Implementing the Strategic Guidelines for EU aquaculture

Good husbandry practices for aquaculture

European Maritime, Aquaculture and Fisheries Fund (EMFAF)

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LIST OF ACRONYMS

Term	Description
AAC	Aquaculture Advisory Council
AAM	Aquaculture Assistance Mechanism
ADD	Acoustic Deterrent Device
AGD	Amoebic Gill Disease
ASC	Aquaculture Stewardship Council
BIM	Bord Iascaigh Mhara (Ireland's Seafood Development Agency)
BoA	Board of Ambassadors of the Aquaculture Assistance Mechanism
CEFAS	Centre for Environment, Fisheries & Aquaculture Science
CI	Condition Index
CNC	Comité National de la Conchyliculture (France)
DG MARE	Directorate-General for Maritime Affairs and Fisheries
EC	European Commission
EAS	European Aquaculture Society
EE	Environmental enrichment
EEA	European Economic Area
EFFAB	European Forum of Farm Animal Breeders
EMFAF	EU Maritime, Fisheries and Aquaculture Fund
EFSA	European Food Safety Authority
EU	European Union
EUMOFA	European Market Observatory for Fisheries and Aquaculture Products
EWS	Early warning system
FAO	Food and Agriculture Organisation of the United Nations
FCR	Feed Conversion Ratio
FEFAC	European Feed Manufacturers' Federation
FF	Functional feed
FHF	Norwegian Seafood Research Fund
FOS	Fructo Oligosaccharides
FKSM	Fenugreek Seed Meal
GHP	Good Husbandry Practice
GMO	Genetically Modified Organisms
HAB	Harmful algae blooms
HAPO	Hellenic Aquaculture Producers Association
IAEA	International Atomic Energy Agency
INTECMAR	Instituto Tecnolóxico para o Control dorganico Medio Mariño de Galicia
IOC	Intergovernmental Oceanographic Commission
IPNV	Infectious Pancreatic Necrosis Virus

Term	Description
MAPA	Ministerio de Agricultura, Pesca y Alimentación (Spain)
MS	Member State
OIE	Office International des Epizooties (now WOAH)
PECH	European Parliament's Committee on Fisheries
PL	Polar lipid fraction
PVC	Polyvinyl chloride
RAS	Recirculating aquaculture system
RSPCA	Royal Society for the Prevention of Cruelty to Animals
RUMA	Responsible Use of Medicines in Agriculture Alliance
SB	Selective breeding
TRL	Technology Readiness Level
VHWP	Veterinary Health and Welfare Plan
WFD	Water Framework Directive
WOAH	World Organisation for Animal Health
WHO	World Health Organisation

1. INTRODUCTION

In May 2021, the European Commission adopted a *Communication on strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030*[1] ('the Strategic Guidelines'). These guidelines set the vision for EU aquaculture to grow into an even more competitive and resilient sector and become a global reference for sustainability by 2030. They are the result of extensive consultation with EU Member State experts on aquaculture and the Aquaculture Advisory Council (AAC) as well as a public consultation.

The Strategic Guidelines cover all issues that are relevant for the sustainable development of aquaculture in the EU and provide concrete recommendations and proposals for action to the Commission, Member States and the AAC. Among other actions, they propose that the Commission develops guidance and good practices on various aspects of aquaculture activities. In this regard, the Strategic Guidelines, in Annex I section 2.1.3, call for the Commission to "*map good husbandry practices, in particular environmental enrichment, the use of functional feed, and selective breeding*".

This document provides a non-exhaustive list of general and species-specific good husbandry practices (GHPs) on key topics related to welfare and health in the different production techniques of some of the main European aquaculture species, notably common carp *(Cyprinus carpio),* rainbow trout *(Oncorhynchus mykiss),* Atlantic salmon (*Salmo salar),* European sea bass (*Dicentrarchus labrax*), gilthead sea bream (*Sparus aurata*), and Mussels. In addition, two species of cleaner fish - ballan wrasse (*Labrus bergylta*) and lumpfish (*Cyclopterus lumpus*) – mainly used for sea lice control, have been considered. Due to the increasing demand for cleaner fish as biological controllers of Atlantic salmon lice, it is important to monitor their health and welfare in marine farms.

The selected GHPs aim to help implementing, in a practical way, key legal obligations for operators - and sometimes go beyond the key legal obligations – on animal health and welfare requirements and their relationship to the environment. The GHPs have been selected from the 27 EU Member States as well as from Norway and UK.

The document is intended primarily for aquaculture producers and is therefore designed to be practical and user-friendly. It also distinguishes between practices that are currently implemented by the sector and those related to innovative practices that are still under research, mainly coming from scientific literature.

[1] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030 (COM/2021/236 final) (Aquaculture guidelines (europa.eu)

This document will be updated in the future including additional GHPs and additional species-specific factsheets. The Commission will provide these updates via the EU Aquaculture Assistance Mechanism website[2]. It is important to note that hyperlinks included in this document are valid at the time of its publication. Updates of these hyperlinks might be necessary in the future, and they will also be provided via the EU Aquaculture Assistance Mechanism website.

For aspects more specifically linked to farmed fish welfare, the Commission will support the development of a code of good practice. This code will build on aspects on fish welfare already covered in this document. The issues of "transport" and "slaughter" have been excluded from this document as they will be addressed in future Commission work.

Also, the issue of "predator control" covered in this document will be further developed in a future Commission document covering both health and welfare and biodiversity aspects.

[2] Aquaculture Assistance Mechanism website accessible at: https://aquaculture.ec.europa.eu/

2. OVERVIEW OF THIS DOCUMENT

To present the above contents, this document has been organised in different chapters and annexes, which are:

- List of topics covered by the GHPs (**Chapter 3**).
- Description of EU legislation, **general GHPs** on the selected topics and country specific examples **applicable to all the species** addressed in this document - except for mussels (**Chapter 4**).
- **Methodology**, describing the methodological approach used to produce this document (**ANNEX I**).
- **Description of 8 species-specific factsheets:** 1 factsheet per specie with GHPs for some of the main aquatic species which are currently farmed in the EU and for cleaner fish, at all stages of their life cycle (**ANNEX II**). These factsheets include a selection of the best and most useful GHPs per species, considering the topics presented in Chapter 3. Moreover, each factsheet includes - per each topic - a list of the key species-specific mandatory requirements under relevant EU legislation[3], a description of the GHPs, and information on the countries where the GHPs are implemented. When available, the factsheets include specific examples of application mainly in EU countries, Norway and the UK. The relevant documents used for the definition of GHP for each species are listed at the end of each factsheet in a specific section dedicated to references, which includes useful links to these sources.
- **EU legislation related to health and welfare of farmed fish (ANNEX III).**

The factsheets take into consideration **all types of production and stages of the life cycle** of the species and groups of species in Europe covered in this document. Most of the first stages (i.e. broodstock units, larvae and juveniles rearing) of the life cycle of these species are carried out mainly in Recirculating Aquaculture Systems (RAS) facilities. However, in the on-growing and harvest phases different technologies are used, as shown in the table below.

[3] To this end, 18 EU Regulations and Directives on animal health and animal welfare have been analysed (see Annex I). In addition, the EU Regulations on organic production and labelling of organic products (Regulations (EU) 2018/848 and 2020/464) have also been considered since organic production shall pursue the following general objective: “contributing to high animal welfare standards and, in particular, to meeting the species-specific behavioural needs of animals” (art. 4).

Figure 1. Types of aquaculture production technologies considered for the analysed species (on-growing and harvest phases)

Farmed species (on-growing + harvest)	Types of production technologies
Atlantic salmon	Net pens at sea and a few in RAS
Rainbow trout	RAS, land-based flow-through raceway systems and net pens at sea or lakes
Common carp	Ponds
European sea bass	Net pens at sea[4]
Gilthead sea bream	Net pens at sea[5]
Mussels	On-bottom culture, bouchot culture, longline culture, and raft culture
Ballan wrasse	RAS and net pens
Lumpfish	RAS and net pens

Source: Own elaboration

[4, 5] Please, note that the production of European sea bass and Gilthead sea bream in ponds and sea lagoons does not fall within the scope of this Background Document because it involves activities to improve the existing productivity of the natural resources of the pond/sea lagoon ecosystem rather than focused on health and welfare of the fish.

3. KEY TOPICS ADDRESSED

The "Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030" mention explicitly GHPs on "environmental enrichment (EE)", "functional feed (FF)" and "selective breeding (SB)". However, the scope of this document is broader and includes other basic topics that are important for the health and welfare of aquatic animals throughout the whole production cycle. The latter include "feeding," "handling," "mortality removal," "fallowing," "predator control," "minimising the risk of escapes," "water quality," "stocking densities," "disinfection and cleaning," as well as "vaccination and treatments" were relevant for a given species.

The selected topics take into consideration the five domains increasingly used in the aquaculture sector to define, quantify, and compare animal welfare with the aim of ensuring a "life worth living": i) nutrition, ii) physical environment, iii) health, iv) behavioural interaction, and v) overall mental state of the animal[6]. The following table presents the key topics addressed in this document as well as a brief description of each of them.

Figure 2. Description of key topics addressed

Topic	Description
Feeding	Feeding refers to the provision of food and nutrients to aquatic animals. It includes feeding and feeding-related activities, but not feed production per se. Feeding is a crucial operation in aquaculture as it has a direct bearing on the health and welfare of aquatic animals. Feeding should ensure both the availability of feeds for all fish in the farm at the right times and in appropriate quantities, and a match between the composition of the feeds and the nutritional requirements of the species for each growth stage. This promotes good health and development of aquatic animals and reduces undesirable social interactions.
Handling	Handling comprises different operations, the main ones being grading and harvesting. ➢ **Grading** is a means of separating larger fish from smaller ones. It represents an important part of rearing, as it prevents excessive size variations and competition, and promotes uniform fingerlings and juveniles' size. However, the grading process is stressful for the fish and requires the withdrawal of feed. ➢ **Harvesting** is the process of collecting aquatic animals that have reached commercial size. It is a delicate operation as it may involve stressing the animals and they may also suffer physical damage.
Mortality removal	Mortality removal refers to the method for extracting dead aquatic animals from a facility, as well as the periodicity with which it is carried out.

[6] https://bim.ie/wp-content/uploads/2021/11/Operational-Welfare-Indicators-Fish-Health-Guide.pdf

Topic	Description
Fallowing	Fallowing refers to the practice of allowing sites used for fish farming to recover for a part or entirety of a growing season. Fallowing is a recognised health management strategy known to assist in the control of disease transmission and parasite problems. The goal of fallowing is to break infection cycles by removing susceptible hosts and by decreasing infection pressure at a given location. Fallowing procedures should be based on an evaluation of anticipated benefits, site and area level risk factors, and disease history.
Predator control	Predator control relates to the use of methods that comply with relevant regulations to prevent some species from causing damage to or the loss of farmed aquatic animals (i.e. diving birds, such as cormorants, wading birds, i.e. herons and others such as otters).
Minimising risk of escapes[7]	Fish can escape in weather events like severe storms, from damaged nets, or during harvest operations. Escapes of aquatic animals can present risks to wild populations but also of farmed species, such as spread of diseases. Therefore, this topic relates to the use of methods aimed at preventing fish escapes to avoid health and welfare damages to farmed species.
Water quality	Poor water quality elicits a stress response in aquaculture animals. When the water conditions become too challenging, they cannot support homeostasis and experience chronic stress, which can impair immune function, growth, and reproductive function. Therefore, species-specific levels of water quality are desired for aquaculture production. This is fundamental to ensure the welfare of aquaculture animals. Some important parameters are oxygen, pH, and temperature, among others. The potential for serious welfare issues related to water quality is highest in intensive RAS where fish are raised at high densities in highly controlled environments with narrow margins for error.
Stocking density	Stocking density (also known as “per-unit stocking amount” or “stocking rate”) refers to the quantity of individuals per unit of water area, is expressed as the number or weight of fish per unit area (square metres) or water volume (cubic metres). Too high stocking densities can have a negative impact on the health and welfare of aquaculture animals. Appropriate stocking density contributes to fish welfare and ensures good water quality.
Disinfection & cleaning	Cleaning is the removal of dirt from solid surfaces. Ideally, cleaning should remove all bacteria. Disinfection first requires clean and dry surfaces. Disinfection consists of a chemical and physical process that kills microorganisms and brings their numbers to a level that is not harmful to health. Aquaculture facilities should be disinfected regularly after cleaning. It is important to also highlight the beneficial role of both microbes and the microbiome in good husbandry practices for aquaculture[8]. Disinfection needs to be followed by “microbial management” practices.
Vaccination & treatments	Vaccination is a preventive measure against diseases and is important to ensure good health and welfare of aquatic animals. A vaccine is defined as a biologically based preparation that is developed to improve immunity towards a specific disease or a group of diseases. Treatments refer only to the use of authorised or prescribed medicines to cure aquatic animals for a disease. Any factor producing stress or difficulty to the

[7] Please note that this topic will be addressed from an environmental perspective in the Guidance document on Environmental Performance developed by the AAM.

