STUDY
Requested by the PECH Committee

Animal welfare of farmed fish

Fisheries

Policy Department for Structural and Cohesion Policies
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RESEARCH FOR PECH COMMITTEE

Animal welfare of farmed fish

Abstract

This study investigates the welfare of the main fish species reared in the European Union, and highlights current knowledge on fish welfare, knowledge gaps, fish needs and husbandry methods of concern for fish welfare. The study focuses on production systems and production phases in a species-specific way. Research includes a literature review, an evaluation of the regulatory framework, a stakeholders' consultation, case studies and a SWOT analysis. Conclusions and policy recommendations relevant to EU decision-making are provided.

This document was requested by the European Parliament's Committee on Fisheries.

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LIST OF ABBREVIATIONS

AAC	Aquaculture Advisory Council
AGD	Amoebic gill disease
AHAW	Animal health and welfare
CMS	Cardiomyopathy syndrome
CoE	Council of Europe
EC	European Commission
EFSA	European Food Safety Authority
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FAWC	Farm Animal Welfare Council
FEAP	Federation of European Aquaculture Producers
FHA	Fish Health Authorisation
GHG	Greenhouse gas
HACCP	Hazard Analysis Critical Control Point
IASP	International Association for the Study of Pain
NaTiMon	National Animal Welfare Monitoring *(Nationales Tierwohl-Monitoring)*
NGO	Non-governmental organisation
OIE	Office International des Epizooties (now WOAH)
OWI	Operational welfare indicators
PD	Pancreas disease
PECH	European Parliament's Committee on Fisheries
POM	Particulate organic matter

QoL	Quality of life
RAS	Recirculating aquaculture system
RSPCA	Royal Society for the Prevention of Cruelty to Animals
SPS	Sanitary and phytosanitary
STECF	Scientific, Technical and Economic Committee for Fisheries
SWIM	Salmon Welfare Index Model
SWOT	Strengths, Weaknesses, Opportunities, Threats
T-AP	Standing Committee of the European Convention for the Protection of Animals kept for Farming Purposes
UK	United Kingdom
WMO	World Meteorological Organization
WOAH	World Organisation for Animal Health

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EXECUTIVE SUMMARY

KEY FINDINGS

- The concept of **fish welfare** has philosophical, scientific, and legal dimensions and public **debate** and multi-disciplinary **research** should be supported.
- Research to gain a better understanding of EU **farmed fish welfare needs**, in relation to the different farming systems, production cycle, husbandry practices and managerial operations is required.
- Research on the development of reliable and user-friendly operational welfare **indicators**, species-specific welfare **scoring systems** and welfare **assessment tools** should be supported.
- Development of **fish welfare courses** that will support the training for veterinarians, fish health professionals and fish farm personnel is a high priority.
- There is a need to improve the **EU legislative framework** on fish welfare.

This study presents the current scientific data, knowledge gaps and regulatory framework on fish welfare for the main species that are reared in the EU. It also provides welfare priorities and policy recommendations relevant to EU decision-making, for the Members of the European Parliament.

For meeting the objectives of this research project commissioned by the PECH Committee the following **research questions** are addressed:

1. What do we know about the **welfare of the main EU farmed fish species** and what are **knowledge gaps**?
2. What is the impact of critical **production operations** and **husbandry practices** on farmed fish welfare?
3. What are the **welfare gaps** in the current regulatory framework of the sector?
4. What **level of implementation** and **enforcement** of the regulatory framework exists in Member States?
5. How can the **welfare status** of fish in aquaculture operations be **improved** in EU territory?

Fish welfare is a major component of sustainable fish farming and has attracted considerable attention in recent years. The widespread view amongst the scientific community is that welfare is intimately connected with the absence of stress and disease. Stress is an essential, genetically embedded, adaptive mechanism designed to secure survival and other critical biological functions; therefore, it is crucial to determine, in a manner that is specific to the species, life-stage and farming system, at what point do we cross the red line, where stress impairs fish welfare. Moreover, as stated by Broom, '*when an animal's health is poor, so is its welfare, but poor welfare does not always imply poor health*'[1]. Thus, interlinks between stress, disease resistance and welfare of farmed fish should be further investigated.

[1] Broom, D.M. (2007 a) Welfare in relation to feelings, stress and health. Revista Electronica de Veterinaria VIII: 1695-7504.

Four **major challenges** are identified in this study:

- the interplay between **science** and **ethics** (Chapter 2);
- **assessing fish welfare**, especially on-site (Chapters 2 and 3);
- the identification of **species-specific needs** and welfare assessment, according to the farming system, husbandry operations and managerial practices (Chapter 3);
- the appropriate **regulatory framework** for farmed fish welfare needs (Chapter 4).

The interplay between science and ethics

As the concept of welfare has philosophical, scientific, and legal dimensions, views on welfare can be expected to differ, which often leads to heated public debates. Three main differing views can be identified, when talking about animal welfare, which in general are **function-**based, **feeling**-based, and **nature**-based[2]. These views are not necessarily mutually exclusive, but may be conflicting in specific situations. At the applied level, the view of welfare emphasised will determine the criteria and results of welfare assessment. Scientific data indicate that fish can experience pain and possess a sophisticated and effective sensory system and cognitive abilities, making them capable of adapting to an incredible array of habitats. However, the question of **fish sentience** and awareness is both experimental and conceptual in nature and needs to be further investigated (see Chapter 2).

Assessing fish welfare

All farmed fish have **common welfare needs**, such as adequate nutrition, proper water quality, good health/fitness, behavioural freedom, and safety. However, **species-specific differences** exist, as do individual differences within the same species with regard to coping styles[3], stress tolerance and disease resistance, in relation to the developmental stage of the fish and its physiological condition. These should all be considered when developing **fish welfare indicators** that are valid, repeatable, reliable, and usable by farmers and regulatory authorities in order to assess welfare status on farms. Further research and technological advances are required to develop operational welfare indicators and methods to assess fish welfare on-site in an impartial manner (see Chapter 3).

Production methods and welfare challenges by farmed fish species

Five case studies were undertaken, one for each of the five main freshwater and marine fish species reared in the EU namely Atlantic salmon, rainbow trout, common carp, gilthead sea bream and European sea bass, reared under different production systems and life cycle phases in captivity. The case studies present (1) **production data** per Member State, (2) the main on-growing **production systems**, (3) the production cycle in relation to **life cycle for each species** of fish, (4) the biological characteristics and **welfare needs** of the species being studied, and (5) welfare challenges at each respective critical production phase and operation.

Finally, a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was conducted to establish welfare strategies in specific areas of interest (see Chapter 3):

[2] Frazer, D. (2008) Understanding animal welfare. Acta Veterinaria Scandinavica 50, S1.

[3] A coping style can be defined as a coherent set of behavioural and physiological stress responses which is consistent over time, and which is characteristic to a certain group of individuals (Koolhaas et al., 1999).

Outcome of legislative review

The study identifies three categories of regulatory and non-regulatory **provisions that are in place** regarding fish welfare.

1. **Standards**, **codes of conduct** and **good practices**.
2. **Recommendations** from public institutions ('soft' rules), generally from EFSA or other public authorities.
3. **Rules**, in a strict sense ('hard' rules): these are binding and mandatory for farmers and operators involved in the different phases of the fish farming operations.

An analysis of the legislation in place at both EU and Member State level reveals that rules on the matter (except for organic aquaculture and some specific provisions on key aspects referred to in this document) do not directly impose specific welfare requirements for farmed fish.

Thus, there is a need to **improve the legislative framework** on welfare of farmed fish. The updated legislation should include:

- the fundamental **legislative objectives** and fish welfare principles in general;
- the delegation of **authority** and establishment of **enforcement** mechanisms;
- the framework for developing **new law** on important areas of fish welfare, including management, handling/keeping, transportation and slaughter.

It is recommended that **welfare codes of practice** be developed by producer organisations or associations and submitted for **approval to the competent authorities**. The competent authorities would then verify that the codes of practice are in line with the principles of legislative framework for fish welfare, and the verified codes of practice would be enforceable and obligatory for members of producer organisations and associations.

Policy recommendations

The following recommendations are set out:

1. Encourage scientific, ethical and public **debate**, and support multi-disciplinary **research** on welfare of farmed fish.
2. Support research on the identification of **welfare needs** and standards for farmed fish species depending on the farming systems and the production phases, especially during early development and harvest.
3. Support research on the development of **technological tools** to monitor and analyse farmed fish **behaviour** on-site.
4. Support research on the development of reliable and user-friendly **operational welfare tools** for the assessment of farmed fish welfare.
5. Support the development of species-specific **welfare scoring systems** that will ensure welfare assessment by fish farmers on-site and evaluation of farmed fish welfare status by the competent authorities.
6. Emphasise on the development and implementation of **humane slaughter methods**.

7. Develop and promote fish welfare **training courses for veterinarians** and health professionals, who specialise in fish to support fish farm staff.

8. Develop and promote **basic training programmes for fish farmers** to provide fundamental knowledge on fish biology and behaviour, relevant EU and national regulations and standards, husbandry procedures that can cause suffering, and good husbandry practices leading to improved fish welfare.

9. Develop and promote **life-long education and training of fish farm personnel** to certify that staff responsible for the care of fish is competent, well-trained and have management skills appropriate to the technical requirements of the farming system and production phase.

10. Nominate a **welfare officer** for each fish farm. The person in charge must safe-guard that fish welfare needs and the implementation of fish welfare recommendations are taken care of. The welfare officer is responsible for preparing all relevant documentation for the competent authorities (annual report on fish welfare related outputs, including mortalities, injured animals, and disease outbreaks).

11. Develop **support measures for the industry** to incorporate recent technological advances for implementing welfare monitoring and humane slaughter methods.

12. Improve the **legislative framework on animal welfare**, for example through amending Directive 98/58/EC, with clearly defined provisions to avoid suffering, pain, and distress of fish in farming operations, focusing also on fish welfare and incorporating the latest scientific advances in this field. The updated legislation should include:

    a) the fundamental legislative **objectives** and general **fish welfare principles**,

    b) the delegation of authority and establishment of enforcement and **official auditing mechanisms**, and

    c) the framework for the development of secondary legislation on areas such as **management**, **handling**/treatments, **transportation**, and **slaughter**.

13. Incorporate **species-specific requirements** as annexes of **animal welfare legislation** and/or promoting the development of codes of good practice by interested parties (i.e. producer organisations).

1. INTRODUCTION

Aquaculture and fisheries are of critical importance for global food security, global food systems, regional development, and the economy. Fish is a major source of protein and unsaturated fatty acids and is a healthy, high nutritional value food. Aquaculture and fisheries also provide several commercially utilised by-products and pharmaceutical compounds. The FAO's **State of World Fisheries and Aquaculture** report, issued in June 2020, estimates that '*total fish production is set to increase to 204 million tonnes in 2030, up 15 % from 2018, with aquaculture's share growing from its current 46 %*'. Aquaculture has been the fastest expanding food production sector globally for the last 50 years, growing at an average of 5.3 % per year since the turn of the century.

The new **Strategic guidelines** for a more sustainable and competitive EU aquaculture for the period 2021 to 2030 (European Commission, 2021)[4] state that '*more attention should be paid to the welfare of fish, and not only because of the increasing public interest in – and demand for – high welfare fish products. Keeping fish under good welfare conditions also has economic benefits for the industry, through reduced costs and better-quality products.*'

Over recent decades, the welfare of farmed animals has been gaining greater attention in Europe. There is a **growing public demand** for livestock production that **respects animal welfare needs** and provides the conditions for a 'good life' (Mellor, 2016). From an economic standpoint, fish reared under adequate welfare standards are more likely to be healthy, robust, and disease resistant. In addition, humane slaughter procedures can increase product quality.

As the **concept of animal welfare** has philosophical, scientific, and legal dimensions, it is expected that views on welfare will differ and often lead to debates in the public arena. In general, when talking about animal welfare, three main different views can be identified: function-based, feeling-based, and nature-based views (Fraser, 2008)[5]. The function-based approach is predicated on '*the state as regards their (the fishes') attempts to cope (physiologically) well with environmental and farming conditions*', while the feeling-based approach focuses on the qualitative experiences of their affective and physiological states. The nature-based view presumes that welfare depends on the ability of fish to display their inherent natural behaviours. These views are not necessarily mutually exclusive and may also conflict with each other in specific situations.

All **fish species have common welfare needs** like adequate nutrition, proper water quality, good health/fitness, behavioural freedom, and safety (Stien et al., 2020, Kristiansen et al., 2020). However, differences between species of animals, but also individuals within the same species, in adaptive capacity, feeding behaviour, stress response and tolerance to noxious stimuli, necessitate differentiated research for each farmed species. Moreover, rearing fish with different rearing methods (extensive, semi-intensive, intensive) and production systems (ponds, flow-through systems, recirculating systems, net cages, and offshore cages) underlines the **necessity for species-specific welfare research**, recommendations and regulations.

Consequently, the development and evaluation of operational and laboratory-based **welfare indicators and tools** is a high priority. These indicators must be applicable to all rearing systems and should be valid and reliable for assessing fish welfare in each respective production system. These

4 European Commission (2021). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on '*Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030*'. COM (2021) 236, Brussels, 12.05.2021. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:236:FIN.

5 Frazer, D. (2008) *Understanding animal welfare.* Acta Veterinaria Scandinavica 50, S1.

indicators may form the basis for the development of welfare assessment tools, policy recommendations and a more solid regulatory framework.

Finally, **climate change also impacts the welfare of farmed fish**. The atmospheric greenhouse gas (GHG) concentrations are predicted to continue to rise and will lead to long-lasting climate changes around the world, resulting in warmer temperatures and more unstable and unpredictable weather impacting the water environment (WMO, 2022). The scale of these changes will depend on how rapidly GHG emissions can be reduced. In European aquaculture, climate change will have consequences for production sites, production intensity, farmed species diversification, fish health and welfare, and will affect the future development of the industry.

The **rise of air and water temperature** affects important aspects of **fish physiology** (e.g. oxygen demand and consumption, metabolic and growth rate, thermal stress tolerance, health and welfare) and aquaculture production (productivity of current reared fish, production intensity, species diversification), in a species, geographical region and farm's location specific way (Reid et al., 2019; Cubillo et al., 2021; Mugwanya et al., 2022). A rise in water temperatures will provide faster growing rates to reach harvest weight earlier, but also higher daily oxygen consumption, in certain species (e.g. European sea bass), but at the same time, more days with sub-optimal growth conditions for others (e.g. salmonids) (Besson et al., 2016; Mugwanya et al., 2022). It is important to note that heat waves may raise temperatures especially in lakes, ponds, and rivers, but also in the sea, above species' tolerance ranges; floods may lead to degradation of water quality; and droughts may lead to a lack of available water resources. Marine heat waves in the seas and oceans, with high water temperatures and low oxygen levels, amplify the risk of harmful algal blooms, providing a challenge for fish producers (Global Underwater Hub, 2022).

The overall aim of this report is to present factual information on **scientific knowledge**, **legal aspects** and the challenges relating to the **welfare of the five most important farmed fish species** in EU, namely Atlantic salmon (*Salmo salar*), rainbow trout (*Oncorhynchus mykiss*), common carp (*Cyprinus carpio*), gilthead sea bream (*Sparus aurata*), and European sea bass (*Dicentrarchus labrax*), reared under different production systems and life cycle phases in captivity. The relevant **legislative framework** in place for fish welfare, at both EU and Member State level will be summarised, as will the degree of enforcement. The study identifies what we know and what **knowledge gaps** exist with regard to the welfare of those species and how we manage fish welfare through the legislative framework. Finally, the report provides science-based **policy recommendations** to improve and ensure the welfare of farmed fish in order to bridge the gap between what we know and how we act.

This study consists of the following chapters:

Chapter 2 presents a summary of the **state of knowledge of fish welfare** in relation to fish farming systems. It describes existing **welfare indicators**, **knowledge gaps** and **welfare assessment tools**.

Chapter 3 describes fish **welfare practices** by providing **case studies**, representing the aforementioned **five species** and **different production systems** (earthen ponds, flow-through systems, recirculating aquaculture systems (RAS), and sea cages).

Chapter 4 provides an assessment of the **regulatory framework for fish welfare**, at EU and Member States level, during rearing and **in critical production phases** such as livestock transport, stunning and slaughter, along with recommendations for further improvements.

Chapter 5 summarises the main **outcomes and conclusions** of the study.

Chapter 6 provides **policy recommendations**, relevant to **EU decision-making**, so that welfare requirements for farmed fish species can be ensured under the different production systems and methods used in the EU.

2. STATE OF KNOWLEDGE ON FISH WELFARE IN AQUACULTURE PRODUCTION

2.1. Farmed fish welfare

Fish are the most **diverse and numerous vertebrate group** with over **33 000 species**. They are found in all aquatic ecosystems, from freshwater to highly saline areas, from still waters to fast-flowing streams, from sub-zero temperatures to warm tropical waters and from shallow enclosures to the abyssal plain. Fish display a variety of physiological, metabolic, and behavioural adaptations that ensure their survival, fitness, and reproduction in such diverse habitats, making each single species unique from a scientific point of view. **Fish welfare** is a major component of sustainable fish farming and, in contrast to other production animals, has recently been attracting significant attention.

Over recent decades, awareness of the welfare of farmed animals has been growing in Europe. In 1976, the 'European Convention for the Protection of Animals kept for Farming Purposes'[6] introduced **general welfare principles** for keeping, care and housing of animals in intensive stock-farming systems. In 1979, the **five freedoms**, five minimum animal welfare requirements, entered by the 'Farm Animal Welfare Council' (FAWC) in the UK, established a framework for standards and welfare assessment and have strongly influenced animal welfare legislation. The five freedoms as currently expressed are as follows:

1. Freedom from **hunger or thirst** by ready access to fresh water and a diet to maintain full health and vigour.
2. Freedom from **discomfort** by providing an appropriate environment including shelter and a comfortable resting area.
3. Freedom from **pain, injury or disease** by prevention or rapid diagnosis and treatment.
4. Freedom to **express (most) normal behaviour** by providing sufficient space, proper facilities and company of the animal's own kind.
5. Freedom from **fear and distress** by ensuring conditions and treatment which avoid mental suffering.

It is obvious that FAWC had the basic needs of terrestrial farm animals in mind and focused on 'freedom from' suffering. Nowadays, it is more accepted that animals require more than just minimising negative states to achieve a good **quality of life**.

It was not until the 1990s that the first concerns about the welfare of farmed fish were raised in the UK (Lymberly 1992, FAWC 1996), and in 1998, the EU issued **Council Directive 98/58/EC** concerning the protection of animals kept for farming purposes[7], which also included fish. Article 3 stated that: '*Member States shall make provisions to ensure that the owners or keepers take all reasonable steps to ensure the welfare of animals under their care and to ensure that those animals are not caused any unnecessary pain, suffering or injury*.'

[6] European Convention for the protection of animals kept for farming purposes, OJ L 323 17.11.1978, p. 14. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01978A1117%2801%29-19921231. Summary document available at: https://eur-lex.europa.eu/EN/legal-content/summary/european-convention-for-the-protection-of-animals-kept-for-farming-purposes.html.

[7] Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes; OJ L 221, 8.8.1998, p. 23–27. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01998L0058-20191214.

The Directive was later implemented in national legislation, and animal welfare, including fish welfare, has been a priority research topic funded by the European Commission during the last two decades (Kristiansen and Bracke, 2020). In 2005, the Council of Europe[8] also adopted a recommendation on the welfare of farmed fish that entered into force on 5 June 2006.

The **European Food Safety Authority** (EFSA) also played an active role in facilitating a better understanding of the factors affecting fish welfare and a science-based foundation for European policies and legislation. EFSA's scientific opinions focused on helping risk managers to identify methods to reduce unnecessary pain, distress and suffering, and to improve animal welfare wherever possible. In 2004, EFSA's independent **Panel on Animal Health and Welfare** (AHAW) issued scientific opinions regarding the transport and stunning/killing of farmed fish (EFSA 2004). In the years 2008 and 2009 the panel published eight scientific opinions on the welfare and husbandry systems of Atlantic salmon (*Salmo salar*), common carp (*Cyprinus carpio*), European sea bass (*Dicentrarchus labrax*), gilthead sea bream (*Sparus aurata*), rainbow trout (*Oncorhynchus mykiss*), European eel (*Anguilla anguilla*) (EFSA 2008 a-e), and the stunning and killing of turbot (*Scophthalmus maximus*) and Atlantic bluefin tuna (*Thunnus thynnus*) (EFSA, 2009ab). In 2009, this was followed by a general approach to fish welfare and to the concept of sentience in fish (EFSA, 2009c).

Nowadays the **concept of fish welfare** has been acknowledged by all relevant sectors throughout Europe and recent scientific advances suggest the need to shift even further from the idea of freedom from negative experiences to providing positive experiences for farmed animals. As proposed by Mellor (2016), 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*'. This **quality of life** (QoL) scale approach may be the next challenge for farmed fish welfare as well. Moreover, from an economic standpoint, fish reared under good welfare standards are more likely to be healthy, robust, and disease resistant.

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 an easy to understand manner. It is known that stress is an essential, genetically embedded, adaptive mechanism designed to secure survival and other critical biological functions, thus stress is a **normal part of life** for every single individual. It is therefore crucial to determine in a manner that is specific to species, life-stage and production system, the point at which the red line is crossed and where stress actually does impair fish welfare. It is also important to identify individual differences as due to different genetic and environmental interactions. A given individual may display a different response following exposure to the same noxious stimulus or stressor based on its cognitive capacity and coping style (Korte et al., 2007). Recent scientific advances also show that **fish health and fish welfare are not synonymous** terms. As stated by Broom (2007a), '*when an animal's health is poor, so is its welfare, but poor welfare does not always imply poor health.*' 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. Moreover, fish reared under adequate welfare standards are more likely to be healthy, robust, and disease resistant.

Fish welfare has recently attracted significant **public attention**. All fish species have **biological requirements**, such as adequate feed composition and proper environmental conditions, and if these are not met, their welfare will be impaired. These requirements, also termed **welfare needs**, should be established for farmed fish on a **species-specific** basis and based on different **critical phases** of the

[8] Council of Europe (2005). Recommendation concerning farmed fish adopted by the Standing Committee of the European Convention for the Protection of Animals Kept for Farming Purposes (T-AP) on 5 December 2005. Council of Europe. Available at: https://www.coe.int/t/e/ legal_affairs/legal_co-operation/biological_safety_and_use_of_animals/Farming/Rec%20fish%20E.asp.

development/life cycle in captivity (larvae, weaning, on-growing, sexually mature broodfish). It should also be in line with the **production system** (ponds, flow-through system, recirculating systems, net cages, offshore cages) and the **scale of production** (extensive, semi-intensive, intensive).

The literature critically evaluates **common practices and operations of concern for welfare**, such as handling, grading, transportation, vaccination, veterinary treatments, anaesthetisation, and slaughter. Moreover, key data from scientific publications and reports provide recommendations to improve fish welfare in relation to potential **natural stressors** (e.g. low or high water temperatures, low oxygen, shifts in salinity, water quality changes, water currents, noise) and **non-natural stressors** (crowding, confinement, netting, pumping, air exposure, high stocking density, abrupt changes in social interactions). Lastly, the literature review shows that an array of operational- and laboratory-based **welfare indicators and tools** are available for **assessing fish welfare** (Noble et al., 2018; 2020; Pavlidis and Samaras, 2020; Stien et al., 2020).

All farmed fish have **common welfare needs**, i.e. adequate nutrition, proper water quality, good health/fitness, behavioural freedom, and safety. However, different **lifestyles**, species-specific differences in **stress tolerance** and **disease resistance**, as well as **individual differences** within species, should be considered when assessing welfare status and husbandry practices. For example, **European sea bass** (*Dicentrarchus labrax*) has been described as a **stress-sensitive** species, as indicated by the much higher basal and post-stress plasma cortisol levels compared to the other European aquaculture farmed species (Fanouraki et al., 2011; Samaras et al., 2015; Samaras & Pavlidis, 2018). On the contrary, the **common carp** (*Cyprinus carpio*) has been described as a **very resilient and stress-insensitive** species, which may lead to rough treatment of fish by farmers. Therefore, a **species-specific approach** is needed to identify those husbandry practices and operations that pose welfare challenges, their magnitude and long-term impacts on the fish and what strategies should be put in place to mitigate them.

The **desk literature review** revealed that scientific research on a variety of fish species has focused on better understanding the **genetic, physiological** and **neuro-endocrine mechanisms** involved in the regulation of the stress response and anxiety-like behaviour (Cerqueira et al., 2021; Daskalova, 2019; Gesto et al., 2020; Hoem & Tveten, 2020; Jerez-Cepa & Ruiz-Jarabo, 2021; Raposo de Magalhaes et al., 2020; Sadoul et al., 2021) and identifying the **biological needs** of farmed fish in relation to the **environmental, nutritional and husbandry conditions** of the particular rearing system and managerial practices (Hodkovicova et al., 2020; Gharib et al., 2022). From an applied point of view, published welfare data mostly deal with the impact of handling stress, stocking density, water quality, artificial photoperiod, selective breeding, feeding/starvation, transport, and stunning/slaughter. Recently, emphasis has been placed on the development of reliable, measurable and **easy to use welfare indicators** that will **assist welfare assessment** (for details see Sections 2.4 and 2.5, as well as Chapter 3), by both producers and competent authorities.

2.1.1. Broodfish practices of concern for welfare

There has been a long tradition of **genetic improvement programmes** for rainbow trout and Atlantic salmon since the early 1970s (Thodesen and Gjedrem, 2006), while for European sea bass and gilthead sea bream genetic selection programmes started 30 years later during the early 2000s[9]. Atlantic salmon broodstock and egg production are mainly undertaken by a few breeding companies with their own breeding programmes.

[9] https://thefishsite.com/articles/advancing-selective-breeding-in-seabass-and-seabream.

The literature review revealed the **main ordinary practices** and operations of welfare concern that can impact intensively reared broodfish welfare in a positive or negative way and that are **common to all species**:

(i) **water** quality (Duncan et al., 2013; Stien et al., 2013; Alfonso, 2020; Berlinsky et al., 2020));

(ii) **feeding** protocol (Cardona et al., 2019; Cerdá et al., 1994);

(iii) **stocking** density/social interaction (Ferrari et al., 2015; Saillant et al., 2003);

(iv) use of **pharmaceuticals and chemicals** for disease treatment and anaesthesia (Munday et al., 2002; Jia et al., 2021);

(v) **handling, material** and **equipment used** during routine husbandry work (Engin, 2022; Zahl et al., 2012);

(vi) **cleaning** of tanks and **hygiene** measures (Fernández-Míguez et al., 2023; Lee et al., 2021).

Change of photoperiod and temperature cycle for out of season egg production is also a common **husbandry practice of welfare concern** for salmon, trout, gilthead sea bream and European sea bass, and hormonal treatment for induced spawning for common carp, gilthead sea bream and European sea bass (Altunok & Peker, 2016; Corriero et al., 2021; Fornies et al., 2001; Mehdi et al., 2011; Vazirzadeh et al., 2008; Villamizar et al., 2012; Zanuy et al., 1995). Skin health problems (ulcers, inflammations), eye cataracts and injuries, fungus on gills and skin and disease control (vertically transmitted diseases) are noted to be **indicators of poor welfare** for Atlantic salmon broodfish (Bang Jensen et al., 2019; Birlanga et al., 2022; Bjorgen et al., 2019; Boerlage et al., 2020; Garseth et al., 2018); while oxygen shortage, lack of circulation because of technical failure are issues for rainbow trout (Garcia-Meilan et al., 2022; Lagarde et al., 2023; Prchal et al., 2023). For common carp, lack of experienced veterinary supervision, unavailability of vaccines and lack of appropriate and effective treatments were also pointed out, as were husbandry practices such as netting capture that increase stress, injuries, and disease outbreaks (Jia et al., 2021; Rapp et al., 2012; Rapp et al., 2014). European sea bass females frequently exhibit unpredictable spawning and reduced egg production and males low milt volumes (Forniés et al., 2001, Mañanós et al., 2002; Superio et al., 2021), an issue that should be better investigated.

Well-substantiated scientific evidence, such as feeding protocols, stocking densities and appropriate sex ratio, is available for several of these **broodfish welfare challenges**, while for other practices and operations (such as genetic selection for a better growth rate, structural complexity (enrichment) of the holding tank, noise stressors, and hormonal treatment for induced spawning), **further research is needed** to identify their impact on cognitive abilities and welfare. Moreover, in most cases, there is a lack of methods for the **inspection of welfare status**, as well as a lack of methods for the **management of welfare risks** and the implementation of contingency plans.

2.1.2. Embryos and non-feeding yolk sac larvae

European Parliament and Council adopted Directive 2010/63/EU[10], UK law and Canadian guidelines, consider only fish with independent feeding, as entities of welfare concern. Therefore, no ethical clearance for yolk sac dependent larval is required (Sloman et al. 2019). However, little is still known regarding to what extent early life programming or exposure to stressful stimuli at early ontogeny affect fish characteristics, robustness and performance at subsequent stages of development. Recent data indicate that environmental enrichment at early ontogeny affected global DNA methylation in

[10] Directive 2010/63/EU of the European Parliament and the Council of 22 September 2010 on the protection of animals used for scientific purposes (Text with EEA relevance); OJ L 276, 20.10.2010, p. 33–79; Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02010L0063-20190626.

brains of rainbow trout at the egg and alevins stage, i.e. during the developmental period, when the animals in the wild are in close physical contact with the substrate (Reiser et al. 2021). Additionally, research into Atlantic salmon has indicated that elevated temperatures (above 8°C) during egg incubation are not recommended, since these lead to a higher ratio of vertebral malformations (Fraser et al., 2015). Moreover, early life temperature affects swimming performance and skeleton development at a later stage in the development of gilthead sea bream (Kourkouta et al., 2021). For common carp, water quality and sanitary measures are critical for successful fertilisation and larval development. Therefore, further research is required to identify optimal conditions for proper development during early ontogeny and robustness in later developmental stages.

2.1.3. Larval rearing practices of concern for welfare

After first feeding, larvae are considered sentient beings with the ability to experience pain, stress and express anxiety-like behaviour. The technological requirements for larval rearing in all the species being studied are well-known. However, husbandry conditions should fulfil larval biological welfare needs either under fully controlled indoor (hatchery) conditions, or in the case of common carp, in ponds. Water and feed quality, exposure to artificial, altered light and temperature conditions, noises and vibration in the rearing facilities, hygiene and cleaning measures, quality and availability of feed, handling and transportation to weaning tanks, are welfare issues for all farmed fish species (Ayala et al., 2020; Bhandiwad et al., 2021; Ramos et al., 2021), but especially for the very small and vulnerable larvae (3-5 millimetres), for example of gilthead sea bream, European sea bass and common carp (in indoor facilities). Additionally, pH variations, changes in temperature, wind conditions, stocking density versus natural feed availability poses welfare challenges for common carp larvae.

The larval phase is very sensitive, and additional research is needed to identify to what extent common husbandry practices and exposure to noxious stimuli may affect fish characteristics, robustness, and performance at subsequent stages of development. Furthermore, appropriate, validated welfare indicators and tools are still missing. Risk management analysis indicated that personnel responsibility and training were the most important risk mitigation input activities, whereas setting mortality limits is the most important in terms of output activities.

