

REVIEW

Welfare of farmed fish: moral considerations, science, and problems of implementation

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The question whether fish are worthy of moral consideration, and thus, can be included in humanity's expanding moral circle, was first raised in the 1990s. After the turn of the millennium, "fish welfare" was used by more and more scientists in the field of aquaculture, animal advocates, politicians, legislators, the fish farming industry, and consumers (Kristiansen and Bracke, 2020). For several years, the widespread view amongst the scientific community was that welfare was intimately connected with the absence of stress and disease. There is no doubt that, stress, health, and welfare are strongly interrelated, but not in a simplistic manner. Stress response is an essential, genetically embedded, adaptive mechanism designed to secure survival and other critical biological functions. Therefore, it is crucial to determine, in a species- and life-stage specific way, at what point do we cross the red line that stress does impair fish welfare. We should also characterise allostatic load and overload, as well as coping styles and behavioural traits, over time and across situations, leading to differential stress response among proactive and reactive individuals. This is important as due to different gene x environmental interactions a given individual may show a different response following exposure to a stressor of the same nature, duration, and intensity, based on its cognitive capacity, cognitive ability and appraisal of the controllability and predictability of the situation or challenge (Korte et al., 2007).

Welfare, Health and Stress

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same nature, duration, and intensity, based on its cognitive capacity, cognitive ability and appraisal of the controllability and predictability of the situation or challenge (Korte, Olivier, and Koolhaas 2007).

The link between fish health and welfare is obvious. However, fish health and fish welfare are not synonymous terms. Herein, we consider that health is a part of welfare, and we adopt Broom's approach that "when an animal's health is poor, so is its welfare, but poor welfare does not always imply poor health" (Broom 2007). For example, fish under chronic stress situations may not show signs of poor health, for a certain period, but this poor welfare status indicates a health risk in the future, as long activation of physiological - neuroendocrinological mediators of allostasis and of behavioural coping mechanisms may lead to immune-suppression and abnormal behaviour, and in turn to increased disease susceptibility, physical injury, body damage and infections (Broom 2007). Besides, fish that are reared with adequate welfare standards are more likely to be robust and healthy, and less prone to spread disease.

Science and Ethics interplay

In daily life, fish farmers, aquaculture scientists, and consumers, believe that fish welfare poses mainly empirical questions that ask for empirical evidence-based decisions (Bovenkerk and Meijboom 2012). However, moral considerations are always present to play an important role too. Questions like "is there a morally relevant difference between fish and other animals, in particular mammals?" or "are farmed fish entities of moral concern?", are normative questions in nature. Empirical in nature questions provide also challenges, towards a scientific approach for fish welfare: "how to characterise coping styles?", "how to determine allostatic load and overload?", "How to measure fish welfare?" And finally, there is also another set of important questions, like: "how do we define fish welfare?", "how do we weigh fish welfare?", "do fish have personalities?", "do they have emotions?", that are both of normative and empirical nature and entail, science-ethics interactions. Very often, the view of welfare one emphasises will determine the criteria and results of welfare assessment. In general, talking about animal welfare, three main different views, not necessarily mutually exclusive, can be found: function-based, feeling-based, and nature-based views. "Function" approach is based on fish state as regards its attempts to cope well with environmental and farming conditions; "feeling" approach is based on affective state and the assumption that fish have feelings which are a fundamental component of welfare, and "nature" approach presumes that welfare depends on the ability of fish to display their inherent natural behavior.

Measuring Fish Welfare

We define welfare state as the effort for an individual fish to cope well to its environment and its own experienced affective state, at a given moment of life stage and time. We also see five fish welfare needs (Stien et al. 2020):

