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Cover photograph: Arctic char in aquaculture pond. © Petri Heinimaa.

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PREPARATION OF THIS DOCUMENT

This is the final report of the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) project "Welfare of Fishes in Aquaculture" 2014–2018. The project was initiated by the Commission because welfare in animal husbandry is of increasing public concern and of increasing importance. It was identified as important topic for the research institutes associated with EIFAAC Member countries to investigate and to publish an FAO report on findings concerning the welfare of fishes in aquaculture. EIFAAC, as the only pan-European body addressing inland fisheries and freshwater aquaculture, was ideally fitted to this task. The draft version of this document received comments from several stakeholders whose comments and suggestions were valuable and helpful in improving the quality of the report. The final version was reviewed by Members of the EIFAAC Technical and Scientific Committee and approved by the EIFAAC Management Committee for publication by FAO.

ABSTRACT

The welfare of fish in aquaculture is of increasing public concern in Europe and thus of growing importance for fish farmers. Although the topic can be regarded as controversial, due in particular to the lack of available knowledge, there is nevertheless an urgent need for fish farmers, authorities and scientists to develop criteria, approaches and practices to monitor and safeguard the welfare of cultured fish. The objective of this document is to provide the opinion of EIFAAC Member institutions– as the reference body in the field of inland fisheries and aquaculture – on how, given the current state of scientific knowledge, fish welfare issues can be integrated into best practice guidelines for fish culture.

This report deals with the welfare of farmed finfish and neither addresses capture fisheries, be they commercial or recreational, nor welfare issues related to the culture of crustaceans and molluscs. The report focuses on the welfare issues of on-growing fish while giving little to no attention to larvae/fry and broodstock. Likewise, the report focuses primarily on the culture conditions for farming of fish and gives little attention to welfare aspects related to transport and slaughter. Finally, emphasis is given to the culture of freshwater fish, but marine species are included where appropriate. It is understood that the principal welfare issues are comparable for freshwater and marine fish culture.

The report is, as much as possible, generic, not focusing on species-specific issues (except where absolutely necessary). However, unavoidably, the report is biased due to the fact that the available information on welfare issues is not equally distributed across fish species.

CONTENTS

1. INTRODUCTION

The increasing importance of fish welfare in aquaculture comes from ethical considerations as well as from the perspective of improving standards and quality of fish production technologies and aquaculture products. The welfare status of the fish has direct implications for their production and for the sustainability of the industry as a whole. Fish kept under good welfare conditions are less stressed and less susceptible to diseases and therefore they require less medication and treatment, show better growth rates and food conversion and ultimately provide a better-quality product. Finally, the economic benefits are obvious. In addition, consumers care about welfare issues potentially associated with intensive production practices, and they expect from the fish farmers that the welfare of farmed fish is addressed.

In response to the actual discussions on fish welfare, authorities are developing regulations for welfare standards in fish farming. Current regulations at the European Union level include, for instance, Council Directive 98/58/EC, Regulation (EC) 882/2004, Regulation (EC) 1/2005, Council Directive 2006/88/EC, Regulation (EC) 710/2009 (revision in preparation), and Regulation (EC) 1099/2009. With the exception of Regulation (EC) 710/2009, the abovementioned rules do not impose any specific requirements on the keeping, transport or slaughter of fish. In addition to EU regulations, many member states have specific national legislation for animal welfare, which often include specific recommendations for fish. In this context, it should be emphasized that the aquaculture-relevant animal welfare legislation is often not harmonized among European countries.

The key challenge in developing recommendations and regulations on the welfare of farmed fish is that both scientific knowledge and practical experience in this area are still limited:

- It is not well-understood to what extent welfare concepts and definitions as they have been developed for common warm-blooded farm animal species can be applied to fish. As stated by the European Food Safety Authority (2009): “The concept of welfare is the same for all farm animals, i.e. mammals, birds and fish, used for human food and given protection under the Treaty of Amsterdam. Fish welfare, however, has not been studied to the same extent as terrestrial farm mammals and birds, neither welfare concepts nor welfare needs have been clearly understood for the various species of farmed fish.”