[8] For instance, water disinfection is an important step in ensuring proper biosecurity but this means that all the good bacteria are also killed and we have largely underestimated their important role in preventing opportunistic bacteria (especially Vibrio species) from taking over (express virulence through quorum sensing) and cause disease (different forms of Vibriosis) (Sorgeloos, P. et al, 2023)

Topic	Description
	aquatic animals decreases its resistance to disease and increases the likelihood of disease problems.
Environmental enrichment	Environmental enrichment refers to the modifications to the captive environment to enhance the level of physical and social stimulation provided to the aquatic animals by helping to cope better with stressful situations and improving cognitive abilities, as well as, to enhance the rearing environment and encourage the expression of normal species-specific behaviours. Environmental enrichment is a way of improving the living conditions of farmed fish, to promote positive mental and physical well-being. The broad types of enrichments include **social** (e.g., contact with other salmonids for schooling), **physical** (e.g., addition of objects, substrates, or shelters), **sensory** (e.g., appropriate tank colour), and **dietary** (e.g., varied, or novel feed types). Environmental or dietary changes need to be monitored to ensure that they positively enhance welfare and do not cause health and welfare or production issues.
Functional feed	Functional feed is foodstuff that provides specific health benefits beyond basic nutrition, by favourably affecting the physiological conditions of animals, including their resilience to stress factors. Functional feed does not include medicated feed, as defined in Regulation 2019/4, which is a route for administration of veterinary medicinal products under veterinary prescription to prevent, treat or cure a disease.
Selective breeding	Selective breeding includes programmes that improve quantitative observable or measurable characteristics (physical appearance, behaviour, metabolism, etc.) in populations of farmed fish. Selective breeding programmes have been conducted to improve growth rate, disease resistance, age at sexual maturity, survival, flesh quality and processing yields and other quantitative observable or measurable characteristics. The use of selective breeding is still relatively limited in aquaculture species, although a growing number of companies are starting to or have already initiated one or more selection programmes. The most frequently selected trait is growth performance, but the number of selected traits has been increasing over the years through the addition of disease resistance or product quality, among others.[9]

Source: Own elaboration

The topics presented above are addressed throughout the document, although some of them have been excluded from the factsheets dedicated to the species as they do not apply to all of them. For instance, in common carp aquaculture, "escapes" do not occur because there are no nets, or “treatments” do not apply to mussels. In addition, some topics such as "mortality removal" or "fallowing" are not included in all factsheets because very little information has been found.

The nomenclature of the topics has been used consistently in the document. However, some of them have been tailored to the specificities of the aquatic animals. In particular, this is the case of the factsheet on mussels, where the topic “Disinfection and cleaning” has been replaced by “Depuration and cleaning” and “Mortality removal” by “Disease prevention”.

[9] See the following report for further information on selective breeding: https://doi.org/10.1007/s10499-016-9985-0

Finally, GHPs related to “Minimising the risk of escapes” are common to all species and they have therefore only been included in the General Good Husbandry Practices factsheet.

4. GENERAL GOOD HUSBANDRY PRACTICES

This chapter includes a factsheet that compiles general GHPs that apply to all the aquatic animals[10] considered in the scope of this document, except mussels.

General Good Husbandry Practices for common carp, rainbow trout, Atlantic salmon, European sea bass, gilthead sea bream, ballan wrasse and lumpfish								
	General					Specific		
Topics addressed	Feeding	Handling	Mortality removal	Fallo-wing	Predator control	Environmental enrichment	Selective breeding	Functional feed
	☒	☒	☒	☒	☒			
	Minimi-sing risks of escapes	Water quality	Stocking densities	Disin-fection and cleaning	Vaccina-tion and treat-ments	☒	☒	☒
	☒	☒	☒	☒	☒			

FEEDING

Mandatory requirements

Mandatory requirements for fish farmers related to feeding are inter alia foreseen in the following EU legislation:

- Regulation (EC) No 178/2002[11]: Chapter I and II.
- Regulation (EC) No 1831/2003[12]: Chapter II.
- Regulation (EC) No 767/2009[13]: Chapter 2, article 4.1.b) and Chapter 3. Art 10 List of intended uses of feed intended for nutritional purposes.

In addition to the above mentioned horizontal rules, the following production rules apply for organic certified products: the main relevant provision concerning good feeding practices are following: Regulation (EU) 2018/848[14]: articles 6.m), 6.p) (in accordance with Regulation (EU) No 1380/2013 or with organic feed composed of agricultural ingredients resulting from organic production, including organic aquaculture, and of natural non-agricultural substances) and 8; Annex II, Part III, point 3.1.3. Other relevant rule for organic

[10] Please note that mussels have been excluded due to their specificities. In addition, some clarifications have been made for cleaner fish (i.e. lumpfish and ballan wrasse)

[11] Regulation (EC) No 178/2002 of the European Parliament and of 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.

[12] Regulation (EC) No 1831/2003 of the European Parliament and of the Council of 22 September 2003 on additives for use in animal nutrition.

[13] Regulation (EC) No 767/2009 of the European Parliament and of the Council of 13 July 2009 on the placing on the market and use of feed, amending European Parliament and Council Regulation (EC) No 1831/2003 and repealing Council Directive 79/373/EEC, Commission Directive 80/511/EEC, Council Directives 82/471/EEC, 83/228/EEC, 93/74/EEC, 93/113/EC and 96/25/EC and Commission Decision 2004/217/EC (Text with EEA relevance).

[14] Regulation (EU) 2018/848 of the European Parliament and the Council of 30 May 2018 on organic production and labelling of organic products and repealing Council Regulation (EC) No 834/2007.

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common carp, rainbow trout, Atlantic salmon, European sea bass, gilthead sea bream, ballan wrasse and lumpfish

aquaculture feeding is also under Implementing Regulation (EU) 2021/1165[15] for the feed ingredients which may be used as external inputs.

General good husbandry practices

1. Feeding practices must ensure that feed is provided in sufficient quantity and rate, over a large enough area and spread at regular intervals to minimise fish crowding and damage. These practices should be adapted to the species, life cycle stage, physiological state, and environmental conditions (IFA Aquaculture, 2017).
2. In large systems automatic feeders are required to better distribute and disperse the food (EFSA, 2008).

Examples

- Ireland implements GHP #1 for salmonid species.

HANDLING

Mandatory requirements

Mandatory requirements for fish farmers related to harvesting and grading are *inter alia* foreseen in the following **EU legislation**:

- Regulation (EC) No 853/2004[16]: Annex III, Section VIII.

The following production rules apply for organic certified products: the main relevant provision Regulation (EU) 2018/848 on organic production and labelling of organic products[14]: the main relevant provisions concerning good handling practices are set under points 3.1.6.1 3.1.6.2, 3.1.6.6, 3.1.6.7 and 3.1.6.9 of Part III of Annex II and under Commission Implementing Regulation (EU) 2020/464[17] Annex II.

General good husbandry practices

1. To ensure the welfare of the fish, any handling should be limited to the minimum necessary in relation to the nature of the production. In addition, operations should be carried out quickly and carefully to prevent damage to the fish. On-farm movements are movements of fish within the aquaculture facility that tend to short term in nature, usually lasting less than 30 minutes (EFSA, 2008). Mechanical damage should be minimised with well-equipped, skilled, and dedicated staff (FAO, 2011).
2. Animals should be handled in a skilled manner. Removal from water and handling must only be carried out when necessary. Live fish must never be held by the gill covers or tail only or thrown over solid objects. Time out of water for a live fish must be kept to the minimum possible and never exceed 15 seconds for a live fish (unless anaesthetised) (RSPCA, 2018) (EFSA, 2008) (CIWF, 2023).
3. Personnel must be properly equipped and qualified to minimise physical damage (EFFAB, 2023).
4. Larvae should not be siphoned or removed from the water, but they should be transferred in plastic bags (RSPCA, 2020).
5. Handling should be done when the fish have lower metabolic activity and their need for oxygen is lower (EFSA, 2008).
6. Fish should be kept in water with sufficient oxygen content (EFSA, 2008).
7. Fish should be in good condition before handling (IFA Aquaculture, 2017) (RSPCA, 2020).

[15] Commission Implementing Regulation (EU) 2021/1165 of 15 July 2021 authorising certain products and substances for use in organic production and establishing their lists.

[16] Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin.

[17] Commission Implementing Regulation (EU) 2020/464 of 26 March 2020 laying down certain rules for the application of Regulation (EU) 2018/848 of the European Parliament and of the Council as regards the documents needed for the retroactive recognition of periods for the purpose of conversion, the production of organic products and information to be provided by Member States.

General Good Husbandry Practices for

common carp, rainbow trout, Atlantic salmon, European sea bass, gilthead sea bream, ballan wrasse and lumpfish

8. In every handling procedure, it is essential to remove dead fish to prevent the spread of possible diseases or the introduction of pathogens (Pavlidis, et al., 2023).
9. The use of passive grading[18] systems[19] wherever possible is encouraged (IFA Aquaculture, 2017) (RSPCA, 2021).

Examples

- UK implements GHPs #2, #4, #7, #9 for rainbow trout.
- Ireland implements GHPs #7, #9 for salmonid species.

FALLOWING

Mandatory requirements

Mandatory requirements for fish farmers related to fallowing are *inter alia* foreseen in the following **EU legislation**:

- Commission Delegated Regulation (EU) 2020/689: article 64.

In addition, the following production rule applies for organic certified products:

- Regulation (EU) 2018/848 on organic production and labelling of organic products[20]: Articles 3.1.4.1.g and 3.1.4.3 of Part III Annex II.

General good husbandry practices

Fallowing is a good husbandry practice used as a sanitary treatment in aquaculture infrastructures (raceways, ponds, net pens, etc.) with the objective of breaking the life cycle of diseases and parasites. It involves removing fish from ponds, net pens, etc., emptying aquaculture facilities, cleaning, and disinfection, including nets, to eliminate possible pathogens (Zhulay, Reiss, & Reiss, 2015).

Examples

- Norway and Ireland implement GHP #1 for salmonid species.

MORTALITY REMOVAL

Mandatory requirements

Mandatory requirements for fish farmers related to mortality removal are *inter alia* foreseen in the following **EU legislation**:

- Regulation (EC) No 1069/2009[21]: chapter II (articles 12, 13 and 14) of Tittle I.
- Regulation (EU) 2016/429[22]: Article 10.4b.vi.

In addition, the following production rule applies for organic certified products: Regulation (EU) 2018/848[14]: Articles 3.1.4.1.h) of Part III of Annex II.

General good husbandry practices

[18] Passive grading involves installing a panel with holes for different sizes inside the land-based flow-through/raceway systems, ponds and net pens. So, you choose the size of the fish you want to grade, preventing others from passing. The fish pass through voluntarily without stress.

[19] In aquaculture, passive grading methods are used to separate fish or other aquatic animals into different size or quality classes without the need for mechanical graders or manual sorting.

[20] Regulation (EU) 2018/848

[21] Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002.

[22] Regulation (EU) 2016/429 of the European Parliament and of the Council of 9 March 2016 on transmissible animal diseases and amending and repealing certain acts in the area of animal health ('Animal Health Law').

