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Report on Currently Available Welfare Assessment Systems for Farmed Fish

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Abstract

Welfare assessment systems are important tools for evaluating the welfare of animals. This report provides a comprehensive review of existing welfare assessment systems for farmed fish, focusing on their methodologies, strengths, and limitations. It highlights the importance of welfare monitoring due to rising social concern and the ethical obligation to safeguard the welfare of farmed fish. Key findings include the variability of welfare indicators, scoring systems and integration models across species and farming systems. While many systems provide reliable insights into fish health, stress, and behaviour, challenges persist, including the lack of species-specific indicators, standardization of methodologies across species and production systems, and integration with farming operations. The report recommends the development of more holistic and standardized monitoring solutions to improve welfare outcomes and align with industry and regulatory expectations.

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INTRODUCTION

The origin of animal welfare science dates back a few decades, when the concept of Five Freedoms (which recently updated and renamed the Five Domains Model), a foundational framework for assessing animal welfare, was first introduced in 1965. In its early years, animal welfare science focused on understanding the needs of farm animals and designing suitable housing systems alongside proper husbandry practices [1]. While this approach significantly improved living conditions for farmed animals, it soon became clear that by itself it was insufficient for a comprehensive assessment of animal welfare. To address this, welfare evaluations began incorporating direct measures of both rearing conditions and the animals themselves.

Defining animal welfare is challenging, because it encompasses diverse perspectives, including the emotional state, physical health and behaviour of the animal, as well as ethical considerations, which vary across cultural, scientific, and individual viewpoints. Quantifying the state of animal welfare presents significant challenges linked to the interplay between philosophy, ethics and sciences and, in certain instances, due to the lack of proper scientific knowledge regarding the welfare needs of the particular animal species, the specific phase of its life cycle and the conditions under which it is being farmed. Additionally, assessing an animal's welfare state is complicated by its subjective nature. For that reason, it is crucial to develop measurable parameters, which reflect the welfare state of the animals in a valid, reliable and repeatable way. These parameters are termed welfare indicators (WI), and they are empirical measurements of specific traits or states that, based on evidence, are deemed to be correlated to a greater or lesser extent with an individual's affective state. The first comprehensive works on this aspect were published in the 80s, initially describing indicators of poor welfare [2]. This study, in particular, recognized two categories of indicators, "one demonstrating that an individual has failed to cope with an environment, the other indicating the effort involved and the extent of an individual's attempts at coping". Later work included assessments of suffering [3] and behaviour [4] as indicators of animal welfare, acknowledging, therefore, not only the physiological, but also the behavioural and emotional dimensions of welfare.

For current state-of-the art in animal welfare science, welfare indicators are usually divided into two categories, based on the type of information they provide: input welfare indicators reflect the environment (resource-based), such as water temperature and production processes (management-based), for instance the stocking density; while outcome welfare indicators are collected directly from the animal, and indicate how the animal copes with the influencing factors. These can either be group indicators, for instance swimming behaviour, or individual indicators, such as the skin condition of individual fish (**Figure 1**).

INDICATOR/SCORE	0	1	2
SKIN CONDITION	Intact skin or less than 5% scale loss	5-15% skin damage*	> 15% skin damage*
			

Figure 1. *Example of an individual animal-based outcome welfare indicator (skin condition) for European sea bass. The welfare indicators can be measurable and receive a score, which can be used in welfare assessment systems. Image used with permission from Pavlidis et al., 2024 "Welfare assessment study for European sea bass" [44].*

Novel approaches in animal welfare science aim to integrate information from multiple welfare indicators into a single metric, often referred to as an overall welfare assessment [5] [6] [7]. This process simplifies the evaluation by consolidating various measures (welfare indicators) into one comprehensive score (**Figure 2**). The first step involves selecting scientifically-validated welfare indicators that address fundamental needs, and assigning scores to them. Examples of fundamental needs are those outlined in the Five Domains Model, a framework for assessing animal welfare. This model identifies five key domains that define animal welfare: nutrition, environment, health, behaviour, and mental state. These indicators are then integrated to generate an overall welfare score. However, this integration poses important challenges, including: the intercorrelation between certain indicators; differences in their relative significance (weighting); and determining the extent to which one indicator can compensate for another [7].