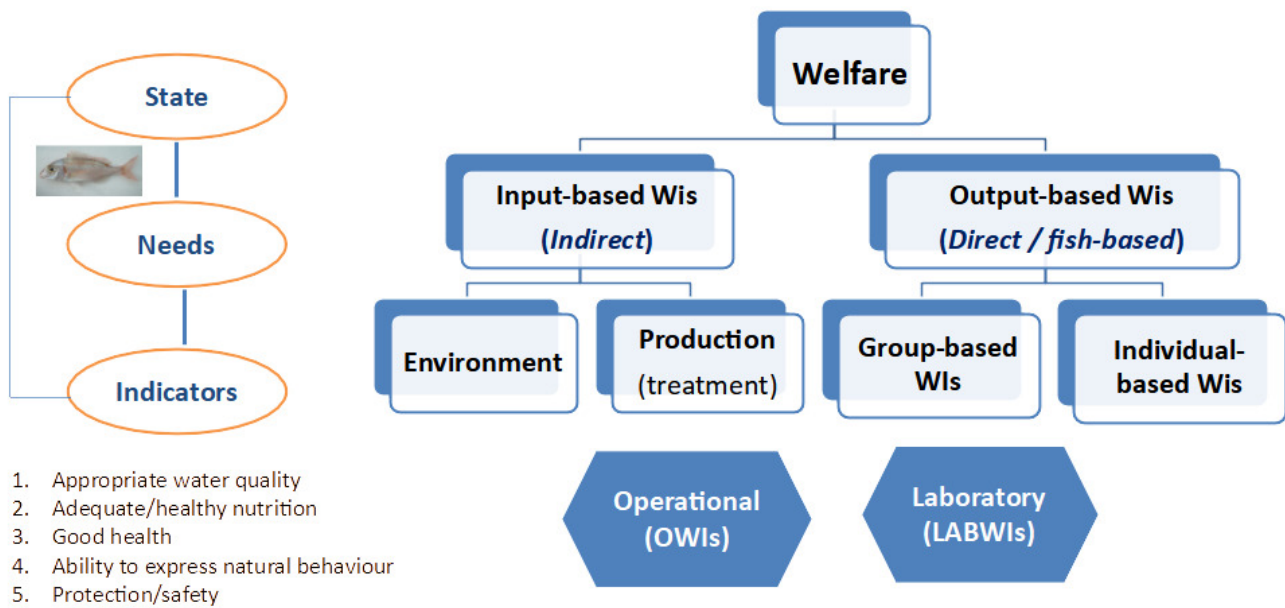


Figure 1. Fish welfare needs and indicators for an adequate assessment of fish welfare status under intensive culture conditions (modified from Stien et al. 2020).

appropriate water quality, adequate/healthy nutrition, good health, ability to express natural behavioural tendencies and protection/safety. To assess welfare state of farmed fish, it is necessary to develop and validate a set of measurable, reliable, scalable, and easy-to-use welfare indicators that are (i) species-specific, (ii) life-cycle specific, (iii) production system/phase specific and (iv) fulfill the welfare needs of a given species.

Welfare indicators ([Figure 1](#)) can be either input- or output-based (Noble et al. 2018, 2020; Pavlidis and Samaras 2020). Input-based indicators refer typically to parameters regarding the environment (physical and reared) and the available resources the animals are subjected to. Output-based (or animal-based) indicators measure the outcome or the consequences, of how well the welfare needs are met under certain life stage, farming conditions and husbandry procedures, and can be further based on observations of a group/stock of individuals (like mortality percentage, swimming behaviour) or on observations of individual fish. Welfare indicators may also group into operational welfare indicators, that the farmer should be able to assess and interpret on farm, and laboratory welfare indicators, requiring sending samples to a designated, specialised laboratory for further analysis and evaluation.

Input-based indicators (like water temperature, oxygen, pH, water current speed) are objective and can be easily recorded. However, their interpretation is dependent on exposure duration, interactions with the other environmental parameters and fish robustness. Group-based indicators focus on observations of the fish within rearing tanks and sea cages (e.g., mortality, feeding behaviour, schooling behaviour, growth rate, disease, presence of scales or blood in water).

Individual-based indicators assess the physiology, condition indices, health parameters, behaviour and external morphology/physical appearance of individual fish. It is worthy to mention that several of these direct welfare indicators, characterise product quality too.

Physiological indicators are among the most widely used welfare indicators. They are objective, quantitative and of affordable cost. They can be used on site by using portable devices. However, they are mostly related to the evaluation of the acute stress response and presence of disease, which often but not always reflect the welfare state of the fish. The search for valid welfare physiological indicators, which could be used as reliable chronic stress, health, and welfare indicators, is still in progress. Precision livestock farming and smart aquaculture offer significant opportunities and new tools for monitoring and evaluating farmed fish welfare. Artificial intelligence, especially machine learning and computer vision applications, seems to be the next frontier technology of welfare data systems. Sensor technology, IoT, big data and cloud computing, deep learning, system integration and precision control are important components of fish welfare assessment in a digital world.

Quality of Life

The five freedoms, introduced back in 1965 by the Brambell Report (Brambell 1965), formed a break-through in the way we see intensive livestock farming practices and have had major impact on animal welfare thinking internationally. However, recent scientific advances prompt us to move further on; fish can have both negative and positive experiences, and that the net balance between them will vary over time. The “Quality of Life” (QoL) scale approach, proposed by Mellor (Mellor 2016), is based on the relative balance of positive and negative experiences animals may have. Mellor defines five categories in the QoL scale: (i) good life, (ii) life worth living, (iii) point of balance, (iv) life worth avoiding and (v) life not worth living. In a “Good life”, the balance of salient positive and negative experiences is strongly positive; it is achieved by full compliance with best practice advice, well above the minimum requirements of codes of practice or welfare (Mellor 2016). Such an approach may potentially update standards in codes of fish welfare.

Conclusions

The definition of animal welfare has changed over time, with early definitions emphasising in the absence of negative experiences, disregarding the presence of positive experiences. Fish are sentient beings, and they belong in the moral community. When it comes to defining and judging welfare, a combination of scientific approaches and value judgments is at work. Research (empirical study) on fish needs and capacities is evidence-based, but it is not normatively neutral. The welfare of an individual is its state as regards its attempts to cope well with its environment and its experienced affective state, at a given moment of time. Welfare, stress, and health are interrelated but not in a simplistic manner. Fish welfare is species-specific for a given production system. Welfare

indicators and assessment schemes are available - validated for a limited number of reared fish. The One Health approach, recognising that the health of humans, animals and ecosystems are interconnected and defining a set of success metrics for farmed fish welfare is needed and should be embedded into aquaculture sustainability.

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