- Fish culture involves a huge number of species, with each species and its respective life stages having different welfare requirements. Ideally, welfare measures are based on the understanding of the needs of the various species, but the understanding of their welfare-relevant biology is indeed very limited.

- As a consequence of the limited knowledge of and the diversity of cultured species, relatively few operational welfare indicators (OWI) for farmed fish have been validated to date.

In the understanding of EIFAAC and the Working Group, aquaculture is an efficient tool to produce food. However, it is also our understanding that welfare of fish is an intrinsic part of fish production. Only when the basic biological requirements of the fish (water quality, feed and others) are adequately fulfilled will food utilization, growth, physical integrity and health of farmed fish be optimal and the fish can be reared and produced in a manner that is both ethically defendable and economically sustainable. Fish under suboptimal welfare conditions will perform poorly; for instance, they may show slow growth and increased susceptibility to disease. This negatively affects fish production and compromises the image of the industry. Therefore, it is in the self-interest of the aquaculture industry to optimize culture conditions in order to support and promote fish welfare. Fish welfare in culture also extends to the practices associated with harvesting and killing (harvest, stunning, killing, exsanguination and evisceration), aiming at reducing stress to the animal and therefore also optimizing the quality of the product.

In order to advance the knowledge on how good fish welfare can be achieved under the various aquaculture production systems and technologies, and how fish welfare can be monitored, intensive

discussion and communication among scientists, regulators and fish farmers is needed. There currently exists a lively and controversial discussion on what "good welfare" means in the case of farmed fish and how it can be ensured and assessed. This discussion has generated a number of reviews and position papers (see Table 1). The aim of the present report is to contribute to this discussion by providing the perspective of EIFAAC as the reference institution in the field of inland fisheries and aquaculture. The questions that will be discussed include the factors and conditions of the farm environment that may impact the welfare of fish, which practical measures could be instrumental to support the good welfare of farmed fish, which parameters may be used as operational welfare indicators and, finally, how fish welfare could be promoted and monitored within the industry. Importantly, the report does not aim to present a review of the scientific knowledge on fish welfare. The report argues from the caretaking point of view and asks how, despite the limited available knowledge, good fish welfare can be achieved in practical fish farming.

2. WELFARE CONCEPTS

If we take the definition of welfare according to Broom (1986) as "the welfare of an animal is its state as regards its attempts to cope with its environment," the key challenge is how to translate such a principal statement into welfare concepts of practical relevance within the farm environment. Defining and legislating a welfare concept will have direct implications on the production of aquaculture animals and on how animal welfare is assessed and measured. Also, by which parameters can we measure that cultured fishes are able to cope with their environment? Can we reduce welfare to the absence of negative factors such as injury and disease, or does welfare, as formulated in the principles of the "Five Freedoms,"(Farm Animal Welfare Advisory Committee 1979) also include positive measures such as the freedom to express normal behaviour? This debate is further complicated by the still-unresolved question of whether fishes are sentient animals. What is a proven fact is that fish do experience stress and fight-or-flight responses, as can be seen through hormonal changes. What is discussed controversially, however, is whether fish experience feelings and emotions and are conscious of pain and fear, although there exists substantial neuroanatomical, physiological and ethological evidence that fish are sentient.