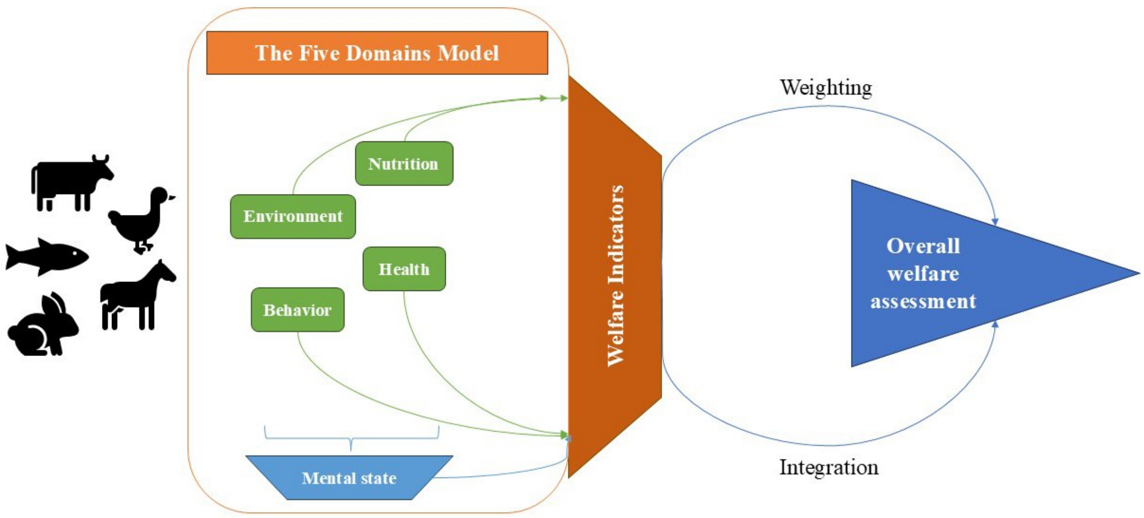

Figure 2. *Schematic representation of a welfare assessment framework for generating an overall welfare score for farmed animals. Welfare indicators should capture essential welfare needs, such as those outlined in the Five Domains Model. To produce an overall welfare score, these indicators must be aggregated with careful consideration of key factors, including the appropriate weighting of each indicator.*

Research on welfare assessment in terrestrial farmed animals has advanced a lot during the last few decades. Work on fish welfare, however, has progressed at a slower rate. The first studies on fish welfare emerged in the early 2000s, initially providing practical guidelines and codes of conduct focusing on quality [8]. Research then expanded to include welfare indicators [9] [10] [11], building on earlier studies from previous decades that had already explored fish pain and stress [12] [13]. Shortly thereafter, the European Food and Safety Authority (EFSA), through the Scientific Panel on Animal Health and Welfare, formed Working Groups to prepare scientific opinions on animal welfare aspects of husbandry systems for farmed Atlantic salmon [14], trout species [15], European eel [16], carp species [17] as well as European seabass and gilthead seabream [18]. In these scientific opinions the factors that affect animal welfare were categorized into:

1. Environmental conditions – Abiotic factors
2. Environmental conditions – Biotic factors
3. Food and Feeding
4. Husbandry and Management
5. Genetics
6. Impact of diseases on welfare
7. Disease control measures

The EFSA Expert Opinions primarily addressed the welfare needs of fish and identified potential risks to their welfare but did not propose specific welfare indicators or an assessment framework. These reports highlighted the diversity of fish species in aquaculture compared to terrestrial animals and stressed the importance of developing welfare indicators tailored to each species, life stage, and production phase.

A milestone in fish welfare science was achieved in 2013 with the publication of a study on Atlantic salmon [19]. This study introduced the first comprehensive welfare assessment framework for farmed fish, the Salmon Welfare Index Model (SWIM 1.0). The model used a holistic approach based on semantic modelling, integrating weighted welfare indicators into welfare categories and needs in order to generate an aggregate overall welfare score. Details of this model will be provided in section 2 below.

Nearly a decade after EFSA's Scientific Opinions on fish welfare, fish welfare science saw another significant advancement with the publication of detailed welfare guides for various cultured fish species. The first guide to be published was for Atlantic salmon [20], followed by European seabass and gilthead seabream [21], rainbow trout [22], lumpfish [23] and ballan wrasse [24].

Nowadays, documents related to welfare indicators have been published by various organizations and initiatives, including Food and Agriculture Organization (FAO) [25], the Animal Welfare Own Initiative Group on Fish [26], EU advisory bodies such as the Aquaculture Advisory Council (AAC) [27], but also national aquaculture producer organizations, such as the Hellenic Aquaculture Producers Organization (HAPO) [21], the Registered Association of German Fisheries Administrators and Fisheries Scientists (VDFV) [28] and the Spanish Aquaculture Business Association (APROMAR) [29] [30]. Finally, the Non-Governmental Organization Compassion in World Farming (CIWF) has published a series of documents presenting welfare indicators for various fish species, including Atlantic salmon, rainbow trout, European sea bass and gilthead seabream, during rearing and slaughter [31].

METHODOLOGY

Systematic desk research was carried out in which existing data was collected and analysed, with the focus being placed on welfare assessment systems for farmed fish. This process involved reviewing scientific studies and grey literature, including fish welfare guides, welfare indicator reports, welfare assessments and certification schemes.

The study systematically searched the prominent academic research databases, including Scopus, PubMed, Web of Science, ScienceDirect, and BioMed Central. These sources provided access to peer-reviewed articles that cover a wide range of scientific fields relevant to fish welfare in aquaculture.

In addition to academic databases, other bibliographic resources were searched to gather diverse forms of information. This included Google Scholar, WorldCat, Open Grey and Google, which provided access to grey literature such as technical reports, studies, and findings from bodies, including advisory bodies, producers' organizations, NGOs and research centers. This broad search captured insights beyond peer-reviewed studies, including industry insights, practical reports, and unpublished studies, contributing to a wider perspective on fish welfare practices and needs.