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common carp, rainbow trout, Atlantic salmon, European sea bass, gilthead sea bream, ballan wrasse and lumpfish

1. Removal of dead fish is essential to prevent the spread of diseases. In freshwater tanks/pens, mortalities should be removed and quantified daily. In net pens, nets may need to be raised to ensure all mortalities can be removed using a hand net. Disposal of mortalities must adhere to relevant waste management regulations of Member State concerned (IFA Aquaculture, 2017).
2. Removal of dead fish in marine net pens should be performed often (i.e. at least twice a week), except when adverse weather conditions pose a danger to personnel. In land-based systems, the removal should occur daily. Mortality checks must be recorded as soon as possible after grading (RSPCA, 2018).
3. The number of deaths and, where possible, the cause of death should be recorded (IFA Aquaculture, 2017).
4. Dead larvae should be removed daily (EFSA, 2008).

Examples

- Ireland implements GHP #1, #3 for salmonid species.
- UK implements GHP #2 for rainbow trout.

PREDATOR CONTROL

Mandatory requirements

Mandatory requirements for fish farmers related to predator control are *inter alia* foreseen in the following **EU legislation**:

- Directive 2009/147/EC on the conservation of wild birds protects cormorants[23]: Article 9 affords Member States the flexibility to derogate from the strict protection.
- Council Directive 92/43/EEC of 21 May 1992[24]: Annex II and IV.

For organic certified products, in addition to the above mentioned horizontal rules, the following production rules applies: Regulation (EU) 2018/848 on organic production and labelling of organic products[14]: point 1.7. of Part III of Annex II.

General good husbandry practices

1. Preventive measures (such as the use of nets, scare crows and dogs, and Acoustic Deterrent Devices (ADD) whenever their use is allowed by law) should be prioritised over lethal methods (RSPCA, 2021).
2. Place steep sided ponds with deep water (1 m or more) to discourage of grey herons (*Ardea cinerea*) because the latter usually lands on the bank and then wades into shallow water (FAO, 1989) (ICWDM, 2024).
3. Reducing stocking rates may make ponds less attractive to depredating birds (ICWDM, 2024).
4. Eliminate attractive places for predators as well as possible refuges, such as heavy vegetation around aquaculture facilities (IFA Aquaculture, 2017).
5. Coordinated prevention among different stakeholders such as expert groups, aquaculture producers, NGOs should be organised to avoid the presence of cormorants, through the use of different deterrent methods (shooting to scare and using different types of fireworks and pyrotechnic devices). This method may be suitable for other migratory birds provided that their ecology, physiology, current population of the species, their movements, fishing sites, etc. are studied to establish actions in hot spots rather than wide areas (Marzano & Carss, 2006).

Examples

- UK implements GHP #1 for Atlantic salmon.
- Ireland implements GHP #4 for salmonid species.
- Israel implements GHP #5 for common carp.

[23] Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (codified version)

[24] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora

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MINIMISING RISKS OF ESCAPES

Mandatory requirements

Mandatory requirements for fish farmers related to minimising risks of escapes are *inter alia* foreseen in the following **EU legislation**:

- Regulation (EU) 2016/429[25]: Part I, Chapter 3, Section 1, Article 10, 4. (a)(iii).

For organic certified products, in addition to the above mentioned horizontal rules, the following production rule applies: Regulation (EU) 2018/848 on organic production and labelling of organic products: in particular main provisions under articles 3.1.5.7 and 3.1.5.8 of Part III of Annex II[14].

General good husbandry practices

1. Any measures to minimise the risk of escapes should also take into consideration any potential impact on the health and welfare of farmed aquatic animals.
2. The EU Project Prevent ESCAPE (Assessing the causes and developing measures to prevent the escape of fish from sea-cage aquaculture), based on the Norwegian experience of dealing with the problem of escapes, recommends a range of measures for other countries to introduce effective anti-escape measures: (1) Mandatory reporting of all escape events, (2) A defined mechanism to collect, analyse and learn from the mandatory reporting, (3) As causes of escapes estimated by farmers are often inaccurate, they recommend mandatory, technical assessments to determine the causes of 'large-scale' escape incidents, (4) Introduction of a technical standard for sea-cage aquaculture equipment coupled with an independent mechanism to enforce the standard, (5) Certain operations within fish farming (e.g. correct anchoring and mooring, connecting net-cages to floaters and correct weighting of net-cages in currents) are likely to pose a higher risk of an escape event occurring if they are done incorrectly.
3. The identification of processes that could lead to escapes of aquatic animals, as well as the provision of mandatory training to the staff who carry them out results in a reduction of human errors that cause escapes (Jensen et al, 2010).

Examples

- Norway implements GHP #1 for salmonid species.

WATER QUALITY[26]

Mandatory requirements

For organic certified products, the following production rules apply: Regulation (EU) 2018/848 on organic production and labelling of organic products[27]: The main provisions concerning good practices for water quality are ser under points: 1.1, 1.2, 1.5, 1.6, 1.9, 3.1.4.1.a) and h); 3.1.5.2, 3.1.5.3, 3.1.5.4, 3.1.5.6, 3.1.6.4 and 3.1.6.5; of Part III of Annex II). Commission Implementing Regulation 2020/464: Annex II

General good husbandry practices

1. Regular monitoring of water quality parameters (i.e. temperature, dissolved oxygen, pH, salinity, ammonia) (RSPCA, 2021) (Scottish Salmon Producers Organisation, 2015) (Pavlidis, et al., 2023).
2. The correct management of the different physic-chemical parameters involved in the production system, help to reduce the state of stress in which the aquatic animals under farming can find themselves in, thus reducing the appearance of diseases (García-Ortega & Calvario-Martínez, 2003).

[25] Regulation (EU) 2016/429 of the European Parliament and of the Council of 9 March 2016 on transmissible animal diseases and amending and repealing certain acts in the area of animal health (Animal Health Law).

[26] Please note that GHPs related to water quality vary according to the optimal production conditions of each species and the geographical locations where aquatic species are farmed.

[27] Regulation (EU) 2018/848

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Examples

- UK implements GHP #1 for Atlantic salmon.

STOCKING DENSITIES

Mandatory requirements

- For organic certified products under Regulation (EU) 2018/848[28] the following detailed production rules apply: Point 3.1.5.3 of Part III of Annex II and Commission Implementing Regulation (EU) 2020/464[29]: Article 22 and Annex II

General good husbandry practices

1. For species located in natural ponds, the stocking density is adapted to the life cycle stage, natural pond productivity and temperature conditions (EFSA, 2008).

2. Taking into account the species-specific maximum stocking densities that meet the needs of the fish including (Eurogroup for Animals, 2022):
    - Control aggressive behaviours.
    - Minimise stress and injuries.
    - Maintain adequate environmental conditions.
    - Ensure appropriate access to feed in the system.

DISINFECTION AND CLEANING

Mandatory requirements

Mandatory requirements for fish farmers related to disinfection and cleaning are *inter alia* foreseen in the following **EU legislation**:

- Regulation (EC) No 852/2004[30]: Chapter II and Annex I
- Regulation (EC) No 853/2004[31]: Annex III, Section VIII.
- Regulation (EU) 2016/429[32]: Chapter 3 of Part I.
- Commission Delegated Regulation (EU) 2020/691[33]: Annex I

For organic certified products, in addition to above horizontal rules, the following production rules apply: main relevant provisions Regulation (EU) 2018/848 on organic production and labelling of organic products[34] (in particular for adequate prevention good practices for cleaning and disinfection are set under the following main provisions: Article 24. e) and point 3.1.4.1. and 3.1.4.3. of Part III of Annex II) and Commission Implementing Regulation 2021/1165[35]: Article 5 and part A of Annex IV.

General good husbandry practices

1. The conditions associated with an emergency response require different disinfection approaches than those used in routine biosecurity. In an emergency, it is best to avoid transmission routes than to rely on disinfection. Equipment should not be moved from an infected aquaculture establishment until effective disinfection has been carried out. Disinfection is also an essential part of any emergency response to support disease control activities, such as quarantine of affected aquaculture establishments and the procedures used (Costache & Dobrota, 2020).

[28] Regulation (EU) 2018/848

[29] Commission Implementing Regulation (EU) 2020/464

[30] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs

[31] Regulation (EC) No 853/2004

[32] Regulation (EU) 2016/429

[33] Commission Delegated Regulation (EU) 2020/691

[34] Regulation (EU) 2018/848

[35] Commission Implementing Regulation 2021/1165

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2. Disinfectants should be in contact with all surfaces and left for the recommended period by the producer. They should be stored in suitable and clearly labelled containers. This area should be restricted and always locked. All used disinfectants, organic matter washes and rinse water should be disposed of properly, rinse the area with clean water to remove the disinfectant residues (IFA Aquaculture, 2017).

3. All equipment used for mortality disposal should be disinfected after the operation is completed (IFA Aquaculture, 2017).

4. Disinfection or changes of footwear should be performed by all personnel entering or leaving the farm (Scottish Salmon Producers Organisation, 2015) (Best Aquaculture Practices, 2023).

5. Cleaning and hygiene should be maintained in all types of production facilities were possible and for all phases of the production cycle, as it is essential to the health and welfare of the fish, especially in the larvae stage (highly susceptible to diseases), where food and faeces should be removed from the bottom once or twice a day using a disinfected siphon (EFSA, 2008).

6. Ensure a complete disinfection of fertilised eggs (Scottish Salmon Producers Organisation, 2015).

7. The on-growing production phase: change the nets often (15-20 days in summer) to eliminate fouling organisms and apply periodic antifouling treatments to avoid deterioration of the nets (EFSA, 2008).

Examples

- Scotland implements GHPs #4, #6 for Atlantic salmon.
- Ireland implements GHPs #2, #3 for salmonid species.

VACCINATION AND TREATMENTS

Mandatory requirements

Mandatory requirements for fish farmers related to vaccination and treatments are *inter alia* foreseen in the following **EU legislation**:

- Regulation (EU) 2016/429[36]: Part I, chapter 3; Part III: chapter 2 of Title I and article 69 of Title II; Part IV, Title II.
- Regulation (EU) 2019/6[37]: Art. 114.
- Regulation (EU) 2019/4[38]: Chapter IV
- Commission Delegated Regulation (EU) 2021/578[39]: Art. 15.2.d)
- Part I and II
- Regulation (EC) No 853/2004[40]: Chapter II, Annex III, Section VIII.

For organic certified products in addition to above horizontal rules, the following production rule applies: main relevant provisions Regulation (EU) 2018/848 on organic production and labelling of organic products[41] (in particular main relevant provisions are under point 3.1.4.1, 3.1.4.2 and 3.1.4.3 of Part III of Annex II).

General good husbandry practices

1. If effective oral vaccines are available, these should be the preferred method of vaccination. All vaccination procedures must be conducted with care and with the minimum possible distress caused to the fish (RSPCA, 2020). When necessary, sedation should be applied.

2. To maintain fish health and minimise the risk of disease transmission, all fish, at all stages in the life cycle, are sourced from a supply that is of equal or better health status than its own stock and fish that

[36] Regulation (EU) 2016/429

[37] 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

[38] 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

[39] Commission Delegated Regulation (EU) 2021/578

[40] Regulation (EC) No 853/2004

[41] Regulation (EU) 2018/848

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are moved off site, at all stages in the life cycle, are moved to a location of equal or lesser health status. This is a requirement under EU animal health regulations (ASC, 2019).

3. The use of therapeutic agents, or protective immunostimulants, which can be delivered in the feed without the need for handling and manipulation should be privileged (CIWF, 2018).

4. Use of blood test sample to monitor cortisol associated with stress or disease before the manifestation of visible symptoms, should be considered in certain warranted situations. (Sun, et al., 2022) (Currie, et al., 2022).

5. During periods of elevated risk to the health and welfare of the fish, like vaccinations and treatments periods, reduce handling (BIM).

6. Guidelines regarding the "Responsible Use of Vaccines and Vaccination in Fish Production" produced by the Responsible Use of Medicines in Agriculture Alliance (RUMA) should be followed (FAO, 2005).

7. Initiate treatment for every disease or parasite infection only under direct veterinary approval, strictly follow treatment protocols and complete the entire course of treatment using correct dosages (European Commission, 2022).

Examples

- Ireland implements GHP #5 for salmonid species.
- UK implements GHP #1 for rainbow trout.
- Denmark, Finland, Germany, Greece, Iceland, Italy implement GHP #2 and for salmonid species.