There are three broad concepts under which animal welfare has been defined: nature-based, function-based and feelings-based definitions. Although these definitions each take a different viewpoint, they are not mutually exclusive. The nature-based definition considers animal welfare to be in good order if the animal can engage in natural behaviour. With this concept, it will be difficult if not impossible to realize a good welfare status for cultured fish. The function-based concept considers welfare to be satisfied if the animal is in good health and shows normal biological functioning and good growth. This concept is often criticized as being too reductionist in that it neglects the mental dimension of welfare. According to Ashley (2007): "Physical health is the most universally accepted measure of welfare and is undoubtedly required for good welfare. … However, for many, good welfare goes beyond just physical health and also involves a lack of mental suffering." This comment approaches the third welfare concept, which understands animals as sentient beings that can experience positive and negative feelings and that can suffer emotionally from poor culture conditions. This definition explicitly assumes that animals possess the awareness for positive and negative mental states – a question that is discussed controversially for fish. For instance, chronic stress would be problematic not only because of the associated functional impairments but also because of the psychological suffering (cf. Ellis *et al.*, 2012). However, as long as we cannot determine whether and to what extent fish are sentient and possess emotional states, it is pragmatic to address fish welfare from a precautionary point of view. This implies that we identify those factors and conditions in the farm environment that impact the normal biological functioning and health status of the fish, and it allows us to identify indicator parameters (often referred to as operational welfare indicators, or OWI) to monitor whether the conditions of farming, transport or slaughter have a negative impact on the fish. In addition, ensuring the physical health of the cultured fish will also partly support mental health, and it represents a pragmatic approach to fish welfare as long as our understanding of fish emotions and sentience is still limited.

The subsequent sections in this report will look in more detail at practices that can affect welfare, at potential indicators for monitoring, and at methods for improving welfare in farmed fish.

3. PROCESSES AND FACTORS IN AQUACULTURE THAT CAN BE CRITICAL FOR FISH WELFARE

Fish farming is a multifaceted operation involving biology, technology, personnel management and economy. Many of the working procedures on a fish farm are linked to fish welfare. Fish farmers should thus be aware that safeguarding good fish welfare is an omnipresent task in daily farm management. As a first step for safeguarding welfare in aquaculture, the processes and factors that can be critical for fish welfare have to be identified. In the following, several critical issues are indicated, with the understanding that the list is not final.

3.1 Staff (education, training, responsibility)

Fish reared in aquaculture eventually depend completely on man. Hence, well-trained staff are a critical factor in supporting the good welfare status of the fish. "Trained" means that the personnel responsible for the fish are educated in welfare-related issues, including knowledge in the biological requirements of fish in general as well as in the specific requirements of the particular species cultivated and in considerate handling. The personnel know the normal behaviour of the fish species cultivated and are aware of their environmental requirements. The staff are trained in detecting abnormalities in fish behaviour and in fish health that possibly indicate a welfare problem. Training also involves technical knowledge in the overall functioning of the rearing system and how to react if problems show up. Finally, well-trained staff will be able to evaluate critical situations within the farming system, including critical fish behaviour indicative of deteriorated water quality, and will be able to immediately take action to sustain functioning of the technical systems.

3.2 Fish (species, life stage, domestication)

According to FAO (2018), more than 350 finfish species are cultivated in aquaculture. Many of these species evolved in a variety of entirely different habitats and adapted to different environmental conditions and thus developed highly diverse biological traits. Consequently, each species and each stage of life has its own specific requirements from the rearing environment. For the majority of species used in European aquaculture, basic requirements are known and can be found in the literature. Importantly, strains of a species may vary in their adaptation to environmental conditions. This is especially true for some species that have been subjected to domestication and intensive genetic selection, such as rainbow trout, carp, or Atlantic salmon. Through domestication, ranges in behaviour and tolerance may be changed compared to the respective undomesticated species.

3.3 Husbandry techniques

A number of husbandry factors and practices can impact the welfare status of the cultured fish. Again, due to the number of species reared in freshwater aquaculture, the requirements of the respective species vary considerably. Therefore, in the following only general hints can be given.

3.3.1 Water quality (physical, chemical parameters)

Fish are in intimate contact with water. Thus, water quality is arguably one of the most critical factors for fish welfare and needs to be closely monitored. Poor water quality or rapid changes of water parameters can lead to both acute and chronic health and welfare problems. Each species has its specific requirements for water quality. Under all circumstances, water quality has to be kept at optimal levels. Water quality parameters include temperature, conductivity, pH, oxygen concentration, nitrogenous compounds such as ammonia, nitrite and nitrate concentration, and more. The flow rate of the water in a culture system (the exchange rate of a rearing unit, in other words) is a critical determinant of water quality, as it provides fresh oxygen supply and dilutes and disperses metabolic waste. At a high flow rate, a certain culture system may tolerate much higher fish stocking densities than at a low flow rate.