Search keywords included combinations of the following: welfare AND/OR guide AND/OR indicators AND/OR assessment AND/OR good husbandry practices AND/OR certification AND/OR score AND/OR overall AND/OR fish AND/OR species name (Atlantic Salmon; Salmo salar OR European sea bass; Dicentrarchus labrax OR gilthead seabream; Sparus aurata OR rainbow trout; Oncorhynchus mykiss OR common carp; Cyprinus carpio OR lumpfish; Cyclopterus lumpus). The species being studied represent the main European aquaculture fish species plus lumpfish, a species utilized in salmonid aquaculture. All studies identified through the literature search underwent screening for duplicate removal and assessment of relevance to the search criteria.

WELFARE ASSESSMENT SCHEMES

Atlantic salmon

As mentioned in historical background, the first holistic welfare assessment scheme was published for Atlantic salmon (SWIM 1.0) [19]. This assessment scheme uses semantic modelling, in other words it is "based on the meaning of available scientific information about animals' welfare needs and their relationship to overall welfare." The model assesses fish welfare by linking welfare indicators to specific welfare needs, which are divided into two categories: "Physical needs" (with six welfare needs) and "Behavioural needs" (with ten welfare needs). Each welfare indicator corresponds to at least one of the 16 welfare needs.

Indicators are further classified into (1) sea cage welfare indicators (WIs) for group assessments, like those conducted in cages; and (2) individual fish welfare indicators for assessments on single fish. Each welfare indicator was thoroughly reviewed in the literature to assign it ranking levels, from 0 (worst) to 1 (optimum) and a Relative Weighting Factor (RWF). The individual score for each indicator, termed the Indicator Welfare Score (IWS), was calculated based on its ranking level and RWF. To calculate the Overall Welfare Index (OWI), the IWS values were summed to produce a final score ranging from 0 (worst welfare) to 1 (best welfare).

As a proof of concept, the SWIM 1.0 was retrospectively used to assess animal welfare in a sea farm in Western Norway in 2011 and showed that when a low OWI (0.37 for sea cage welfare indicators) was observed, a 2.36% overall rise in mortality followed two days after the assessment [19]. Moreover, the model was tested in the same study with novel data from a sea farm in Western Norway during the winter of 2012 and a sea cage OWI of 0.59 was calculated, as were an individual fish OWI of 0.79 and a total OWI of 0.69 [19].

A major criticism concerning the model (and semantic modelling in general) is its subjectivity. In particular, the study acknowledges that the decisions regarding the division of indicators into levels, the assignment of indicators to weighting categories and weighting scores are partly subjective [19]. Improved and higher-quality scientific knowledge can help mitigate this challenge.

Three years after its original publication, the SWIM 1.0 model underwent on-farm evaluation by the same research group, prompting a discussion on various theoretical and practical considerations [32]. In this study it was shown that, in practice, the model can be put into practice in fish farms, requiring a small amount of time. It was also observed that the model could generally differentiate cages selected as the "best" and "worst" performing ones according to the farmer's ratings before applying the SWIM 1.0 model. The challenges that emerged by this practical application of the model were related to the need for a better explanation of the welfare indicators and their levels, as well as the need to reconsider the sampling protocols used to evaluate the individual fish OWI. However, the authors highlighted the fact that the model is flexible and should periodically be updated to include novel scientific knowledge and user feedback. Shortly after its publication, SWIM 1.0 was applied in scientific studies evaluating the welfare of Atlantic salmon subjected to experimental treatments or innovative technologies, such as submerged cages [33] [34] [35].

An extended model intended for fish health professionals was subsequently published [36]. SWIM 2.0 followed the same principles as SWIM 1.0, but was based on a selection of animal-based welfare indicators that need expertise in fish pathophysiology, such as the condition of the heart, vaccine-related pathology and necropsy of dead fish. This model aims at supplementing and improving the outcome of the farmer-oriented SWIM 1.0 model.

Apart from the SWIM model, in 2015 a report on welfare assessment on thermal de-licing in salmonid species using simple and easy-to-use individual animal-based welfare indicators was published [37]. This report looked at 10 welfare indicators that described the external morphology and injuries of fish, such as gill pallor, scale loss and fin condition, in order to assess the effects of thermal de-licing in the welfare state of fish.

In 2018, a new, comprehensive welfare guide and scoring system for Atlantic salmon entitled “Welfare Indicators for farmed Atlantic salmon: tools for assessing fish welfare” [20] was published. This guide details the welfare needs of Atlantic salmon and presents a range of welfare indicators—operational, on-farm, and laboratory-based—assigned to specific production systems and husbandry practices. Finally, it proposes a scoring system for animal-based welfare indicators with the aim to assist farmers in assessing welfare. In this system 14 animal-based indicators are individually scored using a scale of 1-3, but no overall assessment score is provided.

Recently, novel approaches to assess behavioural aspects of welfare were developed in Atlantic salmon. Specifically, the Qualitative Behavioural Assessment, a protocol initially used in assessing terrestrial animal welfare, was validated [38] and successfully applied in identifying stressed individuals in Atlantic salmon [39]. Future research is still needed before such behavioural assessment schemes can find applications in real-life conditions in fish farms.

European sea bass and gilthead seabream

European sea bass and gilthead seabream are usually examined together in welfare-related studies because they are cultured in the same region (Mediterranean Sea), using similar production systems and usually at the same farming sites by the same companies. As previously mentioned, the first detailed publication about their welfare was the "Mediterranean Fish Welfare: Guide to Good Practices and Assessment Indicators" published in 2020 [21], in which a comprehensive guide of welfare indicators for both species under different culture systems and husbandry practices was presented. This guide, however, didn't provide an assessment system for scoring the individual indicators.