ENVIRONMENTAL ENRICHMENT

Mandatory requirements

For organic certified products, the following production rules apply: Regulation (EU) 2018/848 on organic production and labelling of organic products[42] (in particular main provisions are set under point 3.1.5 of Part III of Annex II) and Commission Implementing Regulation (EU) 2020/464[43]: Article 22 and Annex II

General good husbandry practices

1. Use shelters adapted to the behaviour of the breeding species. Shelters reduce stress and metabolic costs and improve growth rates as well as fin and tail conditions (Jones, Webster, & Salvanes, 2021).

2. Adding complexity in the captive environment enhances cognitive abilities (avoid repetitive behaviours or stereotypes) and improves brain plasticity (Hyvärinen & Rodewald, 2013) (Salvanes, et al., 2013).

3. For land-based flow-through, raceway systems and ponds the background colour should be similar to the natural environment of the species to reduce the risk of predation and stress (Jones, Webster, & Salvanes, 2021).

4. Apart from RAS facilities, which are usually indoors, partial shading of facilities reduces stress and improves fish growth (Näslund & Johnsson, 2016).

Examples

- Norway implements GHP #2 for Atlantic salmon.

SELECTIVE BREEDING

Mandatory requirements

For organic certified products, the following production rule applies:

[42] Regulation (EU) 2018/848

[43] Commission Implementing Regulation (EU) 2020/464

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- Regulation (EU) 2018/848 on organic production and labelling of organic products: in particular, the main provisions concern the prohibition to the use of GMOs (Genetically Modified Organisms)[44] (article 5,f,iii and article 11; and main provisions under point 3.1.2 of Part III of Annex II).

General good husbandry practices

1. Genetic diversity should be kept and the rate of inbreeding restricted (Saura, 2021).

2. The EFABAR aquatic code[45] is a voluntary good practice guide developed by the European Forum of Farm Animal Breeders (EFFAB) and plays a pivotal role towards sustainable and balanced aquaculture breeding. The code promotes breeding programmes that target: i) Better animal health and welfare (disease resistance and discarding genetic defects) using genomic information for selective breeding for improved disease resistance (Odegard, Baranski, & Gjedrem, 2011); and iv) Preserving genetic diversity and monitor and limit inbreeding following the FAO recommendation (EFFAB, 2023).

3. Promote long-term selective breeding programmes (incorporating other innovative technologies such as genomic selection, with proper assessment of risk) through awareness raising, capacity building, appropriate research and development, supportive policies and legislation, and effective engagement of the private sector, with consideration of appropriate resourcing and/or outsourcing (FAO, 2023).

4. Apply proven genetic improvement approaches, with a focus on selective breeding, to develop farmed types adapted to changing environmental conditions caused by climate change (e.g. to expand temperature and salinity tolerances) (FAO, 2023).

5. A prudential approach based on a risk assessment as outlined in the Global Plan of Action for the Conservation, Sustainable Use and Development for Aquatic Genetic Resources for Food and Agriculture should be followed (FAO, 2023).

6. One of the end goals of a selective breeding programme should be to save 1 00-200 select brood fish each generation. This will ensure that a farmer will be able to spawn at least 25 males and 25 females each generation. If this is done, inbreeding-related problems should be minimised for 5 generations. (FAO, 1995).

7. Genetic selection can favour health-relevant traits, such as disease resistance and reduced deformities (Kause, Ritola, Paananen, Wahlroos, & Mäntysaari, 2005).

FUNCTIONAL FEED

Mandatory requirements

Mandatory requirements for fish farmers related to functional feed are *inter alia* foreseen in the following **EU legislation**:

- Regulation (EC) No 1831/2003[46]: Chapter II: article 5.3.f); point 3 and 4.b) and e) of Annex I
- Regulation (EC) No 767/2009[47]: Chapter 2, article 4.1.b).

For organic certified products, the following production rule applies: Regulation (EU) 2018/848 on organic production and labelling of organic products[48] – promote the application of animal husbandry practices which enhance the immune system and strengthen the natural defence against diseases (article 6, l). See also main provisions point 3.1.3. (3.1.3.1, 3.1.3.3 and 3.1.3.4) of part III of annex II and Regulation 2021/1165 for relevant provisions.

General good husbandry practices

[44] Regulation (EU) 2018/848

[45] https://www.effab.info/modern-animal-breeding/responsible-breeding/code-efabar/

[46] Regulation (EC) No 1831/2003

[47] Regulation (EC) No 767/2009

[48] Regulation (EU) 2018/848

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1. Use diets or vitamin and/or immunostimulant supplements for fish species improve growth and response to stressful situations (for example, grading) and strengthen the immune system (IFA Aquaculture, 2017).

2. Adapt the dosage of these supplements and/or probiotics to the needs of the reared species (IFA Aquaculture, 2017).

3. The use of diets supplemented with tryptophan for intensive fish farming of fish species, being of particular interest in those stages of the production cycle where fish may be subject to increased stress, e.g. during handling, transport, change of feeding and/or extreme environmental conditions. Having tested only in intensive fish farming (Ministerio de Agricultura Pesca y Alimentación, 2019).

Examples

- Ireland implements GHP #1, #2 for salmonid species.
- Spain implements GHP #3 for gilthead sea bream.

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5. ANNEXES

ANNEX I - METHODOLOGY

This document has been developed with the support of the EU Aquaculture Assistance Mechanism (EU AAM)[49].

The following data collection activities have been undertaken:

- **Desk research** and **scientific literature review** to analyse both the situation in the different EU Member States on how aquaculture practices are performed, and the existence of norms, private standards or codes regulating or promoting these "good practices". The main source and starting point for information was the current EU animal health and welfare legislation. In addition, the following sources of information have been consulted:

a) International organisations (e.g. FAO, EFSA, WOAH)
b) Standards and codes from EU, UK, Norway, Canada
c) European producers' associations guidance documents and handbooks
d) National regulations
e) NGOs standards
f) Private policies

- **Online survey** targeting EU Member States and the Aquaculture Advisory Council (AAC) and aiming to identify GHPs related to health and welfare for the main aquatic species currently farmed in the EU, at all stages of their life cycle. A total of 21 responses have been received from 17 Member States and Norway. Expert consultation through a **cluster meeting with representatives of relevant EU-funded projects** (i.e. AquaIMPACT, Cure4Aqua, iFishIENCi, IGNITION, MedAID, NewTechAqua, ParaFishControl, FishEthoGroup) and 12 **experts from the Board of Ambassadors** (BoA)[50]. The key objectives of this meeting were to: i) present and revise the main GHPs collected so far; ii) collect additional examples of practices applied in the EU Member States; and iii) identify possible criteria for prioritisation of sources of information. A second survey was launched after the cluster meeting, which resulted in 4 additional contributions. As a result of the cluster meeting, the following criteria for the prioritisation of the sources of information on GHPs were identified: i) the quality of these sources; ii) the type of stakeholders involved (producer association codes or individual companies); and iii)

[49] Home | EU Aquaculture Assistance Mechanism (europa.eu)

[50] Expert consultation group created ad-hoc by the EU Aquaculture Assistance Mechanism (AAM) composed of 21 independent experts from all over Europe

whether they are supported by regulatory initiatives at local, regional, national, and international levels.

- A **bilateral meeting** with experts from the **Aquaculture Stewardship Council (ASC), the European Forum of Farm Animal Breeders (EFFAB), and the National Committee for Shellfish Culture (CNC)** to understand how welfare is currently included in the ASC standards and how it will be included in the new standards and to explore the link between Code-EFABAR and selective breeding as well as to collect concrete examples of its implementation in Member States.

- A **workshop with experts and Member States** organised by the European Commission in Brussels on 18 October 2023 to present and discuss the draft document. Prior to the workshop, the document was sent to participants to allow for a well-informed discussion.

- **Technical seminars with Member States' aquaculture experts** organised by the Commission in the context of the Open Method of Coordination (OMC). During several seminars in 2023-2024 the document and the results of the survey have been extensively discussed.

- **Other sources**: comments were received from the associations EFFAB (European Forum of Farm Animal Breeders), FEFAC (European Feed Manufacturers' Federation), HAPO (Hellenic Aquaculture Producers Association) and the Polish Trout Breeders Association and from several experts.

The **final selection of the GHPs** was carried out based on the prioritisation of:

- Concrete examples from industry and standards;
- Projects with results that are relevant and linked to the industry.

ANNEX II – SPECIES SPECIFIC FACTSHEETS

This chapter includes **8 factsheets** that present a selection of the best and most useful GHPs for the following aquatic species at all stages of their life cycle:

I. Common carp
II. Rainbow trout
III. Atlantic salmon
IV. European sea bass
V. Gilthead sea bream
VI. Mussels
VII. Ballan wrasse
VIII. Lumpfish

Common carp (*Cyprinus carpio L.*)

Good Husbandry Practices

Topics addressed	General					Specific		
	Feeding	Handling	Mortality removal	Fallo-wing	Predator control	Environmental enrichment	Selective breeding	Functional feed
	☒	☐	☐	☐	☒			
	Minimi-sing risk of escapes	Water quality	Stocking densities	Disin-fection and cleaning	Vaccina-tion and treat-ments	☒	☒	☒
	☐	☒	☒	☒	☒			

FEEDING

Mandatory requirements

The following production rules apply for organic certified products: Regulation (EU) 2018/848 on organic production and labelling of organic products[51]: Annex II, Part III, concerns nutrition for carps 3.1.3.4, requirements are also set for pond nutrients see point 3.1.5.3.

Good husbandry practices

1. In hatcheries, larval feed should contain 40-50% protein. The size of the feed particles is extremely important since first-feeding fry can consume food as small as hundred microns in size. In the later part of the nursing period, fry may consume feed up to 1 mm in size. Fry needs good quality supplementary feed with a digestible protein content of 25-30% (EFSA, 2008). In most other cases, carp larvae are transported to specially prepared ponds and feed from the very start on the smallest forms of plankton.
2. In semi-intensive or extensive pond farms, feeding is only practised to complement the energy and protein requirements provided by pond primary production (FAO, 2011). The feeding plan should show the individual rations quantified for each pond and feeding day (Füllner, Pfeifer, & Langner, 2007). An inadequate feeding protocol (in relation to the availability and quality of live food) is one of the main causes of reduced welfare in the broodfish and larvae phases. Inadequate feeding is influencing welfare of all phases of carp growth. An adequate feeding protocol is important only for the larvae and broodstock phase of carp life (Pavlidis M. , et al., 2023).
3. To optimise on-farm feed use and calculate proper feed rations, it is necessary to understand the relationships between feed consumption and growth as well as temperature and fish size. Over-feeding often results in a deterioration of the aquaculture environment. Uneaten feed quickly reduces the water quality, as bacterial populations rapidly set up in uneaten feed (Shipton T. , 2021). This can affect the health and welfare of the carps.
4. Stocking densities in relevant carp ponds categories (1-year old carp ponds, 2-year-old carp ponds, etc.) shall match the natural feed resources to use the natural feed (plankton) and supplementary feeding in the most efficient way (Cieśla, et al., 2023).

Examples

- Saxony State (Germany) implements GHP #2.