Flow speed and direction within a tank should be arranged in a way that all water is exchanged regularly to avoid “dead” unexchanged zones, thus preventing areas with low oxygen content and/or increasing ammonia concentration due to unwanted sedimentation of faeces and uneaten feed.

Modern fish farming often relies on technical equipment to keep water quality at optimal levels. Especially in intensive production systems, system functioning is essential, as malfunctions may rapidly cause serious deteriorations in water quality. Monitoring and alarm systems are necessary to detect and report rapid changes, allowing for respective actions. This includes the redundancy of basic techniques in which, for example, oxygenation, pumps, independent rescue power systems and/or aeration/oxygenation equipment keep functioning even in the case of power failure to secure the survival of the fish in the case of emergency.

In addition to water quality, further environmental factors such as exposure to sunlight, noise and vibrations can impact fish welfare.

3.3.2 Stocking density

Stocking density (kg fish/m³) describes the biomass of fish per unit of water in the cultivation system; it is one of the main characteristics that determine whether a cultivation system is extensive or intensive. Stocking density can have a major impact on fish welfare, as it influences not only water quality but also growth, stress status and social interactions – such as aggression – among the fish. Optimal stocking densities that support good fish welfare depend on biological factors such as species or life stage and also on technical factors such as water flow rates. Stocking density is limited by water quality and thus has to be adjusted to maintain optimal water quality.

For species like rainbow trout, other salmonids, eel, tilapia and catfish, successful rearing is, in general, only possible at densities in which all fish of the rearing unit form a community. If, for instance, the stocking density is too low, single fish may develop dominant behaviour, becoming aggressive to the other fish in the tank**.**

3.3.3 Rearing environment

Rearing environments in current aquaculture facilities are usually optimized under a technical perspective. The rearing environment is constructed in a way that prevents damage to skin, fins, etc. The tanks should allow an easy and effective removal of faeces, avoiding disturbance of the fish as much as possible. Further technical aspects of the rearing environment are, for example, protecting the fish from predators and preventing the escape of farmed fish. In addition, noise due to pumps and other machines can be a disturbing factor to the cultured fish. A question that is gaining momentum in recent years is whether biological needs of fish can be considered in the rearing environment. Certain conditions, such as appropriate illumination of the tanks, can be easily met. A more controversial point is the enrichment of the culture tanks by structures such as hiding places, as they may prevent efficient cleaning of the tanks and thereby promote disease problems.

Minimizing external disturbances such as visitors wanting to view the farm is an important part of any fish farm health plan. Likewise, effective protection against predators such as birds needs to be considered. Having a fish health plan in place, with proper protocols for disease prevention, disinfection and cleaning protocols, site biosecurity, control of disturbance, etc., is an important part of improving the fish welfare in the farm.

3.4 Handling and transport

Handling is needed in many ways throughout the production cycle. Handling includes the transfer of fish within the rearing system as well as for transport between farms and for marketing and slaughter. Fish also have to be handled during grading, which covers aggregation of the fish in a small area of the rearing unit, netting or pumping. As fish are very sensitive to handling, handling should therefore be kept at an absolute minimum. The sensitivity of the fish to handling is in particular dependent on

temperature. At high temperatures, fish usually are more sensitive and handling should be avoided. The same applies to very low temperatures, and at temperatures below zero, fish should not be handled at all. All equipment used for handling must be in a good hygienic condition and, if possible, have a plain surface structure to avoid fish injury.

3.5 Slaughter

The process of harvest for slaughter involves many working steps that are stressful to the fish and may compromise fish welfare and product quality. It includes crowding inside the rearing system, removal from the rearing system and, in the event that the fish are not killed on-site, transport to the abattoir. The operating cycles involved in slaughter should be well-organized to reduce to an absolute minimum the duration and intensity of stress.