The first scoring system for gilthead sea bream was presented shortly after in a deliverable report of MedAID, a Horizon 2020 EU-funded Research and Innovation Action project [40]. In this report, the Welfare Quality® concept of using Operational Welfare Indicators (OWIs) was assigned to Welfare Criteria and Welfare Principles. In total, 21 OWIs, including environment-based, management-based and animal-based ones were assigned to 11 Welfare Criteria, which were related to the 4 main Welfare Principles, namely "Good Feeding", "Good Housing", "Good Health" and "Appropriate Behaviour". Each of the OWIs got a classification (score) between 0 and 2, with 0 reflecting the optimum and 2 the worst condition. The OWIs "Cumulative mortality" and "Mortality event" didn't receive a score because according to the report the aquaculture farms should record their production cumulative mortality rates for the different phases of production and establish their objectives. Moreover, beyond scoring individual OWIs, there was neither a calculation of nor a discussion on the development of an overall welfare score.

That same year, a deliverable report of PerformFish, a Horizon 2020 EU-funded Research and Innovation Action project [41], described a different methodology for assessing welfare in Mediterranean Marine Fish Farming. This report described the use of 24 OWIs, 9 of which are also considered as Welfare Key Performance Indicators (KPIs) validated by the industry and the remaining 15 OWIs were selected on the basis of their suitability through a survey within the consortium. Apart from the welfare KPIs, the rest of the OWIs were not described in detail. Additionally, there was no description of the classification (scoring system) for any of the OWIs used. For the development of the overall welfare scoring system the composite indicator approach, and specifically the Adjusted Mazziotta–Pareto Index (AMPI) tool was used. This tool is used to summarize the performance across multiple indicators and provide a measure of the overall welfare of a unit. This welfare assessment scheme was applied to 12 farms for European sea bass and 10 farms for gilthead seabream, during two production phases of on-growing: (i) the initial stage from stocking to the sea cages until fish reached 50g; and (ii) the whole duration of the on-growing stage from stocking to the sea cages until harvest. This first application managed to successfully differentiate farms based on their welfare score, with scores between farms ranging from 89.9 (lower welfare) to 105.3 (higher welfare).

An on-farm, operational Welfare Assessment manual concerning both species has been published as a delivery report of the Italy-Croatia CBC Programme-funded project "AdriAquaNet: Enhancing Innovation and Sustainability in Adriatic Aquaculture" [42]. This manual aims to provide a practical, easy-to-use welfare assessment scheme for European sea bass and gilthead seabream during on-growing in sea cages. This scheme is based on scoring 25 OWIs (5 environmental-, 8 group- and 12 individual- based) receiving a score from 0 to 1, where 0 indicates a good welfare state (e.g. environmental parameters within recommended ranges, absence of injuries) and 1 reflects poor welfare conditions. These scores are then summed up with equal significance (weights) to provide an overall score that can range between 0 and 25. An overall score below or equal to 5 is considered to represent optimum welfare, between 6 and 10 good welfare, between 11-15 low welfare and above or equal to 16 bad welfare.

An adaptation of the SWIM 1.0 model for application in European sea bass has also been recently published [43]. This study based the welfare assessment on the concept of semantic modelling, as described in detail in the SWIM 1.0 model, assigning a relative weighting factor to each welfare indicator and providing a scoring system for each indicator based on the welfare needs of European sea bass. The adapted model uses the same indicators as SWIM 1.0, but excludes salinity and smoltification status, which are irrelevant for European sea bass. Instead, it includes pH and gill appearance, indicators not used in the Atlantic salmon model. Moreover, in calculating the relative weighting factors for each indicator, the European sea bass adapted model used the same weighting scores and factors suggested for salmon. The model was applied in two farms located at the Mediterranean Sea using cages of the same volume and feeding feeds of the same composition. The application of the adapted model managed to identify differences between the two farms (farm A: Overall Welfare Assessment (OWA) = 1.0; farm B: OWA = 0.81), mainly due to lower oxygen saturation and water current, as well as the presence of parasites in the gills at farm B.

Finally, a welfare assessment study for European sea bass was published in 2024 [44]. The aim of this study was to present a refined set of specific welfare indicators based on expert consultation, as well as methods of evaluation and units of measurement for the welfare assessment of farmed European sea bass. The study suggested a set of prerequisites at a farm level to safeguard the minimum accepted welfare status for aquatic animals. It also promotes the risk assessment of each production condition and husbandry practice to mitigate welfare risks. To achieve this, it provided a detailed description of the factors affecting the welfare of this species and their projected consequences and provided classification (scores) for 25 environment-, management- and animal- based OWIs. The scores range from 0 to 2, while for some indicators with a bilateral nature (as for instance the eye condition), they can range from 0 to 3. In all instances, 0 represents the optimal condition and 2 or 3, depending on the OWI, the worst. This study acknowledged the fact that (i) some indicators are interconnected, necessitating that each measure be assigned to a single criterion, based on its severity or welfare impact to avoid double counting; and (ii) certain indicators may be considered as more important than others. It further suggested that although fish welfare scores should be mathematically processed to produce an overall welfare score for categorizing farms, defining indicator weights and welfare categories requires further development and consultation with experts and stakeholders - a step to be addressed in the next protocol update.