[51] Regulation (EU) 2018/848

PREDATOR CONTROL

Mandatory requirements

Mandatory requirements for carp farmers related to predator control are *inter alia* foreseen in the following **EU legislation**:

- Directive 2009/147/EC on the conservation of wild birds protects cormorants: Article 9 affords Member States the flexibility to derogate from the strict protection.
- Council Directive 92/43/EEC of 21 May 1992: Annex II and IV, Animal and plant species of community interest in need of strict protection, especially for the Otter, *Lutra lutra.*

Good husbandry practices

1. Different tools and techniques to avoid conflict with cormorants can be found in the scientific literature, notably auditory and visual deterrent, netting net pens for fish, reducing fish availability by managing fish stocks to enhance or introduce alternative, less valuable prey species, either in the 'target' fishery or in nearby bodies of water (Russell, Broughton, Keller, & Carss, 2012).
2. Methods potentially useful to alleviate damage made by Great Cormorants (*Phalacrocorax carbo*), which could be applicable to other piscivorous birds, exist and are explained in the results of the INTERCAFE's project:
    a. Scaring piscivorous birds away from farms: Effective visual deterrents methods of predator control are highlighted by the Institute of Parasitology, Abo (Finland) - which mentions the use of scare crows - and by Nordrhein-Westfalen (Federal Republic of Germany) - that mentions dogs. Scare crows and dogs are of a very limited use for bird predators. Furthermore, the installation of special feeding ponds for the birds has been a successful measure in some areas. Nordwürttemberg (Germany) and the United Kingdom both advocate steep-sided ponds with deep water as a protection against grey herons (Ardea cinerea) (FAO, 1989). Other methods are auditory deterrents such as gas cannon, pyrotechnics, shooting to scare, etc. A general consideration with all these devices is noise nuisance, and any national and local controls on their use must be considered. However, it should be considered that a cannon firing repeatedly without any variation in timing or direction quickly loses its potential to scare birds' (Russell, Broughton, Keller, & Carss, 2012).
    b. Protecting the fish by preventing cormorants from reaching them (exclusion techniques): in this case there are different methods such as netting net pens, floating plastic balls, using wires, etc.
    c. Reducing fish availability to cormorants (habitat modification techniques): an interesting practice for local fish farmers to build ponds for cormorants where they can feed on non-valuable species. In these alternative feeding sites, the predators can feed producing a lower economic impact in the farm (Marzano & Carss, 2006). Also, there are simple and modern fish protection plastic systems (Refugium) based on semi-submerged objects that allow fish to take artificial refuge and to avoid predators to approach (Llacunats Dinàmics, 2023).
    d. Reducing fish availability to cormorants (fish stock management techniques): Such techniques attempt to alter the 'quality' of the foraging opportunities available to cormorants by trying to make fish less easy for the birds to catch. For example, draining and removing fish from more vulnerable fish farm ponds prior to the arrival of cormorants, or reducing the fish density in some ponds at times of increased threat from cormorants.

Examples

- Finland, Germany, Israel, Greece and UK implement GHP #2.a.
- Spain implements GHP #2.c.

WATER QUALITY

Mandatory requirements

[52] Regulation (EU) 2018/848

[53] Commission Implementing Regulation (EU) 2020/464 of 26 March 2020 laying down certain rules for the application of Regulation (EU) 2018/848 of the European Parliament and of the Council as regards the documents needed for the retroactive recognition of periods for the purpose of conversion, the production of organic products and information to be provided by Member States

For organic certified products, the following production rule apply for carp producers: Commission Implementing Regulation 2020/464: Annex II Part VI.

Good husbandry practices

1. The welfare of the carps depends on the water quality monitoring. Accordingly, carp farmers must monitor the basic physical and chemical parameters of the water (e.g. temperature, amount of dissolved oxygen, pH) that is fed to and accumulates in the ponds. In case of suspicion of poisoning of the water, the water should be analysed in an accredited laboratory (Pavlidis, et al., 2023).
2. Optimal range for carp production: temperature: 20-28ºC (Füllner, Pfeifer, & Langner, 2007); temperature fluctuations are critical during the overwintering period for juveniles; pH: 6.5-8.5. (FAO, 2011) (Fuller, Pfeifer, & Langner, n.d.); oxygen content of the water in the tanks: minimum 5–6 mg/l (FAO, 2011)
3. For optimal pH, the ponds should be supplemented with limestone. For optimal oxygen, the water flow in the pond should be regulated and/or aerated when possible (Cieśla, et al., 2023).

Examples

- Saxony State (Germany) implements GHP #2.

STOCKING DENSITY

Mandatory requirements

For organic certified products under Commission Implementing Regulation (EU) 2020/464[54] the following detailed production rules apply: Part VI of Annex II. The latter includes a maximum stocking density for organic carps, notably: the total production of species is limited to 1500 kg of fish per hectare per year.

Good husbandry practices

1. Broodstock ponds: 150-200 carps/ha (1.5 Kg) (30%), silver carp (30%) and grass carp (30%) and some other species (10%), such as tench (FAO, 2011).
2. Stocking density of properly prepared nursing pond varies between 1 and 2 million feeding larvae/ha (Jeney & Bekh, 2020).
3. In Poland, the minimum stocking density is 400 2-year-old carps/ha (as highlighted by Polish Trout Breeders Association).
4. The stocking densities of carp in earthen ponds must be correlated with the age of the fish, natural productivity of the pond and temperature conditions. For instance, carp farmed in Central and Eastern Europe on earthen ponds must not exceed 1500kg of fish growth per hectare (Lirski, Siwicki, & Wolnicki, 2007).

Examples

- Poland implements GHP #3.

DISINFECTION AND CLEANING

Good husbandry practices

1. Removing unwanted objects and vegetation, such as dry sedges and reeds, is a step of pond preparation and cleaning. Passing over a dry pond bottom with a disk harrow will ensure healthier life for benthos (FAO, 2011).
2. For larvae welfare, cleaning and hygiene measures in indoor facilities are important (Pavlidis M., et al., 2023).

VACCINATION AND TREATMENTS

Good husbandry practices

[54] Commission Implementing Regulation (EU) 2020/464

1. Due to the size of large ponds (50–100 ha), the stock (often exceeding 1,500 kg/ha) cannot be effectively treated. Therefore, prevention remains the only solution (EFSA, 2008) (Towarzystwo Promocji Ryb, 2014).
2. Quarantine of incoming fish for a minimum of 4 weeks to 2 months, in addition careful handling of fish to avoid stress and safe disposal of dead fish is advised (FAO, 2011).

Examples

- Poland implements GHP #1.

ENVIRONMENTAL ENRICHMENT

Mandatory requirements

For organic certified products, the following production rule applies for carp producers: Commission Implementing Regulation (EU) 2020/464[55] Part VI of Annex II.

Good husbandry practices

1. Brood fish may be kept in covered happas[56] within their tanks. This will prevent fish jumping and being stressed (Jeney & Bekh, 2020).
2. Farming ponds in extensive aquaculture support high value natural conditions (Adámek, Mössmer, & Hauber, 2019).
3. It has been proven that musical (i.e. rhythmic or systematic sound not typically found in the wild) stimuli positively influence growth performance, feeding efficiency and stress reduction (Arechavala-López, Cabrera-Álvarez, Maia, & Saraiva, 2022).
4. The technology of fish cultivation in ponds is adapted to the natural, changing rhythms of the seasons. The increased atmospheric and terrestrial humidity in the proximity of the ponds results in lush vegetation growth and their inhabitation by numerous species, which results in increased biological diversity (Lirski, Siwicki, & Wolnicki, 2007).
5. The species structure in the carp ponds is increasingly often supplemented by fish species other than carp, including rheophilus cyprinid species that are high quality stocking material for surface waters (Lirski, Siwicki, & Wolnicki, 2007).

Examples

- Ukraine and Russia implement GHP #1.

SELECTIVE BREEDING

In Europe, there are currently no breeding programmes for common carp that use modern principles of mass or family-based choice. Individual selection in the breeding programmes is a transitional phase between a rudimentary selection process and a fully integrated breeding scheme (Chavanne, et al., 2016).

Good husbandry practices

1. Controlled selection experiments have been carried out on common carp to improve specific quantitative traits also for robustness and disease resistance (selective breeding has been the norm in this species rather than use of antibiotics and vaccines) (EFSA, 2008).
2. Researchers suggest broadening the genetic composition of the base populations of carp from which the selection programmes start. They also suggest that measures designed to increase effective population size within all farmed populations analysed here should be implemented to manage genetic variability and ensure the sustainability of the breeding programmes. If the current effective population size is small (equal to or less than 50 fish), the sustainability of the breeding programmes is potentially at risk (Saura M., 2021).

Examples

- Czech Republic, Germany and Hungary implement GHP #2.

[55] Commission Implementing Regulation (EU) 2020/464

[56] Happas are net pens, usually made from fine mesh that can be set up in any shallow pond or tank.

FUNCTIONAL FEED

Good husbandry practices

1. Dietary supplementation with 1% sage has a superior effect on the growth performance of *Cyprinus carpio* fingerlings, compared to 1% vitamin E dietary supplementation (Nica A., Mogodan, Petrea, & Simionov, 2021).
2. Fenugreek seed meal (FKSM) can be considered as a beneficial dietary supplement to improve the growth performance and blood indices of common carp fingerling (Roohi, Reza, Jafari, & Taghizadeh, 2015). There are commercial fish feeds available, such as Aller Aqua Winter Edition, which contain additional raw materials to enhance immunity of carp during wintering.

Examples

- Romania implements GHP #1.
- Iran implements GHP #2.

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Rainbow trout (*Oncorhynchus mykiss W.*)

Good husbandry practices

Topics addressed	General					Specific		
	Feeding	Handling	Mortality removal	Fallo-wing	Predator control	Environmental enrichment	Selective breeding	Functional feed
	☒	☒	☐	☒	☒			
	Mini-mising risk of escapes	Water quality	Stocking densities	Disin-fection and cleaning	Vaccina-tion and treat-ments	☒	☒	☒
	☐	☒	☒	☒	☐			

FEEDING

Mandatory requirements

The following production rule applies for organic certified products:

- Regulation (EU) 2018/848 on organic production and labelling of organic products[57]: The main provisions concerning feeding is Part III of Annex II point 3.1.3.3.

Good husbandry practices

1. Small larval fish and fry need to be fed often with a high-protein diet. The frequency and protein content are reduced as the fish grow (EFSA, 2008) (FISHWELL project, 2020) (RSPCA, 2020).
2. Feeding must start only when at least 90% of the alevins have lost their yolk sac (RSPCA, 2020).

Examples

- UK implements GHPs #1, and #2.

HANDLING

Good husbandry practices

1. Where pumps and pipes are used, they must not unnecessarily stress fish and must be free from sharp protrusions, kinks, and bends that are likely to injure fish (RSPCA, 2020) (CIWF, 2023) (Polish Fisheries Promotion Society, 2015).
2. Siphoning of alevins is not allowed under the referenced guidelines produced by the RSPCA. Alevins weighing less than 0.5 grams must not be moved with nets (RSPCA, 2020).
3. The smoltification process must be closely monitored for several weeks as detailed in the farm Veterinary Health and Welfare Plan (VHWP). Farmers should be trained in the procedures for assessing smoltification and minimising any negative effects on fish.
4. Special attention shall be given to changes to photoperiod and/or temperature, a technique which is commonly used to induce out-of-season egg laying. Both the method and intensity of photoperiod

[57] Regulation (EU) 2018/848

changes and the quality of lighting used can also affect animal welfare, e.g. due to growth and feed consumption (Pavlidis & Samaras, 2020).

Examples

- UK implements GHPs #1, and #2.
- Poland implements GHP #1.

FALLOWING

Good husbandry practices

1. Fallowing for three months may be adequate to lower the exposure of *Piscirickettsia salmonis* from one production cycle to the next (Price, Ibarra, Sánchez, & St-Hilaire, 2017).

PREDATOR CONTROL

Mandatory requirements

Mandatory requirements for trout farmers related to predator control are *inter alia* foreseen in the following **EU legislation**:

- Council Directive 92/43/EEC of 21 May 1992: Annex II and annex IV, Animal, and plant species of community interest in need of strict protection, for instance the Otter, *Lutra lutra.*
- Directive 2009/147/EC on the conservation of wild birds protects cormorants: Article 9 affords Member States the flexibility to derogate from the strict protection.

Good husbandry practices

1. The producer must: use all reasonable non-lethal methods of control to protect fish from predation by wild animals; detail the methods specified in the Environmental Action Plan[58] and the ones specified in their own Wild Animal Control Plan[59] (RSPCA; 2020).
2. The primary means of protecting the fish must be physical exclusion. Predator nets must be considered for deployment at high-risk sites during high-risk periods, and at other times as proper if there is a risk of an attack. Any site that is recognised as having an elevated risk of attack or has suffered an attack in the past shall have a working Acoustic Deterrent Device (ADD) in place, where their use is allowed (IFA Aquaculture, 2017)(RSPCA, 2020).

Examples

- UK implements GHPs #1, and #2.
- Ireland implements GHP #2.

WATER QUALITY

Mandatory requirements

Mandatory requirements for trout farmers related to water quality are *inter alia* foreseen in the following **EU legislation** for organic certified products:

- Commission Implementing Regulation 2020/464[60]: Part I of Annex II.