Before killing, fish have to be stunned. The farmers must select an appropriate method for effective and fast stunning that reliably induces unconsciousness of the fish until killing. It also requires well-trained personnel who are able to recognize signs of re-consciousness in the fish species after stunning. For stunning and killing, manual or automated techniques may be used.

For most commercially important fish species, technologies are now available that allow humane slaughter. It is the responsibility of farmers to apply state-of-the-art technologies for the slaughtering of the fish and to spare any avoidable distress and pain during the slaughter procedures.

Slaughter of fish may include exsanguination. This is the process whereby an animal is cut so that it bleeds to death. Fish are cut in highly vascular body regions, and the process is stressful unless the animals are unconscious. If not stunned, according to behavioural and neural criteria, fish may remain conscious for 15 minutes or more between the time when major blood vessels have been cut and when they lose consciousness. Eel brains may continue to process information for 13–30 minutes after being decapitated, and some fish may remain conscious for 20–40 minutes after evisceration.

3.6 Disease prevention and prophylaxis

Disease prophylaxis is a major aspect of safeguarding fish welfare. As a first step, any introduction of disease agents through the transfer of infected fish, the use of contaminated equipment or contamination by personnel should be avoided. This includes the separation of infected fish populations during a disease outbreak and the removal of fish carcasses from the rearing units in order to avoid displacement by vermin. A further measure of disease prophylaxis is the vaccination of fish against the most relevant bacterial and viral diseases for the cultivated species in order to prevent a disease outbreak – although the number of registered vaccines for fish is rather limited. Examples include the vaccination of rainbow trout against enteric redmouth disease (*Yersinia ruckeri*) by immersion or oral vaccine and the vaccination of Atlantic salmon against furunculosis (*Aeromonas salmonicida*). Disease prophylaxis is also the provision of good rearing conditions, including optimal water quality and low levels of stress. We should keep in mind, however, that vaccination itself can cause damage and stress to fish. Likewise, other procedures, such as treatment of parasitic and fungal pathogens by salt or formalin baths, also are stressful for fish.

To support the systematic consideration of the processes and factors that can be critical for fish welfare on an aquaculture farm, the following decision tree may be helpful:

