demonstrated behavioral changes after ammonia exposition. The rise of ammonia causes: reduction of fish distribution into the tank, fish stays on the bottom or on the surface of water column, reduction of swimming and damage on gills, resulting in breathing problems, hyperglycemia and diminish of feeding.[9, 10]

2.3 Transport of live fish

The transport is physiologically stressful to fish, especially over long distances. The main challenge found in transport is the monitoring of water quality, mainly ammonia and temperature parameters. Therefore, the water density of the transport tank must be low. Thus, the oxygen rate will be stable and the ammonia production will be low. The temperature is crucial to maintain the system stability: if temperature is low, fish can become hypothermic; if temperature is high, it raises the ammonia toxicity and declines the dissolved oxygen.[2] During transport, fish lose salt through the gills because of stress and loss of superficial skin mucus protection. This loss leads to osmoregulation disturbances and tissue damage. The movement of the vehicle can also damage the animal. To minimize the stressors, quality equipment is crucial during transport, as well as monitoring fish and water.[1]

2.4 External indicators of welfare

2.4.1 Color changes

Fish can change their body color due to environmental stimulus, social subordination and stress. This change is related to Melanin-concentration hormone, which is secreted by hypophysis. [11, 12, 13]

2.4.2 Respiratory rate

It can be observed by opercular movements. The increase of this rate suggests respiratory difficulties and it can occur by decline oxygen consumption or intense exercise.[14, 15, 16]

2.4.3 Swimming and behavioral patterns

These parameters can change after stress, predation and diseases.[9, 10, 17, 18]

2.4.4 Growth rate

Low growth rate can indicate chronic stress.[19, 20]

2.4.5 Corporal condition

Diseases, infections and improper feeding lead to decrease of corporal condition and it's a common indicator to assess general health. However, chronic stress conditions leads to increase infection and non-infection illnesses susceptibility, as well as changes in normal reproductive cycle, weight gain or loss, etc.[1, 21]

2.4.6 External morfhological abnormalities

Low environmental quality can lead to gill damage (like discoloration), fin and eye damage. These problems could indicate chronic exposition to low quality water.[22, 23]

2.4.7 Food Comsumption

Both acute and chronic stress exposition can affect the food consumption. Food-deprived fish is less resistant to stressors than fed fish.[19, 24]

2.5 Pain perception and fear

Fear can be defined as a behavioral and physiological response after threat or danger perception, which includes behavioral changes that make the individual avoid this threat or danger, resulting in increased of survival. It was observed similar behavioral changes in fish from those known in higher vertebrates.[1] Sentience, other import conception related to fear, is the ability to detect and response to external stimulus.[25] Broom (2014) defined sentience as: to evaluate the actions of other co-specifics and to relate to itself and third parties, remember some of its own actions and knowing their consequences, as well as knowing about risks and benefits, having some feelings and having some degree of consciousness.[26] Ricinque et. al. (2017) suggested that well educated people have higher moral consideration in fish welfare than non-educated people and reported the importance of communication between society and science to improve the welfare around the world.[25]

The inability of verbal communication does not deny the possibility of individual pain experience. Therefore, the requirements to determine pain are: the observation of nociceptors and endogenous opioids, cerebral structures involving pain process, the ability to reduce nociceptive response after analgesic administration, and the learning mechanisms to avoid danger.[1] Sneddon et. al., (2003) found five types of nociceptors innerved by trigeminal nerve, where 35% of them are located in the opercular area, head and lips of trout.[27] Dunlop and Laming (2005) showed that nociceptive signals from skin behind the operculum of rainbow trout and goldfish induced cerebral activity.[28] Mettan et. al (2012) assessed the effects of lidocaine (a local anesthetic) after injecting saline or acetic acid on snout of rainbow trout, similar to the study of Nordgreen et. al. (2009), which tested morphine and had demonstrated pain perception in these fishes.[29,30] Studies have demonstrated, after injury in medial and lateral pallium, avoiding behavioral learning in goldfish and showing involvement by these telencephalic structures in this process.[31,32]

Asphyxia on ice or evisceration without any anesthesia are common examples of killing methods used in fish farming. These methods cause degrees of suffering and pain in fish. After experiencing fear, there are changes in motivational and affective states, that lead to, for example, swimming activity reduction, appetite decrease and changes in fear response. If fish experienced pain, it may pay attention to the affected painful part of its body and rub it against the tank wall.[33] Any kind of management, for example feeding, handling or transportation, can cause a degree of stress and/or pain Awareness during these procedures is the key to increase fish welfare.

III. Conclusion

Fish welfare, in general, needs to overcome the barrier of human empathy. People still do not see fish as an animal that can suffer or even feel and perceive pain, and this is the reason why the scientific community must increase research on this matter. Many behavioral, physiological and immune observations were made along the years in fish, which demonstrated that high vertebrates and fish are not so different when it comes to animal suffering. Thus, fish must receive the same respect and moral consideration as other animals.

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