Rainbow trout

The first tool to provide an overall welfare assessment in rainbow trout (alongside pike-perch) was developed in Germany [45] with the aim to find application in the local fish aquaculture, mainly in flow-through systems. This model was based on semantic modelling, following the concept of the SWIM 1.0 and SWIM 2.0 models for Atlantic salmon, adapted accordingly to fit the welfare needs and production systems of rainbow trout. The model incorporated scientific literature review and expert judgment in order to provide welfare indicators and their respective scores. The outcome was an easy-to-use Excel analysis-tool, where fish producers can enter data from monitoring and evaluating the OWIs and automatically calculate the welfare score of the farm. As proof of concept, the model was validated at several farms, providing useful insight on its capacity to distinguish between bad and good welfare conditions.

For rainbow trout, a detailed guide describing the welfare needs and potential indicators for assessing welfare was published in 2020 [22]. In this study, the proposed welfare indicators – chosen by literature review - were also related to specific production systems and rearing units, as well as different routines and husbandry procedures. As an outcome, the report proposed a classification system for the individual animal-based external morphology indicators. In this, various indicators were given a score between 1 and 3, depicting good to bad conditions, respectively. However, an aggregation system to produce an overall welfare score based on the individual welfare indicators was not provided.

Shortly thereafter, a comprehensive attempt to provide a welfare assessment system for rainbow trout was published [46] accompanied by a free app (https://www.myaquaculturefarm.ch/en/myfishcheck.php). This model, like the SWIM model for salmon, is based on semantic modelling. In order to build the model, the research group first created an ontology for fish welfare, based on current knowledge, ending with up to 12 welfare needs representing function-, feelings-, and nature-based aspects of welfare needs. Subsequently, they defined measurable parameters associated with these welfare needs. Initially, over 200 parameters were identified, resulting in a final list of 80 parameters that were (i) relevant, i.e. clearly portraying fish welfare; (ii) practical, i.e. measured on-farm in cost-effective ways; and (iii) reliable, i.e. having an existing and repeatable measuring method. These 80 parameters were categorized into five distinct modules, namely farm management (management-based indicators), water quality (environment-based indicators), fish group behaviour (animal-based indicators in groups of fish), fish external appearance and fish internal appearance (animal-based indicators in individual fish). Each parameter also received a parameter score, the intervals of which were based on scientific literature, a score weight, to take into account the fact that severe stress results in higher allostatic load, and a parameter weight, taking into account the severity of different stressors. This last step was established through expert opinion evaluation. Finally, a score (termed module grade) was produced for each of the five modules using a mathematical formula to produce a score for 0 (bad welfare) to 1 (optimum welfare).

As a proof-of-concept the model was tested on-site at six farms (4 rearing rainbow trout and 2 pikeperch). The total time needed to complete the assessment was 2.5-3 h. Results of the assessment showed that it was possible to differentiate fish farms based on the proposed model. Specifically, the farm with the lowest management and water quality module scores also exhibited the lowest animal-based module scores, indicating a relationship between management and water quality on behaviour and external morphology.

In summary, this model provides a comprehensive welfare assessment scheme that (i) is based on specific welfare needs of the fish in question, (ii) incorporates allostasis to account for the severity of stressors, (iii) is practical and can be applied on-farm, and (iv) is adaptable, allowing for the exclusion or inclusion of parameters based on practical issues and emerging research, respectively. However, similarly to the SWIM model for Atlantic salmon, the authors of the MyFishCheck system acknowledge a key limitation of the model—and semantic modelling in general— in its inherent subjectivity, particularly in defining relevant parameters, setting interval limits, and weighting scores. This subjectivity was underscored by the variation in weights assigned by different experts.

A year later, a new study [47] proposed an alternative welfare assessment index, challenging the validity and practicality of environment-based and management-based indicators. The study cited issues such as high diversity and variability over time, strong intercorrelations, the limitations of single-point measurements, and the significant time and financial costs of ongoing monitoring. Additionally, it highlighted inconsistencies in analytical methods, timing, and measurement areas across different farms. Moreover, although behaviour was acknowledged as an important welfare indicator, the results of the behavioural survey showed that using behavioural parameters as welfare indicators is difficult and requires well-trained personnel. Therefore, according to the authors, "behaviour was too vague to be implemented in the fish Welfare Evaluation Index, but due to its high importance for welfare, the application of the provided behaviour and health protocol is recommended". According to the above-mentioned reasons, the proposed welfare assessment protocol was based only on external morphological damage.

In total, 12 individual animal-based indicators are included in this index, each receiving a score between 0 (optimum condition) and 3 (worst condition). In certain indicators, severe conditions are assigned a higher weighting to increase the significance of the damage (e.g. 8 additional points when an animal receives a score of 3 in both eyes). The weighted sum of the damage per fish is categorized into very good (fWEI category 0 = 0–5), good to moderate (fWEI category 1 = 6–10), moderate to poor (fWEI category 2 = 11–15), and poor (fWEI category 3 >15) welfare. The final output of the index is the percentage of fish in each respective category. For instance, comparatively, fWEI results are categorized as follows: more than 80% of fish in Category 0 are considered good; 20–40% of fish in Category 0 and over 45% of fish in Category 1 are considered moderate; and less than 15% of fish in Category 0, with more than 20% of fish in Categories 2 and/or 3, are considered bad.