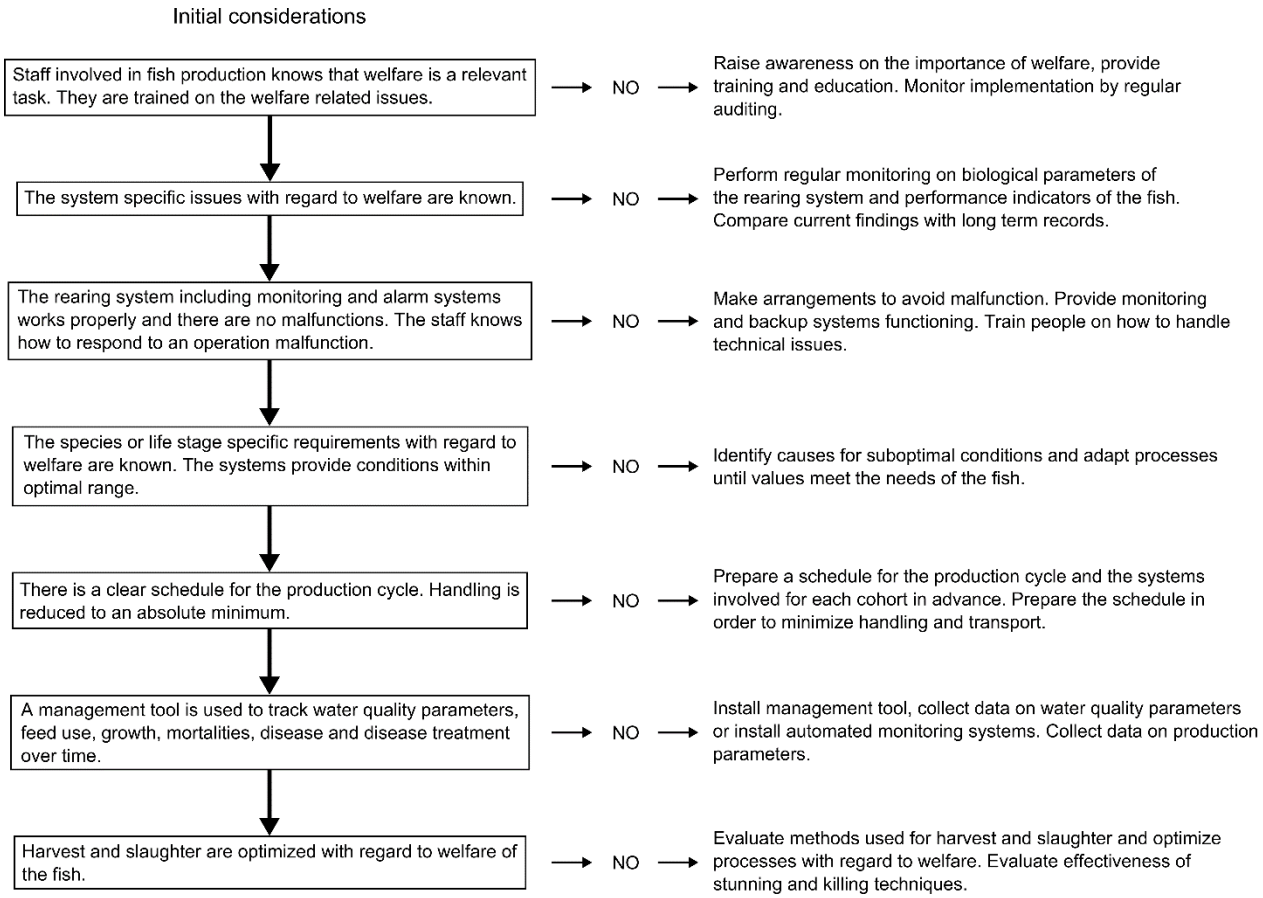

Figure 1: Decision tree in considering the welfare of farmed fish

The decision tree outlines the processes and factors that can be critical for fish welfare on an aquaculture farm. At each process and factor in which welfare might be compromised (left thread), a number of measures for troubleshooting are specified (right thread). When a statement in the left thread is not accurate, the corresponding measure in the right thread might be considered. If a statement in the left thread is accurate, the process moves to the next consideration below. The decision tree might help farmers in setting up a welfare monitoring system, and it might also be used for regular welfare inspection and auditing.

4. ASSESSMENT AND MONITORING OF FISH WELFARE

A few key elements form the basis for the assessment and monitoring of fish welfare. Above all are the training, knowledge and experience of the staff responsible for the running of the respective aquaculture unit. Without experienced and well-trained staff, states of poor fish welfare may remain undetected or may be detected too late. This also includes alarm systems based on site-specific automated monitoring.

Due to the large number of fish species reared in freshwater within the EIFAAC region and the wide variety of aquaculture systems in use, general recommendations are given that may form the basis for species-specific recommendations in the future.

For most species in European aquaculture, a reasonable amount of information on basic biological requirements is available. This information should be implemented in the rearing environment. If it comes to animal-based parameters for assessing the welfare of cultured fish, the primary question is not which parameters are possible but which parameters are practical under real-world farming conditions for daily, routine monitoring of fish welfare. A number of physiological or molecular parameters may be well suitable to assess fish welfare under laboratory conditions. However, they may be less applicable for practical farm conditions. Research is ongoing on the development of operational welfare indicators (OWIs) to monitor the welfare of fish, for use either by farmers or by veterinarians. OWIs are defined