2.1.4. Weaning and pre-growing practices of concern for welfare

Environmental parameters (water temperature; oxygen saturation; pH; ammonia; CO_2 and total amounts of bacteria in the water of closed recirculating systems); and husbandry practices such as grading; sorting for deformities; scratching during netting; cleaning and hygiene measures; use of pharmaceuticals and chemicals for disease treatment; vaccination and transportation practices (fasting, crowding, confinement, transfer to tanks, alterations to water quality of transportation tanks, unloading the vehicle and transfer to on-growing installations) were identified as issues of welfare concern in all species. Additionally, oxygen shortage and lack of circulation because of technical failure are of welfare concern for trout juveniles, and natural feed availability and misuse or unavailability of pharmaceuticals and chemicals for disease treatment are of concern for common carp juveniles at the pre-on-growing production phase. In general, there are rules in place, but some need updating (e.g. transportation of live fish) and others are still missing (such as for handling, sorting and grading – gilthead sea bream, European sea bass, rainbow trout and common carp). The main risk mitigation activities identified are personnel responsibility and training (especially feeding, water quality, hygiene, handling routines and the technical quality of rearing facilities).

2.1.5. On-growing fish and practices of concern for welfare

This is the most diverse production phase, involving **rearing fish in a variety of enclosures**, from earthen ponds to recirculating hyper-intensive systems, and from flow-through raceways to net-pen sea cages. Therefore, practices of concern for welfare in the on-growing phase are presented in detail per farming system and fish species in Section 2.2 and Chapter 3 respectively. In general, and depending on the farming system, husbandry and managerial practices, the following **parameters of welfare concern** were identified:

(i) **water** quality and water shortages (Erikson, 2001; Johansson et al., 2006; Jokumsen & Svendsen, 2010; Harmon, 2009; Noble et al., 2018; Sampaio & Freire, 2016; Santos et al., 2010; Stien et al., 2013).

(ii) imbalances in water **temperatures and O_2** (Almeida et al., 2015; Balbuena-Pecino et al., 2021; Cecchini & Caputo, 2003; Fraser et al., 2015; Lemarié et al., 2011; Vargas-Chacoff et al., 2020);

(iii) lack of specialised **vaccines** and licensed **anaesthetics** (Gomez-Casado et al., 2011; Vendramin et al., 2016);

(iv) lack of **environmental control** and low **biosecurity** (Chen et al., 2015; Muniesa et al., 2022; Osmundsen et al., 2022; Pruder, 2004; Scarfe & Palić, 2020; Yu et al., 2021);

(v) easy access by **predators** (Callier et al., 2018; Forster, 2013; Fujita et al., 2023),

(vi) **stocking density** (Ellis et al., 2002; Johansson et al., 2006; Di Marco et al., 2008; Hoseini et al., 2019; Laursen et al., 2013; Lupatsch et al., 2010; Sánchez-Muros et al., 2017; Saraiva et al., 2022; Stien et al., 2013; Turnbull et al., 2005);

(vii) intensive **handling** (Berbel-Filho et al., 2020; Eissa & Wang, 2016; Jia et al., 2021; Mañanós et al., 2002; Mazur & Iwama, 1993; Rapp et al., 2014; Rodriguez Barreto et al., 2019; Steinhagen et al., 2016; Superio et al., 2021; Wiese et al., 2023; Wilkinson et al., 2006; Xu et al., 2021; Yousaf et al., 2022) ;

(viii) **transportation** and **harvesting** (Brijs et al., 2018; Dobíková et al., 2006; Erikson, 2001; Kayali et al., 2011; Harmon, 2009; Towers, 2010; Poltronieri et al., 2007; Shabani et al., 2016) ;

(ix) **climate**-driven increase in **parasitic diseases** (Burge et al., 2014; Cascarano et al., 2021);

(x) lack of welfare **monitoring tools** on-site (Browning, 2023; Nilsson et al., 2022; Weirup et al., 2022);

(xi) life-long **training** for staff in fish welfare (Medaas et al., 2021; Størkersen et al., 2021).

2.1.6. Stunning and slaughtering methods

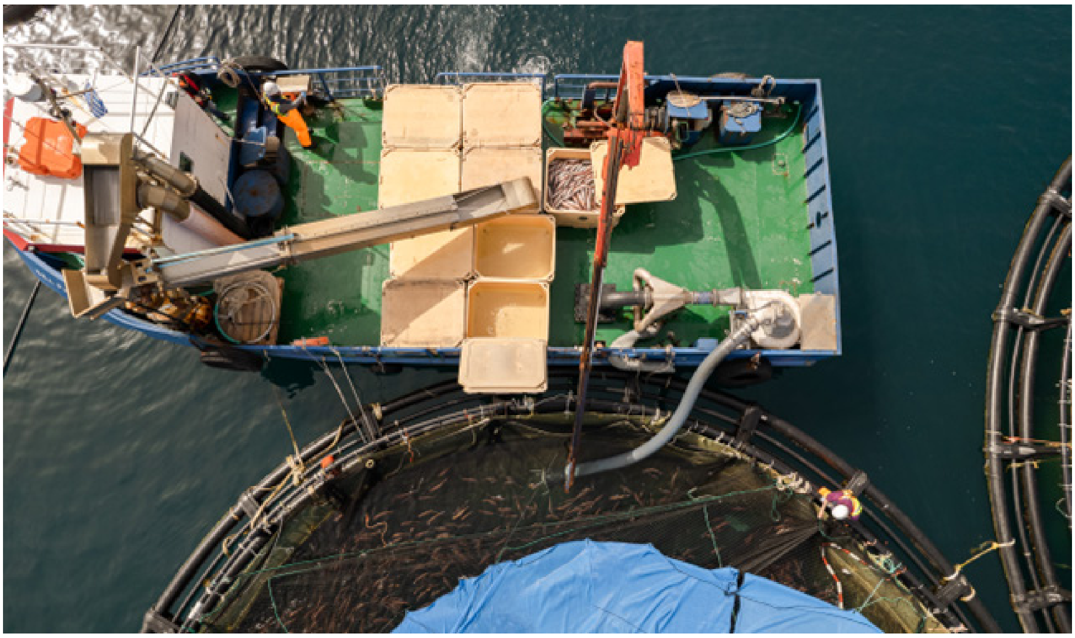
In 2005, the 'Standing Committee of the European Convention for the Protection of Animals kept for Farming Purposes' (T-AP)[11] adopted a recommendation as regards farmed fish, including fish welfare[12], and in 2009, the EFSA published scientific opinions for welfare aspects of the main systems for stunning and killing farmed carp, rainbow trout, gilthead sea bream and European sea bass. In 2017, the Aquaculture Advisory Council (Boyland & Brooke, 2017) published a report on farmed fish welfare during slaughter. The report stated that: '*according to the World Organisation for Animal Health (OIE) and the European Food Safety Authority (EFSA), percussive stunning and electrical stunning systems are best*

[11] https://www.coe.int/en/web/cdcj/farming

[12] https://www.coe.int/en/web/cdcj/2005-rec-farmed-fish

able to provide a humane slaughter for many of the key species farmed in the EU. Spiking or coring, and shooting underwater, can also be humane methods for some species.' Humane slaughter for Atlantic salmon and rainbow trout can be achieved using a combined approach, consisting of stunning with electricity followed by percussive stunning. As regards carp, most EU Member States, including Poland, Czechia, and Germany, curtailed the sale of live fish to consumers and currently fish must be killed by the retailer. The stunning and killing methods in place are – as for salmonids – electrical or percussive stunning, or electrical stunning followed by percussion, with the latter considered highly effective. These stunning methods are followed by killing with exsanguination (Retter et al., 2018). Most gilthead sea bream and European sea bass are currently killed by immersion (live chilling) in ice-slurry, a method that results in prolonged delay to reach the unconsciousness stage (de la Rosa et al., 2021), and death is caused by hypothermia and anoxia. However, recently, proper electrical stunning equipment was developed, and stunning parameters were validated on an industrial scale (Papaharisis et al., 2019). This system was further upgraded (Technology Readiness Level 8), placed on a fishing vessel (**Figure 1**) and is available for industrial use (Pavlidis et al., 2023). Technological solutions are needed to prevent or minimise stress and anxiety caused by harvesting practices (i.e. crowding, confinement, netting, air exposure, pumping, and change in social interactions) in all species. Additionally, further research is needed to investigate whether European sea bass and gilthead sea bream immersed in ice-slurry die from asphyxia or cold shock. Finally, there is a need to develop methods and tools to assess the success of loss of consciousness during slaughtering in stunned fish.

Figure 1: A new harvest and stunning system for farmed Mediterranean marine fish species



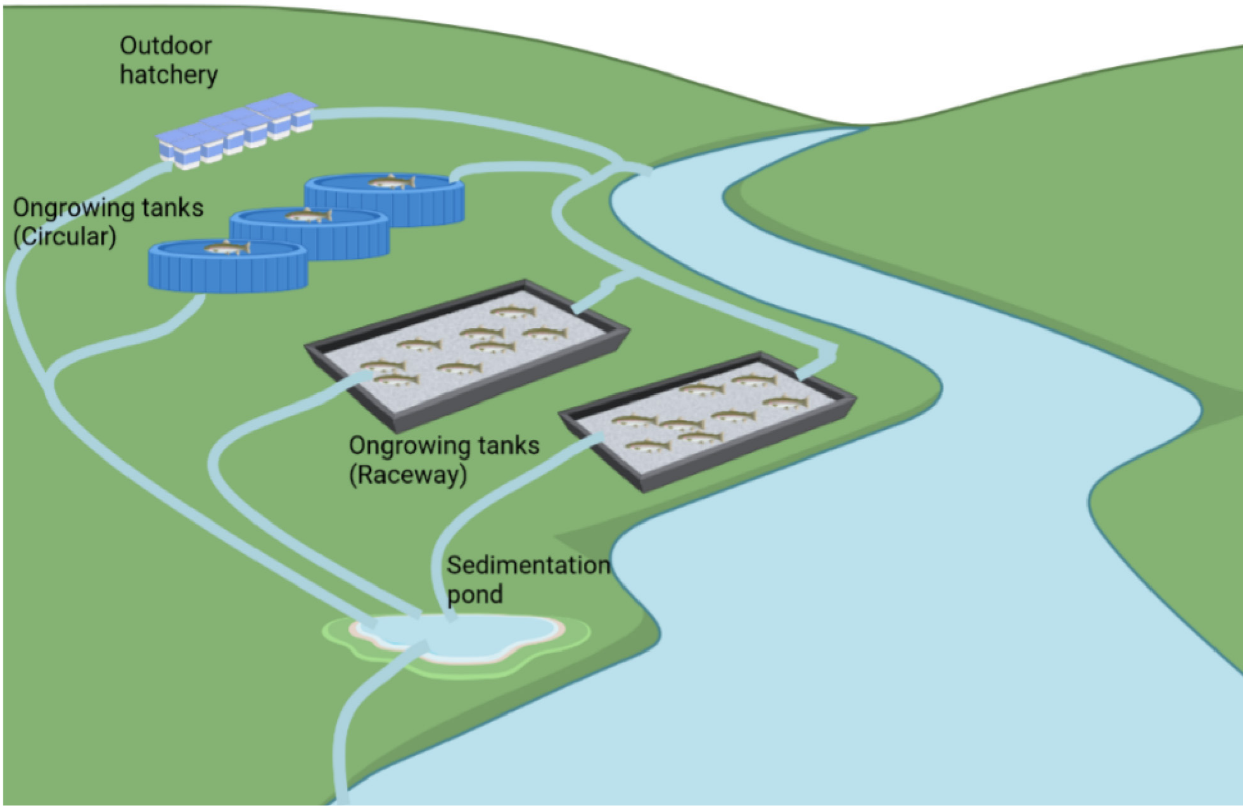
Source: L. Papaharisis, AVRAMAR S.A. and Pavlidis et al., 2023

2.2. Overview of fish farming systems

2.2.1. Land-based flow-through systems

Flow-through farming systems are artificial circular and rectangular basins or canals with a continuous water flow and were the first type of aquaculture system used for the production of salmonids. In European aquaculture, they are widely used for cultivating salmonids, such as rainbow trout, brown trout and arctic charr but also juvenile Atlantic salmon. Flow-through ponds and raceways are of variable size, depending on the life-stage of the fish stocked, with approximately 100 m^2 at the fattening stage. They have reinforced concrete, wooden, or earthen walls, or earthen ponds are covered with plastic liners to simplify cleaning and disinfection. A water inlet and outlet allow for a constant flow of water, with full water volume being replaced at least every hour in order to meet the requirements of the fish for oxygen supply and waste removal. In addition, constant water flow and a length-to-width ratio of 3:1 to 6:1 in ponds, and up to 10:1 in raceways enables the self-removal of sludge. An adapted stocking density and a water level of up to 1 m aids the self-cleaning of the ponds or raceways from sludge, and this may be further aided by a temporal lowering of the water level. The water can be taken from a well, a reservoir or a small creek, and the landscape should allow the supply by gravity. Oxygen levels can be kept high by aeration systems or the use of liquid oxygen. When respiration and waste removal requirements are met, flow-through systems make it possible to raise salmonids at a high stocking density, with a good level of welfare and reasonable economic conditions. For sanitary reasons and to prevent the spread of disease to upper ponds or raceways in an aquaculture farm, individual basins or several sections of a farm should have separate water drainage channels. Many flow-through systems utilise water from the natural environment and release dissolved nutrients and sludge from ponds or raceways into natural waters with the water flow. The environmental impact of these farms is attracting criticism and many farms are implementing some waste water treatment measures, such as sedimentation basins in the drainage system before the water is released into the environment.

Figure 2: Land-based flow-through aquaculture systems



Source: BioRender.com

Ponds and raceways are stocked with fish at the fingerling stage and fish are grown exclusively on manufactured feed. The main processes that take place are: transport of juveniles for initial stocking; feeding; monitoring of water quality; sorting based on fish size and stocking of additional/larger ponds; health monitoring; treatments and/or vaccinations when needed; and harvesting at the end of the production cycle. The infrastructure needed is a permit for utilising the water and fish holding devices like ponds or raceways. The main equipment used is feeders, sorting machines, devices for transporting fish on the farm and a series of nets to handle the farmed fish. These types of farms are located in inland environments with a good supply of cool water of good quality and sufficient flow. Some plants are located in the brackish water area. On many farms, there is a tendency to recirculate the water after passing it through waste water treatment devices.

The main areas of concern for land-based flow-through systems depend on the design of the rearing system, the materials used to construct the system, the type of surfaces in the tanks, the volume of water and the stocking density. In general, they can be related to water quality, which is affected by the input of feed, and to the handling of fish, either for husbandry purposes (sorting, crowding, handling) or for transport and harvesting, but also for curative purposes (bath treatments). Interaction with wildlife surrounding the flow-through farms is of concern due to the potential transmission of pathogens from wild fish to farmed specimens and the threat to farmed animals from predators such as birds and mammals. Welfare challenges coming from the environment could be elevated water temperature or reduced water shedding during drought or heat periods.

A SWOT analysis (**Figure 3**) was performed to assess fish welfare in the land-based flow-through system. The criteria used in the SWOT analysis are the following

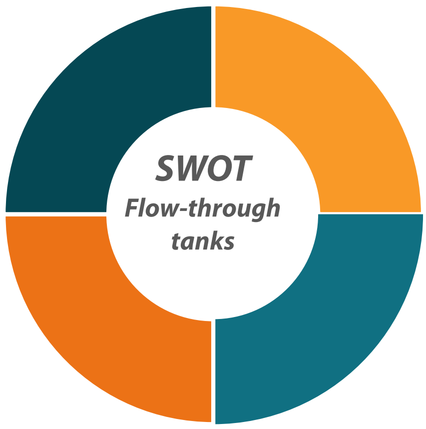
a) How does the land-based flow-through system safeguard fish welfare?

b) Where is this particular system weak in fish welfare?

c) Can changes in the legislative framework for fish welfare in the EU offer opportunities that can be exploited in flow-through production systems?

d) Can changes in the legislative framework for fish welfare threaten the flow-through production systems in place?

Figure 3: SWOT analysis of land-based flow-through systems on aspects of fish welfare



STRENGTHS

- Availability of experts
- Good level of surveillance of fish and water quality
- Land-based easy to-access infrastructure
- Availability of technology

WEAKNESSES

- Water shortages can lead to poor welfare
- Imbalances in water temperature and O_2
- Little or no control on incoming water parameters such as temperature, turbidity pathogen load, impact of extreme weather events
- Easy access by predators
- Lack of specialised vaccines and licensed anaesthetics
- Intensive handling, crowding for treatments

OPPORTUNITIES

- New co-products and species diversification
- Cultural culinary links with society
- Collaborative research for knowledge-based aquaculture development
- Availability of funds to support sector adjustment

THREATS

- Extreme weather events, climate change
- Increased nature conservation requirements
- New legislative requirements for fish welfare might affect operational plans

Source: Own elaboration

Outcome of SWOT analysis for water flow-through establishments

The production system provides accessibility to farmed fish and ease of fish handling practices.

There is a long tradition of using such systems for fish farming, along with strong technical know-how to address the main welfare challenges that have been recognised. Operators' practices can impair fish welfare. New legislation has to focus on capacity improvement of operators such as training and accountability to safeguard fish welfare.

Open-flow land-based production systems are the most vulnerable to climate change and extreme weather conditions. High-quality freshwater shortages are common in many areas during the warm seasons of the year.

Interactions with wildlife and increased nature conservation requirements. Measures to mitigate the impact of predators must be in place.

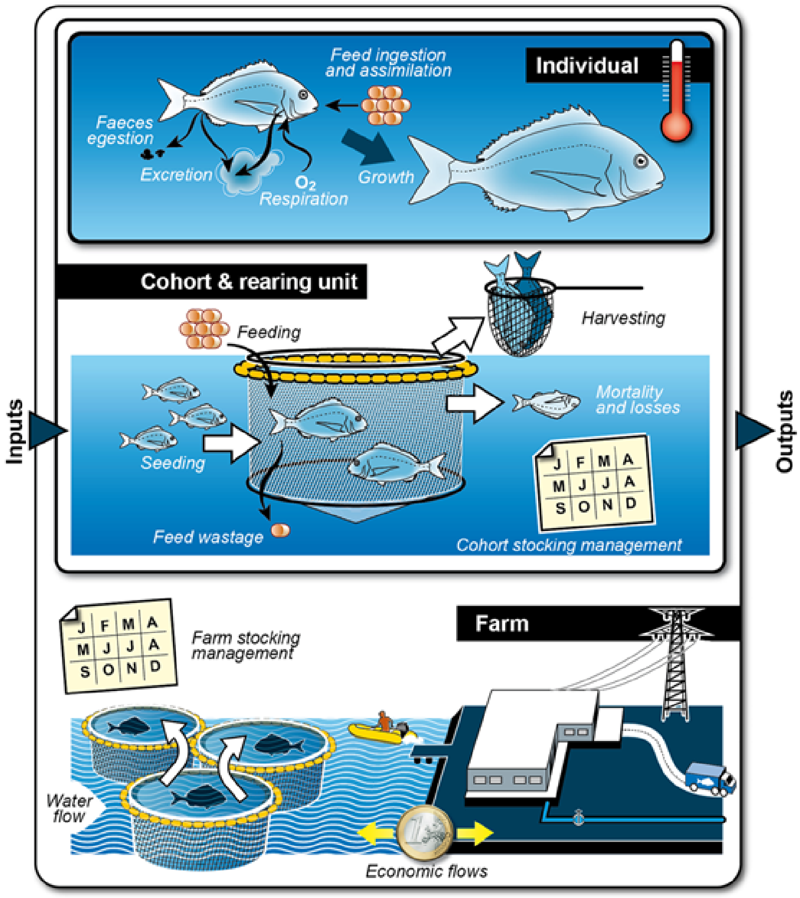
The diversity of flow-through rearing systems makes them vulnerable to new legislation on fish welfare that does not take this diversity into account.

2.2.2. Floating cage open-flow systems

Fish farming in open-flow floating cage systems is considered as an intensive on-growing system with stocking densities varying between 6 kg/m^3 and 25 kg/m^3. In this farming system, the operator buys the juveniles for stocking from hatcheries and fish are grown exclusively on manufactured feed. Husbandry processes of welfare concern are: transport of juveniles for initial stocking, feeding protocol; surveillance by diving; health monitoring and treatments; vaccinations; grading based on fish size; and harvesting at the end of the production cycle. The infrastructure needed consists of a mooring system (anchors, metal chains, ropes and buoys), the fish holding devices such as flexible or rigid floating frames and flexible wall netting.

The main equipment used is boats equipped with grains, vaccination machines, sorting machines and a series of nets to handle the farmed fish. These types of farms are often located in various marine environments, but also in lakes. Marine environments present great variability from sheltered areas to more exposed areas. The current trend is to site fish farms in open sea areas. **Figure 4** presents the model of fish farming in open-flow floating cages at an individual fish level, at a rearing unit level and at a supply chain/operational level.

Figure 4: Model of fish farming processes in open-flow floating cages



Source: Chary et al., 2022

The main areas of concern for fish welfare in open-flow floating cage farming systems are related to the inputs provided, such as feed quality and distribution, repeated handling of fish either for husbandry purposes (grading) or for curative purposes (vaccination, bath treatments), noise and acoustic stress, fish transportation and harvesting. Interactions with wildlife surrounding the net cages are of concern due to the potential transmission of pathogens and the threat to farmed animals posed by predators such as big fish, mammals and birds. Welfare challenges coming from the environment could be extreme variations in temperature, algal blooms and oxygen availability, accumulated waste under the cages and escapees.

A SWOT analysis (**Figure 5**) performed to assess fish welfare in open-flow floating systems. The criteria used in the SWOT analysis are the following:

a) How does the open-flow floating system safeguard fish welfare?

b) Where is the open-flow floating system weak in fish welfare?

c) Can changes in the legislative framework for fish welfare in the EU provide opportunities for open-flow floating production system to exploit?

d) Can changes in the legislative framework for fish welfare threaten the open-flow floating production system in place?

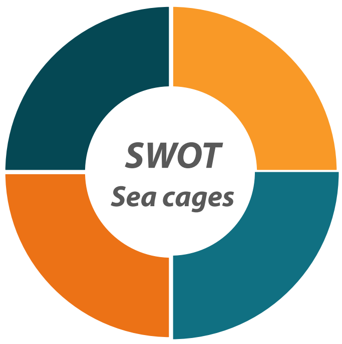
Figure 5: SWOT analysis of open-flow floating cage systems on aspects of fish welfare

STRENGTHS

- Availability of experts
- Relative cheap, safe and well-tested technology
- Availability of sites with good water quality
- Largest and most robust fish are used
- The fish experience more natural conditions
- Low energy use and less need for monitoring and control technology

WEAKNESSES

- Lack of environmental control and low biosecurity
- Technology for marine submerged access
- Lack of specialised vaccines and licensed anaesthetics
- Intensive handling crowding at treatments
- Most operations in sea water (lack of control over environmental conditions, managerial difficulties, high risk of fish escape)



OPPORTUNITIES

- Growing demand expected to fuel production
- EU aims to reduce dependency on food imports
- Research capabilities to assist sector shift
- Funds to support sector adjustment

THREATS

- New legislative requirements for fish welfare might affect operational plans
- Level playing field differences with competitors
- Extreme weather events, climate change

Source: Own elaboration

Outcome of SWOT analysis

The open-flow floating cage production system provides untapped opportunities for high-value protein production within EU territory. This is the most promising production method with a view to reducing EU dependency on fish protein imports.

Technical and scientific human resources are available to improve the current fish welfare status based on solid scientific knowledge. There are funds available to support sector adjustment to more humane production methods.

New legislative requirements for fish welfare are expected to increase the level playing field differences with competitive products imported from non-EU countries if no additional requirements are imposed on imports.

Operators' practices can impair fish welfare. New legislation has to focus on capacity improvement of operators such as training and accountability to safeguard fish welfare given the low level of technological intervention in the sector.

Funding is required for research into species' physiology and behaviour, vaccines and submerged technology in order to fill knowledge gaps and provide operators with more tools for improving fish welfare.

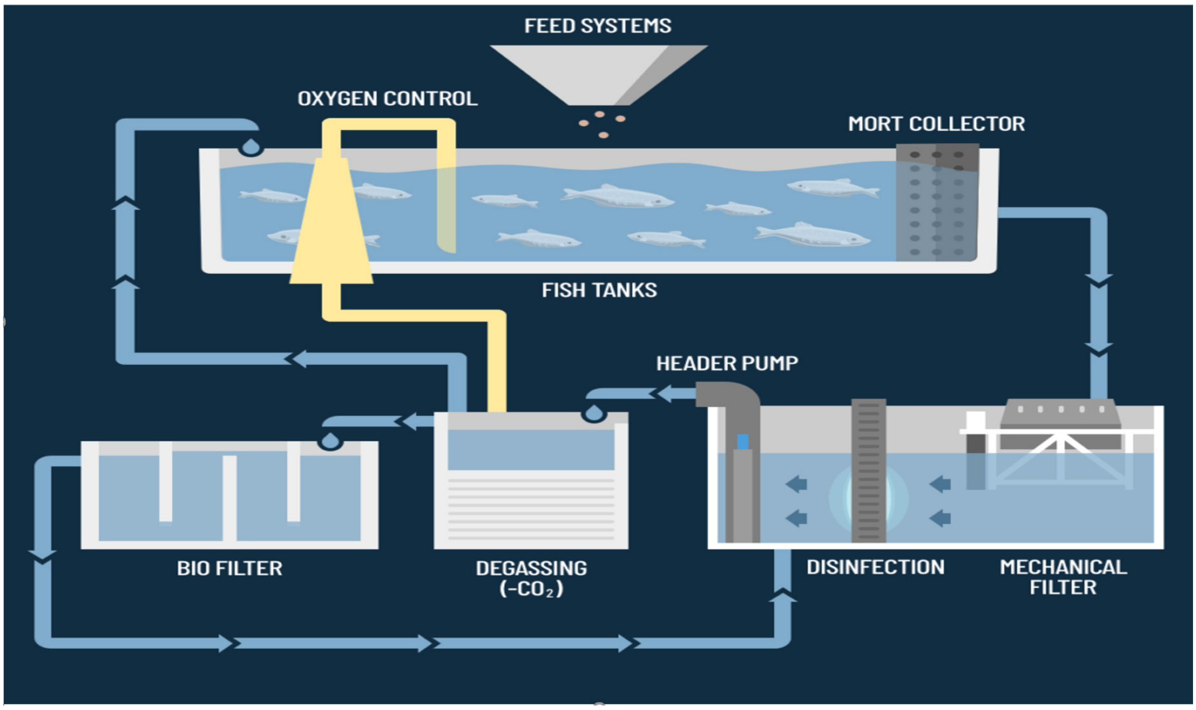
2.2.3. Land-based RAS

Recirculating aquaculture systems (RAS) are inland, highly industrialised, water-conserving aquaculture systems that are gaining ground in intensive fish farming (**Figure 6**). They are one of the systems that can ensure food security in a future where human populations will continue to grow and water scarcity will increase in certain parts of the world due to climate change.

To effectively conserve and reuse water, it must be treated before entering the system and continuously purified within the system. The quality of the incoming water is essential, and treatments may be required to improve its physicochemical properties and/or to remove the microbiological burden from the incoming water. Treatment and purification of the reused (recirculated) water within the system is an indispensable part of RAS. This process includes removal of particles (sludge) and dissolved solids; bio filtration leading to the removal of nitrogen waste; aeration and/or oxygenation to replenish the oxygen used by fish and filter bacteria; and degassing allowing the removal of unwanted gases dissolved in the water (e.g. CO_2). Management of physicochemical water parameters such as pH, alkalinity and temperature is also needed to better match the requirements of both fish and bio filter bacteria. These processes increase the need for continuous monitoring systems, adding complexity, costs, and points of failure. Water recirculation also increases the need to prevent the introduction of pathogens into the system as their removal may be challenging, along with the requirement of highly trained personnel.

The popularity of RAS is due to not only increasing water scarcity but also independence from large bodies of water. The strict control of water parameters required for RAS operations ensures stable and controllable water conditions, even for very exotic fish species. RAS provides the highest yield from a given volume of water.

Figure 6: Land-based recirculating aquaculture system (RAS)



Source: www.derwent.es

The main processes taking place are: the transport of juveniles for initial stocking; adjusting environmental conditions (water flow, water temperature, oxygen saturation, and lighting); feeding; health monitoring and treatments; vaccination; sorting of fish based on their size; and harvesting. Water treatment and reuse is of paramount importance in RAS to save energy costs, especially for the adjustment of temperature and oxygen levels. RAS are installed in land-based establishments and fish are reared in tanks of different shapes and dimensions. A great advantage of RAS is the possibility to significantly increase the biomass reared per water volume used, and to achieve high levels of biosecurity so that fish are protected from infection by pathogens during water filtration.

The main areas of concern for fish welfare in RAS are related to the high level of industrialisation of these systems. The numerous points of failure and the need for constant water treatment means that a malfunction in water pumping or aeration could lead to a total loss of stock. The high level of energy consumption and the operation of filters and pumps may increase the acoustic stress. Limited access to well-trained staff and veterinarians could also lead to reduced fish welfare. High levels of stocking biomass may lead to injuries and trauma. Despite the high biosecurity levels, if pathogens breach the biosecurity measures, they will spread to every tank and they will be difficult to eliminate. Sanitary challenges could lead to extensive use of chemicals and pharmaceuticals. Finally, low consumer awareness and high production prices may limit market accessibility for the fish.

A SWOT analysis (**Figure 7**) performed to assess the RAS for fish rearing. The criteria used in the SWOT analysis are the following:

a) Where do RAS safeguard fish welfare?

b) Where are RAS weak in fish welfare?

c) Can changes in legislative framework for fish welfare in EU, provide opportunities to exploit for RAS?

d) Can changes in legislative framework for fish welfare threaten the RAS in place?

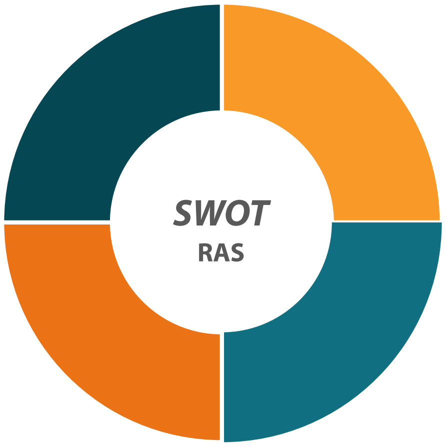
Figure 7: SWOT analysis of recirculating aquaculture systems on aspects of fish welfare

STRENGTHS

- Full monitoring and control of water quality
- High biosecurity and fish health status
- Protection from predators

WEAKNESSES

- Limited availability of experts
- Hyper-intensive conditions, high stocking densities
- Lack of specialised vaccines and licensed anaesthetics
- Vulnerable development stages
- High incidence of malformations



OPPORTUNITIES

- Research capabilities to assist sector
- Availability of funds to support sector adjustment
- EU aims to reduce dependency on food imports

THREATS

- New legislative requirements for fish welfare might affect operational plans
- Increased operational costs (energy, fuels)

Source: Own elaboration

Outcome of SWOT analysis for recirculating aquaculture systems

Rearing fish in RAS provides opportunities in areas where access to good quality fresh water is limited or in marine areas of high biosecurity concerns.