Finally, a report on survey guidelines for national animal welfare monitoring for rainbow trout has been published in Germany [48]. These guidelines, which include site and installation characteristics to be monitored, also feature a scoring system for individual OWIs encompassing both environmental- / management- based (e.g. precautions to ensure adequate oxygen supply) and animal-based OWIs (e.g. swimming behaviour and eye rupture and loss). In addition, OWIs on stunning and killing are also presented. However, apart from the individual scoring of OWIs, no overall welfare assessment score is provided.

Common carp

Common carp is among the most commonly farmed fish species in aquaculture in Europe, yet relatively little information is available on its welfare needs and how to assess its welfare. Specifically, only this year (2024) a report on survey guidelines for national animal welfare monitoring for carp was published in Germany [49]. These guidelines, like the ones reported for rainbow trout by the same institutes, include information about the farm operational structure and management, as well as a classification system to monitor animal-based indicators. These include a scoring system from 0 (optimum welfare) to 3 or 4 (worst welfare) for OWIs finding application during stunning and killing, but also in monitoring fish external morphology as an indicator of welfare.

In 2024, the Horizon Europe EU-funded Research and Innovation project Cure4Aqua organized a Workshop regarding the “Operational Welfare Indicators for Farmed Carp” hosted at the Czech Academy of Sciences in Prague (https://cure4aqua-workshop.eu/2024-FIRST/). The workshop hosted experts from various stakeholder groups involved in carp farming (academia, producers, competent authorities, animal protection groups, etc.) and applied the innovative Delphi methodology, with the aim to build a consensus on the usefulness of various operational welfare indicators during rearing, transport and slaughter of carp. The findings of this study will be used to develop an overall welfare assessment scheme for common carp, based on indicators produced through expert judgement.

Lumpfish

Lumpfish is a cleaner fish that has been increasingly used over the past few decades by the salmon industry. However, serious concerns regarding the species' low welfare led to an extensive scientific effort to identify and address the challenges [50]. At the core of this research is the development of welfare assessment schemes in order to quantify the welfare state of the fish.

Initially, a guide describing science-based welfare indicators for the species was published [23], in which a detailed list of environment- and animal-based Operational welfare indicators as well as laboratory welfare indicators was presented. This guide, however, included neither a classification of the operational welfare indicators nor an overall welfare assessment scheme. Shortly afterwards, two independent publications proposed similar scoring systems to assess the welfare/health condition of lumpfish by measuring parameters related to their external morphology [51] [52]. Specifically, one study [51] assigned scores to 6 criteria ranging from 0 (optimum condition) to 3 or 4 (worst condition) to evaluate fin condition, the presence of deformities, eye condition and the condition factor. As an overall outcome the scores of these criteria were summed with equal weights to provide a score ranging between 0 and 23. The scoring categories were: (1) scores between 0 and 11 indicate no to minimal health deterioration, (2) scores between 11 and 16 indicate a deteriorating health status and (3) scores above 16 indicate potentially compromised health. Similarly, the other study [52] used a refined list of 5 individual-based OWIs following expert consultation and consensus between fish farmers, academics and fish welfare specialists that represented the skin and fin damage, the condition of the eyes and the suction disc as well as the relative weight. Each OWI received a score between 0 (optimum condition) and 2 (worst condition). These were summed to deliver an overall welfare score (termed Lumpfish Operational Welfare Score Index (LOWSI) by the authors) ranging from 0 to 10. Fish with a score below 3 were considered to have good welfare, scores between 3 and 5 indicated moderately compromised welfare and scores above 5 indicated severely compromised welfare.

Based on this study a web application, named "Lumpfish Welfare Watcher" was developed [53]. This tool allows for easy calculation of the Body Mass Index (BMI) of individual lumpfish and their categorization as emaciated, underweight, normal or above normal. Moreover, it calculates the Lumpfish Operational Welfare Score Index (LOWSI) and characterizes individual fish as having good, compromised or poor welfare.

A slightly modified welfare assessment system applicable to sea cages was published [54] in 2022. This system is based on similar operational welfare indicators for external morphology as the two previously mentioned studies, but uses a different approach to (1) aggregating individual OWIs to produce the overall score, and (2) categorizing the welfare condition of the farm under consideration. Regarding the aggregation of OWIs, this guide proposes calculating a weighted sum by calculating the squares of each score and applying weights to reduce the significance of deformities unrelated to the suction cup, while increasing the significance of skin damage. According to authors, squaring the OWI score has the advantage of clarifying differences between individuals, reflecting the varying extents to which they reduce welfare.

To produce the final overall welfare score, a relative sum is calculated, where all the total assessments are expressed as percentages of the maximum achievable weighted sum. This approach allows the model to remain flexible regarding the number of OWIs examined. In other words, if some of the OWIs are not assessed, the overall welfare score is not affected since it is calculated as a percentage of the maximum score based on the examined OWIs. Then, each fish receives a welfare score of "0 – good welfare", when the relative sum equals 0; a welfare score of "1 – slightly reduced welfare", when the relative sum is between 0 and 10; a welfare score of "2 – clearly reduced welfare", when the relative sum is between 10 and 30, or lower than 10, but at least one OWI has received a score of 3; and finally a welfare score of "3 – severely reduced welfare", when an animal receives a relative sum higher than 30. Finally, in order to assign the welfare status at population levels, the percentage of each welfare score is taken into consideration. As an example, good welfare is assigned, when more than 60% of the fish have received a welfare score of 0 and none a welfare score of 2 or 3. In contrast severely reduced welfare is assigned to groups where at least 25% of the fish have a welfare score of 3 regardless of other scores.