as indicators that assess the quality of the rearing environment, provide a valid reflection of welfare, are repeatable and comparable, and are relatively inexpensive and easy to measure on a farm. Water quality parameters such as temperature, oxygen concentration and total ammonia may be used as OWIs. Behavioural observations such as feed intake, swimming activity and schooling behaviour also may be helpful but more difficult to quantify. External appearance such as colour (unusual darkening of a few fish, pale), emaciation (slender backline) or runts, external lesions and fin erosions (fin index) also may be used as OWIs. Further indicators may include production parameters such as mortality, growth rate and developmental abnormalities emerging during rearing and homogeneity in growth. Importantly, there exists no single finite list of OWIs, but OWIs are specific for species and rearing systems and will develop with the growing understanding of fish environmental needs and welfare requirements.

It is obvious that the monitoring and assessment of the welfare of cultured fish cannot rely on the observation of a single parameter but needs the integration of several parameters. For the practical work, a set of OWIs that combines several aspects of the rearing environment in a fish farm should be applied. This combination of OWIs will depend on the farmed species, the life stage and size, and the husbandry system. During recent years, several research projects have demonstrated that combinations of various indicators are instrumental to monitoring the welfare status of farmed fish. There are developments ongoing to use computer models for integrating diverse parameters and OWIs for continuous monitoring of fish welfare in culture systems.

In summary, only a combination of parameters can provide good insight into the welfare status of the respective rearing unit. With ongoing research into operational welfare indicators and/or semantic models, it may become easier to determine welfare objectively in the near future.

5. RECOMMENDATIONS

The objective of this document is to provide the opinion of EIFAAC regarding how, at the current state of scientific knowledge, welfare issues can be integrated into the practice of fish culture. This report identified a number of critical issues in fish culture that are relevant for fish welfare. Also, recent years have seen a rapid change regarding knowledge on the cognitive abilities of fish, moving from seeing fish as “pea brains” to recognizing fish as organisms with complex behavioural and social abilities and needs. Likewise, there is growing evidence that fish are sentient organisms, possessing, for instance, the ability to perceive pain. At the same time, however, there still exist important gaps in our knowledge of the biological and environmental needs of many – if not most – cultured fish species, and there is little agreement on what “good welfare” of cultured fish actually means. This is reflected by the facts that the issue of fish sentience is still controversially discussed and that the available portfolio of operational welfare indicators is still rather limited.

At the current state of knowledge, EIFAAC considers a function-based approach to fish welfare to be most appropriate. Such an approach aims to achieve good health and growth of cultured fish and relies primarily on practical and robust welfare indicators such as growth performance or absence of disease. Also, a humane attitude in the practices of harvesting, stunning, killing, exsanguination and evisceration is required to optimize fish welfare and product quality. A function-based approach to fish welfare also involves the obligation of the aquaculture industry to emphasize appropriate training of fish farm personnel and to implement the best available technology for the monitoring of fish performance and environmental quality. While the function-based approach is reductionist, in the opinion of EIFAAC it represents the best available practical option to ensure at least a baseline level of welfare of cultured fish.

It needs to be emphasized that the function-based approach appears to be appropriate given the current state of knowledge. However, given the rapid growth of the understanding of the biological, social and environmental capacities and needs of fish, this approach urgently needs continuous development and timely updating to ensure improved welfare conditions and welfare monitoring techniques for cultured fish.

6. LITERATURE CITED

Ashley, P.J. 2007. Fish welfare: Current issues in aquaculture. Applied Animal Behaviour Science 104, 199-235.

Broom, D.M. 1986. Indicators of poor welfare. British Veterinary Journal, 142, p. 524.

EFSA 2009. General approach to fish welfare and to the concept of sentience in fish1 Scientific. Opinion of the Panel on Animal Health and Welfare. The EFSA Journal 954, 1-27

Ellis, T., Yildiz, H.Y., López-Olmeda, J., Spedicato, M.T., Tort, L., Øverli, Ø, and Martins, C. I. M. 2012. Cortisol and finfish welfare. Fish Physiology and Biochemistry 38,163–188.

FAO. 2018. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. Licence: CC BY-NC-SA 3.0 IGO.