The RAS is heavily dependent on the availability of energy to operate and on the continuous operation of all parts of the installation. Major risks to biomass survival can arise in the event of malfunctions and energy shortages. Sound risk mitigation measures relating to technical malfunctions must be ensured.

There is currently a lack of technical and scientific know-how for operating such advanced, high-tech systems. Educational institutions are available to support the development of human resources.

Funding is required for research into species physiology and behaviour, vaccines and underwater technology (sensors, pumps, filters) in order to fill knowledge gaps and provide operators with more tools to improve fish welfare.

The main threats to the operation of RAS are the increasing costs of energy and fuel used for water maintenance. In addition, modifying RAS facilities to comply with new fish welfare legislation can be challenging for non-modular concrete-based systems.

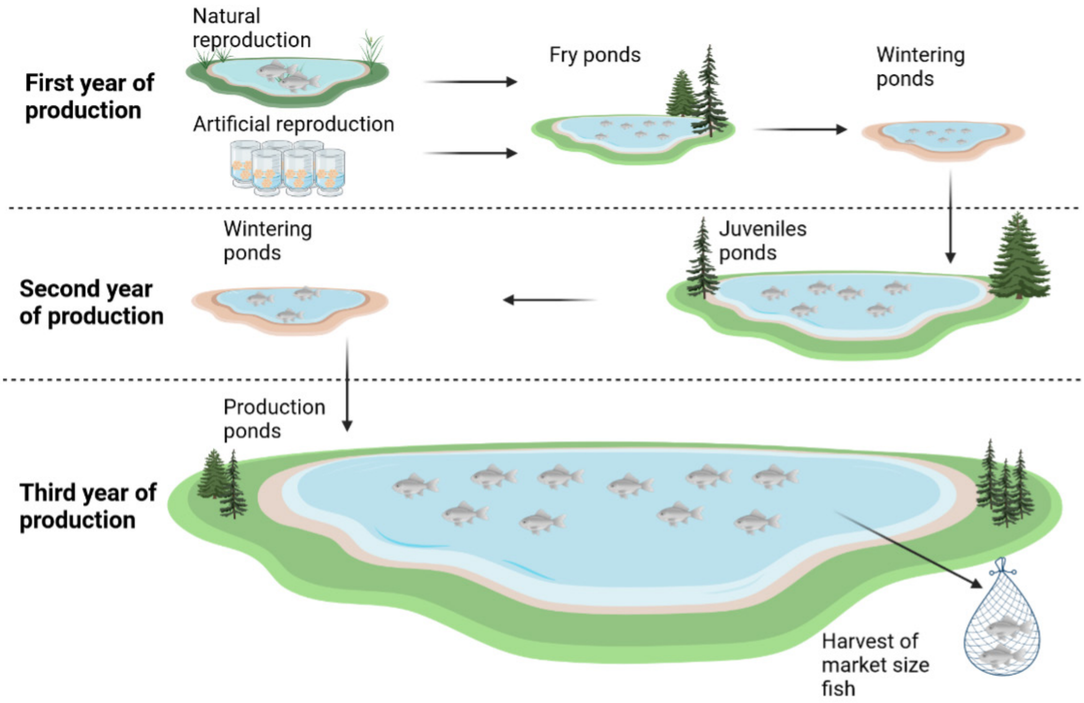
Operators' practices can impair fish welfare. New legislation has to focus on capacity improvement of operators such as training and accountability to safeguard fish welfare.

2.2.4. Pond culture

Pond culture, in the case of common carp (**Figure 8**), is an extensive form of inland fish farming where fish are reared in large earthen ponds. In Europe, carp ponds are often completely artificial bodies of water resembling shallow eutrophic lakes with a regulated water inflow and outflow system. Fresh water requirements are seasonal and typically, low compared to other aquaculture systems (except

RAS). The pond culture of common carp, for example, has historical roots in ancient times and gained popularity through the Middle Ages, until being restructured in the 19th century, when it reached its maturity. Fish farming in large earthen ponds is the least technically extensive method, therefore it is a system of choice for fish with lower commercial value per animal and adapted to fish that are able to survive in stagnant water. Pond farms are the most common and numerous aquaculture system in Europe and are often family businesses.

Figure 8: Pond culture for common carp



Source: BioRender.com

In very extensive cultures, due to low stocking densities and the high fertility of the pond, the natural food web of the pond can provide sufficient feed for fish growth. However, production is often increased by providing external feed for the fish, leading to the semi-extensive or semi-intensive use of the ponds, which is the most economically viable method. Cyprinids such as common carp are ideal for pond culture in Europe. Fish during the first season are produced from fertilised eggs. Fertilisation can be carried out in semi-natural pond conditions or in hatcheries. Following fertilisation, the fry are placed in first season ponds with a high volume of plankton. After overwintering, depending on their size, the fish are reared for one or two seasons in much larger ponds, which can range in size from a few to hundreds of hectares.

The main areas of concern for fish welfare in pond aquaculture are related to the fact that these are extensive, fully open water systems. Predation (cormorants, herons, and otters) is considered a great threat to fish welfare. Exposure to pathogens may also be increased due to contact with the natural environment combined with low accessibility of the fish, which limits treatment options and increases the negative impact of disease on fish welfare. Due to the close contact with the environment, the treatment of fish requires a unique set of skills and well-trained veterinarians to cope with disease prevention and treatment. Fish harvesting from large ponds can affect their welfare. In some cases, particularly where harvesting is not mechanised, fish are exposed to crowding or removed from the water for long periods.

A SWOT analysis (**Figure 9**) was performed to assess the pond farming system for common carp welfare aspects. The criteria used in the SWOT analysis are the following:

a) Where does pond culture safeguard common carp welfare?

b) Where is the pond culture weak in common carp welfare?

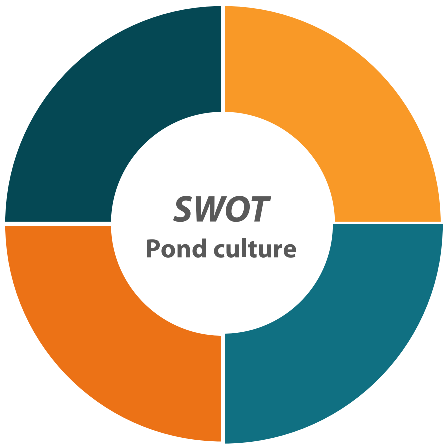
c) Can changes in the legislative framework for fish welfare in EU, offer opportunities to exploit?

d) Can changes in the legislative framework for common carp welfare threaten the pond production system in place?

Figure 9: SWOT analysis of pond culture on aspects of common carp welfare

STRENGTHS

- Extensive, good for fish welfare
- Low-tech sustainable production
- Well-established, integrated into local culture



WEAKNESSES

- Difficulty with hygiene and monitoring fish health status
- Lack of specialised vaccines and treatment options
- Exposure to predators and pathogens

OPPORTUNITIES

- New co-products and species diversification
  - Good consumer perception
  - Low cost, natural production
  - EU aims to reduce dependency on food imports

THREATS

- New legislative requirements for fish welfare may affect operational plans
- Cheaper products from abroad
- Lack of water
- Predators and diseases

Source: Own elaboration

Outcome of SWOT analysis for pond culture

The pond aquaculture production systems provide opportunities for fish production in less industrialised areas including nature conservation areas. Extensive aquaculture is environmentally-friendly and good for fish welfare. Low-tech, sustainable pond-based production units are well-established and integrated into local culture.

Consumers generally view this type of aquaculture favourably. It is low cost, largely based on natural production of the ponds and can easily reduce the EU's dependence on food imports.

Problems with this type of aquaculture include the low accessibility of the fish during the production cycle, which causes difficulties with hygiene and monitoring fish health. Fish culture in ponds suffers from increased exposure to predators and pathogens exacerbated by lack of specialised vaccines and treatment options. This can be a challenge if new legislation on fish welfare is implemented, which requires continuous monitoring and reporting of welfare status centred on fish based operational welfare indicators.

2.3. Welfare challenges and knowledge gaps

The study identified four main challenges and associated knowledge gaps with regard to improving the welfare of farmed fish species.

Challenge 1: The interplay between science and ethics

As pointed out by Kristiansen and Bracke (2020, p. 6): 'despite the growing importance of animal welfare and a common understanding of what is meant by the term, the concept of animal welfare has been surpassingly difficult to define scientifically, and there is still no consensus'. As the welfare concept has ethical, scientific, and legal dimensions, it is to be expected that views on welfare will differ and often lead to public debate. In general, three main welfare approaches can be found, focusing on function-based, feeling-based, and nature-based dimensions (Fraser, 2008, 2009). The function-based approach is established on: 'the state as regards their (the fishes') attempts to cope (physiologically) well with environmental and farming conditions', while the feeling-based approach focuses on their qualitative experiences of their affective and physiological states. The nature-based view presumes that welfare depends on the ability of fish to display their inherent natural behaviours. These views are not mutually exclusive and may be in conflict with each other in specific situations. For example, rearing conditions that have high biosecurity, but do not allow the expression of natural behaviour. Therefore, further multi-disciplinary research and more conceptual clarity and consensus are required.

Are fish sentient beings?

While it is well accepted that higher vertebrates (mammals and birds) are sentient beings, the consciousness issue for fish persists (Gamez, 2018; Birch et al., 2020; Fernö et al., 2020). Animal sentience is the capacity to experience some kind of subjective experiences or qualia, ranging from the simple experience of light and dark to aversive feelings such as pain, fear, boredom, or pleasurable feelings such as a pleasurable taste or joy. Sentience is related to the ability of an animal to experience their environment and predict its own and others' actions in relation to itself, and to remember past experiences and assess information (i.e. cognition) (Broom, 2007b; 2014).

The subjective experiences of fish are not accessible to us, but fish possess a sophisticated and effective brain and sensory system, making them capable of adapting to an incredible array of habitats. Learning and memory abilities have been widely studied in several fish species and spatial learning in particular is comparable to many other vertebrates (Odling-Smee and Braithwaite, 2003; Brown, 2015). They are capable of decision-making, they make choices, they cooperate, they can recognise individuals of their own species and they even possess numerical competency (for review see Brown, 2015, Fernö et al., 2020). Fish also display a strong appetite and aversive anticipatory behaviour, strongly indicating sentient qualitative experiences (Folkedal et al., 2018; Kristiansen and Fernö, 2020).

At an applied level, it is crucial to know whether fish are sentient beings. First, because by being sentient they can suffer and therefore should be included in our 'moral circle' and raise moral considerations. Questions like '*do fish belong in the moral community*?', '*is there a morally relevant difference between fishes and mammals that justifies differential treatment*?' or '*how to make a choice in the absence of consensus*?', are normative in nature (Bovenkerk and Meijboom, 2012). If we just consider their physiological state, ethical considerations will only relate to issues like waste of resources and labour involved in producing dead fish.

A long and ongoing controversy in the scientific community has been the question of whether fish experience pain. The International Association for Study of Pain (IASP) defines (human) pain as: 'An unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage'[13]. In a review paper, Rose (2002) claimed that fish lack the essential brain regions and the neural basis of consciousness and pain, 'making it untenable that they can experience pain'. However, same year a study of nociception in rainbow trout, *Oncorhynchus mykis*s documented nociceptors and that nociceptive information is conveyed to the fish brain (Sneddon 2002). Since then, empirical evidence and supportive arguments for the ability of fish to experience pain have been accumulating and have convinced most scientist and regulators (reviewed by Chandroo et al., 2004ab; Ashley et al., 2007; Sneddon et al., 2018). However, there still remain arguments that fish are unlikely to experience pain or do not feel pain the way that humans do (Rose, 2012; Key, 2015; Browman et al., 2019).

In conclusion, the question of fish sentience and awareness is both conceptual and experimental in nature. Scientific investigation, ethics and public debate should be further encouraged and multi-disciplinary research on this topic should be supported.

Challenge 2: Assessing fish welfare

To a certain degree, the three approaches to welfare (function-, feeling- or nature-based approaches) also determine welfare assessment. Scientists that emphasise the function-based approach mostly uses physiological indicators to monitor/evaluate fish welfare, such as molecular, biochemical, immunological, and hormonal indicators, health status and growth performance. The feeling-based views focus on measurable behavioural variables, such as preferences and, to a secondary extent, on physiological criteria (e.g. feeding, growth and reproductive performance). The welfare status of fish in the nature-based approach is evaluated strictly using ethological criteria. At an applied level, it is evident that the view of welfare emphasised will determine the criteria and results of welfare assessment. As pointed out by Fraser (2009, p. 515): 'the data that we choose to collect when making decisions about animal welfare are determined in part by value-based ideas about what is important for animals to have a good life'.

A review of currently available tools for assessing welfare is presented in Sections 2.4 and 2.5. As stated by Stien et al. (2020, p. 306) the challenge is to develop and validate 'a set of welfare indicators that describe the degree of fulfilment of the welfare needs of the given species and the life-stage under the prevailing farming conditions'. Fish welfare indicators should be valid, repeatable, reliable, scalable, and usable by farmers and regulatory authorities. Proper welfare assessment should also consider (i) species-specific differences; (ii) inter-individual variability on how single individuals cope with the environment and their affective state; and (iii) relevance to the different needs of fish at different critical stages of their life cycle in captivity, with different production systems, production phases, and operational and managerial practices.

Challenge 3: Species-specific needs and welfare assessment

All fish species have biological requirements as perceived by the individual's cognitive emotional appraisal system. Lack of fulfilment of these requirements will lead to welfare impairment. Stien et al. (2020) defined five overarching welfare needs: adequate nutrition, proper water quality, good health/fitness, behavioural freedom, and safety. While these are common needs for all species, different lifestyles, associated species-specificity of the stress response, and variable tolerance to noxious stimuli result in important differences in stress resistance and disease susceptibility among the different farmed fish species.

[13] See: https://www.iasp-pain.org/publications/iasp-news/iasp-announces-revised-definition-of-pain/.

For example, the European sea bass (*Dicentrarchus labrax*) has been reported to be a species that is sensitive to the stress of ordinary husbandry operations, compared to other farmed fish species (Fanouraki et al., 2011; Samaras and Pavlidis, 2018; Samaras et al., 2015). Common carp (*Cyprinus carpio*) have a high blood-oxygen affinity and, thus, much higher oxygen-extraction coefficients relative to those of rainbow trout (*Oncorhynchus mykiss*), making carp extremely tolerant to very low dissolved oxygen waters. This is why, further research is required in order to get an in-depth understanding of the coping styles and behavioural patterns of individual fish within the same fish species; of physiological and metabolic demands at different life stages; and of genetic selection towards developing robust fish.

Therefore, the challenge is to provide policy recommendations and a regulatory framework based on sound scientific knowledge of the welfare needs of farmed fish species, according to their lifestyle, tolerance to a wide range of environmental conditions, variability in stress response and disease resistance.

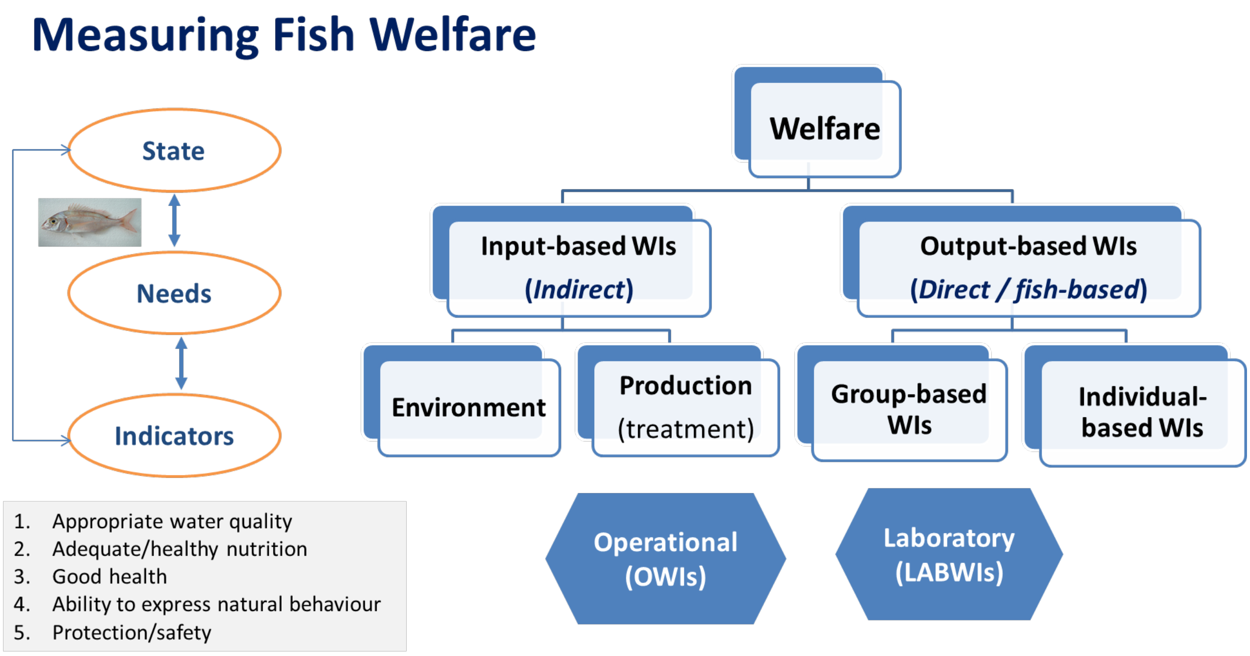
Challenge 4: Welfare assessment in different production systems, operations, and managerial practices

Farmed fish are reared using different types of rearing methods (extensive, semi-intensive, intensive) and production systems (ponds, flow-through systems, recirculating systems, net cages, and offshore cages). Reared fish are also subjected to a variety of operations (grading, transportation, vaccination, veterinary treatments, anaesthetisation, slaughter), are exposed to a variety of potential natural (e.g. low or high water temperatures, low oxygen, salinity change, water quality changes) and non-natural stressors (crowding, confinement, netting, pumping, air exposure, high stocking density, abrupt changes in social interactions), at different critical phases of development (larvae, weaning, on-growing, sexually mature broodfish), that present different welfare hazards and risks. The nature and magnitude of welfare risk also varies between different production systems. Therefore, an overview of operational and laboratory-based welfare indicators and tools, which are applicable to all rearing systems, as well as of those that are useful and reliable for assessing fish welfare in each production system, is required in order to provide policy recommendations and a solid regulatory framework. The challenge for welfare assessment is to move from the elimination of negative experiences to the provision of a 'good life' (Mellor, 2016) and, therefore, to develop a quality of life (QoL) scale based on specific species and production methods.

2.4. Welfare indicators

Welfare indicators (**Figure 10**) can be either input- or output-based (Stien et al., 2020; Pavlidis, 2021). Input-based indicators typically refer to parameters concerning the physical environment (e.g. water temperature, oxygen), the operational system and rearing practices, and the available resources to which animals are subjected. Output-based (or animal-based) indicators measure the outcome or the consequences and evaluate how well their welfare needs are met. They can be based either on observations of a group/stock of individuals (e.g. survival percentage, swimming behaviour) or on observations of individual fish (e.g. presence of blood or scales in the water). Welfare indicators may also be grouped into **operational** welfare indicators that the farmer should be able to assess and interpret on-farm, and **laboratory** welfare indicators that require samples to be sent to a designated, specialised laboratory for further analysis and evaluation.

Figure 10: Fish welfare needs and indicators (WIs) for an adequate assessment of fish welfare status under intensive culture conditions



Source: Pavlidis 2022, modified from Stien et al. 2020

At the request of the European Commission, EFSA released a series of scientific opinions on animal health and welfare in relation to husbandry systems for important fish species (EFSA, 2008 a, b; 2009). In addition, a document prepared for the European Commission provided information on fish welfare practices in European aquaculture as regards the transport and slaughter of farmed fish (European Commission, 2017).

Currently, four handbooks are available that provide welfare indicators and welfare assessment protocols for Atlantic salmon (*Salmo salar*) (Noble et al., 2018), rainbow trout (Noble et al., 2020), gilthead sea bream (*Sparus aurata*) (Pavlidis and Samaras, 2020; APROMAR, 2022) and European sea bass (Pavlidis and Samaras, 2020; APROMAR, 2022). The main scope of these handbooks is: (i) to provide a farm-friendly toolbox of fit-for-objective welfare indicators that can be used on fish farms in relation to current production systems and husbandry practices and operations; (ii) to consolidate practices leading to the improvement of fish welfare and (iii) to produce material in order to further train employees in the aquaculture sector on welfare issues. The validation of the operational and laboratory-based indicators presented in these handbooks was based on background scientific literature concerning the validity of the indicators to be included and on existing welfare assessment and assurance schemes.

In addition, guidelines on water quality and the handling of farmed fish species have recently been published for the use of aquaculture operators and the relevant competent authorities (EU Platform on Animal Welfare Own Initiative Group on Fish, 2022). These guidelines contribute further to the increased awareness of all players in the aquaculture industry of the need for better welfare for farmed fish species. The Eurogroup for Animals (2018) published a report presenting the main operations and processes that take place in intensive fish farming and their impact on fish welfare.

The 'Royal Society for the Prevention of Cruelty to Animals' (RSPCA) has developed comprehensive welfare standards in the form of 'good practice in the care and welfare' of farmed Atlantic salmon and rainbow trout (RSPCA, 2020; 2021). These standards also focus on personnel training, inspection, and record-keeping at different life stages and in different production systems.

The fair-fish database (formerly the FishEthoBase) provides a useful open-access tool for collecting and systematising existing knowledge on fish ethology either in the wild or in reared conditions and contributes to improving the welfare of farmed species (https://fair-fish-database.net/).

The study concludes that there is a shortcoming of information on which **specific welfare indicators are suitable for each species**, and that for **some species** (common carp, European sea bass, gilthead sea bream) are either **unavailable** or **under evaluation**. There is an urgent need for species-specific and life-cycle-specific welfare indicators and **scoring systems**.

2.5. Welfare assessment

Systems for assessing fish welfare are available mostly for salmonids. The 'Salmon Welfare Index Model' (SWIM), developed in 2013, was based on semantic modelling. It aimed to combine the score of different welfare indicators into an overall welfare index, based on a weighting of how much each indicator affects the welfare of the fish (Stien et al., 2013). A similar model is available for pikeperch (*Sander lucioperca*), reared in recirculating systems (Müller-Belecke, 2019). A comprehensive model and user-friendly application (Tschirren et al., 2021) were also developed to assess fish welfare on-site. The model (MyFishCheck) incorporates parameters from all three welfare concepts (function-, feeling-, nature-based,) includes several weighted and scored welfare indicators and helps fish farm personnel perform regular monitoring and control activities in order to improve fish welfare. Recently, a welfare evaluation index has been proposed for rainbow trout, based on external morphological damage of fish (Weirup et al., 2022).

A 'Fish Welfare Assurance System' was proposed (van de Vis et al., 2020) for monitoring and safeguarding welfare at a company level. This HACCP system was based on the analysis of hazards that may impair fish welfare and on the identification of 'critical control points' in the production process that are essential for good welfare of on-growing sea bass, common carp and European eel (*Anguilla anguilla*).

Finally, precision livestock farming, and smart aquaculture offer significant opportunities and new tools for monitoring and evaluating the welfare of farmed fish. Artificial intelligence, especially machine learning and computer vision applications, appears to be the next frontier technology of welfare data systems. The use of sensors and algorithms as novel tools to continuously record, monitor and detect possible deviations in time-series data of metabolic, physiological and activity-related indicators, as well as well the implementation of digital tools to identify individuals within a school of fish and to record and analyse fish behaviour, represent the future of on-farm welfare monitoring and assessment (Føre et al., 2018; O'Donncha et al., 2021). This is further substantiated by a recent review, following analysis of welfare related peer reviewed papers published between 2014 and 2020. This led to the conclusion that precision aquaculture methods will increase the precision and automation of on-farm welfare monitoring and that research on this topic is a top priority (Barreto et al., 2021).

The study concludes that there is an urgent need for the development of **monitoring measures, assessment protocols and tools** to provide a scientifically sound basis for an assessment of the welfare status of fish produced in the EU. Additionally, it is a priority to **provide records and reporting** on fish welfare related outputs that will be available to the national **competent authorities**.

3. ANIMAL WELFARE PRACTICES FOR FARMED FISH SPECIES

Case studies were produced representing the main freshwater (rainbow trout, common carp) and marine (European sea bass, gilthead sea bream, Atlantic salmon) farmed fish species in the EU. These studies also addressed the main production systems, i.e. open sea cages for European sea bass, gilthead sea bream and Atlantic salmon; tanks, raceways and RAS for rainbow trout; and earthen ponds for common carp. The case studies covered the main production areas/countries for each species and production system (**Table 1**).

Table 1: Case studies conducted

	Farmed species	Volume (t)	Percentage	Farming type	Member State
1	Gilthead sea bream	77 300	13.8 %	Cages at sea	Greece, Spain, Italy
2	European sea bass	75 000	13.4 %	Cages at sea	Greece, Spain, Italy
3	Atlantic salmon	12 200	2.2 %	Cages at sea	Ireland
4	Rainbow trout	46 600	8.3 %	Open-flow tanks	Denmark, Italy
5	Rainbow trout	15 071	2.7 %	Tanks in RAS	Denmark
6	Common carp	25 500	4.6 %	Ponds	Poland, Germany

Source: Applicants' calculations based on STECF 20-12

Note: Percentages of total EU finfish aquaculture production in 2018. Total farmed finfish production: 553 000 tonnes

3.1. Atlantic salmon

KEY FINDINGS

- Salmon farmed in **open systems** such as flow-through tanks and sea cages **have low biosecurity**. Viral infections, algae and jellyfish blooms, gill amoeba, and sea lice are the main causes of **mortality** in salmon farms.
- Stress and injuries during **sea lice treatment** are a **main cause of mortality** in salmon cage farms, with diseases as a cofounding variable.
- **Algae and jellyfish blooms** have been a **risk factor** in Ireland.
- Need to provide **digital tools** and **standardised procedures** for identifying and monitoring behavioural and other operational **welfare indicators**.
- Promote the **training of veterinarians**, health professionals and fish farm employees on fish welfare.

Figure 11: Farmed salmon in sea cage

Source: Frode Oppedal, Institute of Marine Research, Norway

3.1.1. Production, husbandry techniques and welfare challenges

Atlantic salmon is mainly an anadromous fish native to the North Atlantic Ocean and the Baltic Sea, except for some small land-locked freshwater populations (Hutchings et al., 2019). After 1 to 5 years (most 1 to 3 years) in the open ocean, salmon start to develop gonads and migrate to their natal rivers, where they spawn in the autumn. During spawning, the females dig a redd in the river gravel in a shallow current-rich part of the river, where the fertilised eggs are deposited and buried in the gravel after spawning. The eggs hatch after approximately 500-degree days[14] in early spring. The alevins stay hidden between the gravel for approximately one or two more months, until their large yolk sac is absorbed. The small fry then swim up and disperse in the river and start to feed, mainly on insects. The salmon then develops to the parr stage with the characteristic parr marks on the skin and large pectoral fins. When they reach around 15 cm in length and have sufficient body reserves, they start to smoltify, a physiological process through which they become sea water tolerant and in late spring they migrate down the river to the ocean (Björnsson et al., 2011). After they leave the river, they are termed post-smolts. The salmon then migrates to the sea. During the sea-phase, survival is usually less than 10 %.

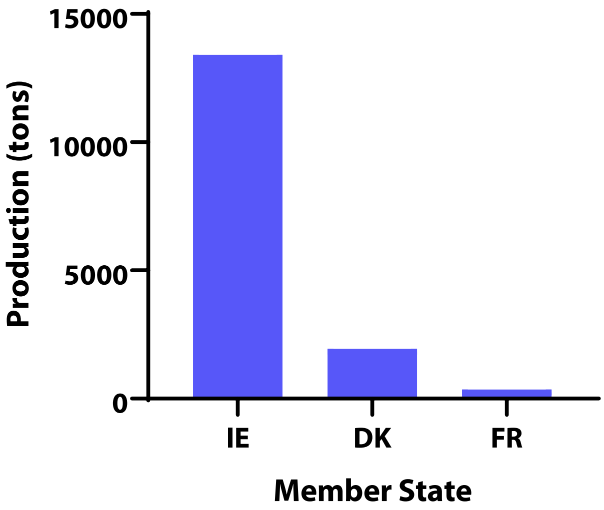
Atlantic salmon (*Salmo salar* L.) is the most important farmed fish species in Europe, with production surpassing 1.8 million tonnes in 2021. However, more than 99 % of its production occurs outside the EU, with Norway, Scotland and the Faroe Islands being the main producers. EU countries are the world's largest consumers of Atlantic salmon, and the salmon trade creates many jobs and great value within the EU in fish processing, smokeries, wholesale, groceries and restaurants (Mowi, 2022). EU imports of salmon exceeded 1 million tonnes in 2020, as constraints on air freight to overseas markets due to the COVID-19 pandemic led to a higher share of the Norwegian production being sold to EU markets (EUMOFA 2021).

Within the EU only Ireland has a significant production of approximately 13 500 tonnes in 2021 (**Figure 12**). The first Irish salmon farms were already established in the 1980s and by 1989 production

[14] Degree days are calculated by adding the mean daily water temperature in ° C for total number of days measured.

had surpassed 24 000 tonnes, but since that time, production has not exceeded 20 000 tonnes. One of the largest fish farming companies in the world owns almost 80 % of Irish salmon farms. Ireland is special in that all salmon production is certified organic and follows Regulation (EC) 2018/848 on organic production and labelling of organic products[15]. Roe, smolt and production plants are all certified, and densities in the sea cages are limited to 10 kg/m^3, whereas regular production density may rise up to 25 kg/m^3. All feed ingredients are certified organic, and the feed has a higher level of marine ingredients, and thus a lower level of vegetable ingredients. The fish meal is solely from trimmings, and the fish oil is from sustainable fisheries. Natural and eco-approved colourants (e.g. of microorganism origin) are used for the salmon's natural pink colour. The cage nets are free from anti-fouling treatments containing copper, and the sites used for organic salmon have a minimum of four months of fallowing between production cycles, compared to a minimum of two months for conventional sites. Use of cleaner fish is allowed, and both wrasses and lumpfish are used.

Figure 12: EU production of marketable-sized Atlantic salmon in 2021



Source: FEAP Production Report – 2023[16]
Note: IE: Ireland, DK: Denmark, FR: France

Atlantic salmon is a relatively robust species and farmed salmon has become fit for aquaculture through 50 years of selection of family groups. Survival from sea transfer to slaughter is on average around 80 %[17,18], a problematic percentage for terrestrial livestock, but much lower than that of a wild salmon population at sea (< 10 %; Chaput, 2012). In intensive salmon farming, and in common with the other fish species included in this study, enclosure design, stocking density (Turnbull et al., 2005; Johansson et al., 2006; Stien et al., 2013), water quality (Johansson et al., 2006; Stien et al., 2013; Noble et al., 2018), food quality and feeding scheme (Cañon Jones, 2012; Waagbø et al., 2017), health management, expression of preferred behaviours (Noble et al., 2018), use of proper material, machinery and equipment during handling, transportation and slaughter methods are parameters and

[15] Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labelling of organic products and repealing Council Regulation (EC) No 834/2007. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018R0848-20230221.