Good husbandry practices

1. The best temperature (ºC) for growth of rainbow trout is in the range of 16-18 °C depending on stage and size (EFSA, 2008). Temperature when water is recycled shall be: 1.0-10.0 (eggs); 1.0-10.0 (alevins); 1.0-12.0 (fry/fingerlings); 1.0-16.0 (on growers) (RSPCA, 2020).
2. Oxygen (% saturation) when water is recycled shall be: ≥ 90.0 (eggs), ≥ 90.0 (alevins); ≥ 70.0 (fry/fingerlings); ≥ 70.0 (on growers) (RSPCA, 2020).

[58] Annual plan recommended by the RSPCA and The Farmed Salmonid Health Handbook to monitor and minimise the impact of the farm on the environment.

[59] Plan requiring RSPCA certification for the control of wildlife that may affect the fish farm.

[60] Commission Implementing Regulation (EU) 2020/464

3. Extreme pH (below pH 5 and above 9) and sudden pH variations should be avoided at all life stages (EFSA, 2008) (IFA Aquaculture, 2017).

Examples

- Ireland implements GHP #3.
- UK implements GHP #1, #2.

STOCKING DENSITIES

Mandatory requirements

For organic certified products, the following main provision concerning rainbow trout stocking densities applies:

- Commission Implementing Regulation (EU) 2020/464[61]: Annex II Part I and II establishes for trout 25 kg/m^3 in fresh water and 10 Kg/m^3 in sea water.

Good husbandry practices

1. The stocking density in net pens in freshwater and seawater lochs should not exceed 10kg/m3 for fish up to 100g and 15kg/m^3 for on-growers weighing more than 100g (RSPCA, 2020) (CIWF, 2023).
2. The stocking density of freshwater units should not exceed 50kg/m^3 at any time of year and 35kg/m^3 during the summer months (RSPCA, 2020) (Ministry of Fisheries Industry and Fisheries of Norway, 2023) (Confédération Suisse, 2022) (IFA Aquaculture, 2017).

Examples

- UK implements GHPs #1, #2.
- Ireland, implements GHP #2.

DISINFECTION AND CLEANING

Mandatory requirements

Mandatory requirements for trout farmers related to disinfection and cleaning are *inter alia* foreseen in the following **EU legislation**:

- Council Regulation (EC) 708/2007 (applicable in aquaculture facilities in places where rainbow trout is an alien species) Annex III.

Good husbandry practices

1. At the end of each day of harvesting, all equipment should be cleaned and disinfected. All organic material should be removed with a detergent. Disinfection of the equipment should then be carried out ensuring that the disinfectant is in contact with all surfaces for the recommended period by the producers (IFA Aquaculture, 2017).

Examples

- Ireland implements GHP #1.

ENVIRONMENTAL ENRICHMENT

Good husbandry practices

1. The use of gentle currents (e.g. 0.9 body lengths per second) shall be allowed whenever possible and has been proven to be beneficial to trout welfare. Through the presence of a water current of 0.9 body lengths/second (<25% of maximum sustainable speed) to induce schooling behaviour and

[61] Commission Implementing Regulation (EU) 2020/464

lower spontaneous or erratic swimming behaviour, fish appeared visibly much calmer (Larsen, Skov, McKenzie, & Jokumsen, 2012) (CIWF, 2023).

2. Shelter provided by physical enrichment (generally refers to any form physical complexity added to housing for captive animals) such as polyvinyl chloride (PVC) pipe can reduce cortisol[62] and stress levels. This improves growth rates (Jones, Webster, & Salvanes, 2021).
3. The use of vertically suspended structures (e.g. aluminium rods, aluminium angles, strings of coloured balls) in circular rearing tanks improved weight gain, feed conversion ratio and individual performance (Kientz JL, Barnes ME, 2016), (Morris B, et al, 2020).
4. Cobble substrates reduce fin erosion, suggesting that natural bottoms are better for rearing than concrete (Bosakowski T, Wagner EJ., 1995). Similarly, artificial seaweed, specially designed to provide structural enrichment in pond bottoms, improve the growth and fin condition. They also act as a surface for the growth of aquatic plants and invertebrates as an added nutritional source to cultured species (Arndt RE et al, 2002).
5. It has been proved that musical (i.e. rhythmic or systematic sound not typically found in the wild) stimuli positively influence growth performance, feeding efficiency and stress reduction (Papoutsoglou SE, et al, 2013).
6. Reared rainbow trout fry in commercial earthen ponds exposed to a sustained swimming condition, using paddlewheel aerators, to create circular flow patterns with a range of current velocities, positively affected the growth (Reiser, Sähn, Pohlmann, Willenberg, & Focken, 2019).
7. Rainbow trout prefer to swim in protected areas by shelters when they are available and there are no negative effects on fish welfare or growth (Eidsmo, Madsen, Pedersen, Jokumsen, & Gesto, 2023). In addition, the shelters have some positive effects on fin and tail condition, but further research is needed to optimise the shelter type and design and the proper timing for its application in trout farming (Gesto & Jokumsen, 2022).
8. Complexifying the environment through the addition of physical structures, such as stones, plants, sand, gravels, which stimulate and encourage fish to explore promotes rainbow trout's welfare in farming conditions (Brunet, et al., 2022).
9. Beige coloured tanks have been correlated with superior growth in rainbow trout and lower cortisol levels. Rainbow trout were larger and returned lowest feed consumption and better FCR (Feed Conversion Ratio) in black tanks (McLean, 2021).
10. Rainbow trout held in enriched conditions, including gravel, plants, and covered areas, showed a better recovery and lesser adverse effects (immobile behaviour, opercular beat rate and high cortisol level). Compared to individuals fed continuously with an automatic feeder, rainbow trout with free access to self-feeders were more homogeneous in weight and showed less mortality for the same final specific growth rate and feed efficiency (Kleiber, et al., 2023).
11. Rainbow trout reared in raceways supplied with cobble showed less fin damage than those reared without substrate, which may be due to both reduced abrasion with the environment and reduced aggression. Earthen-bottom ponds produced rainbow trout with higher marine survival than asphalt-bottom ponds (Näslund & Johnsson, 2016).
12. The predictability of feeding the rainbow trout can be improved by using signals such as "bubble diffusion". This approach led to fewer aggressive behaviours. The combination of temporal and signalled predictability generated the strongest conditioned response, with lower levels of aggression and pre-feeding stereotypes. Additionally, using bubbles as a feeding predictor seems to be an interesting approach to improving the well-being of rainbow trout in aquaculture, acting as both occupational and physical enrichment (Kleiber A., 2022). Occupational enrichment aims to stimulate the cognitive abilities of fish by giving them more control and interaction with their environment.

SELECTIVE BREEDING

Good husbandry practices

1. Improve fish welfare by developing lines of rainbow trout with low levels of cortisol response to stress. Results so far suggest that much can be gained by implementing such selection in aquaculture breeding programmes (Gjoen & Overli, 2009).
2. To address the challenges faced by the rainbow trout breeding program in Finland, good management practices have been employed. These include incorporating genetic diversity through introducing different strains or crossbreeding, implementing strict biosecurity protocols, conducting regular monitoring for temperature-related diseases, collaborating with research institutions for

[62] Cortisol is a hormone released in response to stress.

understanding climate change impacts, and optimising thermal resistance of the rainbow trout strains. Other practices include setting up contingency plans and investing in research and development to enhance resilience against climate change and disease threats. By implementing these practices, the program can become more resilient, ensuring long-term sustainability and success (EFFAB, 2023).

3. The culture of genetically enhanced trout is acceptable when it is due to selective breeding and not due to genetic modification. Selective breeding allows for further progress in feed conversion, disease resistance and environment adaptation (domestication), which should increase the efficient use of local resources (ASC, 2019).

Examples

- France, Finland and Norway implement GHP #3.

FUNCTIONAL FEED

Good husbandry practices

1. Several immunostimulant diets or supplements are currently available for salmonids. These may be used prior to stressful events such as movements or a disease outbreak to boost immunity. At critical/stressful periods during the cycle, fish may be fed through approved diets containing vitamin supplements and/or immuno-stimulants (IFA Aquaculture, 2017).
2. Farmers should ensure that they use feeds that have been formulated specifically for the life-stage of the species being farmed (German Agricultural Society, DLG, 2018) (Polish Fisheries Promotion Society, 2015) (RSPCA, 2020) (CIWF, 2023).
3. While a low dose of probiotic may not stimulate the immune system, a higher dose may be dangerous for the organism, so the optimal dose of different probiotics must be determined for each host (MAPA, 2019).

Examples

- Ireland implements GHP #1.
- Germany, UK and Poland implement GHP #2.

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Atlantic salmon (*Salmo salar, L.*)

Good husbandry practices

Topics addressed	General					Specific		
	Feeding	Handling	Mortality removal	Fallowing	Predator control	Environmental en-richment	Selective reeding	Functional feed
	☒	☒	☒	☒	☒			
	Mini-mising risk of escapes	Water quality	Stocking densities	Disinfec-tion and cleaning	Vaccination and treat-ments	☒	☒	☒
	☐	☒	☒	☒	☒			

FEEDING

Mandatory requirements

The following production rule applies for organic certified products: Regulation (EU) 2018/848 on organic production and labelling of organic products. In particular point 3.1.3.3 of Part III of Annex II.

Good husbandry practices

1. Develop a written feed programme for each life stage in consultation with a nutritionist or another qualified specialist as well as regularly monitor the feed conversion efficiency (following weighing of samples) (National Farm Animal Care Council, 2021) (Scottish Salmon Producers Organisation, 2015).
2. Feeding must start when 90% of the alevins have lost their yolk sac (RSPCA, 2021).

Examples

- UK implements GHPs #1, and #2.

HANDLING

Good husbandry practices

1. During handling operations, it is advised that the salmon should not remain out of the water for more than 15 seconds (live fish should never be held by the gills or tail only) (RSPCA, 2021) (National Farm Animal Care Council, 2021) (Scottish Salmon Producers Organisation, 2015) (CIWF) (Polish Fisheries Promotion Society, 2015) (MOWI, 2022).

1. The smoltification process must be closely monitored for several weeks as detailed in the farm Veterinary Health and Welfare Plan (VHWP)[63]. Farmers should be trained in the procedures for assessing smoltification and minimising any negative effects on fish welfare (RSPCA, 2021) (Scottish Salmon Producers Organisation, 2015) (National Farm Animal Care Council, 2021).
2. Special attention shall be given to changes to photoperiod and/or temperature, a technique which is commonly used to induce out-of-season egg laying. Both the method and intensity of photoperiod changes and the quality of lighting used can also affect animal welfare, e.g. due to growth and feed consumption (Pavlidis & Samaras, 2020).

Examples

- UK implements GHPs #1, and #2.
- Norway and Poland implements GHP #1.

FALLOWING

Good husbandry practices

1. Single Bay Management (Ireland, 1997)[64] enhances the efficacy of lice control and reduces the overall incidence of disease in the stocks. The Single Bay Management plans are subject to revision for each production cycle. The Protocol on Fallowing specifies a minimum period of 30 continuous days for fallowing an individual site. (The Department of Agriculture, Fisheries & Food, 2008).
2. Fallow period should be at least eight weeks after the completion of harvesting and prior to restocking. This information is included in the Fish Health Management Plan (IFA Aquaculture, 2017) (Scottish Salmon Producers Organisation, 2015) (Best Aquaculture Practices, 2023).
3. Fallowing for three months may be adequate to lower the exposure of *Piscirickettsia salmonis* from one production cycle to the next. In salmon farming, the use of farm and area-level fallowing is a strategy to reduce transmission of infectious pathogens between production cycles (Price, Ibarra, Sánchez, & St-Hilaire, 2017).

Examples

- UK implements GHP #2.
- Ireland implements GHP #1, #2.

MORTALITY REMOVAL

Good husbandry practices

1. Dead fish should be accounted for and rapidly removed from holding units to prevent the spread of diseases and to indicate situations where there is poor welfare (IFA Aquaculture, 2017) (EFSA, 2008) (National Farm Animal Care Council, 2021) (Scottish Salmon Producers Organisation, 2015).

2. In seawater pens, dead fish should be removed at least twice a week (Scottish Salmon Producers Organisation, 2015) (IFA Aquaculture, 2017) (MOWI, 2022) (Polish Fisheries Promotion Society, 2015).