Farm Animal Welfare Advisory Committee 1979. "Press Statement". 12.05.1979. https://webarchive.nationalarchives.gov.uk/20121010012428/http://www.fawc.org.uk/pdf/fivefreedoms1979.pdf

7. LITERATURE RELATED TO FISH WELFARE

Table 1: Literature related to fish welfare

Scientific reviews

Year	Title	Reference
1998	Ethics and animal welfare in intensive aquaculture production	Baeverfjord, 1998
2004	An evaluation of current perspectives on consciousness and pain in fishes	Chandroo *et al.*, 2004
2004	Stress and the welfare of cultured fish	Conte, 2004
2006	Current issues in fish welfare	Huntingford *et al.*, 2006
2007	Fish welfare: Current issues in aquaculture	Ashley, 2007
2007	Expanding the moral circle: farmed fish as objects of moral concern	Lund *et al.*, 2007
2007	Effects of growth hormone transgenes on the behavior and welfare of aquacultured fishes: A review identifying research needs	Hallerman *et al.*, 2007
2013	Fish welfare in aquaculture: explicating the chain of interactions between science and ethics	Bovenkerk & Meijboom, 2013
2014	Defining, assessing and promoting the welfare of farmed fish	Huntingford & Kadri, 2014

Reports and miscellaneous records

Year	Title	Reference
1996	Report on the welfare of farmed fish	FAWC, 1996
2002	In too deep - why fish farming needs urgent welfare reform	CIWF, 2002
2002	Fish welfare - Briefing paper 2	FSBI, 2002
2004	Farmed fish and welfare	EU Commission, 2004
2004	Welfare aspects of the main systems of stunning and killing the main commercial species of animals	EFSA, 2004

2005	Standing Committee of the European Convention for the Protection of Animals Kept for Farming Purposes (T-AP)	T-AP, 2005
2008	An HSUS Report: The welfare of animals in the aquaculture industry	HSUS, 2008
2008	Animal welfare aspects of husbandry systems for farmed Atlantic salmon	EFSA, 2008
2008	Animal welfare aspects of husbandry systems for farmed trout	EFSA, 2008
2008	Animal welfare aspects of husbandry systems for farmed fish - European eel	EFSA, 2008
2008	Animal welfare aspects of husbandry systems for farmed European seabass and gilthead seabream	EFSA, 2008
2008	Animal welfare aspects of husbandry systems for farmed common carp	EFSA, 2008
2008	Food Safety considerations of animal welfare aspects of husbandry systems for farmed fish	EFSA, 2008
2009	The welfare of farmed fish	CIWF, 2009
2009	Species-specific welfare aspects of the main systems of stunning and killing of farmed Atlantic Salmon	EFSA, 2009
2009	Species-specific welfare aspects of the main systems of stunning and killing of farmed fish: Rainbow Trout	EFSA, 2009
2009	Species-specific welfare aspects of the main systems of stunning and killing of farmed Eels (Anguilla Anguilla)	EFSA, 2009
2009	Species-specific welfare aspects of the main systems of stunning and killing of farmed Seabass and Seabream	EFSA, 2009
2009	Species-specific welfare aspects of the main systems of stunning and killing of farmed Carp	EFSA, 2009
2009	Species-specific welfare aspects of the main systems of stunning and killing of farmed tuna	EFSA, 2009
2009	Species-specific welfare aspects of the main systems of stunning and killing of farmed turbot	EFSA, 2009
2009	General approach to fish welfare and to the concept of sentience in fish	EFSA, 2009
2014	Opinion on the welfare of farmed fish	FAWC, 2014a
2014	Opinion on the welfare of farmed fish at the time of killing	FAWC, 2014b
2016	Aquatic Animal Health Code	OIE, 2016

Books

Year	**Title**	**Reference**
2008	Fish welfare	Ed.: Branson E
2012	Welfare of farmed fish in present and future production systems	Eds.: van de Vis H, Kiessling A, Flik G, Mackenzie S

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