[16] https://feap.info/wp-content/uploads/2023/04/2023-04-05-production-report-2023.pdf.

[17] https://assets.ey.com/content/dam/ey-sites/ey-com/no_no/topics/consumer-products/pdfs/ey-the-norwegian-aquaculture-analysis-2017.pdf.

[18] Scottish Government FOI request 18/02806: https://www.gov.scot/publications/foi-18-02806/ (2018).

practices of high welfare concern, that vary according to the different phases of the production chain (**Figure 13**).

Figure 13: Production phases in relation to life cycle of Atlantic salmon

Source: Own elaboration

3.1.2. Broodstock unit

Salmon broodstock and egg production are mainly carried out by a few breeding companies. The first genetic selection programme started in Norway as far back as 1971 when broodstock was collected from many Norwegian rivers, and the best family groups have since been selected for growth, disease resistance and product quality. More rapid marker-assisted selection has also been used over the past few decades to select for resistance against diseases. Broodstock are mainly maintained in land-based tanks in controlled environments (e.g. salinity <10 ‰ during the final phases of maturation; Noble et al., 2018) and light conditions, which allow the breeding companies to deliver fertilised eggs to the smolt producers almost every month of the year. The eggs and sperm are stripped from anaesthetised fish. Between fertilisation and hatching, salmon eggs are normally held in either bucket-type containers or shallow baskets with perforated sides, with continuous water flow. They are transported to the hatcheries when they reach the eye stage (approximately 220-degree days).

Repeated handling of broodfish for tagging, sexing, estimation of maturity stage and stripping is an issue of welfare concern. Additionally, genetic selection and breeding strategies must avoid permanent changes of the offspring that may be of relevance for animal welfare (e.g. early maturation in sea water, decreased stress resistance, increased disease susceptibility).

Before hatching, the eggs are transferred to shallow hatching trays (**Figure 14**). Salmon eggs are relatively large and the approximately 25 millimetres-long newly hatched alevins have a large yolk sac that will last for approximately a month. **Embryo** incubation and **yolk sac dependent larvae** rearing do not pose moral considerations, according to the current legislation. However, temperatures that are too high (above 8°C) are not recommended for Atlantic salmon during egg incubation, since this leads to a higher ratio of vertebra malformations (Frazer et al., 2015). In general, stress during egg and larvae incubation will affect the quality and health of the salmon fry and smolts. Therefore, optimal temperature conditions should be defined during this life-stage to avoid development deformities, which impair the welfare of fish in later developmental stages.

Figure 14: Incubation of salmon eggs at a salmon hatchery

Source: https://sinkaberghansen.no/timeline/1530-2/

3.1.3. Smolt rearing

The fry stage starts when the yolk sac is about 80 % absorbed and the fry start feeding. Fry have developed a functional mouth and gut, and in contrast to most marine fish larvae, salmon fry can start feeding on dry formulated feed, which make the juvenile production simpler, cheaper, and easier to control. The fry start being fed in shallow tanks (1-10 m in diameter and up to 1.5 m in depth), with a flat bottom, to allow alevins and fry to maintain their station on the bottom. This was previously one of the most critical stages for salmon farming with the highest mortality rates, but currently many hatcheries have a survival rate greater than 95 %. Once good feeding has been established, the fry are transferred to larger and deeper tanks, with jump guards to prevent fish from jumping out of the tank. Outlet screens prevent egress to the smaller fish. The water supply is designed to provide the requisite water flow for the fish and to allow self-cleaning of the tanks. Parr can be reared in freshwater cages, but this is no longer a common practice.

Water recirculation is increasingly common, to allow raised temperatures and less water use, but this necessitates reoxygenation of the water, particulate matter removal, biological filtration of toxic ammonia and nitrate, and pH buffering, which can be technically challenging. In order to increase the growth rate and reduce the duration of the freshwater production period, temperatures are raised to 12 or 14ºC and continuous light is used to stimulate feeding and growth. Nowadays, most salmon smolts are produced with day-length light and temperature manipulation; this way, the freshwater stage is reduced circa 8 months and smolts are produced year-round.

Practices of concern for the welfare of Atlantic salmon during the rearing stages of fry and parr include repeated sampling, grading, vaccination, cleaning and hygiene measures, use of anaesthetics and disease treatment agents, and transportation to on-growing tanks. **Box 1** outlines the most important welfare issues in Atlantic salmon fry and parrs farming.

Box 1: Atlantic salmon welfare challenges at the fry and parr stage

- lack of biosecurity, presence of infectious diseases, inaccurate disease diagnosis, unsuccessful disease treatment;
- inappropriate water quality (oxygen, CO_2, pH, total ammonia nitrogen, bacteria, particular organic matter, faeces); under- or overfeeding, or technical problems leading to feed deprivation or hypoxia;
- inappropriate stocking density resulting in increased incidences of fin erosion, decreased growth, and aggressive social interactions;
- fin and skin injuries caused by aggressive behaviour, especially if under feed;
- inappropriate temperature and photoperiod regime; insufficient resting opportunities; lack of environmental enrichment;
- handling stress during grading, vaccination and transport to the on-growing tanks.

3.1.4. On-growing

The smolts are transferred to sea water cages (**Figure 15**) when they weigh approximately 100 g (50 to 200 g). Most post-smolt salmon are produced in large floating net cages up to 50 metres deep, with circular 50 metre-diameter floating plastic collars. In more protected areas, square steel frames are still used. Additionally, closed floating cages and land-based tanks are being developed, but still mostly on an experimental basis. It is also increasingly common to keep the post-smolts in land-based tanks until they are up to 1 kg in mass, in order to reduce the period in the cages, when they are vulnerable to sea lice infections. Salmon reach slaughter weight (4 to 6 kg) after 12 to18 months in the sea.

Figure 15: Regular salmon farm in Norway

Source: Institute of Marine Research, Norway
Note: With feed barge and floating circular 59 m diameter plastic collars holding the net cages

In the on-growing phase, parameters of welfare concern in relation to the biological and social needs of fish are dissolved oxygen concentration, long exposure to high temperatures during summer months, high stocking density, handling stress caused by sampling for routine measurements and lice counting, crowding, confinement and pumping; additionally, mechanical or chemical sea lice or other parasite treatments, grading and harvest. Regarding health management, the Marine Institute in Ireland reports that for 2021 the viral diseases pancreas disease (PD) and cardiomyopathy syndrome (CMS) and amoebic gill disease (AGD) were the infectious diseases causing the most mortalities in Irish salmon farms (Doré et al., 2022). Three mortality events involving infectious diseases were also associated with contributory factors, namely freshwater treatments and a phytoplankton bloom. The ecto-parasitic sea louse, a tiny crustacean, is an economically significant pest for Irish farmed salmon, as is the case for the salmon farming industry worldwide. Cleaner fish (farmed ballan wrasse and lumpfish) are often used as a biological control agent against sea lice in salmon on-growing systems. However, this practice raises concerns over the welfare and mortality of cleaner fish (Geitung et al., 2020). **Box 2** outlines the most important welfare issues at the on-growing phase in sea cages.

Box 2: Atlantic salmon welfare challenges during on-growing in floating sea cages

- poor sea water tolerance at sea transfers;
- lack of biosecurity against infectious diseases;
- lack of virus vaccines or effective disease treatment;
- handling stress, injuries, and mortalities due to stressful chemical and mechanical parasite treatments;
- low oxygen saturation during high temperatures and high fish densities;
- vaccine side effects;
- early sexual maturation and poor sea water tolerance;
- stress and poor conditions during transport and slaughter;
- expression of preferred behaviours; insufficient resting opportunities; imbalanced spatial distributions and social interactions;
- increased stress from the presence of predators;
- co-habitation with dead or moribund fish.

3.1.5. Harvest

Prior to slaughter, fish are usually fasted for a period of 2-3 days to reduce their metabolic rate and physical activity, and to empty the gut. Fish to be harvested are crowded with a seine net, at stocking densities of 90-100 kg/m^3, and pumped to either cage side harvest vessels or to well boats for transport to offsite slaughter plants[19]. Upon arrival at the processing plant, fish are pumped directly to the slaughter system or may be kept in holding cages next to the processing plant for some hours or up to few days[16]. Percussive (either manual or automated) or electrical stunning (dry or in-water) are used to cause instant insensibility and to render salmon fully unconscious. Following stunning fish are killed by gill cut, decapitation or spiking[16].

[19] https://www.compassioninfoodbusiness.com/media/7434842/humane-slaughter-atlantic-salmon.pdf.

3.1.6. Welfare indicators and recommendation for Atlantic salmon

Operational welfare indicators that are currently in practice at different levels of standardisation and implementation, as well as recommendations towards welfare assessment and improvement, are summarised in **Table 2**. In Norway, a standardised protocol has recently been developed for the assessment of fish welfare for on-growing of salmon post-smolt containing these indicators (Nillsson et al., 2022).

Table 2: Welfare indicators and recommendations for Atlantic salmon post-smolts

ATLANTIC SALMON POST-SMOLTS	Water quality	Nutrition	Husbandry operations	Social interactions
Parameters:	1. Oxygen 2. Temperature 3. Salinity 4. Turbidity (Secchi depth) 5. Algal blooms 6. Jellyfish blooms	1. Feed amount 2. Feed composition 3. Balanced diets	1. Handling operations 2. Crowding, pumping 3. Sorting 4. Sea lice treatment 5. Transport	1. Fish density 2. Fish weight and variance
Welfare indicators: – Environment-based indicators:	Oxygen, temperature, salinity			
– Group-based indicators:	Behaviour, appetite, mortality			
– Individual-based welfare indicators:	1. Fish length, weight and condition factor; 2. Regular lice counts of fish; 3. Vertebrae deformities; 4. Sexual maturation; 5. Scale loss; 6. Skin bleeding; 7. Wounds; 8. Snout wounds; 9. Jaw deformities; 10. Cataracts; 11. Eye injuries; 12. Gill cover deformities; 13. Gill status; 14. Fin status.			
Recommendations:	1. Staff training in welfare issues to ensure that competent personnel supervise operations; 2. Nominate a person in charge of supervising practical implementation of recommendations for welfare; 3. Staff training so they perform regular welfare monitoring and assessment.			

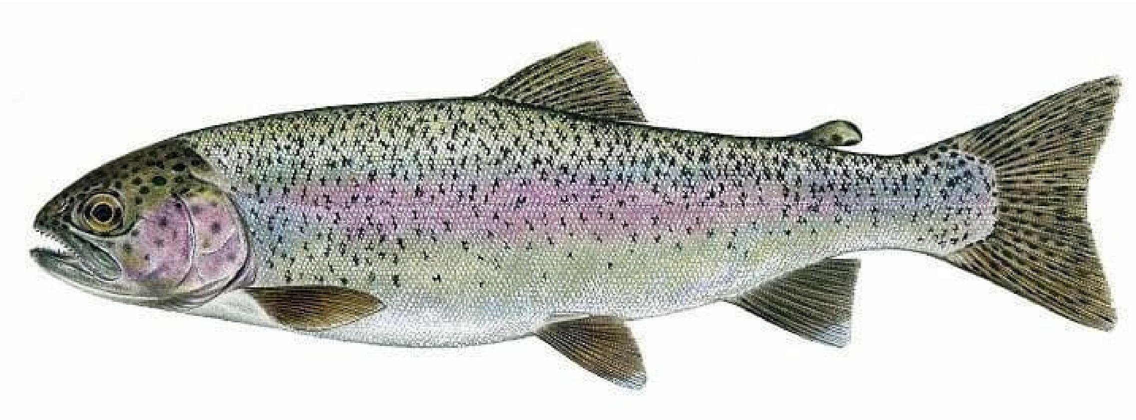
Source: Own elaboration

3.2. Rainbow trout

KEY FINDINGS

- Rainbow trout is considered a stress-sensitive species in ordinary handling practices and operations compared to other European aquaculture farmed species.
- Rainbow trout welfare is vulnerable to challenges posed by climate change (causing water shortages and increased water temperature).
- Laboratory and farm operational welfare indicators are available, but assessment of intra-operational repeatability in fish welfare monitoring is still ongoing.
- Stunning methods are established but operational indicators and monitoring of stunning success needs improvement.
- Training of fish veterinarians, health professionals and fish farm employees on fish welfare is needed to ensure that competent personnel supervise operations.
- Further research and investment are needed to improve prevention and treatment of diseases and on-site behavioural welfare monitoring, especially of on-growing fish.

Figure 16: Rainbow trout



Source: https://www.maine.gov/ifw/fish-wildlife/fisheries/species-information/rainbow-trout.html

3.2.1. Production, husbandry techniques and welfare challenges

Rainbow trout (*Oncorhynchus mykiss*, Walbaum 1792) is the **most frequently raised fish** in European **inland** aquaculture. It makes up 60 % of freshwater aquaculture and in 2019, EU production was 194 450 tonnes of trout valued at EUR 677 million (EUMOFA 2021). Traditionally, rainbow trout are farmed in **ponds** with a constant flow-through of water, and controlled trout farming started in Europe when rainbow trout were imported from North America in the 19th century. While in some rural areas in Central and Eastern Europe rainbow trout are still farmed in small-scale, semi-intensive flow-through ponds, most aquaculture production is derived from intensive flow-through pond farming and from recirculating aquaculture systems (RAS). RAS allow farmers to mitigate the consequences of increasing water shortages which are becoming more common in parts of Europe, and therefore at least partial recirculation of water is gaining popularity and the use of RAS is expected to be increased.

Rainbow trout is a salmonid species from rivers and lakes on the west coast of North America that drain into the Pacific Ocean from southern California to Alaska. It is also found in the Kamchatka peninsula on the northern Pacific coast of Russia. There are river-resident, lake-resident, migrating and non-migrating populations. Eggs of a resident rainbow trout population from the Californian McCloud River (Shasta population) were initially imported to Europe and currently most rainbow trout populations in

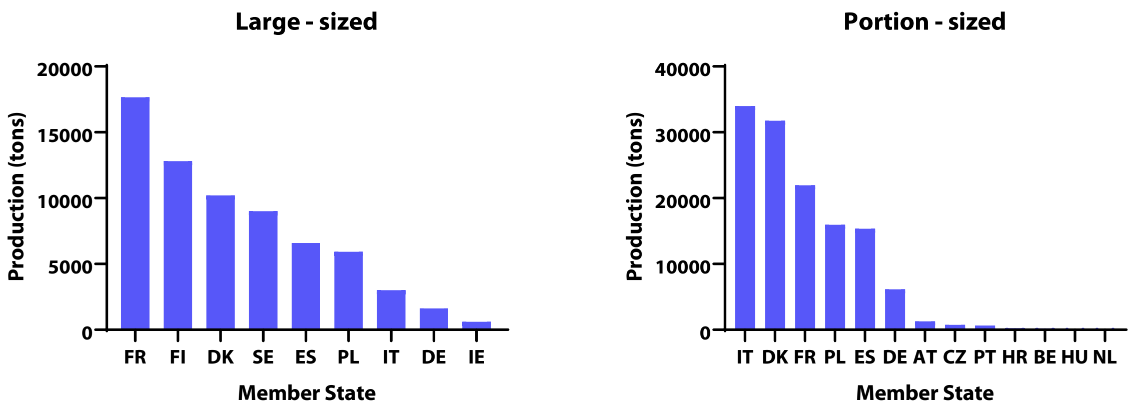
European aquaculture are a mixture of several genotypes but largely similar to the Shasta strain (Gross et al., 2007). Lake-resident rainbow trout are found in cool lakes at moderate depth and in shallower depths with vegetation. Stream-dwelling rainbow trout prefer small-to-medium-sized shallow rivers with moderate water flow and gravel riverbeds.

Rainbow trout from all strains feed on various aquatic invertebrates, including insects, crustaceans and plankton. Young fish form schools, but adults appear to be less gregarious. Overall, rainbow trout is a cold-adapted species with an optimal temperature range of 13 to 17°C, but which can tolerate a temperature of 21 to 24°C in well-oxygenated water for a limited period. The fish can survive at even higher temperatures for short periods and maximum temperature tolerance is highly strain dependent. Higher temperature limits are currently often reached in continental Europe due to climate change and can affect both flow and RAS production systems.

Eggs, larvae, and juveniles, however, have a more limited temperature tolerance. Rainbow trout require high levels of dissolved oxygen, while adults can also cope with lower ranges of dissolved oxygen concentrations and are capable of maintaining constant internal pH even when pH in ambient waters varies widely (EFSA, 2008). Mature adults reproduce from November to March, with females digging a nest in the gravel of the river and spawning yolk-rich eggs, which fall into the spaces between gravel. Digging females are attended by one or several males, which fertilise the eggs as soon as the female spawns. Eggs hatch after 4 to 7 weeks; alevins absorb the remaining yolk for 3 to 7 weeks before feeding.

Rainbow trout production in 2021 was in total 195 834 tonnes from all production systems in the European Union (FEAP, 2023). RAS systems are most popular in Denmark, where the rainbow trout from RAS accounted for 30 % of the country's total aquaculture production in 2020 (STECF, 2023). Italy, Denmark, France and Poland are the countries with the biggest production of **portion-sized** rainbow trout of up the 400 g, with 34 000 tonnes, 31 755 tonnes, 21 945 tonnes and 15 955 tonnes, respectively (**Figure 17**). This production is increasingly obtained from RAS or partial water recirculating systems. **Large-sized** rainbow trout are mainly produced in France, Finland and Denmark with 17 655 tonnes, 12 800 tonnes and 10 203, respectively. This production often takes place in sea or freshwater cages.

Figure 17: EU production of large and portion-sized rainbow trout in 2021



Source: FEAP Production Report - 2023
Note: FR: France, FI: Finland, DK: Denmark, SE: Sweden, ES: Spain, PL: Poland, IT: Italy, DE: Germany, IE: Ireland, AT: Austria, CZ: Czechia, PT: Portugal, HR: Croatia, BE: Belgium, HU: Hungary, NL: Netherlands

Husbandry systems vary greatly within and among Member States. Traditionally, rainbow trout is farmed in flow-through ponds, with gravity water intake from a weir, which is passed through concrete ponds or raceways or in earthen ponds lined with plastic foil for better cleaning and disinfection. In response to water shortages and in order to reduce nutrient discharges from aquaculture into the environment, water recirculation technology is used to varying degrees. Danish trout production in fresh water used recirculation technology in approximately 50 % of farms in 2010, mainly driven by strict environmental legislation to implement the EU Water Framework Directive (Jokumsen & Svendsen, 2010). Due to water shortages, rainbow trout production is increasingly dependent on water recirculation in other Member States as well. Floating cages (freshwater and at the sea) are also utilised for the on-growing of this fish species.

Figure 18: Production phases of rainbow trout in captivity

Source: Own elaboration

Rainbow trout aquaculture units consist of (**Figure 18**):

i. the broodstock unit to ensure a seasonal production of high-quality eggs;

ii. larvae rearing unit;

iii. fry rearing unit;

iv. on-growing unit.

3.2.2. Broodstock unit

Broodfish are kept in outdoor ponds of varying sizes, ranging between 4 x 10 metres and 20 x 40 metres, at natural photoperiod, supplied by flow-through or recirculated water. They can be also kept in indoor facilities with a controlled photoperiod. Before the spawning season, male and female broodfish are separated into different ponds. For reproduction, mature spawners are anaesthetised, and mature eggs or sperm are stripped into buckets from the abdomen of individual fish without contamination with water or faeces. Then, eggs are fertilised using dry fertilisation, by mixing with sperm and subsequently, spermatozoa are activated by the addition of water. After fertilisation, eggs are disinfected and transferred into indoor egg incubation units for embryonic development. During this production phase, husbandry activity includes the constant supply with well-aerated water preferably from a spring or bore well, for stable temperature and water conditions. This water will be further used in other production phases. Alternatively, egg development can be performed using recirculated water, however, in those instances water-cooling systems may be required to provide optimal temperature for egg development during certain periods of the year. In addition, water parameters are strictly controlled, and dead eggs are removed. Eggs at the eyed stage of development may be sold to farms producing juveniles and marketable-sized fish. **Boxes 3a and 3b** outline the most important welfare issues regarding broodfish held at RAS and flow-through water exchange systems, respectively.

Box 3a: Rainbow trout broodfish practices of concern for welfare in recirculating aquaculture systems (RAS)

- change of photoperiod/temperature cycle for out of season egg production;
- water quality;
- feed composition (fulfilment of nutritional needs), food amount and distribution to ensure proper feeding of all fish and avoid water quality deterioration;
- stocking density/social interactions;
- use of pharmaceuticals and chemical for disease treatment;
- handling and anaesthesia exposure (for regular monitoring, sexing, tagging, artificial spawning);
- oxygen shortage, lack of circulation due to technical failure.

Box 3b: Rainbow trout broodfish practices of concern for welfare in flow-through water exchange systems

- artificial photoperiod/temperature cycles for out of season egg production;
- water quality;
- feed composition (fulfilment of nutritional needs), food amount and distribution to ensure proper feeding of all fish and avoid water quality deterioration;
- stocking density/social interactions;
- use of pharmaceuticals and chemicals for disease treatment;
- handling and use of anaesthetics.

3.2.3. Larvae rearing

Following embryonic development, larvae hatching from the egg have a large yolk sac. They are not able to swim and absorb nutrients from their yolk supply (yolk sac larvae). After larval development, free-swimming fry are transferred to the fry rearing unit which consists of indoor circular polyester or concrete tanks (**Figure 19**). In addition, in this case, tanks are preferably supplied with water from a spring or bore well in order to lower the risk of pathogen infection. However, this part of the development cycle can also use RAS technology. Some farmers prefer the recirculation technology, which provides them with full control of water quality and water temperature. During this production phase, ordinary husbandry activities include the provision of feed and cleaning of the tanks. Fish are usually kept in these systems until they reach approximately 5 g of body weight.

Figure 19: Rainbow trout hatchery facilities: egg incubation, larval rearing units and fingerling growing units using flow-through systems

Sources: M. Adamek

Embryos and non-feeding ***yolk sac larvae*** are not considered sentient animals and from a legislation point of view, their rearing has no welfare implications. The biological needs and technological requirements of incubating rainbow trout embryos and larvae are well-known. Exposure to stressful stimuli, in particular elevated temperature and oxygen shortages, at early ontogeny may affect fish development. However, the extent to which early life programming affects fish characteristics, robustness and performance at later stages of development is still unclear (Reiser et al., 2021). Therefore, optimal conditions for proper development should be maintained during this life-stage in order to avoid developmental abnormalities, which are indicative of poor health and affect the welfare of the fish in later life stages.

3.2.4. Juveniles rearing

Fingerling production usually takes place in small outdoor ponds or small raceways in a continuous flow-through system (**Figure 19**) or in a recirculating system. However, RAS technology provides better control of water quality parameters, and can help supply enough water to support high stocking densities. The water can be filtered and reused, and the amount of fresh water needed can be substantially reduced. This is particularly important if there is less water available because of climate change. Feed is spread at regular intervals using automated feeders, as well as manual feeding. Environmental conditions, such as water exchange, water quality and temperature, are under the control of the producer.

Ordinary husbandry techniques involve feeding, removal of dead and moribund fish, grading, sorting, and transportation to tanks for on-growing. In this phase, fish may be exposed to pharmaceuticals and chemicals for disease treatment. Juveniles may be sold to production farms for on-growing to a marketable size.

Parameters, which could impact the welfare of **rainbow trout fry** in RAS, and in flow-through water exchange systems are summarised in **Boxes 4a** and **4b**, respectively.

Box 4a: Rainbow trout fry rearing practices of concern for welfare in RAS

- elevate water temperature, poor water quality, unadjusted flow speed, oxygenation, and CO_2 content;
- increased total amounts of bacteria in the recirculated water;
- feed composition (fulfilment of nutritional needs), food amount and distribution to ensure proper feeding of all fish and to avoid water quality deterioration;
- cleaning and hygiene measures;
- pathogen infection when all the farm water is circulated on one circuit;
- treatments against pathogen infections.

Box 4b: Rainbow trout fry rearing practices of concern for welfare in flow-through water exchange systems

- water shortages, poor water quality, unadjusted flow speed, elevated water temperature;
- feed composition (fulfilment of nutritional needs), food amount and distribution to ensure proper feeding of all fish;
- cleaning and hygiene measures;
- exposure to pathogens via flow-through water and treatments against infections.

Parameters, which could impact the welfare of **rainbow trout juveniles** in RAS, and in flow-through water exchange systems are summarised in **Boxes 5a and 5b**, respectively.

Box 5a: Rainbow trout fingerling rearing practices of concern for welfare in RAS

- environmental parameters such as water temperature, oxygen saturation, ammonia, CO_2 and total bacteria concentration in the water for closed recirculating systems;
- husbandry practices such as sorting/grading, disease outbreaks, use of pharmaceuticals and chemicals for disease treatment, vaccination;
- feed composition (fulfilment of nutritional needs), food amount and distribution to ensure proper feeding of all fish and to avoid water quality deterioration;
- pathogen infection when all the farm water circulates are on a single circuit;
- transportation procedure that includes practices such as fasting, crowding, confinement, transfer to novel tanks, change in water quality parameters, unloading the vehicle and transfer to other trout farms;
- oxygen shortage, lack of circulation because of technical failure.

Box 5b: Rainbow trout juveniles rearing practices of concern for welfare in flow – through water exchange systems

- environmental parameters such as water temperature, oxygen saturation, ammonia concentration during water shortages and/or increased feeding;
- exposure to direct sunlight, lack of shading;
- feed composition (fulfilment of nutritional needs), food amount and dispersal of feed to ensure uniformity of growth, avoid cannibalism or water quality deterioration;
- transportation on-farm or between farms including practices such as fasting and crowding;
- health status, disease treatment;
- fingerling transport.

3.2.5. On-growing

The on-growing (**Figure 20**) production phase starts with juveniles that are approximately 50 g in weight and the fish are grown until they weight 250 to 400 g (portion size) or above 1.2 kg. The fish are stocked in ponds or raceways of different sizes and supplied with recirculated water. During the on-growing period, fish are fed according to a feed table at a ratio below the ad libitum level, in order to increase feed utilisation, growth rate and feed conversion rate. The feed is distributed manually by hand or by clock feeders or self-demand pendulum feeders, which are supplied with the feed according to the feed tables. In addition to feeding, husbandry activities include daily mortality checks and dead fish removal; regular fish weight sampling; fish sorting by size, and stocking to different ponds according to fish growth; and frequent water parameters analysis. The stocking density during the on-growing phase varies between 10 kg m^{-3} and 60 kg m^{-3} and can reach 100 kg m^{-3} or above in water recirculating systems, depending on the size of the fish and water availability. Using RAS can have significant advantages in terms of controlling water quality and provides an optimal use of this resource.

Figure 20: Grow-out phase of rainbow trout production in RAS: raceway concrete ponds, biological filters


Source: M. Adamek

Rainbow trout at all life stages are fed artificial, pelleted feed, which is formulated according to the specific energy and nutrient requirements of the particular life-stage. The pellets are manufactured by extrusion using high pressure and high temperature for a short time. Pellet size varies depending on fish size, and the amount of feed given depends on farming conditions and management requirements. All feed plants are licensed and monitored by the competent authorities in each Member State.

Parameters, which could impact the welfare of **rainbow trout in the on-growing phase** in RAS, and in flow-through water exchange systems are summarised in **Boxes 6a and 6b**, respectively.

Box 6a: Rainbow trout practices of concern for welfare during on-growing in RAS

- water parameters, including oxygen saturation, ammonia, CO_2 and total amounts of bacteria in recirculated water;
- higher probability of increased exposure to high temperatures during summer months driven by the climate change in RAS with low water exchange;
- high stocking densities in intensive RAS farming;
- lack of tank enrichment or presence of enrichments complicating hygiene maintenance;
- lack of vaccines and effective treatments for major diseases;
- inadequacy of veterinarian knowledge level and skills on fish welfare;
- crowding, confinement and alteration of social interactions at harvest;
- expression of preferred behaviours; insufficient resting opportunities; imbalanced spatial distributions and social interactions;
- co-habitation with dead or moribund fish.

Welfare challenges characteristic for flow-through systems are frequently prevalent during the on-growing phase. This phase is carried out in relatively large tanks which require a large amount of water. Water as a resource is becoming scarce in continental Europe; water supply shortages are mitigated by re-using part of the water (partial recirculation), but this compounds the risk of water overheating. Of special concern is the risk of higher than optimal temperatures during summer months driven by climate change. The dependence on surface water can exacerbate the problems with oxygen/CO_2 concentrations in the water, particularly if the farm is not equipped with oxygen supplementation and

CO_2 degassing or stripping. This can lead to excessively low oxygen levels and oversaturation of water with CO_2.

Box 6b: Rainbow trout practices of concern for welfare during on-growing in flow- through water exchange system

- husbandry practices such as netting, exposure to air, sorting/ grading;
- lack of tank enrichment or presence of enrichments complicating hygiene maintenance;
- high exposure to direct sunlight, lack of shading;
- risk of adverse social interaction and predation at low densities;
- overcrowding at high stocking densities, combined with poor water management;
- increased stress and mortalities from the presence of predators;
- inadequate treatment of diseases due to lack of effective vaccines/therapeutics and/or lack of experienced veterinary staff;
- crowding, confinement, and alteration of social interactions at harvest.

Both too low and too high stocking densities may be unfavourable for rainbow trout. Dominant rainbow trout try to establish a group hierarchy by antagonistic interactions, during which individuals are attacked, as indicated by scale losses, bite marks at the fins, and injuries. The prevalence of bite wounds and fin injuries may be higher at lower stocking densities. Increased effects of antagonistic behaviour may be observed at stocking densities below 15 kg/m^3, or even below 25 kg/m^3 (Laursen et al., 2013). At higher stocking density, crowding stress is mainly experienced, along with poor water quality including hypoxia, hyperammonaemia, or high bacterial load (Laursen et al., 2013).

Disease prevention and treatment of disease outbreaks may be particularly problematic in inland trout farming in several Member States. These challenges may be related to a lack of effective treatments, for instance for parasitic diseases, but also to a lack of vaccines and other effective treatments of major diseases affecting trout. These may result in either inadequate use of pharmaceuticals or constant use of chemicals like disinfectants. In organic farming, the general rule concerning a minimal use of therapeutics may result in less effective treatments, combined with higher losses due to infectious diseases. In addition, in some Member States, farmers may lack the support of well-trained veterinary staff with experience in fish medicine.

Presence of predators impose stress and mortalities to farmed populations in outdoor flow-through systems. Although it can be managed much better than in the other open systems by fencing and netting, there is still a risk of predation, mainly from birds and mammals.