3. Increased mortality means unexplained mortality above the level considered accepted for the aquaculture establishment or group of establishments concerned, under the prevailing conditions, and for which the ultimate cause is not known. Any increase in mortality above accepted levels should be reported to the veterinarian. 'Accepted' levels for each site under ambient conditions should be recorded. When they are breached, an investigation should be initiated. On marine salmonid sites, where mortality levels exceed: 1.5% per week over the whole site where fish are < 750 g or 1% per week over the entire site where fish are > 750 g (IFA Aquaculture, 2017).

[63] VHWP: This document should be agreed between those with responsibility for the health and welfare of the fish, which may include the vet, health manager, stockpersons, nutritionist and other relevant personnel. It attempts to identify and define areas of management and husbandry where agreed activities and protocols are aimed at best practice for the maintenance and improvement of the stock health status and welfare.

[64] Single Bay Management | Marine Institute

Examples

- Ireland implements GHPs #1, #2, and #3.
- UK implements GHPs #1, #2.
- Poland and Norway implements GHP #2.

PREDATOR CONTROL

Mandatory requirements

Mandatory requirements for Atlantic salmon farmers related to predator control are *inter alia* foreseen in the following **EU legislation**:

- Council Directive 92/43/EEC of 21 May 1992: Annex II and annex IV, Animal, and plant species of community interest in need of strict protection, for instance the Otter, (*Lutra lutra*).
- Directive 2009/147/EC on the conservation of wild birds protects cormorants: Article 9 affords Member States the flexibility to derogate from the strict protection.

Good husbandry practices

1. The producer must use all reasonable non-lethal control methods to protect fish from predation by wild animals. The primary means of fish protection must be physical exclusion. The deployment of predator nets must be considered at high-risk sites during high-risk periods - and at other times if there is a risk of attack. Any site recognised as being at elevated risk of attack, or which has suffered an attack in the past, must have a working Acoustic Deterrent Device (ADD) in place, where its use is allowed. (IFA Aquaculture, 2017) (RSPCA, 2021) (EFSA, 2008).
2. Management methods (such as decreasing the stocking density of the aquaculture facilities) must be designed to reduce the attraction of predators to culture facilities as well as to prevent predators from attacking fish, thus avoiding stress that could result in an increased risk of disease (IFA Aquaculture, 2017) (Ministry of Industry and Fisheries, 2008).
3. Eliminating or reducing the number of places that predators can use for shelter or nesting. Removing and/or securely storing any wastes that may attract predators (National Farm Animal Care Council, 2021).
4. In case of a lethal incident, assess the risk of lethal incident(s) and demonstrate that concrete steps are taken by the farm to reduce the risk of future incidences (ASC, 2023).

Examples

- Ireland implements GHP #1, #2.
- UK implements GHP #1.
- Norway implements GHP #2, #4.

WATER QUALITY

Good husbandry practices

1. The optimum temperature for Atlantic salmon farming is between 1-18°C, in which: 4-8ºC (eggs); 10-14ºC (fry); 12-14ºC (parr); 3-18ºC (smolts) and 5-18ºC (post-smolts). Avoid sudden changes in temperature (IFA Aquaculture, 2017) (Noble, et al., 2018), (National Farm Animal Care Council, 2021) (EFSA, 2008).
2. The optimum oxygen percentages for each stage of the Atlantic salmon life cycle are: ≥ 90.0 % (eggs); ≥ 70.0 % (alevins); ≥ 70.0 % (Fry) and ≥ 70.0 % (Parr/smolt) (RSPCA, 2021) (EFSA, 2008).
3. The optimum pH for Atlantic salmon farming are: 5.5-8.0 (eggs, alevins, fry and parr/smolt) and 7.0-8.5 (post-smolt) (RSPCA, 2021) (EFSA, 2008).

Examples

- Ireland implements GHP #1.
- UK implements GHP #2, #3.

STOCKING DENSITIES

Mandatory requirements

Mandatory requirements for Atlantic salmon farmers related to stocking density are *inter alia* foreseen in the following **EU legislation** for organic certified products:

- Commission Implementing Regulation (EU) 2020/464[65]: Annex II Part II established 10 Kg/m^3 for Atlantic salmon in sea water.

Good husbandry practices

1. The optimum stocking densities for Atlantic salmon egg culture depending on the production system used: 15,000 eggs per California basket/tray and multi-level: 20,000 eggs per tray.
2. The optimum stocking densities for first feeding tank: 10,000/m2.
3. Optimal stocking densities for freshwater production tank as a function of fish size: 10 Kg/m3 (up to 1gm); 20Kg/m3 (≥ 1-5 gm) (reference to freshwater salmon stocking density out of Reg 2020/464); 30 Kg/m3 (≥ 5-30 gm); 50 Kg/m3 (≥ 30-50 gm); 60Kg/m3 (≥ 50 gm).
4. The optimum seawater maximum stocking density: seawater net pens 17 Kg/m3; seawater net pens maximum 15 Kg/m3.
5. The optimum stocking densities for freshwater net pens ≤ 8 Kg/m3 (RSPCA, 2021) (MOWI, 2022) (Ministry of Industry and Fisheries, 2008).

Examples

- UK and Norway implement GHPs #1, #2, #3, #4, and #5.

DISINFECTION AND CLEANING

Good husbandry practices

1. Nursery: Eggs must be disinfected after fertilisation. Establish and implement site-specific protocols for keeping the surface of eggs clean and monitoring egg mortality and fungal growth (National Farm Animal Care Council, 2021) (Scottish Salmon Producers Organisation, 2015).
2. To support biosecurity and prevent the spread of pathogens, broodstock, and juveniles should be physically separated (Scottish Salmon Producers Organisation, 2015).

Examples

- UK implements GHPs #1, and #2.

VACCINATION AND TREATMENTS

Mandatory requirements

Mandatory requirements for Atlantic salmon farmers related to vaccination and treatments are *inter alia* foreseen in the following **EU legislation**:

- Commission Delegated Regulation (EU) 2020/689[66]: Annex VI, chapter 2 of Part II.

For organic certified products the following production rule applies: Regulation (EU) 2018/848 on organic production and labelling of organic products: the main provisions set under Part III of Annex II point 3.1.4.1. g) .j).

[65] Commission Implementing Regulation (EU) 2020/464

[66] Commission Delegated Regulation (EU) 2020/689

Good husbandry practices

1. In addition to medicinal treatments, the use of freshwater bath treatments, underwater lasers, and cleaner fish are GHPs. It is relevant that good husbandry practices are aligned with the area-based management approach[67].
2. Use of real time data monitoring buoys and other technologies to identify elevation in phytoplankton and zooplankton levels (BIM, 2021) (Pitt, K.A et al, 2024).
3. Use of AI technology to identify the presence of harmful species in the vicinity of cages[68] (Le, K et al, 2022).
4. Careful examination of observable welfare indicators (such as mortality, appetite, behaviour, opercular movement, gill condition, etc.) during high-risk periods, and a reduction in handling during such periods (BIM, 2021).
5. Use of barrier systems such as bubble curtains (is created by releasing compressed air from a perforated tube at depth, forming a plume of bubbles that entrain the water to create a vertical current) to reduce or exclude exposure of fish to jellyfish (Haberlin, D. et al, 2021) (BIM, 2021).

Examples

- Ireland implements GHP #2, #4, #5.

ENVIRONMENTAL ENRICHMENT

Good husbandry practices

1. The presence of shelters in juvenile salmon rearing systems is associated with indicators of reduced stress (EFSA, 2008) (Scottish Salmon Producers Organisation, 2015) (MOWI, 2022).
2. Adding complexity in the captive environment not only promotes cognitive abilities and improves brain plasticity (Hyvärinen & Rodewald, 2013) (Salvanes, et al., 2013), but also decreases parasite occurrence and improves infection resistance and survival (Karvonen, et al., 2016) (Räihä, Sundberg, Ashrafi, Hyvärinen, & Karvonen, 2019).
3. Inserting a series of plastic tubes suspended in the rearing tank improves the feed conversion ratio (Jones, Krebs, Huysman, Voorhees, & Barnes, 2019).
4. Shade in aquaculture settings has been shown to reduce levels of sea lice in pen-reared Atlantic salmon (Jones, Webster, & Salvanes, 2021).
5. Inducing sustained exercise in Atlantic salmon using a lighting device centrally placed in semi-commercial tanks that provided an apparently moving light pattern, presented enhanced rates of growth and feed conversion, and reduced levels of plasma cortisol, improving productivity and welfare (Herbert NA, et al, 2011).
6. When juvenile salmonids are reared in flowing water (0.75-1.5 body length per second; BL s-1), they tend to grow faster, making more efficient use of the food and showing uniformity of growth rates and a reduce size range at harvest (Jobling M, et al., 1993).
7. A moderate water velocity (0.36-0.63 BL s-1) can be favourable for growth rates and performance of post-molt Atlantic salmon during the entire on-growing period in commercial closed contained systems (Nilsen, et al., 2019).
8. Background colour be like the gravel of the habitat in which fish are released to reduce the risk of predation (Jones, Webster, & Salvanes, 2021).
9. The provision of a varied thermal environment improved measures of welfare and growth in Atlantic salmon (Jones, Webster, & Salvanes, 2021).
10. Apparent accelerated smoltification observed in Atlantic salmon reared in light grey tanks. Light colours are probably unsuited for the rearing of salmonids (McLean, 2021).
11. The omission of an expected reward causes frustration in Atlantic salmon which is expressed by harmful effects on growth, aggression, and neurobiology. Restricted access to the self-feeder causes more aggressive behaviours linked to an increased competition. The provision of live prey (brine shrimp) together with physical enrichment enhances its foraging performance and may thus improve the post-release survival rates of hatchery-reared fish (Kleiber, et al., 2023).
12. The presence of a shelter (i.e. not necessarily the utilisation of it) has beneficial effects for Atlantic salmon, leading to reduced basal metabolic rate. In a study on Atlantic salmon, fish reared with

[67] https://www.marine.ie/site-area/areas-activity/aquaculture/sea-lice/single-bay-management

[68] https://aquaculture.otaq.com/products/live-plankton-analysis-system/

environmental enrichment foraged more efficiently on novel prey, but only if they also had experience of live food. Atlantic salmon were less stressed and grew better with partial cover (Näslund & Johnsson, 2016).

Examples

- Germany, Spain, France, Italy, Poland , Norway and UK implement GHP #1.

FUNCTIONAL FEED

Good husbandry practices

1. The use of organic acids and salts - such as potassium diformate - improves amino acid digestibility in Atlantic salmon (Storebakken, et al., 2010).
2. The use of prebiotics such as fructo oligosaccharides (FOS) (10 g/Kg feed) increases feed intake and digestibility of Atlantic salmon (Grisdale-Helland, Helland, & Gatlin III, 2008).
3. Use of diets or vitamin and/or immunostimulant supplements for salmonids prior to stressful events such as movements or to boost immunity before a disease outbreak, as well as during critical/stressful periods of the cycle (IFA Aquaculture, 2017).

Examples

- Ireland implements GHP #3.

SELECTIVE BREEDING

Good husbandry practices

1. **Traits.** The selective breeding goals for Atlantic salmon include production, disease resistance and carcass quality traits as well as early maturation. Feed efficiency is selected for as correlated responses to growth and energy/lipid efficiency. Temperature and oxygen tolerance traits are to be included in the breeding goals. Methodology to select for improved animal welfare traits related to stress and behaviour is under study.
2. **Selection method.** Genomic selection (Meuwissen, Hayes, & Goddard, 2001) is the standard selection method in breeding programs of Atlantic salmon. It is a particularly powerful selection method to increase selection accuracy for traits that cannot be recorded on selection candidates themselves e.g. slaughter traits and disease resistance traits.
3. **Management of genetic variation** is a very important part of breeding programs. Rates of inbreeding are controlled by using optimum contribution selection (Meuwissen, 1997) software that presents a list of candidates to use as parents for the next generation. These softwares are developed to maximise genetic gain, while controlling rates of inbreeding in the population.
4. The breeding programme in Ireland is currently focused on cardiomyopathic syndrome (CMS), growth, late sexual maturity, and pigment. The weights on each of these traits differ between the nucleus and production broodstock program. Good practices include maintaining inbreeding to less than 1% per generation, using a broad selection index in the nucleus compared to production broodstock, placing a strong focus on disease resistance, and committing to responsible breeding through Code EFABAR 2023 (EFFAB, 2023).