The applicability of this system was put into practice at 4 fish farms/sites [55]. The welfare assessment revealed that the majority of lumpfish (60.7%) experienced slightly reduced welfare, while 18.3% exhibited good welfare. Additionally, 18.8% had clearly reduced welfare, and 2.2% showed seriously reduced welfare. The welfare assessment scheme managed to capture differences between sites and between time, with welfare generally declining over time in sea cages, with a peak in mortality and welfare deteriorating at approximately 11-12 months. No direct relationship was observed between routine procedures like net maintenance or delousing and lumpfish welfare. However, a decline in welfare post-delousing was noted, particularly regarding skin, eye, and fin injuries.

Other fish species

Scientific publications on the welfare assessment of cultured fish species with low or no interest in the EU aquaculture sector also exist. A recent study published an overall welfare assessment scheme for Nile tilapia, using a weighted scoring system across four welfare principles—environment, health, nutrition, and behaviour—to produce an overall welfare score [56] [57]. In a similar concept an overall welfare assessment scheme for grass carp has also been published [58].

CERTIFICATION SCHEMES

Certification schemes in fish aquaculture play a vital role in promoting sustainability, environmental responsibility, and quality in seafood production. These schemes provide frameworks that ensure aquaculture operations adhere to rigorous standards for environmental protection, animal welfare, social responsibility, and food safety. These certification programs aim to address the growing consumer demand for responsibly produced seafood while supporting sustainable practices within the industry.

The European Union has launched an EU organic certification based on the concept of organic farming (REGULATION (EU) 2018/848). This certification acknowledges fish welfare as an important factor in organic farming. For instance, criteria taking into consideration basic welfare needs like nutrition, environment (good water quality), production practices (strict maximum stocking densities and handling of the fish) are used in the public certification scheme. Numerous certification programs aim to address the growing consumer demand for responsibly-produced seafood, while supporting sustainable practices within the industry.

Numerous private initiatives also exist. Numerous certification schemes, developed by various organizations, often prioritize distinct criteria, with some placing greater emphasis on welfare than others. Additionally, most of the certification schemes including welfare criteria have focused on Atlantic salmon, followed by rainbow trout, and only lately have other species been included.

The Aquaculture Stewardship Council (ASC) has published a series of certification standards for various fish species (https://asc-aqua.org/producers/asc-standards/). However, although some welfare parameters were described, welfare didn't play a major role in these schemes. Only recently, in February 2024, the ASC published a new document for public consultation on updated standards for certification, which includes a specific principle is devoted to Health and Welfare [59]. These standards have yet to find application in the certification scheme.

Certification schemes with a focus on welfare have been developed by various certifying bodies, such as the Global Animal Partnership (G.A.P.) Aquaculture Standards [60] and the Royal Society for the Prevention of Cruelty to Animals (RSPCA) for Atlantic salmon [61] and rainbow trout [62]. These schemes focus on fish welfare by assessing husbandry conditions and practices, equipment used to handle the animals, transport and slaughter procedures, as well as animal-based welfare indicators, such as external morphology and body condition. It is also important to note that both schemes include cleaner fish welfare evaluation. Another certification scheme focusing on the welfare of a variety of farmed fish is the one published by the Friends of the Sea [63]. This document describes various welfare standards that are either important or recommended for a welfare certification to be obtained.

Apart from the aforementioned welfare-oriented schemes, there are other schemes available focusing on parameters such as sustainability, environmental responsibility as well as fish quality, including welfare as one of the factors of assessment. For instance, the standards for certification for fish species culture published in 2023 by the Best Aquaculture Practices certification program [64] include parameters of food safety, social accountability, environmental responsibility, animal health and welfare, as well as traceability. The same organization published a series of standards focusing on salmon aquaculture, parametrizing factors related to the community, environment, animal welfare, food safety and traceability [65]. In 2024, the updated standards for organic farming certification were published by the Germany-based organization Naturland [66]. There, various welfare-related parameters are used for many fish species, including salmonids, carp, perciforms, carangiformes, gadiformes and tropical freshwater fish.

OVERALL EVALUATION OF THE AVAILABLE FISH WELFARE ASSESSMENT SCHEMES

Fish welfare science has encountered challenges due to the vast diversity of cultured species, each with unique welfare requirements and production systems. These challenges, together with the limited knowledge and low societal awareness of previous years, have delayed the initiation of welfare research compared to terrestrial farm animals. This has also been reflected in the production of fish welfare assessment schemes, which were first published around a decade ago and have expanded over the last 5 years. However, these schemes vary significantly, not only between species but also within the same species, due to the use of varying conceptual approaches.