Despite having the enormous advantages regarding water supply needs, RAS are also exposed to some challenges which could affect fish welfare. Water heating during recirculation both by longer exposure to increased air temperatures and by the operation of pumps, aeration and accumulation of metabolic heat from the fish may expose fish to unfavourable conditions. The filter operation and cleaning have a critical impact on water quality and oxygen content. Any disruptions due to malfunctioning of this system can lead to catastrophic outcomes for the fish (partial or total loss of all fish), as frequent high volumes of water cannot be exchanged in RAS systems to improve water quality during filter malfunctions or during complete technical failure of water recirculation.

RAS allow for higher biosecurity compared to flow-through systems, where the water is supplied from springs or bore well. Additionally, in RAS supplied with surface water, this water can be disinfected as lower volumes are constantly flowing into the system. However, if pathogens breach the biosecurity measures, their elimination can be difficult. Water recirculation can also allow pathogens to spread to all tanks in the system. Therefore, management related to disease prevention or treatment is particularly problematic for inland trout farming in several countries.

The sanitary challenges in RAS could lead to either inadequate or constant use of pharmaceuticals and chemicals. This can be intensified by the lack of vaccines and effective treatments for major diseases affecting trout. Some deficiencies in preparedness of the veterinarian knowledge base allowing the effective treatment of fish diseases in RAS can have a particular effect on the relatively sensitive rainbow trout. Not all veterinarians may be sufficiently educated in fish biological and physiological needs, which differ greatly from the main warm-blooded terrestrial animals farmed in Europe. Lack of training for farm operating staff could also be a factor jeopardising the welfare of animals.

The transfer of the fish to the cages is a critical point: osmotic stress and inadequate transport can lead to reduced welfare, stunted fish growth and even significant mortality during the first part of the grow-out at sea. In the extreme, this may force seasonality of production in cages because of a lack of knowledge about how to prepare smolts at certain times of the year. The smoltification process in rainbow trout is not well understood and there is some evidence that fish prepared for sea transfer at certain times of the year perform much worse in cage culture.

Depending on cage location, different challenges to fish welfare can be present related to water quality, oxygenation and salinity. Fjords are subject to rising temperatures, water stagnation, algal blooms and poor water quality, especially in summer. All these factors can lead to oxygen starvation of the fish. If the intensity of these factors increases, a situation may arise where cage cultures will only be possible seasonally, for example in the Baltic Sea. In contrast to this, cages at the coastline or in the open sea do not experience water stagnation but can be exposed to rough weather and intense currents, which in extreme situations can damage the cage, leading to fish escapes or trapping the fish in limited space.

Cage culture in both fresh and sea water can be exposed to any adverse organism residing in the water column surrounding the cages. Poisonous algae, viruses, bacteria, parasites, or jellyfish have free entry to the cage and fish cannot reposition themselves to avoid exposure. Additionally, some vulnerability to predators (mainly fish-eating birds and mammals) is still possible. Cage operations are also inherently related to the induction of stress in fish. Sanitary measures related to delousing the fish are of particular welfare concern, but also increased or prolonged netting, grading and transportation to slaughter may jeopardise the fishes' wellbeing. The same concerns as in other types of farming apply to the cage cultures of rainbow trout, namely lack of experienced veterinarians, effective prevention and treatment of diseases. The welfare challenges of rainbow trout reared in floating cages are presented in **Box 7**.

Box 7: Rainbow trout practices of concern for welfare in floating cages

- transportation into the cage/novel environment;
- uncontrolled water parameters such as temperature and oxygen saturation;
- increased exposure to high temperatures during summer months (especially in fresh water or parts of the Baltic Sea) driven by climate change;
- husbandry practices (e.g. netting, air exposure);
- high stocking densities or too low stocking densities that may induce adverse social interaction and predation;
- climate-driven increase in parasitic diseases and algal blooms;
- predation from birds and mammals;
- lack of vaccines and effective treatments for major diseases;
- inadequate veterinary knowledge and skills on welfare issues;
- crowding, confinement and alteration of social interactions at harvest and transport to slaughter;
- expression of preferred behaviours; insufficient resting opportunities; imbalanced spatial distributions and social interactions;
- increased stress from the presence of predators;
- co-habitation with dead or moribund fish.

3.2.6. Harvest

Prior to harvest, fish are usually fasted for 2-3 days. Fish are harvested with a seine net or by draining the production ponds, depending on the size of the pond/raceway and the number of fish to be harvested. In case of floating cages, a seine net is used to crowd the fish and a smaller net is used to catch them. Percussive and electrical stunning machines are commercially available. Stunned fish are killed by percussion, decapitation, spiking/coring and gill cutting (for large trout only)[20].

3.2.7. Welfare indicators and recommendation for rainbow trout

Welfare indicators that are currently in practice at different levels of standardisation and implementation, as well as recommendations towards welfare assessment and improvement, are summarised in **Table 3**. In Norway a standardised protocol has recently been developed for the assessment of fish welfare for rainbow trout (Nillsson et al., 2020) and in Germany a welfare evaluation index has been proposed, based on external morphological damage of fish (Weirup et al., 2022).

[20] See: https://www.compassioninfoodbusiness.com/media/7434844/humane-slaughter-rainbow-trout.pdf.

Table 3: Welfare indicators and recommendations for maintaining the welfare in on-growing rainbow trout

RAINBOW TROUT	Water quality	Nutrition	Husbandry operations	Social interactions
Parameters:	1. Oxygen 2. Temperature 3. Salinity 4. Turbidity 5. Algal blooms 6. Jellyfish blooms	1. Feed amount 2. Feed composition 3. Balanced diets	1. Handling operations 2. Crowding, pumping 3. Sorting 4. Sea lice treatment 5. Transport	1. Fish density 2. Fish weight and variance
Welfare indicators: – Environment-based indicators:	Oxygen, temperature, salinity			
– Group-based indicators:	Behaviour, appetite, mortality			
– Individual-based welfare indicators:	1. Fish length, weight and condition factor (emaciation); 2. Fin status (pectoral, caudal, dorsal, pelvic, anal fin damages); 3. Snout wound; 4. Scale loss; 5. Skin wounds and / or Skin haemorrhages; 6. Exophthalmia; and / or Cataract; 7. Jaw deformities; 8. Operculum shortage			
Recommendations:	1. Training of employees in welfare issues to ensure that competent employees supervise operations; 2. Nominate a person in charge of supervising practical implementation of recommendations for welfare; 3. Training of employees to perform regular welfare monitoring and assessments.			

Source: Nillsson et al., 2020; Weirup et al., 2022

3.3. Common carp

KEY FINDINGS

- Common carp is a **robust** fish species and its farming closely reflects its natural habitat conditions, nevertheless it is still sensitive with **unique challenges for fish welfare**, such as handling, predators and disease.
- Candidate **welfare indicators** were proposed, for all life stages, apart from larvae, however their practicability and usability are **still under evaluation**.
- **Exposure of all life stages** kept in the earthen ponds **to predators** (cormorant, otter) **and diseases** are of particular welfare concern.
- **Further research** is needed for the development of (i) a validated, practicable and reliable set of **welfare indicators** and standards and (ii) on-site behavioural **welfare monitoring tools** for on-growing fish that are not accessible by visual inspection (transponder/sonar tracking).
- Providing highly skilled **fish veterinarians** and developing effective **disease prevention** and treatment is necessary in order to enhance carp welfare.
- Stunning methods are established, but operational indicators and **monitoring of stunning success** needs improvement.

Figure 21: Common carp

Source: Modified from www.ndow.org

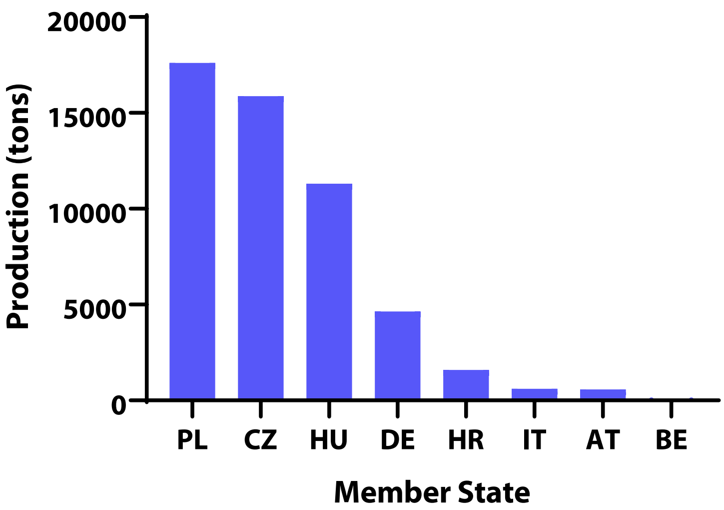
3.3.1. Production, husbandry techniques and welfare challenges

Common carp, known as European carp or Eurasian carp (*Cyprinus carpio L.*), is an important fish cultured in inland freshwater aquaculture in Europe and Asia. Common carp has significant socio-economic and cultural significance in Europe. Traditionally, common carp was introduced to European aquaculture in the late Roman Empire period and became omnipresent in small ponds in Medieval Europe. Currently, the common carp is farmed using a method developed by Thomas Dubish in the 19th century in a semi-intensive fashion, which takes place in large freshwater earthen ponds. Since that time, artificially stimulated reproduction has been widely adopted, facilitating access to high-quality stocking material and genetic improvements of the broodstock.

Common carp is a freshwater fish species that inhabits the lakes and slow flowing rivers of Eurasia. The origin and taxonomy of common carp is somewhat complicated. European breeds of common carp most likely come from the feral carp of the Danube River, which were geographically separated from feral carp of the Amur River in central Asia. Common carp are an omnivorous[21] species feeding on planktonic and benthic organisms. Young fish form schools, but adults appear to be less gregarious. They can tolerate a wide range of water temperatures (2 to 34°C), with eggs, larvae and juveniles having more limited temperature tolerance. Juveniles and adults are largely hypoxia-insensitive and are able to cope with low levels of dissolved oxygen concentrations and furthermore are capable of maintaining a constant internal pH, even when the pH in ambient waters varies widely (EFSA, 2008). Reproductive mature adults spawn small eggs that stick to water plants in relatively warm shallow waters.

European production of common carp has been stable over the last few years and was 52 244 tonnes in 2021, which makes it the second most farmed freshwater fish in the EU (FEAP, 2021). Poland, Czechia and Hungary are the main common carp producers with 17 616 tonnes, 15 880 tonnes and11 309 tonnes, respectively. Lower levels of production take place in Germany (4 641 tonnes), Croatia (1 585 tonnes), Italy (600 tonnes), Austria (573 tonnes) and Belgium (40 tonnes). Data are shown in **Figure 22**.

Figure 22: EU production of common carp in 2021



Source: FEAP Production Report – 2023

Note: PL: Poland, CZ: Czechia, HU: Hungary, DE: Germany, HR: Croatia, IT: Italy, AT: Austria, BE: Belgium

The common carp reared in the EU was historically farmed using semi-extensive or semi-intensive production systems. The current dominant production system takes place in monoculture or polyculture in earthen ponds with a very large water surface. Only artificial reproduction (egg production), egg hatching, and sometimes larval rearing take place indoors in highly specialised facilities (**Figure 23**).

[21] Omnivores are animals that are able to eat and survive on both plant and animal diets

Figure 23: Production phases in relation to life cycle of common carp

Source: Own elaboration

3.3.2. Broodstock unit

Carp normally **reproduce once a year.** Reproduction can also be performed **naturally** in **"Dubish ponds",** where the male and female **broodstock are mixed** and females drop their **eggs,** which **stick to the pond plants.** *Broodfish* rearing presents very similar challenges to the culture of on-growing fish. In addition, broodstock must be kept alive for much longer and are exposed more frequently to mistreatment and pathogen pressure for longer periods of time. An increasing number of studies suggest that stress-related epigenetic markers can be transferred to the offspring (Miao et al., 2021, Barreto et al., 2019, Berbel-Filho et al., 2020). Therefore, the main welfare issues relating to the biological and social needs of sexually mature fish that need to be addressed for production of high-quality offspring are as follows. The welfare challenges of common carp broodfish are presented in **Box 8**.

Box 8: Common carp broodfish practices of concern for welfare

- inappropriate water quality parameters;
- inappropriate feeding protocol (availability and quality of live feed);
- cleaning and hygiene methods;
- use of pharmaceuticals and chemicals for disease treatment;
- regular handling and anaesthesia exposure (for regular monitoring, sexing, tagging, induced spawning);
- use of hormonal treatment for spawning induction;
- lack of experienced veterinary supervision, unavailability of vaccines and appropriate and effective treatments;
- common husbandry practices including netting, air exposure, handling for the assessment of sexual maturation), that can cause wounds, fin damage and stress that may lead to disease outbreaks (e.g. cyprinid herpesvirus 3).

3.3.3. Larval rearing

After fertilisation and hatching, larvae they reabsorb the yolk sac while still attached to the plants. The feeding fry can also be stocked in shallow ponds containing large amounts of plankton. The stocking density is relative to the amount of natural feed and can range between 100 and 600 fry/m^2. The availability of plankton is critical at this stage; therefore, certain ratios of the amount of rotifer organisms and fry should be followed. Generally, understocking is preferred, as good survivor rates can provide enough stocking material even if low densities of 1 000 000 – 2 000 000 fry per hectare are stocked. In highly fertile (or fertilised) ponds this number can be increased to 6 000 000 fry per hectare.

Figure 24: Common carp hatchery: egg incubation and hatching unit, larval rearing unit

Source: M. Adamek

Although, according to current legislation, ***embryo*** incubation and ***pre-larva*** rearing (**Figure 24**) are of no moral consideration, this period of development is very short in common carp and has an impact on the further development of the stock. Therefore, it is advisable to maintain high-quality standards, especially given that this is the only part of development carried out in a highly controlled environment. Water quality and sanitary measures are critical for successful fertilisation and larval development.

The biological needs of common carp ***larvae*** have to be fulfilled in the pond conditions. Therefore, intensive rearing is very much related to the amount of natural feed, which can be manipulated by husbandry measures. Furthermore, proper, validated welfare indicators and tools have yet to be put in place. Practices of concern for welfare, in relation to the biological, sanitary and social needs of common carp larvae are shown below. The welfare challenges of common carp larvae are presented in **Box 9**.

Box 9: Common carp larvae practices of concern for welfare

- natural feed availability;
- uncontrolled changes of temperature, wind conditions;
- inappropriate feeding protocol in indoor facilities;
- stocking density vs natural feed availability;
- cleaning and hygiene measures in indoor facilities;
- handling and transportation to earthen ponds.

3.3.4. Juveniles rearing

Further rearing of juveniles can be carried out in the same ponds as the fry. Otherwise, juveniles are transferred to the new ponds at a weight of 0.1 to 0.2 grams. Plankton availability is critical at this stage.

Wintering is an important part of the production cycle, as in continental Europe the winter period leads to low temperatures of the water, while common carp lower their metabolism to levels associated with hibernation.

Temperature fluctuations are critical during the overwintering period for ***juveniles***, as excessively high temperatures and low water flows can lead to hypoxia and ammonia poisoning. Crowding also increases the likelihood of parasite infections (*Ichthyophthirius multifiliis*, *Ichthyobodo necator*) and viruses such as carp edema virus. In the pre-growing phase, parameters of welfare concern in relation to the biological and social needs of juveniles (EFSA, 2008), are as follows. The welfare challenges for common carp juveniles are presented in **Box 10**.

Box 10: Common carp juveniles practices of concern for welfare

- natural feed availability;
- inappropriate water quality;
- husbandry practices such as scratching during netting, stress during crowding and sampling for quality control, grading and sorting for deformities;
- misuse or unavailability of pharmaceuticals and chemicals for disease treatment and vaccination;
- transportation practices such as fasting, crowding, confinement, netting, transfer to novel tanks, altered water quality parameters, unloading transportation vehicles and transfer to the on-growing ponds;
- uncontrollable temperature fluctuations during the overwintering period.

3.3.5. On-growing

The K2/K3 production phase **in-growing ponds** start with juveniles of 20 to 150 g in weight and the semi-intensive production system is considered environmentally and animal friendly. Aerial pictures of various types of ponds are presented in **Figure 25 A**. Small fry ponds are located in between the large on-growing ponds at the edges of the picture. Pond-side photos of large earthen on-growing ponds are presented in **Figures 25 (B, C, and D)**.

Figure 25: Grow-out phase of common carp production

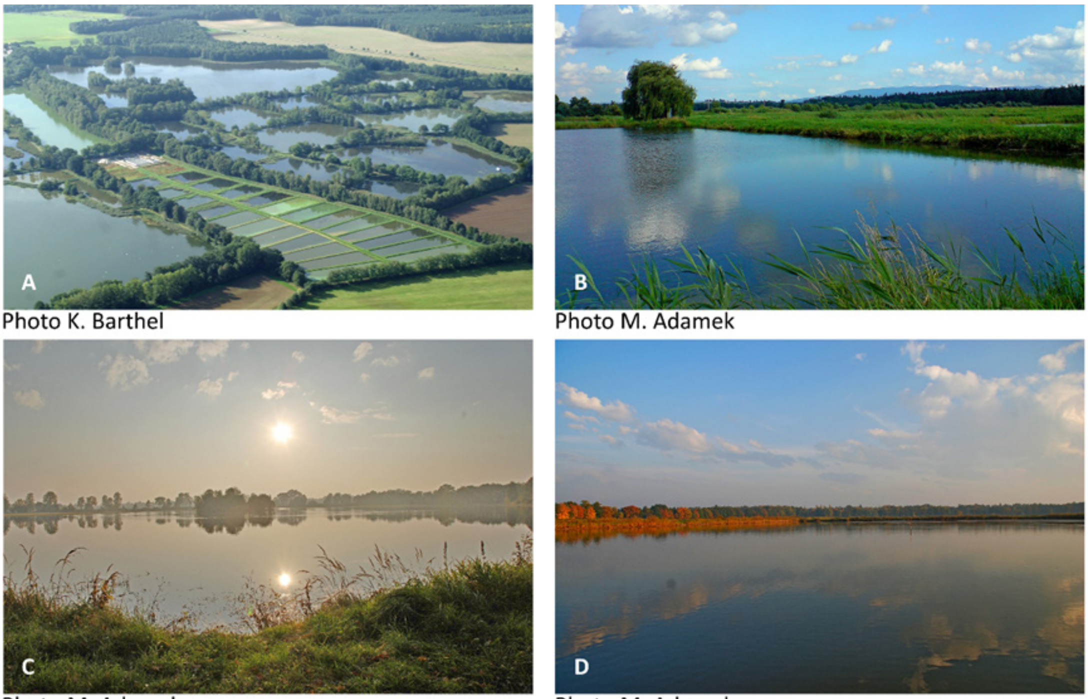


Photo K. Barthel

Photo M. Adamek

Photo M. Adamek

Photo M. Adamek

Carp can be grown at several **levels of intensification** (modified from Skibniewski, 2013):

1) **Extensive (natural) rearing** – based on natural pond production of fish food (plankton, benthos), with no supplementary feeding. However, this is a low-yield (150 to 350 kg/ha) production process. Highly fertile ponds can yield a fish gain of a maximum of 500 to 600 kg/ha. As only natural feed is used, this production method reflects the natural conditions encountered by carp in the wild (lakes or slow flowing rivers).

2) **Semi-extensive to semi-intensive rearing** – the most popular form of common carp rearing still reflects the natural conditions carp encounter in the wild. The ratio of natural feed produced by the pond and supplemented by feed given by the farmers is still quite high and ranges between 1:1 and 1:4. This provides growth yields of 500 to 600 (semi-extensive) to 1 200 to 1 500 kg/ha[1] (semi-intensive). This level of production intensification currently covers most of the pond farms in Europe as it has a low environmental burden and relatively cheap cereal feeds can be used. Cereals combined with a high proportion of natural feed (up to 50 %, depending on the fertility of the pond and stocking density) provide the best economical balance for carp production.

3) **Intensive rearing** – where pond fish production ranges from 1 500 to 3 000 kg/ha[1]. The fish can still be fed cereal feeds as a base diet, but these growth rates can be only achieved with the addition of significant proportion of pellets or granulates. The proportion of natural food in the carp diet becomes increasingly insignificant (1:5 to 1:10).

4) **Highly intensive rearing** – also known as industrial fattening – is possible for carp, but it is rarely utilised in the EU for producing fish for human consumption. Total growth can easily exceed 3 000 kg/ha[1] when high-protein fattening pellets are used for feeding. The natural productivity of the pond is not considered for this type of production so it can be performed in concrete ponds with high water flow.

During the grow-out period various husbandry operations are performed, including regular fish weight sampling and fish pathology examinations that increase stress levels and can lead to outbreaks of cyprinid herpesvirus 3 (CyHV-3, also known as koi herpesvirus, KHV) (Steinhagen et al., 2016).

In the **on-growing phase**, parameters of welfare concern in relation to the biological and social needs of fish (EFSA, 2008; NaTiMon project 2022[22]), are listed below.

[22] https://www.thuenen.de/en/newsroom/mediathek/thuenen-explaines/the-national-animal-welfare-monitoring.

Box 11: Common carp practices of concern for welfare during on-growing

- presence of predators (cormorants, otters) causing fish stress, wounding and decimating;
- unpredictable/uncontrollable increases in winter temperature and ammonia concentrations, associated with decreases in oxygen concentrations, due to climate change;
- husbandry practices such as handling with inadequate materials and equipment, grading, netting, keeping fish for long time periods out of water;
- lack of water quality monitoring;
- outbreaks of infectious disease including viral infections;
- lack of experienced veterinary supervision, unavailability of vaccines and suitable and effective treatments;
- lack of water exchange in pre-slaughter holding or wintering tanks – increased ammonia and nitrite;
- use of inhumane slaughter methods;
- expression of preferred behaviours; insufficient resting opportunities; imbalanced spatial distributions and social interactions;
- increased stress from the presence of predators;
- co-habitation with dead or moribund fish.

3.3.6. Harvest

Marketable sized fish of 1.2 to 2 kilograms are harvested after lowering the water, concentrating the fish at the outlet of the pond (monk), which is related to increased fish densities and stress. For human consumption the fish are killed by bleeding after stunning by percussion or electrical current, however a combination of those two is recommended to ensure a stage of insensibility. Prior to slaughter, fish are usually fasted for at least several days and are exposed to crowding in high densities.

3.3.7. Welfare indicators and recommendation for common carp

The common carp has been described as a very resilient and stress-insensitive species. This, unfortunately, can lead to rough treatment of fish by farmers. Therefore, it is important to set out and precisely describe those operational and managerial practices and operations that pose welfare challenges for common carp. The welfare outcome of such practices should be projected long-term and requires the development of mitigation strategies. A list of indicators to measure the welfare of farmed common carp has not yet been established in any European country for use in self-monitoring. **Candidate** indicators include environmental **parameters** such as the presence or abundance of predators (cormorants, herons, and otters), the impact of management practices, hygiene and biosecurity management, and individual welfare indicators such as fin, skin, scale, eye, jaw and operculum changes. However, these indicators need to be evaluated and validated before implementation. In Germany, this is currently being undertaken as part of the 'National Welfare Monitoring' (NaTiMon) project, which will propose a set of welfare indicators that have been evaluated for validity, practicality and intra- and inter-observer reliability of scoring**.**

3.4. European sea bass

KEY FINDINGS

- European sea bass is considered a stress-sensitive species in ordinary handling practices and operations compared to other farmed species in European aquaculture.
- Further research is needed to identify larval biological requirements and optimum welfare conditions.
- Further research and investment are needed for on-site behavioural welfare monitoring.
- Development of a scalable welfare score and welfare standards is a high priority.
- Training of staff in welfare issues is a high priority to ensure that competent staffs supervise operations.
- Development of humane slaughter methods is needed; stunning methods, prior to slaughter in ice-slurry, have been developed but are not in full operation due to the high cost of investment.

Figure 26: European sea bass

Source: https://ourmarinespecies.com/c-fishes/european-sea-bass/

3.4.1. Production, husbandry techniques and welfare challenges

European sea bass is a marine, brackish, demersal, and oceanodromous[23] fish species, inhabiting coastal (no more than 100-metres depth) but mostly shallow waters (Froese and Pauly, 2000). It is found in the littoral zone, in lagoons and estuaries, and occasionally in rivers of the Eastern Atlantic (Norway to Morocco, the Canary Islands and Senegal), the Mediterranean and Black Sea. Sea bass is a carnivorous[24] species that preys on fish, prawns, crabs, and cuttlefish. Young fish form schools, but adults appear to be less gregarious. In nature European sea bass is exposed to temperatures typically ranging from 6 to 28°C (Dülger et al., 2012), while minimum and maximum survival water temperatures are reported to be at 2 and 32°C, respectively[25]. For European seabass eggs and larvae, a temperature range of 10 to 20°C and for larger fish of 8 to 28°C is recommended in terms of acceptable welfare (EFSA, 2008). Abrupt and substantial changes in temperature should be avoided as are likely to lead to poor welfare. Adults can also cope well with large ranges of dissolved oxygen concentrations and can maintain constant internal pH even when pH in ambient waters varies widely (EFSA, 2008).

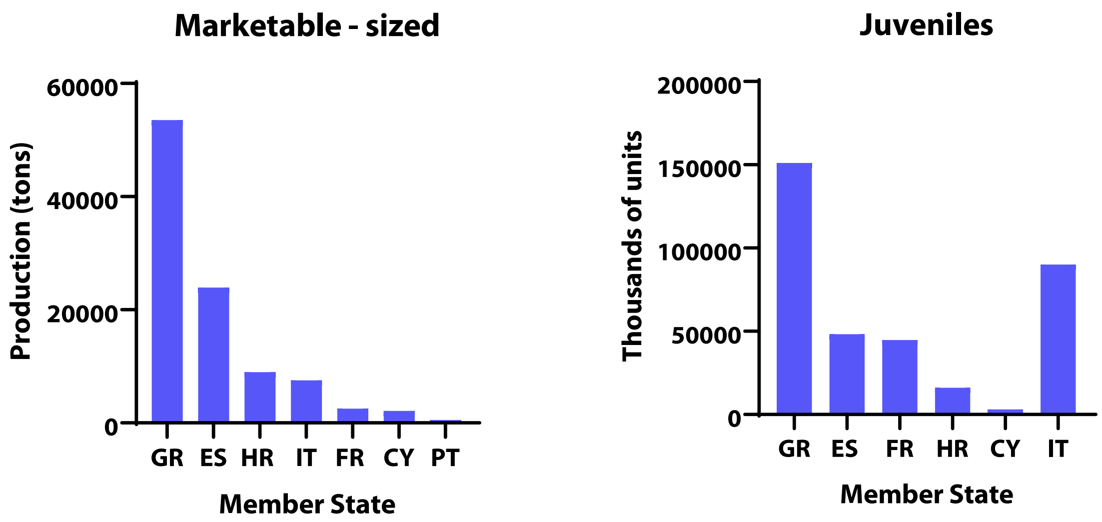
[23] Oceanadromous: a migratory fish that spends its whole life in salt water.
[24] Carnivorous: a species feeding on other animals.
[25] https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2008.844.

Reproductive mature adults spawn small pelagic eggs near to estuaries, lagoons, river mouths or in littoral areas, where the salinity is between 30 and 35‰. Juveniles commonly spend their first winter period in coastal lagoons instead of returning to the open sea.

European sea bass (*Dicentrarchus labrax* L.) is the first Mediterranean marine fish that was successfully reared under intensive conditions in Europe (Bagni 2005, Vandeputte et al., 2019). Traditionally, European sea bass was, and in certain areas (e.g. Egypt) still is farmed in extensive or semi-intensive seawater or brackish ponds and lagoons, however, most of the aquaculture production comes from sea cage farming. The first laboratory breeding trials started in the 1970s in France, and in the early 1980s the first intensive larval rearing trials were developed (Chatain & Chavanne 2009, Vandeputte et al., 2019).

EU Member States production of **European sea bass** in 2021 was approximately **99 000 tonnes** (FEAP, 2023). **Greece** and **Spain** are the countries with the largest sea bass production with 53 500 tonnes and 23 924 tonnes, respectively (**Figure 27**). The EU production of **European sea bass juveniles** was approximately **353 million**. **Greece** was leading production numbers, with 151 million juveniles, followed by **Italy** (90 million), **Spain** (48.3 million) and **France** (44.8 million).

Figure 27: EU production of European sea bass marketable-sized fish and juveniles in 2021



Source: FEAP production report 2023
Note: GR: Greece, ES: Spain, HR: Croatia, IT: Italy, FR: France, CY: Cyprus, PT: Portugal

The current dominant production system of European sea bass is carried out in (a) highly specialised, high-tech on-land facilities (the 'Mediterranean hatchery'), where reproduction (egg production), egg hatching, larval rearing and weaning takes place; and (b) in net-pens (open sea cages), where on-growing and harvesting occur (**Figure 28**).

Figure 28: Production phases in relation to life cycle of European sea bass in captivity

Source: Own elaboration

The **Mediterranean hatchery** consists of:

i. the broodstock unit to ensure year-round production of high-quality eggs;

ii. the fertilised egg incubation unit;

iii. the larval rearing unit;

iv. the live food production unit (algae, *Artemia* sp., rotifers and copepods production parts).

3.4.2. Broodstock unit

Broodfish are kept in rectangular or circular 10 to 25 m^3 polyester tanks (**Figure 29 A**), equipped with photoperiod, temperature, and water quality control systems. **Repeated handling of broodfish** for tagging, sexing and ovarian biopsies is an issue of welfare concern. Sea bass hatcheries rely on spontaneous, volitional mass spawning and out of season egg production is feasible by the application of altered photoperiod/temperature regimes. However, European sea bass females frequently exhibits inconsistent spawning and reduced egg production/quality and males low milt volumes (Forniés et al., 2001, Mañanós et al., 2002; Superio et al., 2021). Hormonal induction of spawning, followed by abdominal massage (stripping), is a common practice in genetic selection programmes. This is a stressful procedure with adverse health consequences too (e.g. reproductive dysfunction at subsequent spawning periods or death of females due to spawning failure). During the spawning period, the released pelagic eggs are collected and transferred to the **egg incubation** unit.

Figure 29: Hatchery facilities

Photos: Y. Krontira, Kefalonia Fisheries S.A.
Note: A: broodstock unit; B: larval rearing unit; C and D: weaning unit

3.4.3. Larval rearing

Following embryonic development and hatching, pre-larvae are transferred to the larval rearing unit, which consists of indoor circular polyester tanks (**Figure 29 B**), in a closed-water system with full control of water quality, water temperature and lighting conditions. ***Embryo*** incubation and ***pre-larvae*** (i.e. yolk sac dependent larvae) rearing do not pose moral consideration, according to the current legislation. However, it is still unknown to what extent early life programming or exposure to stressful stimuli at early ontogeny affect fish characteristics, robustness and performance at subsequent stages of development. ***Larvae*** rearing practices of welfare concern involve artificial lighting and photoperiod regime, inlet water quality and water flow, stocking density, repeated sampling for estimation of growth rate and larvae quality, food quality and feeding protocol, cleaning of tanks and transportation to weaning tanks. Associated welfare challenges are presented in **Box 12**.

Box 12: European sea bass welfare challenges at larval rearing

- inappropriate water quality, water flow, light intensity and lighting quality, temperature/ photoperiod regime;
- inappropriate provision of live feed (timing, distribution, quality); inappropriate feeding regime (food access, unbalanced commercial diets);
- lack of biosecurity, increased mortalities, high incidence of skeletal malformations;
- transportation stress during transfer to the weaning installations;
- lack of proper, validated welfare indicators and scoring system.

3.4.4. Juveniles - weaning

Weaning takes place in on-land tanks maintained in a continuous flow-through system (**Figure 29 C**) supplied with seawater (35-38‰) or well or deep well water, ensuring constant water temperature (17 to 19°C) and salinity (30‰), year-round. RAS are also used to control water quality parameters, water temperature and to ensure high stocking densities (60 to 100 kg/m^3 vs 20 to 35 kg/m^3 in conventional rearing systems). Pre-growing takes place in continuous flow-through tanks at land-based installations (**Figure 29 C and 29 D**). Rarely, a recirculating system to control water temperature may also be used either on a year-round basis or during winter/spring months. Often, deep well water is used to ensure low fluctuation of water temperature and proper salinity. Feed is spread at regular intervals using automated feeders, as well as manual feeding or self-feeders. Environmental conditions such as water exchange, water quality and temperature, and lighting are fully controllable.

Ordinary husbandry techniques and practices of welfare concern involve artificial lighting, photoperiod/temperature regime, inlet water quality and water flow, food quality and feeding protocol, stocking density, handling (crowding, confinement, netting, air exposure, and anaesthesia), use of pharmaceuticals and chemicals for disease treatment, grading, vaccination, removal of dead and moribund fish, and transportation to weaning tanks. Associated welfare challenges are presented in **Box 13**.

Box 13: European sea bass welfare challenges during weaning

- inappropriate water quality, water flow, light intensity, lighting quality, temperature/photoperiod regime;
- inappropriate feed quality, food quantity and distribution;
- use of unsuitable materials, machinery, and equipment when handling fish during routine husbandry practices;
- co-habitation with dead or moribund fish;
- transportation stress during transfer to the on-growing installations;
- lack of proper, validated welfare indicators and scoring system.

At the end of the weaning period, 2 to 20-gram fish are transported to open sea cages for on-growing. Delivery time varies from 1 to 2 hours up to 3 to 4 days for distant destinations, and it is mostly performed in closed containers equipped with aeration-oxygenation systems, and occasionally with automated systems for recording water quality and cooling systems.

3.4.5. On-growing

Cage culture (**Figure 30**) production phase starts with juveniles of 2 to 5 g in weight up to a size of around 20 g. During the ***on-growing*** period various husbandry operations of welfare concern are carried out on the fish or the cages: split and spread into larger volume cages; net changes; cage movements; net inspections and mending by divers; daily mortality checks and dead fish removal; fish grading by size; fish counting; regular fish weight sampling; fish pathology examinations; and regular water and fish analysis. The stocking density during the on-growing phase varies from 5 kg/m^3 to 20 kg/m^3 depending on the size of the fish.

Figure 30: Grow-out of European sea bass and gilthead sea bream production

Photos: AVRAMAR farms in sheltered and exposed areas

The cage sites have all been licensed or registered by the competent authority in each Member State. Most Member States have an aquaculture zoning regime in place under the jurisdiction of the fisheries/aquaculture management authority. The intention is to boost the development of the blue economy and to manage the increasing demand of marine areas for the establishment of economic activities (European Commission, 2022). One of the measures is the establishment of marine aquaculture farms in areas selected to be at a safe distance from sources of potential biological or chemical contamination (such as towns, industrial areas, agricultural activities, etc.). Fattening is carried out with commercial fish feed, which comes in the form of extruded dry pellets, supplied exclusively by feed factories licensed by the competent authorities. Feed is produced in specific feed plants due to the technology needed to meet specific characteristics, such as slow sinking in marine water and to meet species' nutritional needs.

Welfare challenges during the on-growing phase are presented in **Box 14**.

Box 14: European sea bass welfare challenges during on-growing in floating sea cages

- long exposure to high water temperatures and low oxygen saturation during summer - early autumn months;
- inappropriate feed quality and/or access to foodfood.
- use of unsuitable materials, machinery, and equipment when handling fish during routine husbandry practices;
- inappropriate stocking density that can lead to fin erosion, injuries, decreased feed intake and increased disease susceptibility;
- lack of biosecurity, inaccurate disease diagnosis, unsuccessful disease treatment;
- expression of preferred behaviours; insufficient resting opportunities; imbalanced spatial distributions and social interactions;
- increased stress from the presence of predators;
- co-habitation with dead or moribund fish.
- reduction of anxiety-like behaviour at slaughter and use of non-humane slaughter method;
- lack of proper, validated welfare indicators and scoring system.

3.4.6. Harvest

Before slaughter, fish are usually fasted for 1 to 6 days, depending on the sea temperature and harvest planning. At harvest, marketable-sized gilthead sea breams are being crowded and dragged in a net for up to 1 hour, at very high densities (70 to 100 kg/m3) (Towers, 2010). Fish are moved from the crowding pen by braille nets and following air exposure are immersed in ice slurry containers placed on a well boat close to the rearing pens[26]. Electrical stunning, as part of a humane slaughter system, is currently only used on a small number of European sea bass farms.

3.4.7. Welfare indicators for European sea bass

A guide to good practices and for the assessment of welfare indicators for Mediterranean aquaculture fish has recently been developed in Greece (Pavlidis and Samaras, 2020). Welfare indicators that are currently in practice at different levels of standardisation and implementation, as well as recommendations towards welfare assessment and improvement, are summarised below.

[26] See: https://www.compassioninfoodbusiness.com/media/7434843/humane-slaughter-european-sea-bass-and-gilthead-sea-bream.pdf.

Table 4: Welfare indicators and recommendations for on-growing European sea bass

EUROPEAN SEA BASS	Water quality	Nutrition	Husbandry operations	Social interactions
Parameters:	1. Oxygen 2. Temperature	1. Feed amount 2. Feed composition 3. Balanced diets	1. Handling 2. Crowding 3. Grading 4. Fouling control 5. Slaughter	1. Fish density 2. Fish weight and variance
Welfare indicators: – Environment-based indicators:	Oxygen, temperature, light intensity			
– Group-based indicators:	Behaviour (swimming and feeding), good appetite, mortality			
– Individual-based welfare indicators:	1. Fish length, weight and condition factor (emaciation); 2. Fin status (pectoral, caudal, dorsal, pelvic, anal fin damages); 3. Eye condition (exophthalmia, cataract, eye loss); 4. Skin haemorrhages, wounds and scale loss; 5. Jaw deformities; 6. Operculum shortage			
Recommendations:	1. Train personnel in welfare issues to ensure that competent personnel supervise operations. 2. Nominate a person in charge of supervising practical implementation of recommendations for welfare. 3. Automated monitoring of water quality parameters. 4. Ensure proper feeding. 5. Ensure health inspection by vets and skilled personnel. 6. Clarify early-end points (prior to morbidity). 7. Select suitable equipment and anaesthetic for handling operations. 8. Have contingency plans to address emergencies and minimise possible stress caused to fish at various ordinary husbandry practices of concern for welfare (e.g. during transport, handling, harvest). 9. Establish welfare standards – overall welfare scoring system. 10. Ensure implementation of the standards including appropriate certification or possible accreditation.			

Source: Own elaboration

3.5. Gilthead sea bream

KEY FINDINGS

- Further research is needed to identify larval biological needs and optimum rearing conditions.
- Further research and investment are needed for on-site behavioural welfare monitoring.
- Development of a scalable welfare score/welfare standards is of high priority.
- Provision of welfare courses and training for personnel is of high importance.
- Development of humane slaughter methods is needed; stunning methods, prior to slaughter in ice-slurry, have been developed but are not in full operation due to the high cost of investment.

Figure 31: Gilthead sea bream

Source: Roberto Pillon, see: http://www.fishbase.us/photos/UploadedBy.php?autoctr=13070&win=uploaded

3.5.1. Production, husbandry techniques and welfare challenges

Gilthead sea bream (*Sparus aurata*) is a benthopelagic[27], eurythermal[28] and euryhaline[29] species, present in coastal areas with a variety of habitat preferences. It inhabits sea grass beds, rocky and sandy bottoms either in the surf zone or in depths of 30 m. Adult fish are solitary but also form small aggregations and may be found up to a depth of 150 metres. It is mainly carnivorous, eating molluscs, crustaceans and fish, but also herbivorous[30] (Mylonas & Pavlidis, 2011). Minimum and maximum survival water temperatures are 5 to 34°C, respectively (EFSA, 2008). For gilthead sea bream eggs and larvae, a temperature range of 12 to 22°C and for larger fish, a range of 8 to 30°C is appropriate in terms of acceptable welfare (EFSA, 2008). Abrupt and substantial changes of temperature should be avoided as are likely to lead to poor welfare. Gilthead sea bream are sensitive to cold water temperatures and acute decreases, from 15 to 9°C, have been shown to be a significant thermal stressor (EFSA, 2008). EFSA guidelines report that pH values in the range of 6.5 and 8.5 and oxygen saturation levels above

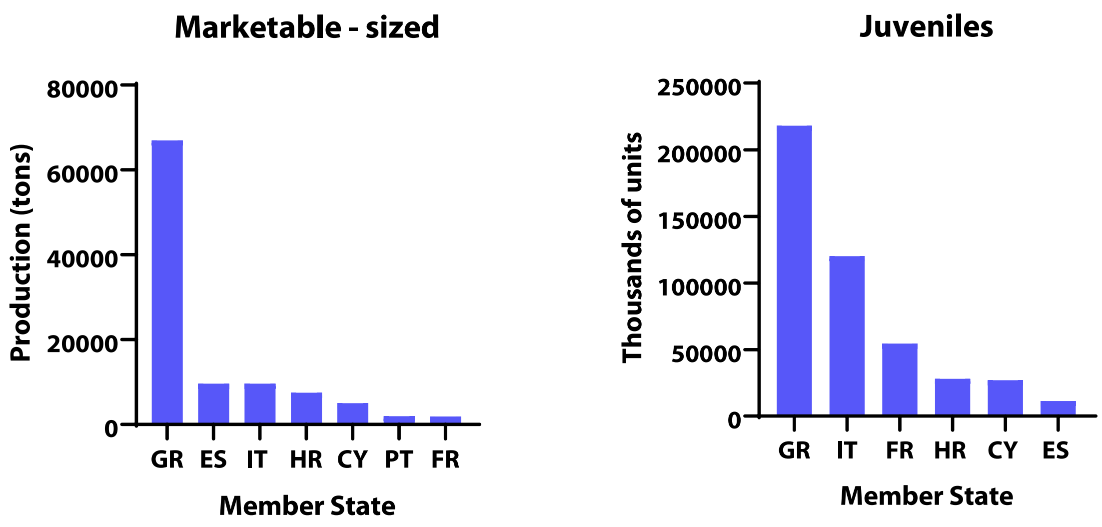
27 Benthopelagic: a species inhabiting near the bottom, midwaters or near the surface of the water column.
28 Eurythermal: an organism that can tolerate and be functional at a wide range of ambient temperatures.
29 Euryhaline: an organism able to adapt at a wide range of salinity; gilthead sea bream can live in brackish waters as well as in sea water.
30 Herbivorous: an animal species eating plants.

40 % are tolerated by the species (EFSA, 2008). Gilthead sea bream is a protandrous hermaphrodite[31] species with most specimens being functional males during the first two years and then functioning as females. The spawning period is between December and April with water temperature tolerances ranging from 13°C to 17°C (Cataudella et al., 1995).

Gilthead sea bream has been farmed for centuries in extensive systems in the lagoons of the North Adriatic Sea. Fishers used to harvest gilthead sea bream and mullet juveniles from the estuaries and stock them in traditional 'valli' (Cataudella et al., 1995). In the early 1990s, large-scale production of gilthead sea bream juveniles became feasible, and nowadays, gilthead sea bream is farmed in all countries of the Mediterranean basin. It is a euryhaline marine fish and well-suited to captivity and intensive farming conditions.

European production of gilthead sea bream in 2021 was 102 632 tonnes (FEAP, 2023). **Greece** and **Spain** are the countries with the largest gilthead sea bream production with 67 000 tonnes and 9 632 tonnes, respectively (**Figure 32**). The European production of sea bream juveniles was approximately 458 million juveniles. **Greece** produced 218 million juveniles followed by, **Italy** (120 million), **France** (54.4 million), **Croatia** (28 million), **Cyprus** (27 million) and **Spain** (11.3 million).

Figure 32: EU production of gilthead sea bream marketable-sized fish and juveniles in 2021



Source: FEAP Production report 2023
Note: GR: Greece, ES: Spain, IT: Italy, HR: Croatia, CY: Cyprus, PT: Portugal, FR: France

Since 1990, most production comes from open sea cage farming. The current dominant production system for sea bream is carried out in (a) highly specialised, **high-tech on-land facilities** where reproduction (egg production), egg hatching, larval rearing and weaning take place, and (b) in **net-pens** (open sea cages) where on-growing and harvesting occur (**Figure 33**).

[31] Protandrous: a hermaphrodite species maturing first as a male (i.e., releasing sperm) and at the subsequent spawning seasons as a female (i.e., releasing eggs).

Figure 33: Production phases in relation to life cycle of gilthead sea bream in captivity

Source: Own elaboration

The **Mediterranean hatchery** consists of:

i. the broodstock unit to ensure all-year-round production of high-quality eggs;

ii. fertilised egg incubation unit;

iii. larval rearing unit;

iv. live food production unit (algae, *Artemia* sp., rotifers and copepods production parts).

3.5.2. Broodstock unit

Broodfish are kept in rectangular or circular indoor polyester tanks of 10 to 25 m^3 water volume (**Figure 29**), equipped with photoperiod, temperature, and water quality control systems. A male to female ratio of 3:1 is maintained, to achieve a good fertilisation rate, since in gilthead sea bream sex reversal is socially determined. Ordinary practices of welfare concern include **repeated handling of broodfish (**for tagging, sexing and ovarian biopsies), exposure of fish to artificial photoperiod/temperature regimes for out of season egg production, use of pharmaceuticals for disease treatment and anaesthetics. Sea bream hatcheries rely on spontaneous mass spawning, however, hormonal induction of egg release, followed by abdominal massage (stripping), is still in use for the synchronisation of spawning in genetic selection programmes. Hormonal treatment is a stressful procedure often leading to reproductive dysfunction at subsequent spawning periods. During the spawning period, the released pelagic eggs are collected and transferred to the **egg incubation** unit.

3.5.3. Larval rearing

Following embryonic development and hatching, pre-larvae are transferred to the larval rearing unit, which consists of indoor circular polyester tanks (**Figure 29**), in a closed-water system with full control of water quality, water temperature and lighting conditions. ***Embryo*** incubation and ***pre-larvae*** rearing do not pose any moral considerations, according to the current legislation. However, further research is needed to characterise the impact of early life programming and/or exposure to stressful stimuli at early ontogeny on fish performance at subsequent stages of development. ***Larvae*** rearing practices of welfare concern involve the use of artificial lighting and photoperiod regime, quality of inlet water, water flow, stocking density, repeated sampling for estimation of growth rate and larvae quality (under anaesthesia), food quality and feeding protocol, cleaning of tanks and transportation to weaning tanks. Associated welfare challenges are presented in **Box 15**.

Box 15: Gilthead sea bream welfare challenges at larval rearing

- inappropriate water quality and/or water flow, light intensity and lighting quality, temperature/photoperiod regime;
- inappropriate provision of live feed (timing, distribution, quality); inappropriate feeding regime (food access, unbalanced commercial diets);
- lack of biosecurity, increased mortalities, high incidence of skeletal malformations;
- transportation stress during transfer to the weaning installations;
- lack of proper, validated welfare indicators and a scoring system.

3.5.4. Juveniles - weaning

Weaning takes place in land-based tanks maintained in a continuous flow-through system (**Figure 29**) supplied with seawater (35 to 38‰) or well/deep well water, ensuring a constant water temperature (17 to 19°C) and salinity (30‰) year-round. A recirculating system, to control water temperature may also be used either on a year-round basis or during winter/spring months. Frequently, deep well water is used ensuring low fluctuation of water temperature and a proper salinity. Feed is spread at regular intervals using automated feeders, as well as manual feeding or self-feeders. Ordinary husbandry techniques involve feeding, cleaning, grading, exposure to pharmaceuticals and chemicals for disease treatment and fish handling, removal of dead and moribund fish, and transportation to sea cages. Associated welfare challenges are presented in **Box 16**.

Box 16: Gilthead sea bream welfare challenges during weaning

- inappropriate water quality, water flow, light intensity, lighting quality, temperature/photoperiod regime;
- inappropriate feed quality, food quantity and distribution;
- use of unsuitable materials, machinery, and equipment when handling fish during routine husbandry practices;
- co-habitation with dead or moribund fish;
- transportation stress during transfer to the on-growing installations;
- lack of proper, validated welfare indicators and scoring system.

At the end of the weaning period, 2 to 20 g fish are transported to open sea cages for on-growing. Delivery time varies from 1 to 2 hours up to 3 to 4 days for distant destinations, and it is mostly carried out using closed containers equipped with aeration-oxygenation systems, and occasionally with automated systems for recording the water quality and cooling systems.

3.5.5. On-growing

Cage culture (**Figure 30**) production phase starts with juveniles of 2 to 5 g in weight until they are approximately 20 g or (b) starts with 20-gram juveniles. During the on-growing period, various husbandry operations are carried out on the fish or the cages: thinning down in bigger volumes of cages' net changes; cage movements; net inspections and mending by divers; daily mortality checks and dead fish removal; fish grading; fish counting; regular fish weight sampling; fish pathology examinations; and regular water and fish analysis. The stocking density during the on-growing phase varies from 5 kg/m^3 to 20 kg/m^3 depending on the size of the fish.

The cage sites have all been licensed or registered by the competent authority in each Member State. Most Member States have in place an aquaculture zoning regime under the jurisdiction of the fisheries/aquaculture management authority. The intention is to boost the development of the blue economy and to manage the increasing demand of marine areas for the establishment of economic activities (European Commission, 2022). One of the measures is the establishment of marine aquaculture farms in areas selected to be at a safe distance from sources of potential biological or chemical contamination (such as towns, industrial areas, agricultural activities, etc.). Feeding is carried out with commercial fish feed, which comes in the form of extruded dry pellets, supplied exclusively by feed factories licensed by the competent authorities. Feed used is produced in specific feed plants due to the technology needed to meet specific characteristics such as slow sinking in marine water and to meet species' nutritional needs. All feed plants are licensed and monitored by the competent authorities in each Member State.

Welfare challenges during the on-growing phase are presented in **Box 17**.

- long exposure to high water temperatures and low oxygen saturation during summer - early autumn months;
- inappropriate feed quality and/or access to food;
- use of unsuitable materials, machinery, and equipment when handling fish during routine husbandry practices;
- inappropriate stocking density that can lead to fin erosion, injuries, decreased feed intake and increased disease susceptibility;
- lack of biosecurity, inaccurate disease diagnosis, unsuccessful disease treatment;
- expression of preferred behaviours; insufficient resting opportunities; imbalanced spatial distributions and social interactions;
- increased stress from the presence of predators;
- co-habitation with dead or moribund fish;
- reduction of anxiety-like behaviour at slaughter and use of non-humane slaughter method;
- lack of proper, validated welfare indicators and scoring system.

3.5.6. Harvest

Before slaughter, fish are usually fasted for 1 to 6 days, depending on the sea temperature and harvest planning. At harvest, marketable-sized gilthead sea breams are being crowded and dragged in a net for up to 1 hour, at very high densities (70 to 100 kg/m^3) (Towers, 2010). Fish are moved from the crowding pen by braille nets and following air exposure are immersed in ice slurry containers placed on a well boat close to the rearing pens. Electrical stunning, as part of a humane slaughter system, is currently only used on a small number of gilthead sea bream farms.

3.5.7. Welfare indicators for gilthead sea bream

A guide to good practices and for the assessment of welfare indicators for Mediterranean aquaculture fish has recently been developed in Greece (Pavlidis and Samaras, 2020). Welfare indicators that are currently in practice at different levels of standardisation and implementation, as well as recommendations towards welfare assessment and improvement, are summarised below.

Table 5: Welfare indicators and recommendations for on-growing gilthead sea bream

GILTHEAD SEA BREAM	Water quality	Nutrition	Husbandry operations	Social interactions
Parameters:	1. Oxygen 2. Temperature	1. Feed amount 2. Feed composition 3. Balanced diets	1. Handling 2. Crowding 3. Grading 4. Fouling control 5. Slaughter	1. Fish density 2. Fish weight and variance
Welfare indicators: – Environment-based welfare indicators:	Oxygen, temperature, light intensity			
– Group-based welfare indicators:	Behaviour (swimming and feeding), good appetite, mortality			
– Individual-based welfare indicators:	1. Fish length, weight and condition factor (emaciation); 2. Fin status (pectoral, caudal, dorsal, pelvic, anal fin damages); 3. Eye condition (exophthalmia, cataract, eye loss); 4. Skin haemorrhages, wounds and scale loss; 5. Jaw deformities; 6. Operculum shortage			
Recommendations:	1. Train staff in welfare issues to ensure that competent staff supervises operations. 2. Nominate a person in charge of supervising practical implementation of recommendations for welfare. 3. Automated monitoring of water quality parameters. 4. Ensure sufficient and high-quality feeding. 5. Ensure health inspection by vets and skilled personnel. 6. Clarify early-end points (prior to morbidity). 7. Availability of suitable equipment and anaesthetic for handling operations. 8. Have contingency plans to address emergencies and minimise possible stress caused to fish at various routine husbandry practices (e.g. during transport, handling, harvest). 9. Validate the practicability and reliability of different welfare indicators on-site. 10. Establish welfare standards – overall welfare scoring system. 11. Ensure implementation of the standards including appropriate certification or possible accreditation.			

Source: Own elaboration

3.6. Research priorities

The study identified the following gaps in knowledge and areas for further research in welfare of farmed fish species in EU.

3.6.1. Basic biology

- Define larval welfare needs in relation to the rearing system.
- Investigate how early life stress and programming affects fish welfare and performance at subsequent production phases / stages of development.
- Identify behavioural preferences and develop practices to ensure the expression of typical behaviours (including positive social behaviour), especially in on-growing fish and broodfish.
- Investigate the origins and mechanisms behind observed mortalities and malformations in larvae and juvenile fish.
- Define at which point feed withdrawal impairs metabolic state and becomes an issue of welfare concern.
- Investigate links between cognition, pain perception, coping styles, and fish welfare.
- Identify the welfare implications of common handling operations (e.g. grading, vaccination, parasite treatments, tagging, sexing, stripping, fin clipping) and possible approaches to improve technology and procedures, e.g. pain control.
- Evaluate the impact of genetic selection programmes on stress resistance and fish welfare.
- Develop of vaccines against viral and bacterial diseases and parasites (when no effective vaccines exist).

3.6.2. Rearing units

- Identify and evaluate necessary requirements for the fish farming technology and procedures to meet the welfare needs of the farmed fish.
- Investigate how environmental enrichment contribute to positive welfare and how different types of enrichment can be implemented at different production phases.
- Identify the impact of different light intensities, lighting quality (spectral composition), photoperiod/temperature regimes and noise (intensity, duration) on fish physiology, early maturation, and welfare at all life stages.
- Investigate the complex relationship between stocking density, fish welfare and influencing factors (related to fish species, individuals, and physical and rearing environment, managerial practices) at different life stages.
- Enhance biosecurity and prevention of diseases by improving fish farming technology and protocols.

3.6.3. Harvest

- Develop of methods to assess loss of consciousness at harvest.
- Develop humane slaughter methods for common carp, European sea bass and gilthead sea bream.

3.6.4. Welfare assessment

- Develop and validate laboratory and operational reliable and user-friendly indicators to assess stress status and welfare.
- Develop and incorporate methods to monitor and evaluate fish behaviour on-site.
- Develop species-specific welfare scoring systems at the different stages of production.

4. REGULATORY FRAMEWORK FOR FARMED FISH WELFARE IN THE EU

4.1. European level

Over recent years, there has been increasingly heated debate about the need to provide a decisive impetus to the study of all aspects regarding fish welfare and regulation of fish welfare standards. Fish farming has been on the increase, and policy-makers, scientists and consumers are increasingly focused on farming practices that have the potential to impair fish welfare. Scientific approaches to assessing fish welfare are continuously evolving. However, the great diversity of farmed species, locations and production systems make it difficult to find a single, sound approach. The shortage of scientific evidence and the need for species-specific and production-based approaches are the main reasons why a binding common specific regulation has not yet been issued.

Three kinds of regulatory and non-regulatory provisions are in place regarding fish welfare:

a) **standards** and **codes of conduct**, and **good practices** (from NGOs, producers' associations, certification scheme owners and lobbies);

b) **recommendations** from public institutions ('soft' rules) generally from EFSA or other public authorities, usually from a scientific standpoint and species-specific;

c) **laws,** in a strict sense ('hard' rules): these are binding and mandatory for farmers and operators involved in the different phases of the fish farming operations.

The current situation can be summarised as follows:

- The **European Convention for the Protection of Animals kept for Farming Purposes**[32] signed by the Parties of the Council of Europe (CoE) in 1978, and revised in 1992[33], sets out general principles and asks for the establishment of experience and scientific knowledge on animal welfare. **Council Directive 98/58/EC** concerning the protection of animals kept for farming purposes[34] incorporated the mandates of the Convention into EU legislation. Science in the field of animal welfare in general and of fish welfare in particular has moved on considerably in recent years.

- The World Organisation for Animal Health (**WOAH**) sets out the general obligation that animal husbandry operations should avoid suffering, distress and pain in its Terrestrial[35] and **Aquatic Animal Health Codes**[36]. The Animal Health Code, in its two versions (terrestrial and aquatic animals), sets veterinarian standards and recommendations for the welfare of farmed fish during transport, slaughter and destruction for disease control reasons. These codes are recognised by the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary (SPS) Measures. The EU and Member States competent authorities should use the standards and principles of Aquatic Animal Health Code to develop measures for animal

[32] European Convention for the Protection of Animals kept for Farming Purposes (1978). Text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:21978A1117(01)&from=EN.

[33] Council of Europe (1992). Protocol of amendment to the European Convention for the protection of animals kept for farming purposes, Strasbourg, 6.11.1992. Available at: https://rm.coe.int/168007bd27.

[34] Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes; OJ L 221, 8.8.1998, p. 23–27. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01998L0058-20191214.

[35] World Organization for Animal Health (2019). Terrestrial Animal Health Code, twenty-eighth edition. Available at: https://rr-europe.woah.org/wp-content/uploads/2020/08/oie-terrestrial-code-1_2019_en.pdf.

[36] World Organization for Animal Health (2019). Aquatic Animal Health Code, twenty-second edition. Available at: https://rr-europe.woah.org/wp-content/uploads/2020/08/oie-aqua-code_2019_en.pdf.

health, animal welfare and use of antimicrobial agents. EU Member States have adopted mandatory rules (laws/acts and/or administrative regulations) setting some clear binding rules regarding the general principles of farmed animals, and in particular farmers' duty to avoid undue pain, suffering or distress of farmed animals, including fish.

- The **European Convention for the Protection of Animals during International Transport**[37] firstly concluded 1968, and revised in 2003, provides recommendations for the transportation of livestock and horses and recognises that local slaughter houses are preferable to transportation. EU institutions have been laying down a few first-level rules focused on specific aspects in some of the following matters: **Regulation (EU) 2016/429** on the transmission of animal diseases[38] (this is the most binding rule on the matter, although it only indirectly concerns welfare).
- **Directive 2010/63/EU** for the protection of animals used for scientific purposes[39] is a very good example of managing animal welfare through legislation. The directive names the principles of using animals for scientific purposes and describes minimum standards relating to housing and care. Finally, it requires regular risk-based inspections of establishments that hold animals for scientific purposes. The reduce, refine, replace (3Rs) principle is also a legal requirement in the EU when conducting experiments with farmed fish species to improve their health, welfare and rearing conditions.
- A series of EU Regulations pertaining to various aspects related to fish farming, many of which **directly or indirectly also affect fish welfare**. Specifically, of these: **Regulation (EC) 178/2002** sets general principles and requirements for food law (including feed)[40]; **Council Regulation (EC) 1/2005** on the protection of animals during transport[41]; **Council Regulation (EC) 1099/2009** on the protection of animals at the time of killing[42]; **Regulation (EU) 2019/4** for placing medicated feed on the market and use of medicated feed[43] and **Regulation (EU) 6/2019** on veterinary medical products[44].

EU regulations in place set requirements for fish health supervision by experts to avoid transmissible diseases, designate minimum requirements and approved ingredients to ensure the safety and good health of farmed animals, and provisions on the medicated feed and medicines provided to farmed

[37] CoE (2003). European Convention for the Protection of Animals during International Transport (Revised), European Treaty Series - No. 193. Text available at: https://rm.coe.int/1680083710.

[38] Regulation (EU) 2016/429 on transmissible animal diseases and amending and repealing certain acts in the area of animal health ('Animal Health Law'), OJ L 84, 31.3.2016, p. 1–208. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02016R0429-20210421.

[39] Directive 2010/63/EU of the European Parliament and the Council of 22 September 2010 on the protection of animals used for scientific purposes (Text with EEA relevance); OJ L 276, 20.10.2010, p. 33–79. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02010L0063-20190626.

[40] Regulation (EC) No 178/2002 of the European Parliament and the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety; OJ L 31, 1.2.2002, p. 1–24. Consolidated version available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri= CELEX%3A0 2002R0178-20220701.

[41] Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97; OJ L 3, 5.1.2005, p. 1–44. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02005R0001-20191214.

[42] Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing (Text with EEA relevance), OJ L 303, 18.11.2009, p. 1–30. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02009R1099-20191214.

[43] Regulation (EU) 2019/4 of the European Parliament and of the Council of 11 December 2018 on the manufacture, placing on the market and use of medicated feed, amending Regulation (EC) No 183/2005 of the European Parliament and of the Council and repealing Council Directive 90/167/EEC (Text with EEA relevance), OJ L 4, 7.1.2019, p. 1–23. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0004&qid=1685696586441.

[44] Regulation (EU) 2019/6 of the European Parliament and of the Council of 11 December 2018 on veterinary medicinal products and repealing Directive 2001/82/EC (Text with EEA relevance), OJ L 4, 7.1.2019, p. 43–167. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02019R0006-20220128.

animals. Although there is a legislative framework for the 'Protection of Animals kept for Farming Purposes' and many directives and regulations that manage aspects that impair fish welfare, there is a lack of focus and lack of integration between them.

4.2. National level in case study countries

EU regulations are applicable and enforceable directly at national level, whereas directives need to be incorporated into national legislation. Requirements derived from these regulations create a common level playing field for fish farming within the EU. These requirements govern fish feed manufacturing within the EU, the production and marketing of medicines and medicated feed, the licensing and registration scheme of aquaculture activities and the measures in place to avoid transmission of fish diseases among others animal diseases. Enforcement of these regulations is proactive through licensing (e.g. aquaculture activity authorisations include the duty to comply with current legislation, under penalty - in the most serious cases - of license revocation) and audit schemes (e.g. IFS, BRC, ISO, MSC standards that in their respective fields demonstrate best practices and undergo a periodic audit). Enforcement of these regulations is either proactive through licensing and audit schemes (competent authorities are looking for evidence that the relevant legislation requirements are in place and are followed by the farmers), or more passive by reacting when a problem or complaint is recorded (in this case competent authorities when farmers engaged in irregular conduct as regards the relevant legislation).