In this review, a study was considered to present a welfare assessment, if it included both a list of validated welfare indicators and a classification (scoring) system (Appendix Table 1). If no scoring for the indicators was provided, the study was described as a welfare guide (Appendix Table 2) Since welfare assessment schemes are relatively new for many species, it was not mandatory for studies to propose an aggregation method for delivering an overall welfare score in order to be included in the review, as further development is needed in this area. Additionally, a common feature of all welfare assessment schemes reviewed is that the scores assigned to each welfare indicator were based on scientific data, which was in some cases supplemented by expert judgment.

On the other hand, the differences between diverse welfare assessment schemes were in most cases extensive, apart from the cases where a scheme proposed for one species was based on previous work on another species (e.g. adaptation of the SWIM 1.0 to European sea bass [43] and rainbow trout [45]). Specifically, conceptual differences existed between welfare assessment schemes. For instance, some schemes are based on semantic modelling, assigning welfare indicators to specific welfare needs and attributing relative welfare scores to them. This approach is considered to examine the welfare of fish holistically but is criticized due to its subjectivity in assigning indicators to welfare needs and providing scores. Conversely, some welfare assessment schemes take a less holistic approach, solely animal-based, evaluating the external condition of fish as a proxy for their welfare status. These schemes aggregate relative scores without applying any weighting.

In terrestrial farm animals two scientific welfare assessment frameworks, the Welfare Quality® and the Animal Welfare Indicators (AWIN) were developed and set the outlines of welfare assessment schemes. Welfare Quality® uses a holistic framework of four welfare principles and twelve welfare criteria that are represented by welfare measures (indicators). AWIN, on the other hand, focuses more on practical, evidence-based indicators that are reliable and easy to implement on farms.

As previously noted, a standardized framework for establishing prerequisites and guidelines for fish welfare assessment is still lacking. Thus, developing similar initiatives in fish welfare to address this gap is essential. The current review has highlighted a few basic recommendations that should be taken into consideration when developing a welfare assessment scheme. Specifically, fish Welfare Assessment Schemes should:

1. Be species-specific and production-system-specific.
2. Use science-based Welfare Indicators that validly and reliably cover all welfare principles (needs) of the species under consideration.
3. Be practical and feasible to carry out on a farm.
4. Involve stakeholders' opinions and expert judgment during their development.
5. Take into consideration the interrelations between indicators and the differences in the weight of each indicator.
6. Provide a scientifically sound aggregation system to reach an overall welfare assessment score.
7. Provide a scientifically sound ranking system to categorize the overall welfare assessment score from worst to optimum.

Other characteristics that would be important additions to future welfare assessment schemes include:

a. Welfare prerequisites: to secure a basic level of animal welfare such as accountability, clear responsibilities, and adequate personnel training.
b. Risk assessment tools: to evaluate the welfare risk level and to list risk mitigation measures.

c. Adaptability: to allow for the integration of the latest advances in fish welfare science, ensuring regular updates based on state-of-the-art insights.

d. Positive welfare indicators: to include measures that reflect not only the absence of harm but also the presence of positive welfare states.

e. Training and expertise: to evaluate the need for specialized training or technical skills and ensure effective implementation.

f. Third-party verification: to facilitate independent audits to minimize bias and enhance credibility.

g. Actionable feedback: to offer clear guidance for corrective actions to address identified welfare deficits.

h. Economic considerations: to account for implementation costs and assess market acceptance and ensure feasibility and practicality.

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About EURCAW-Aqua

EURCAW-Aqua is the European Union Reference Centre for the welfare of aquatic animals. It focuses on farmed fish (rainbow trout, common carp, Atlantic salmon, European seabass, gilthead seabream) welfare, and covers the entire life cycle of fish from the early ontogenetic stages to the end of life. EURCAW-Aqua will also review the welfare of cephalopods and decapod crustaceans. Furthermore, during the development of new aquatic organisms farming operations, the welfare of any novel/emerging fish species will be evaluated upon specific queries arisen either by the European Commission Services or the Member States' Competent Authorities (CA's).

EURCAW-Aqua supports:

- Inspectors of CA's;
- Aquatic animals welfare policy workers;
- Bodies supporting CA's with science, training, and communication.

Website and contact

EURCAW-Aqua's website https://www.eurcaw-aqua.eu offers relevant and actual information to support enforcement of aquatic animals' welfare legislation. Are you an inspector or aquatic animals welfare policy worker, or otherwise dealing with advice or support for official controls of aquatic animals' welfare? Your question is our challenge! Please, send us an email with your question and details and we'll get you in touch with the right expert.

info@eurcaw-aqua.eu

https://www.eurcaw-aqua.eu

Services of EURCAW-Aqua

- **Legal aspects**

European fish welfare and farmed aquatic animals legislation that has to be complied with and enforced by EU Member States.

- **Welfare indicators**

Fish and decapod crustaceans' welfare indicators, including resource based, management based, group and individual animal-based indicators, that can be used to verify compliance with the EU legislation.

- **Training**

Training activities and training materials for inspectors, including bringing forward knowledge about ambivalence in relation to change.

- **Good practices**

Good and best practice documents visualising the required outcomes of EU legislation.

- **Demonstrators**

Farms, transport companies and relevant stakeholders demonstrating good practices of implementation of EU legislation.

Partners

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- University of Crete, Greece
- Biology Centre CAS, Czech Republic
- Universitat Autònoma de Barcelona, Spain