4.2.1. Regulatory provisions during rearing of farmed animals

All Member States covered in the current study have enacted laws that generally impose the obligation on farmers to preserve the health of animals and 'avoid unnecessary suffering'. The Council Directive 98/58/EC lays down minimum standards for the 'Protection of Animals kept for Farming Purposes'. Although no specific rules are in place for fish, the general provision is that farmed animals' owners or keepers should "*take all reasonable steps to ensure the welfare of animals under their care and to ensure that those animals are not caused any unnecessary pain, suffering or injury*", (Article 3, Council Directive 98/58/EC), and this is valid and transposed in national laws.

At a Member State level, many countries have also incorporated the protection of animals as **constitutional principles**. That is the case with the **German** Constitution, which, following the reform carried out in May 2002, includes in Article 20a[45], that *"the state shall protect the natural foundations of life and animals by legislation and, according to law and justice, by executive and judicial action, all under the constitutional order."*

- Similarly, in the Constitution of **Luxembourg**, whose Article 11 bis (revision 29 March 2007[46]) lays down that "*The State […] shall promote the protection and welfare of animals*".
- Likewise, the preamble to the **Austrian** Constitution also mentions animals in Article 11(3)[47] ("*Animal protection, to the extent not being in the competence of Federal legislation according to other regulations, with the exception of the exercise of hunting or fishing*").
- The **Slovenian** Constitution also refers to animals by ordering in Article 72 that the law must protect animals against cruelty[48].

[45] https://www.gesetze-im-internet.de/gg/art_20a.html.
[46] https://mjp.univ-perp.fr/constit/lux1868.htm.
[47] https://www.constituteproject.org/constitution/Austria_2013.pdf?lang=en.
[48] https://fra.europa.eu/en/law-reference/constitution-republic-slovenia-23.

On the other hand, the **Criminal Law** of many European countries[49] is increasingly punishing certain behaviours of unnecessary cruelty to animals as a crime:

- In **Germany**, the Animal Welfare Act considers cruelty punishable and similarly causing unjustified death to vertebrate animals[50].
- In **Italy**, the Criminal Law 189/2004[51] - Article 544-ter, amended by Law 201/2012, states that "*there is a crime when an animal is subjected to injury, abuse, unbearable conduct or hardships, or to treatments from which it will derive damage to its health or moreover when it is subjected to the administration of prohibited substances*".
- In **France**, Decree n° 59-1051, adopted on 7 September 1959, penalises the mistreatment of animals. This decree[52] considers it criminal to "*without necessity, publicly or not, mistreat domestic or tame animals or animals held in captivity*".
- **Spanish** Articles 340 bis, 340 ter 340 quarter and 340 quinques of the Spanish Criminal Code punishes causing unjustified injuries that seriously undermine an animal´s health. These Articles are introduced by the new Spanish Law 7/2023[53] against the abuse of animals.

In addition, binding rules mandating concrete welfare provisions, especially on slaughter methods are in place. They either directly (laws on stunning) or indirectly implement rules on banning avoidable suffering of animals:

- In **Germany**, animal welfare matters are regulated through the 'Animal Welfare Act'[54], the 'Animal Welfare Slaughter Ordinance'[55]; the 'Animal Protection Transport Ordinance'[56], and the 'Animal Protection - Livestock Ordinance'[57]. These national laws cover and implement provisions of Regulation (EU) 2016/429 on animal health law[58], Regulation (EC) 178/2002 on general food law[59], Regulation (EC) 1/2005 on the protection of animals during transport[60] and Regulation (EC) No 1099/2009 on the protection of animals at the time of killing[61].
- In **France**, there are also several orders from the health authority, although nothing specific has been issued in addition to EU Regulations. For example, a 2008 Decree pertaining to the licensing

49 https://www.globalanimallaw.org/database/national/.
50 http://www.gesetze-im-internet.de/tierschg/BJNR012770972.html; English version: https://www.animallaw.info/statute/germany-cruelty-german-animal-welfare-act.
51 https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:2004-07-20;189, and https://www.globalanimallaw.org/downloads/20171108-law-20-july-2004-n189.pdf.
52 Décret n° 59-1051 du 7 septembre 1959 réprimant les mauvais traitements exerces envers les animaux, *JORF* 11 septembre 1959, p.8884. Available at : https://www.animallaw.info/sites/default/files/stfrdecreeno59_1051.pdf.
53 Ley 7/2023 de 28 de marzo, de protección de los derechos y el bienestar de los animales. Available at; https://www.boe.es/eli/es/l/2023/03/28/7/dof/spa/pdf
54 http://www.gesetze-im-internet.de/tierschg/BJNR012770972.html ; English version: https://www.animallaw.info/statute/germany-cruelty-german-animal-welfare-act.
55 https://www.gesetze-im-internet.de/tierschlv_2013/.
56 https://www.gesetze-im-internet.de/tierschtrv_2009/.
57 https://www.gesetze-im-internet.de/tierschnutztv/.
58 Regulation (EU) 2016/429 on transmissible animal diseases and amending and repealing certain acts in the area of animal health ('Animal Health Law'), OJ L 84, 31.3.2016, p. 1–208. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02016R0429-20210421.
59 Regulation (EC) No 178/2002 of the European Parliament and the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety; OJ L 31, 1.2.2002, p. 1–24. Consolidated version available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri= CELEX%3A0 2002R0178-20220701.
60 Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97; OJ L 3, 5.1.2005, p. 1–44. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02005R0001-20191214.
61 Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing (Text with EEA relevance), OJ L 303, 18.11.2009, p. 1–30. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02009R1099-20191214.

or authorisation of aquaculture production sites NOR: AGRG0825592A[62] states that good husbandry practices are compulsory and sets out a monitoring plan to ensure good fish health conditions. There are also technical notes to the local competent authorities that have to be implemented. These technical notes describe the content of the application, the process to issue initially a temporary and after the instalment and audit a permanent licence for the establishment of the farm. The aim of the legislation is that a reliable health monitoring system is in place that monitors the risk to spread diseases on other farms, and on wild populations.

- In **Italy**, the respective regulation (Legislative Decree of 26 March 2001, no 146)[63] implements Council Directive 98/58/EC[64] that generically regulates all farmed animal species, including fish, but does not provide specific suggestions as regards the ethical concerns and breeding techniques for fish. The explanatory and application notes as well as the checklists pertaining to this do not provide for a precise assessment of farmed fish welfare as they are mainly oriented to the assessment of the welfare of terrestrial animals. Another Legislative Decree of 2 February 2021, no 27[65] harmonises Italian national legislation to the provisions of Regulation (EU) 2017/625 on official controls and other official activities performed to ensure the application of food and feed law, rules on animal health and welfare, plant health and plant protection products[66].
- In **Greece**, Presidential Decree 374/2001[67] focused on the practices that protect animals kept for farming purposes, in accordance with Directive 98/58/EC (on social interactions, hygiene, and nutrition and water quality). Health control requirements for aquaculture animals are also imposed. Ministerial Decision 2481/289147/2020[68] amending partially Presidential Decree 28/2009[69], lays down preventive measures for aquatic animal health, in compliance with Council Directive 2006/88/EC[70]. Provisions stated on Presidential Decree 28/2009 and Ministerial Decision 2481/289147/2020 are complying acts in the area of animal health protection referred in Regulation (EU) 2016/429[71] of the European Parliament and of the Council repealing Council

[62] Arrêté du 4 novembre 2008 modifiant l'arrêté du 8 juin 2006 relatif à l'agrément ou à l'autorisation des établissements mettant sur le marché des produits d'origine animale ou des denrées contenant des produits d'origine animale. https://www.legifrance.gouv.fr/loda/id/JORFTEXT000019732796.

[63] Italian legislative decree of 26 March 2001, no 146. Available at: https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo 2001-03-26;146!vig=, and at: https://faolex.fao.org/docs/pdf/ita25032.pdf.

[64] Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes; OJ L 221, 8.8.1998, p. 23–27. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01998L0058-20191214.

[65] Italian legislative decree of 2 February 2021, n. 27. Available at: https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2021;027, and at: https://faolex.fao.org/docs/pdf/ita205875.pdf.

[66] Regulation (EU) 2017/625 of the European Parliament and of the Council of 15 March 2017 on official controls and other official activities performed to ensure the application of food and feed law, rules on animal health and welfare, plant health and plant protection products, amending Regulations (EC) No 999/2001, (EC) No 396/2005, (EC) No 1069/2009, (EC) No 1107/2009, (EU) No 1151/2012, (EU) No 652/2014, (EU) 2016/429 and (EU) 2016/2031 of the European Parliament and of the Council, Council Regulations (EC) No 1/2005 and (EC) No 1099/2009 and Council Directives 98/58/EC, 1999/74/EC, 2007/43/EC, 2008/119/EC and 2008/120/EC, and repealing Regulations (EC) No 854/2004 and (EC) No 882/2004 of the European Parliament and of the Council, Council Directives 89/608/EEC, 89/662/EEC, 90/425/EEC, 91/496/EEC, 96/23/EC, 96/93/EC and 97/78/EC and Council Decision 92/438/EEC (Official Controls Regulation) Text with EEA relevance; OJ L 95, 7.4.2017, p. 1–142. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02017R0625-20220128.

[67] Greek Presidential Decree 374/2001. Available at: https://www.e-nomothesia.gr/kat-agrotike-anaptukse/ktenotrophia/pd-374-2001.html

[68] Ministerial Decision 2481/289147/2020. Available at: https://www.e-nomothesia.gr/kat-agrotike-anaptukse/upourgike-apophase-2481-289147-2020.html

[69] Greek Presidential Decree 28/2009. Available at: https://www.e-nomothesia.gr/kat-agrotike-anaptukse/nomothesia-pathologias-zoon/proedriko-diatagma-28-2009.html

[70] Council Directive 2006/88/EC of 24 October 2006 on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals; OJ L 328, 24.11.2006, p. 14–56. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02006L0088-20140306. No longer in force, date of end of validity: 20/04/2021, repealed and replaced by 32016R0429.

[71] Regulation (EU) 2016/429 on transmissible animal diseases and amending and repealing certain acts in the area of animal health ('Animal Health Law'), OJ L 84, 31.3.2016, p. 1–208. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02016R0429-20210421.

Directive 2006/88/EC. It contains provisions for the prioritisation and categorisation of diseases of Union concern, on early detection, notification and reporting of diseases, on the registration and approval of establishments and transporters, on the entry of animals and germinal products into the Union and on the emergency measures to be taken on the event of a disease emergency situation. The competent veterinary authorities carry out regular official inspections of fish farming facilities based on a risk assessment. Finally, Presidential Decree 56/2013[72] lays down measures for the protection of animals used for scientific purposes in compliance with Directive 2010/93/EC.

- In **Spain,** the Royal Decree 348/2000[73] on the protection of animals kept for farming purposes incorporates Directive 98/58/EC as a national law. The specific law sets out the conditions in which animals are raised or kept, considering their species and development stage, adaptation and domestication, as well as their physiological and ethological needs in accordance with acquired experience and scientific knowledge. It was recently modified (March 2023) to introduce provisions for the application in Spain of the European Union regulations on official controls on animal welfare). Royal Decree 751/2006[74] incorporate rules regarding the protection of animals during transport and related operations in accordance with Regulation (EU) 2016/429[75] of the European Parliament and of the Council repealing Council Directive 2006/88/EC [76]. Royal Decree 53/2013[77] establishes the basic standards for the protection of animals used in experimentation and other scientific purposes including teaching, in accordance with Directive 2010/93/EC.
- In **Denmark,** Order 1597/2021 on the protection of animals kept for farming purposes incorporates Directive 98/58/EC as a national law. The order declares that 'animals are living beings and must be treated responsibly and protected as best as possible against pain, suffering, anxiety, lasting injuries and significant inconvenience'. There are no fish-specific rules and there is limited enforcement of this law by the national authorities.

4.2.2. Stunning and slaughter of animals intended for human consumption

Stunning animals before slaughter is the most humane killing method for animals intended for human consumption. **Regulation (EC) 1099/2009[78]** for the protection of animals at the time of killing lays the framework for stunning land animals before slaughter. Therefore, business operators and employees involved in animal slaughter should take the appropriate measures to achieve a painless, humane method of killing that avoids distress and suffering. The Regulation **excludes farmed fish** because of their physiological differences to land animals, the different working environment that fish are slaughtered and killed in (on fish farms and not in slaughterhouses), and the fact that research and available technology in this field lags behind that relating to land farmed animals. In recent years, since

[72] Geek Presidential Decree 56/2013. Available at: https://www.e-nomothesia.gr/kat-zoa-suntrophias-prostasia-zoon/pd-56-2013.html

[73] Spanish Royal Decree 348/2000. Available at: https://www.boe.es/buscar/act.php?id=BOE-A-2000-4698.

[74] Spanish Royal Decree 751/2006. Available at: https://www.boe.es/buscar/doc.php?id=BOE-A-2006-11289.

[75] Regulation (EU) 2016/429 on transmissible animal diseases and amending and repealing certain acts in the area of animal health ('Animal Health Law'), OJ L 84, 31.3.2016, p. 1–208. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02016R0429-20210421.

[76] Council Directive 2006/88/EC of 24 October 2006 on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals; OJ L 328, 24.11.2006, p. 14–56. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02006L0088-20140306. No longer in force, date of end of validity: 20/04/2021, repealed and replaced by 32016R0429.

[77] Spanish Royal Decree 53/2013. Available at: https://www.boe.es/buscar/act.php?id=BOE-A-2013-1337.

[78] Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing (Text with EEA relevance), OJ L 303, 18.11.2009, p. 1–30. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02009R1099-20191214.

Regulation (EC) No 1099/2009 entered into force, both science and technology for farmed fish have advanced.

- In **Germany**, fish intended for slaughter are considered as farm livestock according to the general administrative regulation for the implementation of the German Animal Welfare Slaughter Ordinance[79]. As set out by EU Regulations, German law requires that animals be stunned in such a manner that they are placed rapidly and without pain or suffering in a state of perceptual and sensory deprivation, which lasts until death. According to the law, any person who slaughters or kills fish must stun the fish immediately before slaughter or killing accordance to provisions referred to in an Annex. In this Annex, different combinations of stunning/killing methods are described for different aquatic animals.
- In other countries covered in the current study (**Spain, Greece, France, Italy, Ireland, Denmark**) there are no specific provisions for fish stunning and killing. Monitoring plans for farms and processing plants include controls of slaughtering methods. The results of these audits report that the slaughtered fish do not suffer unnecessary or avoidable pain or stress.

4.2.3. Livestock transport

Transport provisions for livestock animals are some of the clearest and most binding on the matter (Council Regulation (EC) No 1/2005)[80]. The EFSA´s scientific opinion on the welfare of several species of animals during transport (2004)[81,82,83] describes a variety of hazards incompatible with a minimum welfare condition for several animals, including fish (though limited to avoiding exposure to air during loading and unloading operations; providing adequate levels of oxygen in the water; and maintaining an appropriate stocking density).

As general handling rules, loading and unloading should be gentle; the water quality and temperature parameters should be closely controlled and monitored; stocking densities must be sufficiently low to avoid deterioration of water quality; and additional oxygen should be available in case of delays. Suitable measures should also be taken to ensure biosecurity and ensuring that only healthy fish are transported.

- In **Spain** there are two Royal Decrees (542/2016 and 728/2007) requiring mandatory rules for the transportation of all vertebrate animals, including farmed fish. The Royal Decrees set rules on documentation of the journeys, authorisation for vehicles and training of transporters. The personnel who handle live animals must have received training that includes the provisions of Annexes I and II of Council Regulation (EC) No 1/2005[84]. The training must be documented.
- In **France,** there is no additional local law for live fish transportation. The provisions referred to in Council Regulation (EC) No 1/2005 are the rules in force. The French Association of Aquaculture Producers proposed a guide of good practices for live fish transportation to the competent authority. The guide has not yet been validated.

[79] German Animal Welfare Slaughter Ordinance: https://www.gesetze-im-internet.de/tierschlv_2013/.
[80] Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97; OJ L 3, 5.1.2005, p. 1–44. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02005R0001-20191214.
[81] https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2011.1966.
[82] https://food.ec.europa.eu/news/efsa-publishes-studies-animal-welfare-during-transport-2022-09-07_en.
[83] https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2004.44.
[84] Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97; OJ L 3, 5.1.2005, p. 1–44. Consolidated text available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02005R0001-20191214.

- In **Greece,** all fish transportation vehicles are registered and licensed by the veterinary office of the prefecture to which they belong. The vehicles have to maintain a log for all fish transportation journeys carried out, including the species they carry and the farms visited. They are also required to record incidents and report losses. Records on equipment cleaning and disinfection are obligatory. Vehicle licences are requested during the official audits on hatcheries.
- In **Denmark,** all general rules related to other animals are also applicable to fish transportation. All live fish transporters are authorised for short and long journeys and the vehicles that cover long distances are approved. Annual training of fish transporters is obligatory. The training course for fish transporters covers Annexes I and II of Council Regulation (EC) No 1/2005 and is performed by the Danish Aquaculture Organisation. The Danish Veterinary and Food Administration runs a campaign focusing on the loading of fish on the farms. During the last few years, official vets have inspected 15-20 fish farms for fact-finding purposes.
- **Italy** follows Council Regulation (EC) No 1/2005 on the protection of animals during transport and related operations, applicable to all animal species, but includes no specific references to the transport of aquaculture animals. This created difficulties in applying it to farmed fish in the first period of its application due to the distinctive features that characterise their transport. Some explanatory notes by the Ministry of Health addressed to both operators and inspectors clarified the basic rules for transporting live fish. In addition, the Italian 'Manual for the management of fish welfare control during road transport' represents a useful aid for operators in the sector and for all those who carry out activities in the field of prevention and control of violations of protections for animals during transport.

4.3. Review of regulatory gaps at EU and national level

Legislation on the **welfare of farmed fish is poorly developed and enforced** compared to other farmed animals, mainly due to the fact that scientific evidence only became available recently, along with the great diversity of species farmed and production systems in place. The **EU Strategy on Animal Welfare**[85] **(2012)** is an instrument focused on all the farmed animals, which includes a wide variety of species, where terrestrial mammals had, and still have, a vast advantage over farmed fish, and both in terms of scientific knowledge or technical equipment, and in terms of binding provisions and regulations. In fact, the 2012 EU Communication from the Commission on the EU Strategy on animal welfare only mentions the word "fish" six times, and always referred to set as an "strategic action" studying and investigating the farmed fish welfare, and recognising the "farmed fish will be subject to specific evaluations". And clearly recognised too that although farmed fish are covered by the scope of the EU legislation on the protection of animals during transport and at the time of killing, there were no specific rules for fish at 2012 (epigraph 3.6).

The report on the Evaluation of EU Strategy on Animal Welfare[86] (European Court of Auditors, 2018) with specific focus on fish welfare suggests that most of the objectives of the strategy remains relevant, although some progresses have been achieved. Since 2012, the evolution of the enforceable legislation on fish farmed welfare has been very rare and insignificant. Lack of concrete binding provisions on the characteristic welfare indicators is still evident. Absence of species-specific regulations lead to lack of provisions that will improve animal welfare status. Compliance among Member States has not been achieved. The reluctance of some non-EU countries to adopt equivalent animal welfare standards leads to differences in level playing field with EU producers. The strategy failed to simplify the EU legislative

[85] EU Strategy on Animal Welfare.
[86] Animal welfare in the EU: closing the gap between ambitious goals and practical implementation.

framework and had limited contribution providing to consumers information on animal welfare status for Member States produce.

The 'Fitness check', an evaluation report on the EU legislation on the welfare of farmed animals[87] (EU Commission, 2022), concludes that animal welfare rules need to include new science and technological developments, as well updates of social demand recorded. The lack of concepts and tools to measure evolution of animal welfare is evident. Robust welfare indicators and baseline data are missing. It is a need to establish indicators to monitor overtime if animal welfare status is improving, remaining stable or decreasing.

Today, a direct **EU legislation regarding concrete binding provisions on fish welfare** (not only generic principles and rules) **is lacking**. This legislation should include general principles, standards of compliance and enforcement mechanisms across the EU. The new legislation could be the link between existing EU directives and regulations, by integrating the scope of the previous and more generic binding rules with concrete provisions through a the possible future regulation on fish welfare. In the current regulations, there are **no concrete rules** relating to live fish transportation and stunning as well as slaughtering, which are considered to be the most likely to cause pain or distress. These gaps should be filled by updating the existing regulations to incorporate specific provisions for handling fish, water quality provisions, stocking densities and life support systems when transporting fish. **Accepted stunning methods per species and their parameters could be part of fish slaughtering provisions**. The additional provisions could be part of the current relevant regulations or could be included in a fish welfare Regulation.

The binding rule laying down the abstract **prohibition of avoidable pain, distress and suffering**, is **in force in national laws**. Unfortunately, this is a general clause, likely to be individually applied by official veterinarians or auditors, and it creates room for the latter to decide whether a fish is suffering unnecessary or avoidable pain or distress.

Additional **recommendations** come mainly **from NGOs** (Compassion in World Farming[88], Eurogroup for Animals[89], Royal Society for the Prevention of Cruelty to Animals (RSPCA)[90], Aquaculture Stewardship Council[91], Conservative Animal Welfare Foundation[92], Fish Welfare Initiative[93], Aquatic Animal Alliance[94]) due to the lack of legislation regarding important aspects that impair fish welfare. NGOs recommend introducing legal provisions on the following matters:

- ensure environmental conditions that meet animals' physical, mental and ethological needs and overall accommodation;
- specify acceptable stocking densities;
- establish water quality parameters, including temperature, pH, oxygen content, etc.;
- develop codes of good practice for handling techniques to reduce stress such as requirements for moving fish in water;

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87 https://food.ec.europa.eu/animals/animal-welfare/evaluations-and-impact-assessment/revision-animal-welfare-legislation_en and Fitness check of the EU Animal Welfare Legislation.
88 Compassion in World Farming.
89 Eurogroup for Animals.
90 Royal Society for the Prevention of Cruelty to Animals.
91 Aquaculture Stewardship Council.
92 Conservative Animal Welfare Foundation.
93 Fish Welfare Initiative.
94 Aquatic Animal Alliance.

- ensure appropriate diet to meet the nutritional needs of farmed fish according to species and stage of life and restricting the use of fasting periods to only those that are essential and in any case for no longer than is required for fish welfare benefits;
- prohibit mutilations;
- promote husbandry practices that ensure good health and lower the risk of disease;
- develop contingency plans for anticipated risks.

4.4. Guidelines related to fish welfare

The welfare of farmed fish is an issue of increasing interest to the public, producers, the scientific community, and public authorities. Many organisations of both public and private interest have published **guidelines on fish welfare**. The main driver for these publications was to fill the gap between the outcomes from the recent research initiatives and the operational measures in place in fish farming practices. Given the diversity of the sector, both in terms of species farmed and production systems, most of the guidelines are generic and very few of them are species-specific. In this category, the EFSA holds an executive position because of its numerous **scientific opinions on fish welfare** for all species of major importance for the EU. Guidelines are not mandatory; they are used on a consultative or voluntary basis. The guidelines and codes of conduct related to fish welfare aspects will be presented below.

4.4.1. Council of Europe

The **Council of Europe** (CoE) approved a recommendation concerning farmed fish[95] laying down various provisions for owners and staff, both on daily handling, farming facilities and equipment and on special situations as emergency killing, fish investigation and injuries. The recommendation is not binding to the Member States; however, it provides a policy framework and proposals that governments can implement on the national level. For the CoE, the objective on farmed fish welfare is avoiding '*detrimental effects on their welfare, including health*', considering the scientific evidence, the practical experience available, and the farming system used. In that context, Member States are required to ensure that owners or keepers take '*all reasonable steps*' to ensure the welfare of animals under their care and to ensure that those animals are '***not caused any unnecessary pain, suffering or injury***.' This is a general claim, commonly used by most guidelines and standards on the one hand, and by laws and governmental regulations when available on the other. In order to put this general provision into practice, the CoE recommends that specialised (?) personnel should recognise the health and behaviour of the fish and: "*appreciate the suitability of the total environment for the fishes' welfare, including health*". The Council of Europe recognises the diversity of production systems and species reared and for this reason adds that this recommendation should be *"[…] completed with species-specific appendices, as soon as adequate scientific knowledge or practical experience, in particular on the requirements for water quality, stocking density, feeding, social behaviour and environmental structures*". The effect of this recommendation is not binding for Member States, although it sets clear objectives.

[95] Council of Europe (2005). Recommendation concerning farmed fish adopted by the Standing Committee of the European Convention for the Protection of Animals Kept for Farming Purposes (T-AP) on 5 December 2005. Council of Europe. Available at: https://www.coe.int/t/e/legal_affairs/legal_co-operation/biological_safety_and_use_of_animals/Farming/Rec%20fish%20E.asp.

4.4.2. World Organisation for Animal Health

In 2008, the **World Organisation for Animal Health** (WOAH) adopted the **Aquatic Animal Health Code**[96], setting out standards on the welfare of farmed fish. Acceptance of the WOAH Code relies on an **honour system of conduct** between the official authorities for animal health. The Aquatic Animal Health Code sets out **general principles** for using handling methods appropriate to the biological characteristics of fish and the environment in which they are farmed, and special recommendations on their welfare during transport and slaughter. The Aquatic Code recommends the need to improve welfare during **slaughter**. It states as a general principle that farmed fish should be stunned before killing, and that the method should ensure immediate and irreversible loss of consciousness. Correct **stunning** includes loss of body and respiratory movement. Specific recommendations are given in **Article 7.3.6** for the different killing methods (electrical stunning, percussive stunning, spiking, coring, or shooting; chilling with ice in holding water, carbon dioxide in holding water, live chilling with ice and CO_2 in holding water, etc.). For **live fish transport,** there are recommendations about the characteristics of vehicles and fish handling equipment, the water parameters to be monitored during the trips and preparatory actions before starting the trip and loading the fish. WOAH calls for substantial **improvements in species-specific knowledge** in order to be able to **lay down a regulatory system** based on fish behaviour, physiology, disease indicators and indicators of poor welfare.

4.4.3. EU Platform for Animal Welfare

The '**EU Platform for Animal Welfare**' is an EU Commission initiative to promote a dialogue on animal welfare among competent authorities, scientists, operators, and civil society. In 2021, the EU Platform for Animal Welfare published the '**Guidelines on Water Quality and Handling for the Welfare of Farmed Vertebrate Fish**'[97]. Specific guidelines about **critical water parameters** for fish welfare are presented for the different development stages and for different practices (i.e. live fish transport), however **no species-specific figures** are provided as the guidelines are not species-specific. Guidelines for **fish handling** have also been elaborated. Requirements about employees' **technical knowledge** and hands-on practice are described. Specific instructions about **how to handle the fish** during sampling, transfer between tanks, loading on trucks for live transport, sampling for health examinations and harvesting are included. In addition, in the case of handling standards, the guidelines are generic, or **production system requirements** are not taking in account. It is intended to continue working on species-specific guidelines.

4.4.4. Code of conduct for the Mediterranean fish farming sector

This is a **voluntary code of conduct** created as part of the PerformFISH Horizon 2020 project[98] by the Mediterranean Fish Farmers' Associations. Although the code of conduct is **not obligatory for members of** Federation of European Aquaculture Producers (**FEAP**), the fact that it has been developed by Mediterranean Fish Farmers Associations (FGM, APPROMAR, API, SFAMN, and CEE-CAA), in collaboration with relevant stakeholders, indicates that Mediterranean producers are aware of fish welfare issues. The code of conduct combines **mandatory requirements** referred to in relevant EU

[96] World Organization for Animal Health (2019). Aquatic Animal Health Code, twenty-second edition. Available at: https://rr-europe.woah.org/wp-content/uploads/2020/08/oie-aqua-code_2019_en.pdf.

[97] EU Platform on Animal Welfare Own Initiative Group on Fish (2022). Guidelines on Water Quality and Handling for the Welfare of Farmed Vertebrate Fish. Text available at: https://food.ec.europa.eu/system/files/2022-07/aw_platform_plat-conc_guide_farmed-fish_en.pdf.

[98] PerformFISH is a Horizon 2020 Research and Innovation Action http://performfish.eu/.

legislation and **good practices** on the farming of marine Mediterranean species. The four requirements referred to below are expected to contribute significantly to farmed fish welfare:

- ensure **optimal conditions** to growing;
- adopt **veterinarian health plans** to minimise diseases;
- adopt **good practices** relating to husbandry, vaccination, handling, feeding, transport, confinement and harvesting;
- **implement OWIs** (operational welfare indicators) to measure and report on welfare conditions.

In the same project, the producers' associations committed to supporting setting-up a **platform for** providing **figures for OWIs** on an individual farm basis.

4.4.5. Fish from Greece – the Mediterranean Fish Welfare Guide

This is another initiative for a **species-specific welfare guide** driven by producers. A 'Mediterranean Fish Welfare Guide' (Pavlidis M., Samaras A., 2020) prepared by the University of Crete with the active participation of the Scientific Technical Team of the Hellenic Aquaculture Producers' Organisation. The guide gives **details of all the major areas of concern** for fish welfare for practices in place in the production of marine Mediterranean species. There is a detailed presentation of the **physiological needs** of marine species, **environmental indicators** of fish welfare in production establishments, and selected biological **welfare indicators**. Finally, an assessment of **operational welfare indicators** for the different husbandry practices and fish development stages is presented. This guide is also used for **educational purposes** for the employees in Mediterranean marine fish farms and as **promotional material** for the stakeholders of the sector. Implementing the guide's recommendations will be mandatory for the members of the Hellenic Aquaculture Producers' Organisation.

4.4.6. European Food Safety Authority

The **European Food Safety Authority** (EFSA) recommends that provisions to improve welfare should be adapted to each **species**, to different production **systems**, and to the specific requirements of each life-**stage**.

Two general recommendations have been communicated by EFSA[99]:

- "*measures to improve welfare should be adapted to different production systems and should take into consideration the specific requirements of each life-stage', as well as during handling…*";
- the need to keep the fish in water with sufficient oxygen content, either by removing the fish as quickly as possible or by introducing fresh, oxygen-rich water into the catchpit.

Following the above recommendations, EFSA published a series of scientific opinions related to fish welfare on different husbandry systems and for stunning and killing fish, an operational practice of high concern for fish welfare.

More specifically, the following **scientific opinions** have been published by EFSA on **fish welfare**:

- **General approach** to fish welfare and to the **concept of sentience** in fish – Scientific opinion of the panel of Animal Health and Welfare;[100]

[99] https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2009.954.
[100] General approach to fish welfare and to the concept of sentience fish.

- Species-specific welfare aspects of the main systems of **stunning and killing** of farmed **sea bass** and **sea bream**; Scientific opinion of the panel of Animal Health and Welfare; [101]
- Species-specific welfare aspects of the main systems of **stunning and killing** of farmed **Atlantic salmon**; Scientific opinion of the panel of Animal Health and Welfare; [102]
- Species-specific welfare aspects of the main systems of **stunning and killing** of farmed fish: **rainbow trout**; Scientific opinion of the panel of Animal Health and Welfare; [103]
- Species-specific welfare aspects of the main systems of **stunning and killing** of farmed **carp**; Scientific opinion of the panel of Animal Health and Welfare; [104]
- Food safety considerations of animal welfare aspects of **husbandry systems** for farmed fish – Scientific opinion of the Animal Health and Welfare Panel on Biological Hazards.[105].

4.5. Stakeholder consultation

4.5.1. Consultation objectives and participation

The main objective of the **stakeholder consultation** conducted in the study was to gather information on (a) current **fish welfare** knowledge and practices and (b) **perceptions** towards fish welfare and practices prevailing in European aquaculture among fish farm owners, fish farm employees, aquaculture researchers, and animal welfare NGOs.

To this end, a questionnaire was developed (see **Annex I**), translated into seven European languages (English, German, Spanish, Italian, Greek, Polish and Czech) and distributed online to the target groups. Methodological data and responses per target groups are presented in Tables 7 to 11. The response rate was moderate (in total **109 questionnaires** were received and analysed), given the difficulties to reach the target population, the time limits and the available resources. Response rate per target group and employment or occupation status per business location and Member State, are presented in **Tables 6 and 7**, respectively. Responses received per Member State (geographical location), per farmed species and per production system are shown in **Tables 8, 9 and 10**, respectively.

The low number of responses is an obvious limitation, especially when it comes to subgroups (different countries, different types of fish production), and the results cannot be generalised to the whole target group. This is why the approach was distinctly called "stakeholders consultation" and not "survey"; given the aforementioned limitations we could not run a probability sampling method, therefore, we did apply a snowball - purposive technique (non-probability method) to get at least an idea of what stakeholders think about fish welfare.

[101] Species specific welfare aspects of the main systems of stunning and killing of farmed Sea bass and Sea bream.
[102] Species specific welfare aspects of the main systems of stunning and killing of farmed Atlantic Salmon.
[103] Species specific welfare aspects of the main systems of stunning and killing of farmed fish: Rainbow trout.
[104] Species specific welfare aspects of the main systems of stunning and killing of farmed carp.
[105] Food safety considerations of animal welfare aspects of husbandry systems for farmed fish.

Table 6: Response rate per target group

Target group	Completed questionnaires
Fish farm owners	20
Fish farm employees	37
Researchers specified on the topic	22
Animal welfare NGOs	10
Other	20
Total	**109**

Source: Own elaboration

Table 7: Employment or occupation status per business location and Member State

Target group	CZ	IT	DE	EL	PL	ES	Other	Total
Fish farm owners	3	6	4	1	3	2	1	20
Fish farm employees	4	4	1	9	3	16	0	37
Researchers	1	0	6	4	1	6	4	22
Animal welfare NGOs	1	0	4	0	1	0	4	10
Other	0	0	6	3	0	4	7	20
Total	**9**	**10**	**21**	**17**	**8**	**28**	**16**	**109**

Source: Own elaboration
Note: CZ: Czechia, IT: Italy, DE: Germany, EL: Greece, PL: Poland, ES: Spain

Table 8 Geographical location of the production process

Member State	Frequency	%
CZ	9	8.3
IT	10	9.2
DE	21	19.3
EL	17	15.6
PL	8	7.3
ES	28	25.7
Other	16	14.6
Total	**109**	**100.0**

Source: Own elaboration
Note: CZ: Czechia, IT: Italy, DE: Germany, EL: Greece, PL: Poland, ES: Spain

Table 9: Geographical location of the production process according to farmed species

Fish species	Geographical location of the production process							
	CZ	IE	IT	DE	EL	PL	ES	Other
Atlantic salmon		X						X
Rainbow trout	X	X	XX	XX		X	XX	X
Carp	XX		X	X		XX		XX
Gilthead sea bream			X		XXX		XXX	X
European sea bass		X	X		XXX		XXX	X

Source: Own elaboration
Note 1: CZ: Czechia, IE: Ireland, IT: Italy, DE: Germany, EL: Greece, PL: Poland, ES: Spain
Note 2: X = less than 5 answers, XX = 5 to 10 answers, XXX = more than 10 answers

Table 10: Number of participants per production system type

Production system	Number of participants
Open sea cages	35
Flow-through tanks and raceways	48
RAS	24
Ponds	39

Source: Own elaboration

4.5.2. Main results

The **main results** of the stakeholders' consultation were (**Tables 11 and 12**):

- The stakeholders unanimously stated that **improving welfare** will, in parallel, **improve the quality of fish** offered on the market.
- Fish farmers agree on the need to develop **species-specific training courses** for their personnel.
- It is commonly agreed among researchers, that observed mortalities of a given fish cohort, body injuries, inferior appearance and frequent disease outbreaks are **signs of poor welfare** conditions during farming.
- The vast majority of the fish farm owners and fish farm employees stated that they do **monitor the welfare indicators** (mortalities, injuries, diseases, and/or inferior appearance) on a regular basis during pre-growing and on-growing and most of them do so during larval rearing and harvesting.
- Most of the fish farmers and owners are aware of **operational welfare indicators**, which they perceive as useful tools to monitor welfare on-site.
- Most of the fish farmers and owners stated that they do not apply a **scoring system of welfare indicators** to assess fish welfare status on-farm.
- It is a common ground among researchers that **elevating stocking densities** can impact fish welfare.

- There is disagreement between fish farm employees and researchers on whether **immersion in ice-slurry as a slaughter method for warm water fish** respects animal welfare. While fish farm employees consider it a slaughter method that respects animal welfare, researchers do not.
- Most of the fish farm owners believe that EU rules regarding the **protection of fish during transport** are adequate, whereas not all researchers and NGOs share their views. There is a visible minority among researchers and NGOs that believes EU rules on the protection of fish during transport are not adequate.
- While most researchers and fish farm employees believe that there is a **need for a European welfare label** to certify audited, high welfare fish production, most fish farm owners disagree.
- The various stakeholders share the view that it is important to implement a **morphological indicator scoring system**, as well as a **behavioural indicator scoring system** to monitor the welfare of live fish.
- Only a small minority of the fish farm owners know that **electro-sedation technology** is available for slaughter processes in open net-pen sea cages.

Table 11: Analysis of stakeholder's responses per specific question

Y=Yes/Agree, N= No/Disagree, N/O=No opinion	Fish farm owners			Fish farm employees			Researchers			NGOs		
%	Y	N	N/O	Y	N	N/O	Y	N	N/O	Y	N	N/O
Improving fish welfare will also improve fish quality	90	5	5	95	5	0	87	8	5	95	0	5
It is possible for the regulatory provisions to frame conditions that will improve fish welfare	40	35	25	54	27	19				70	10	20
There is a need for the development of species-specific fish welfare training courses	85	15	0	97	3	0						
The companies are interested to incorporate personnel training in fish welfare in the future	65	35	0	78	8	14						
It is justified enough that mortalities, injuries, diseases, and/or inferior appearance are related with poor welfare conditions							86	9	5			
They do monitor the welfare indicators (mortalities, injuries, diseases, and/or inferior appearance) on a regular basis during larval rearing	78	22	0	68	11	22	64	0	36			
They do monitor the welfare indicators (mortalities, injuries, diseases, and/or inferior appearance) on a regular basis during pre-growing	100	0	0	86	5	8	73	0	28			
They do monitor the welfare indicators (mortalities, injuries, diseases, and/or inferior appearance) on a regular basis on-growing	100	0	0	86	5	8	82	0	18			

They do monitor the welfare indicators (mortalities, injuries, diseases, and/or inferior appearance) on a regular basis during harvesting	85	5	10	84	5	11	77	0	23			
Operational welfare indicators are currently available for fish farmers	75	20	5	92	3	5	68	18	14	70	20	10
Operational welfare indicators are useful tools to monitor welfare on-site	85	10	5	97	3	0	91	9	0	90	10	0
They do apply scoring system of welfare indicators to assess fish welfare status on-farm	40	60	0	40	49	11						
Specific maximum stocking densities (expressed in kg of biomass per m^3 of water volume) should be set according to the rearing system used	35	45	20	51	32	16	64	18	19			
Specific maximum stocking densities should be set according to the water temperature	45	45	10	38	46	16	50	27	23			
Specific maximum stocking densities should be set at larval rearing	15	60	20	35	41	24	45	27	28			
Specific maximum stocking densities should be set on-growing	35	50	15	59	24	17	68	14	19			
Specific maximum time out of water should be set during operations such as grading and vaccination	20	60	20	35	38	27	82	9	9			
Stunning methods are required to induce immediate or rapid state of unconsciousness prior to slaughter	75	10	15	81	14	5	77	9	14			
Immersion in ice-slurry is a respectful of animal welfare slaughter method for warm water fish	25	15	55	51	19	30	23	50	27			

EU rules are on the protection of fish during transport adequate	70	0	30				36	32	32	60	30	10
Accepted mortality percentages should be decided/developed at each respective production phase	50	30	20	77	16	7	54	23	23			
It is possible to use improved fish welfare as a marketing tool compared to competitive products (wild fish, imported from non-EU countries, other farmed)	65	25	10	76	16	8						
It is possible for an intensive EU legislative framework on farmed fish welfare to be a marketing tool compared to competitive products	50	40	10	73	19	8				80	10	10
There is a need for a European welfare label to certify audited, high welfare fish production	20	50	30	52	24	24	60	8	32			
It is important to implement a morphological indicator scoring system to monitor the welfare of live fish	60	30	10	65	14	21	82	9	9			
It is important to implement behavioural indicators scoring system to monitor the welfare of live fish	65	25	10	68	16	16	82	5	13			
Electro-sedation technology is available for slaughter processes in open net-pen sea cages	10	25	65	38	16	46	5	41	54	50	0	50

Source: Own elaboration

Table 12: Analysis of responses by fish farmers to specific questions

Questions	**Responses by fish farmers**			
	Simple quantitative recording	Post mortem analysis on-site	Further investigation of mortality causes unexplained or unattributed to fish health	All the above
Which of the following processes for **monitoring mortality** do you use on the fish farm?	X	0	0	XXX
	Temperature increase	Water shortage	Increased pathogen pressure	Predators
Which of the following **climate/environmental factors** do you think affect the welfare of your fish?	XXX	XXX	XXX	XX
	Justification of need	Employee training	Impacts on productivity	Investment funds
Among the following ones, what are the main obstacles to adopting **new techniques**?	XX	X	X	XXX
Among the following ones, what are the main obstacles to adopting **new legislative requirements**?	XXX	X	XX	XX
	Direct funding	Employee training	Finance research	Impose equal legislative requirements to competitive products
What are the **most useful tools** for mitigating potential impacts when transitioning to new fish welfare requirements?	XXX	XX	X	XX

Source: Own elaboration
Note 1: It should be noted that the results per targeted sub-group cannot be generalised to the respective populations, due to small numerical bases. Nevertheless, the results are clear indications of the attitudes and perceptions of each stakeholder group studied.
Note 2: X = less than 5 answers, XX = 5-10 answers, XXX = more than 10 answers
Zero answers: respondents stated that they do not use post mortem analysis on-site or further investigation of mortality causes unexplained or unattributed to fish health

4.6. Conclusions on current regulatory framework

Over the last 40 years, the European Union has adopted a very comprehensive and advanced set of legislation on animal welfare. Nevertheless, for farmed fish there is a **need to improve the legislative framework on animal welfare**, such as Directive 98/58/EC, to include a more in-depth focus on fish welfare and to incorporate the latest scientific advances in this field. The updated legislation should include:

- the fundamental **legislative goals** and the general **fish welfare principles**;
- the **delegation of authority** and establishment of **enforcement mechanisms**;
- the **framework** for the development of **secondary laws** on important **areas of fish welfare**, such as management, handling/keeping, transportation and slaughtering.

4.6.1. Legislation goals and principles

The main scope of legislation on fish welfare should be the **improvement of farming conditions and practices** to secure high standards of fish welfare **uniformly across the EU** for each **species** and for all different farming **systems** and to the specific requirements of each **life-stage.** They should safeguard fish health status, the avoidance of any unnecessary pain, suffering and injuries, the provision of nutritious feed and **the ability of fish to express their natural behaviour in the farming installations**. In this respect, it is important to ensure level playing conditions with fish farmed in non-EU countries for placing on the EU market.

4.6.2. Delegation of authorities and enforcement mechanisms

Competent authorities should be specific at EU, national and regional level according to the governance structure of each Member State. Competent authorities should be staffed by qualified experts trained in fish physiology and aquaculture practices. Physical audits on a regular basis should be performed. The frequency of the physical audits should be decided based on a risk analysis scheme involving the farmed species, the farming system and the findings of previous audits. Structured questionnaires and audit check lists per farming system and species farmed should be the same or equal across the EU.

4.6.3. Legislative framework

The knowledge recently gained about fish welfare should be incorporated into secondary legislation that has yet to be developed. A regulation focused on fish welfare or updates of existent regulations for the protection of animals during transport, for the protection of animals at the time of slaughter and finally for the access to nutritious feed and veterinarian treatments should include general requirements respecting fish welfare. Given the fact that the available technology and scientific evidence described so far are not at the same level for all species, there is the need either to incorporate species-specific requirements as annexes on fish welfare regulations or to promote the development of industrial codes of practice.

According to Article 152 of the CMO Regulation (EU) No 1308/2013[106], codes of good practices can be among the main objectives of producer organisations. If those practices are covered appropriately by

[106] Regulation (EU) No 1308/2013 of the European Parliament and of the Council establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R1308

industry codes of practice for the species concerned, they can be considered as accepted good practice and it should be possible to enforce them directly, under a double umbrella: their general acceptance by the industry as a source of law, and the general laws which in most Member States include the duty to respect animal welfare, prohibit animal cruelty and stressful treatment throughout their entire life cycle, including the methods used to slaughter them. Codes of practice adopted from producers' organisations or associations should be submitted for approval by the competent authorities. Competent authorities should verify that the codes of practice are in line with the requirements of fish welfare legislation, respect the principles of EU legislative framework for fish welfare and contribute to the implementation of the scope of the legislation. Following verification by the competent authority, the code of practice will be obligatory for the members of producers' organisations and associations and be enforceable.

5. CONCLUSIONS

5.1. SWOT analysis

The SWOT analysis, a very helpful managerial tool to illustrate strategies in specific areas of interest, was applied in the current study to answer the specific research questions, with the aim of providing reliable answers on animal welfare issues. The following **criteria** were used in the SWOT analysis:

a) Where the **production methods** in place in EU fish farming sector **safeguard fish welfare**?

b) Where the **production methods** in place in EU **are weak in fish welfare**?

c) Which **fish welfare improvements** based on peer reviewed literature can provide **opportunities** to exploit?

d) Which fish **welfare improvements** based on peer reviewed literature can **threaten the production systems** in place?

Outcomes of the SWOT analyses were used as points of differentiation between the welfare status of aquatic animals farmed in the EU and farmed fish from non-EU countries.

5.1.1. Strengths

- The EU legislation acknowledges fish as **sentient animals** and requires active **preventive measures** to minimise avoidable suffering, distress, and pain.
- A **legal framework exists** for farmed fish welfare, including feed ingredients, obligation for traceability at farm / batch level, restrictions for veterinary treatments, farm registration, and farm biosecurity and hygiene status.
- When being compared to other farmed fish production countries, the EU aquaculture sector has several **welfare practices already in place**.
- Producers acknowledge that **product quality will be enhanced** if welfare is further improved.
- EU consumers prefer the **consumption** of locally produced fish or fish produced in the EU.
- There are well-established **co-operations between producers and researchers** on aquatic animal welfare research.

5.1.2. Weaknesses

- **Lack of common farmed fish welfare legislation** across the Member States.
- **Broad range of production systems**, methodologies, and environments for fish in the EU.
- **Lack of specific preventive welfare measures** for high risk activities and operations, such as transportation of live fish and harvesting/slaughtering practices.
- Scientific data have not fully addressed the **welfare impact of several routine practices**.
- **Consumers are not aware** of the existing EU framework for fish welfare and there is no indication on consumer-faced products about farming fish under this framework.
- **Lack of trust** between **aquatic animal producers and NGOs** interested on animal welfare.

- **EU farmed fish production is more expensive** than competitors' products imported from non-EU-countries. A firm commitment on the part of the European Commission on the application of **level playing field mechanisms is lacking**.

5.1.3. Opportunities

- The **EU is committed to improve animal welfare of fish** produced in EU territory, as set out in the European Green Deal and its Farm-to-Fork Strategy.
- The EU is committed to **improve the legislative framework** for aquatic animal welfare.
- Improved fish welfare conditions are likely to **boost production efficiency** and **product quality**.
- Promoting a **better image of EU fish farming** as a food production activity that respects animal welfare and protects animal health.
- European fish farming is becoming **more recognised as a commercial sector**, increasing its potential to attract investment.
- Putting financial tools in place to **support the sector's shift** to better animal welfare practices.

5.1.4. Threats

- **Consumer behaviour discrepancy**: on the one hand, the EU public demands significant improvements in the welfare of farmed species intended for human consumption; on the other hand, consumers often choose cheaper products from outside the EU without any considerations to animal welfare.
- **New legislation** on aquatic animal welfare **might create burdens and obstacles to farming operations in EU territory** and could negatively impact the competitiveness of EU farmed products.
- How will the proposed **legislation be enforced**?
- **Loss of consumer trust** due to negative campaigns by consumer groups interested in animal welfare and nature conservation.
- In **non-EU countries,** competitive products for the EU market are produced under **less stringent legal frameworks** and at lower cost.

5.2. Rearing systems, husbandry and fish welfare

All farmed fish have **common welfare needs**, i.e. adequate nutrition, proper water quality, good health/fitness, behavioural freedom, and safety. However, different **lifestyles**, **species-specific differences** in stress tolerance and disease resistance, and **individual differences** within species should all be considered when assessing welfare status and husbandry practices in the different production systems.

The published literature critically evaluates **common practices and operations of concern for welfare**, such as handling, grading, transportation, vaccination, veterinary treatments, anaesthetisation, and stunning / slaughtering. There are reports available on production practices that cause pain and suffering to animals and disrupt their wellbeing. However, further research is needed on several other practices and daily/routine operations. Moreover, in specific cases, there is a lack of rules in place to manage welfare risks.

A **series of actions** are needed to safeguard farmed fish welfare in EU territory. These actions will help operators to make further improvements to the welfare of fish farmed in the EU by addressing the scientifically verified welfare risks. This report could provide a sound basis for a structural dialogue between the EU institutions. The **conclusions** include elements relevant for the EU decision-making process bearing in mind the European Parliament competencies:

- **Improve the legislative framework** on animal welfare, such as Directive 98/58/EC, with clearly defined provisions to avoid suffering, pain, and distress of fish in farming operations, focusing also on fish welfare and incorporating the latest scientific advances in this field. The updated legislation should include: (a) fundamental legislative **objectives** and general fish welfare **principles**; (b) the delegation of **authority** and establishment of **enforcement** and official auditing mechanisms; and (c) a framework for the **development of secondary legislation** on areas such as management, handling/treatments, transportation, and slaughter.
- **Legislation on fish welfare has to be linked to** the legal frameworks in place regarding **feed** ingredients, aquatic animal **health**, aquatic animal **traceability**, **veterinary treatments** applied, as well as **farm hygiene** and **biosecurity**.
- Taking into account the different lifestyles and welfare needs of different fish species, the variety of production systems, husbandry practices and managerial methods, there is a need to incorporate science-based **species-specific requirements as Annexes to fish welfare regulations**.
- Finance campaigns to **showcase best practices** of fish farming companies in the EU. Good practices in place related to fish welfare, measures to secure fish health, feed ingredient requirements to preserve food safety and nutritional value and provisions in place to safeguard minimal environmental footprint must be promoted further to EU consumers.
- Finance **research** projects to cover the **knowledge gaps** on **fish welfare needs**, in cooperation between researchers and producers.
- Support **research** on the characterisation of **welfare needs and risks** at different production phases and fill the knowledge gaps, especially at early development and at harvest.
- Support **research** on the development of **operational welfare tools** and species-specific **welfare scoring systems**.
- Support **research** on **disease and predator prevention** and mitigation (vaccines, novel treatments, monitoring on predation).
- Hold **round table discussions**, hosted by EU institutions, between the producers, academia and NGOs, working towards an action plan to improve farmed fish welfare. Provide regular publicity for achievements and common actions.
- Provide **structural funds** to the industry to assist the **transition to** recent technological advances in **welfare monitoring** and **humane slaughter**.
- Assign **responsibilities** regarding fish welfare: nominate a person in charge (**welfare officer**) of ensuring the implementation of welfare recommendations and preparing all relevant documentation (annual report to competent authorities).
- Implement validated, **indicator-based welfare monitoring** in order to provide a scientifically sound basis for an assessment of the welfare status of fish produced in the EU. Provide **records**

and reporting on fish welfare related outputs, including mortalities, injured animals, and disease outbreaks at each production phase.

- Promote the **training of veterinarians** and **health professionals** who specialise in fish to provide sufficient support to EU aquaculture.
- Support personnel **training on welfare** by authorised educational institutions and training centres, such as (a) short-term executive training for welfare officers and (b) generic training for staff who handle fish on welfare aspects and operational working instructions.
- Establish mechanisms to maintain the same **level playing field** with competitors' products imported from non-EU countries.

6. POLICY RECOMMENDATIONS

The following recommendations are set out:

1. Encourage scientific, ethical and public **debate**, and support multi-disciplinary **research** on welfare of farmed fish.
2. Support research on the identification of **welfare needs** and standards for farmed fish species in different farming systems and production phases, especially during early development and at harvest.
3. Support research on the development of **technological tools** to monitor and analyse farmed fish **behaviour** on-site.
4. Support research on the development of reliable and user-friendly **operational welfare tools** for the assessment of farmed fish welfare.
5. Support the development of species-specific **welfare scoring systems** to ensure welfare assessment by fish farmers on-site and evaluation of farmed fish welfare status by the competent authorities.
6. Emphasise on the development and implementation of **humane slaughter methods**.
7. Develop and promote fish welfare **training courses for veterinarians** and health professionals, who specialise in fish to support fish farm staff.
8. Develop and promote **basic training programmes for fish farmers** to provide fundamental knowledge on fish biology and behaviour, relevant EU and national regulations and standards, husbandry procedures that can cause suffering, and good husbandry practices leading to improved fish welfare.
9. Develop and promote **life-long education and training of fish farm personnel** to certify that staff responsible for the care of fish is competent, well-trained and have management skills appropriate to the technical requirements of the farming system and production phase.
10. Nominate a **welfare officer** for each fish farm. The person in charge must safe-guard that fish welfare needs and the implementation of fish welfare recommendations are taken care of. The welfare officer is responsible for preparing all relevant documentation for the competent authorities (annual report on fish welfare related outputs, including mortalities, injured animals, and disease outbreaks).
11. Develop **support measures for the industry** to incorporate recent technological advances for implementing welfare monitoring and humane slaughter methods.
12. Improve the **legislative framework on animal welfare**, for example through amending Directive 98/58/EC, with clearly defined provisions to avoid suffering, pain, and distress of fish in farming operations, focusing also on fish welfare and incorporating the latest scientific advances in this field. The updated legislation should include:
    a) the fundamental legislative **objectives** and general fish welfare **principles**,
    b) the delegation of authority and establishment of enforcement and **official auditing mechanisms**, and
    c) the framework for the development of secondary legislation on areas such as **management**, **handling**/treatments, **transportation**, and **slaughter**.

13. Incorporate **species-specific requirements** as annexes of animal welfare legislation and/or promoting the development of codes of good practice by interested parties (i.e. producer organisations).

ANNEX
STAKEHOLDER QUESTIONNAIRE

Introduction

The aim of the questionnaire is to record the opinions of stakeholders regarding the current welfare status of farmed fish and the ways in which it can be improved. Each production stage poses different challenges for fish welfare. The production stages considered in this research are as follows:

Breeders, larva rearing, pre-fattening, juvenile transport, feeding, health management, husbandry, harvesting, live fish on market.

General information

1. What is your current employment status?

A. Fish farm owner

B. Fish farm employee

C. Researcher

D. NGO

E. Other

2. Where is your business located?

A. Czech Republic

B. Denmark

C. Ireland

D. Italy

E. France

F. Germany

G. Greece

H. Poland

I. Portugal

J. Spain

3. Your fish farm produces …

A. Atlantic salmon

B. Rainbow trout

C. Carps

D. Gilthead sea bream

E. European sea bass

4. The main production takes place in …. You may choose more than one answer.

A. Open sea cages

B. Flow-through tanks and raceways

C. RAS

D. Ponds

Specific questions

Q1. Do you believe that improving fish welfare will also improve fish quality?

A. Definitely not related

B. Probably not related

C. Probably related

D. Definitely related

E. I don't know

F. I don't want to answer

Q2. Is it possible for regulatory provisions to frame the conditions/practices that will improve fish welfare?

A. Yes

B. No

C. I don't know

D. I don't want to answer

Q3. Do you agree that there is a need for the development of species-specific fish welfare training courses?

A. Strongly agree

B. Agree

C. Somewhat agree

D. Somewhat disagree

E. Disagree

F. Strongly disagree

G. I don't know

H. I don't want to answer

Q4. Is your company interested in training personnel on fish welfare in the future?

A. Yes

B. Probably yes

C. Probably no

D. No

E. I don't know

F. I don’t want to answer

Q5. Is it adequately proven that mortalities, injuries, diseases, and/or inferior appearance are related to poor welfare conditions?

A. Definitely not related

B. Probably not related

C. Probably related

D. Definitely related

E. I don't know

F. I don’t want to answer

Q6. Do you monitor the welfare indicators referred to in Q5 (mortalities, injuries, diseases, and/or inferior appearance) on a regular basis during:

A. Larval rearing Yes / No

B. Pre-growing Yes / No

C. On-growing Yes / No

D. Harvesting Yes / No

E. I don't know

F. I don’t want to answer

Q7. Do you agree that operational welfare indicators (i.e. those which can be assessed on-farm) are currently available for fish farmers?

A. Strongly agree

B. Tend to agree

C. Tend to disagree

D. Strongly disagree

E. I don't know

F. I don’t want to answer

Q8. Do you believe that operational welfare indicators (i.e. those which can be assessed on the fish farm) are useful tools to monitor welfare on-site?

A. Strongly agree

B. Tend to agree

C. Tend to disagree

D. Strongly disagree

E. I don't know

F. I don’t want to answer

Q9. Do you apply a scoring system of welfare indicators to assess fish welfare status on-farm?

A. Yes

B. No

C. Partially

D. I don't know

E. I don't want to answer

Q10. Do you think that specific maximum stocking densities (expressed in kg of biomass per m^3 of water volume) should be set according to the rearing system used?

A. Yes

B. No

C. I don't know

D. I don't want to answer

Q11. Do you think that specific maximum stocking densities should be set according to the water temperature?

A. Yes

B. No

C. I don't know

D. I don't want to answer

Q12. Do you think that specific maximum stocking densities should be set at…?

A. Larval rearing Yes / No

B. On-growing Yes / No

C. I don't know

D. I don't want to answer

Q13. Do you think that specific maximum time out of water should be set during operations such as grading and vaccination?

A. Yes

B. No

C. I don't know

D. I don't want to answer

Q14. Do you agree that stunning methods are required to induce an immediate or rapid state of unconsciousness prior to slaughter?

A. Yes

B. No

C. I don't know

D. I don't want to answer

Q15. Do you believe that immersion in ice-slurry is a slaughter method for warm water fish that respects animal welfare?

A. Yes

B. No

C. I don't know

D. I don't want to answer

Q16. Are EU rules on the protection of fish during transport adequate?

A. Adequate

B. Fairly adequate

C. Not very adequate

D. Not adequate

E. I don't know

F. I don't want to answer

Q17. Do you believe that accepted mortality percentages should be decided/developed at each respective production phase?

A. Yes, in all phases

B. Yes, in most phases

C. Yes, in a few phases

D. No

E. I don't know

F. I don't want to answer

Q18. Which of the following processes for monitoring mortality do you use on the fish farm?

A. Simple quantitative recording

B. Post mortem analysis on-site

C. Further investigation of mortality cause unexplained or unattributed to fish health

D. All the above

E. None of the above

F. I don't know

G. I don't want to answer

Q19. Is it possible to use improved fish welfare as a marketing tool compared to competitors' products (wild fish, imported from third countries, other farmed)?

A. Definitely possible

B. Probably possible

C. Probably not possible

D. Definitely not possible

E. I don't know

F. I don’t want to answer

Q20. Is it possible for an intensive EU legislative framework on farmed fish welfare to be a marketing tool compared to competitors’ products (wild fish, imported from third countries, other farmed)?

A. Definitely possible

B. Probably possible

C. Probably not possible

D. Definitely not possible

E. I don't know

F. I don’t want to answer

Q21. Is there a need for a European welfare label to certify audited, high welfare fish production?

A. Yes

B. No

C. I don't know

D. I don’t want to answer

Q22. The implementation of a morphological indicators scoring system to monitor the welfare of live fish is:

A. Important

B. Moderately important

C. Not important at all

D. I don't know

E. I don’t want to answer

Q23. The implementation of a behavioural indicators scoring system to monitor the welfare of live fish is:

A. Important

B. Moderately important

C. Not Important at all

D. I don't know

E. I don’t want to answer

Q24. Do you believe that electro-sedation technology is available for slaughter processes in open net-pen sea cages?

A. Yes

B. No

C. I don't know

D. I don’t want to answer

Q25. Which of the following climate/environmental factors do you think affect the welfare of your fish?

A. Temperature increase Yes / No
B. Water shortage Yes / No
C. Increased pathogen pressure Yes / No
D. Predators Yes / No
E. None of above
F. I don't know
G. I don't want to answer

Q26. Among the following, what are the main obstacles to adopting new techniques in your operations? <u>You may choose more than one answer</u>.

A. Justification of need
B. Employee training
C. Impact on productivity
D. Investment funds
E. I don't know
F. I don't want to answer

Q27. Among the following, what are the main obstacles to adopting new legislative requirements? <u>You may choose more than one answers</u>.

A. Justification of need
B. Employee training
C. Impact on productivity
D. Investment funds
E. I don't know
F. I don't want to answer

Q28. Choose the most useful tools for mitigating the potential impact of transitioning to new fish welfare requirements. <u>You may choose more than one answer</u>.

A. Direct funding
B. Employee training
C. Research funding
D. Imposing equal legislative requirements on competitors' products
E. None of the above is a useful tool for me
F. I don't know
G. I don't want to answer

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This study investigates the welfare of the main fish species reared in the European Union, and highlights current knowledge on fish welfare, knowledge gaps, fish needs and husbandry methods of concern for fish welfare. The study focuses on production systems and production phases in a species-specific way. Research includes a literature review, an evaluation of the regulatory framework, a stakeholders' consultation, case studies and a SWOT analysis. Conclusions and policy recommendations relevant to EU decision-making are provided.

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