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European sea bass (*Dicentrarchus labrax L.*)

Good husbandry practices

Topics addressed	General					Specific		
	Feeding	Handling	Mortality removal	Fallo-wing	Predator control	Environmental enrichment	Selective breeding	Functional feed
	☒	☒	☒	☒	☒			
	Mini-mising risk of escapes	Water quality	Stocking densities	Disin-fection and cleaning	Vaccina-tion and treat-ments	☒	☒	☒
	☐	☒	☒	☒	☒			

FEEDING

Good husbandry practices

1. Broodstock units (inshore culture in RAS):
    a. Two distinct feeding regimes are usually applied: a maintenance diet after spawning until the start of gametogenesis, and a boosted diet, enriched in n-3 PUFA and essential micronutrients during gametogenesis and spawning. Maintenance diet includes both dry feed (0.5 % biomass) and fresh feed (1.0 % biomass), using a combination of cuttlefish, sardines, hake/whiting, crustacea and molluscs (EFSA, 2008).
    b. During the breeding period, dry feed is integrated with commercial integrators and natural components, such as squid oil, to provide nutrients essential for ensuring proper gametogenesis and excellent quality eggs and larvae (EFSA, 2008).
    c. Distribution of dry feed during the maintenance period usually takes place 6 times per week, and for fresh feed twice a week. This is increased up to six times per week during vitellogenesis (EFSA, 2008).
    d. Feed is manually distributed to reduce waste and to prevent deterioration of water quality in tanks (EFSA, 2008).
    e. During spawning, seabass is generally starved for a few days (EFSA, 2008).
2. Larval rearing units (inshore culture in RAS):
    a. Inappropriate provision of live feed (timing, distribution, quality) and feeding regime can lead to reduced welfare. Thus, it is necessary to give importance to food quality and feeding protocol (Pavlidis M., et al., 2023).
    b. Larval feeds have enriched nauplii of *Artemia* sp., crustaceans and *Brachionus* sp. rotifers. There are also larval rearing protocols that include the added provision of *Chlorella* sp. phytoplankton (the pseudo-green water method). To improve larval survival and growth, these feeds are enriched with polyunsaturated fatty acids, phospholipids, and amino acids (Pavlidis & Samaras, 2020).
3. Juvenile – weaning units (inshore culture in RAS):

   a. Feed shall be spread at regular intervals using automated feeders, as well as manual feeding or self-feeders (Pavlidis M., et al., 2023). Also, attention shall be given to feed quality and quantity (Pavlidis M., et al., 2023).
   b. Feed access shall be maintained to avoid intraspecific aggression (EFSA, 2008).

4. On- growing units (offshore culture):
   a. Regular feeding, in specific times (2-4 times per day), is important to reduce the risk of cannibalism and competition between fish, and to improve growth and production efficiency (Pavlidis & Samaras, 2020).
   b. Delivering food in a random fashion during the day shall be avoided because it may lead to an increase in blood cortisol concentrations and intense activity throughout the day when compared to fish fed at specific times (Pavlidis & Samaras, 2020).
   c. In small cage systems, hand feeding achieves better nutrition strategy, while in larger systems, automatic feeders are required to distribute and disperse better the feed (EFSA, 2008).
5. At feeding time, aggression in European sea bass has been seen to increase when fish are given less than the recommended amount of feed, by the producer, and when it is delivered exclusively to the same area of the tank (Pavlidis & Samaras, 2020).
6. Depending on developmental stage, physiological condition and environmental conditions, the digestion rate and feeding behaviour shall be borne in mind when estimating optimal feeding frequency – e.g. alterations in frequency and quantity in summer compared to winter (Pavlidis & Samaras, 2020).
7. It is important for feeding to take place according to a fixed timetable, as the fish will then know what time feed is delivered by following the innate biological rhythms in their physiology and behaviour that favour optimal feed utilisation (Pavlidis & Samaras, 2020).

Examples

- Greece implements GHP #2.b, #4.a,and 4.b, #5, #6, #7.

HANDLING

Good practices

1. Broodstock units (inshore culture):
   a. Special attention shall be given in repeated handling procedures of broodfish such as tagging, sexing and ovarian biopsies (Pavlidis M., et al., 2023).
   b. Handling manipulations of the broodstock (DNA sample extraction, reproductive maturity audit, sex audit) must be done carefully and by specialised personnel (EFFAB, 2023).
   c. Special attention shall be given to changes to photoperiod and/or temperature, a technique which is commonly used to induce out-of-season egg laying. Both the method and intensity of photoperiod changes and the quality of lighting used can also affect animal welfare, e.g. due to growth and feed consumption (Pavlidis & Samaras, 2020).
2. Larval rearing units (inshore culture):
   a. Repeated sampling for estimation of growth rate and larvae quality (under anaesthesia) and cleaning of tanks shall be done properly (Pavlidis M., et al., 2023).
   b. Specialist handling and transport is necessary during transfer to the weaning installations (Pavlidis M., et al., 2023).
3. Juvenile – weaning units (inshore culture):
   a. When fish are transported to open sea cages for on-growing, delivery time usually varies from 1 to 2 hours up to 3 to 4 days for distant destinations. It is necessary to use closed containers equipped with aeriation-oxygenation systems, and occasionally with automated systems for recording the water quality and cooling systems (Pavlidis M., et al., 2023).
4. On-growing units (offshore culture):
   a. Husbandry operations, such as 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, shall be carried out by trained operators (Pavlidis M., et al., 2023).

5. Fasting during 24-48 hours before operations is needed to empty the gut and to reduce oxygen requirements (never exceed 48 hours of starvation), while, in warmer periods, the starvation time shall not exceed 24 hours (CIWF, 2018) (EU Platform on Animal Welfare Own Initiative Group on Fish, 2020).
6. Once out of water, the fish shall be kept moist, handled using wet hands and for a maximum time of 15 sec, unless they are anaesthetised (CIWF, 2018) (EU Platform on Animal Welfare Own Initiative Group on Fish, 2020).
7. To minimise the negative effects on growth, fish quality and production, grading is typically done when fish weigh between 25-40 g and then again, when they weigh around 100 g (EFSA, 2008).

Examples

- UK implements GHP #5, #6.
- Greece, implement GHP #1.c.

MORTALITY REMOVAL

Good husbandry practices

1. Larval rearing units (inshore culture):
    a. Dead larvae shall be removed daily (EFSA, 2008).
2. Juvenile – weaning units (inshore culture):
    a. Co-habitation with dead or moribund fish shall be avoided (Pavlidis M., et al., 2023).
3. On-growing units (offshore culture):
    a. In cages, dead and moribund fish shall be removed on a daily or weekly basis (EU Platform on Animal Welfare Own Initiative Group on Fish, 2020) (EFSA, 2008).
4. To diminish extreme mortality rates, it is proposed to reduce feed rations as temperatures drop and use formulated feeds to mitigate the effects of thermal metabolic stress (EFSA, 2008) (CIWF, 2018).

Examples

- UK implements GHP #4.

FALLOWING

Good husbandry practices

1. Fallowing may be considered if it is needed, depending on the renewal rate of the waters, its carrying capacity, the depth of the establishment and the participation of aquaculture to the burden of the abiotic and biotic characteristics of the area (Greek legal bulletin, 2011).

Examples

- Greece (Legal bulletin, 2011).

PREDATOR CONTROL

Mandatory requirements

Mandatory requirements for European sea bass farmers related to predator control are inter alia foreseen in the following **EU legislation**:

- Council Directive 92/43/EEC of 21 May 1992[69]: Annex II and annex IV, Animal, and plant species of community interest in need of strict protection, for instance the Common Bottlenose Dolphin, *Tursiops truncatus*.

Good husbandry practices

1. In sea cages, predation shall always be controlled (either by netting or other methods), and recorded (EFSA, 2008).

[69] Council Directive 92/43/EEC

2. Especially in the case of on-growing units, special attention shall be given in predator control otherwise stress is increased (Pavlidis M., et al., 2023).
3. Cover of sea cages by nets or double nets to avoid excess exposure to predators (Pavlidis M., et al., 2023).

WATER QUALITY

Good husbandry practices

1. Broodstock units (inshore culture):
    a. Because the rearing becomes in land-based installations with open or (during vitellogenesis/egg laying periods) closed water circulation systems (very often using boreholes), several of the water parameters may change more markedly than in the sea. For this reason, water temperature, oxygen and pH must be monitored and adjusted where necessary to secure optimal conditions (Pavlidis & Samaras, 2020).
    b. Environmental conditions for spawning are an increasing photoperiod (LD 9:15 to 12:12) and thermocycle (10-15ºC). Spawning has been observed over the temperature range of 9-18ºC, while optimal temperatures are 13-15ºC and spawning stops at temperatures above 18ºC (Cabrita, 2009).
    c. Displaced spawning periods can be obtained by altering both the photoperiod and the thermal cycle, either by phase shifting the cycles, using square wave cycles, or using compressed or expanded cycles. One- or two-month square wave period of long daylength (LD 15:9) in an otherwise constant short daylength (LD 9:15) regime could be applied each month from March through to September to obtain spawning from October through to May (Cabrita, 2009).
2. Larval rearing units (inshore culture):
    a. The optimal range of temperature is 10-20 °C for eggs and larvae (Pavlidis & Samaras, 2020).
    b. Water temperature shall be maintained stabilised during incubation and early development stages (EFSA, 2008).
    c. Minimum oxygen saturation shall never drop below 70% for more than a few hours (CIWF, 2018).
3. Juvenile – weaning units (inshore culture):
    a. Weaning takes place in land-based tanks maintained in a continuous flow-through system supplied with seawater 35 to 38‰ grams per litre (ppt) or well/deep well water, ensuring a constant water temperature (17 to 19°C) and salinity (30‰) year-round (Pavlidis M., et al., 2023). A recirculating system, to control water temperature may also be used either on a year-round basis or during winter/spring months (Pavlidis M., et al., 2023).
    b. Environmental parameters, such as temperature, oxygen, and lighting, can be regulated and determined by producers. On the other hand, salinity and pH must be monitored and adjusted because are characteristics of the source water (e.g. sea or borehole) (Pavlidis & Samaras, 2020).
    c. Water flow shall be maintained to avoid intraspecific aggression (EFSA, 2008).
4. On-growing units (offshore culture):
    a. The optimal range of temperature is 8-28 °C (Pavlidis & Samaras, 2020).
    b. Prolonged exposure to high water temperatures and low oxygen saturation during summer - early autumn months shall be avoided (Pavlidis M., et al., 2023).
    c. During the on-growing phase, any rapid changes in temperature shall only occur within the thermal ranges (2-35 °C) (Pavlidis & Samaras, 2020).
    d. Minimum oxygen saturation shall never drop below 40% for more than a few hours for adults (CIWF, 2018).
5. Temperature changes exceeding 5 °C /day shall be avoided (EFSA, 2008).
6. Oxygen saturation shall be kept as close as 100% (optimal range 70-110%) and oxygen concentration above 5 mg/L (CIWF, 2018).
7. The optimal water pH range is 6.5 to 8.5; pH values below 5 and above 9 shall be avoided (Pavlidis & Samaras, 2020).
8. Optimal performance in terms of growth and feed consumption has been recorded at salinity 30‰ (Pavlidis & Samaras, 2020).

Examples

- UK implements GHP #2.c, #4.d, #6.
- Greece implements GHPs #1.a, #2.a, #3.b, #4.a and 4.c, #7, #8.

STOCKING DENSITIES

Mandatory requirements

The following production rule applies for organic certified products under Commission Implementing Regulation (EU) 2020/464[70]: Annex II, Parts III and IV. Maximum stocking density 15 Kg/ m^{-3} in sea cages, 4 Kg/ m^{-3} in earth ponds (in some cases traditional salt pans transformed into aquaculture production units).

Good husbandry practices

1. Broodstock units (inshore culture):
    a. Broodfish are usually kept in rectangular or circular indoor polyester tanks of 10 to 25/ m^3 water volume (Pavlidis M., et al., 2023).
2. Juvenile – weaning units (inshore culture):
    a. Adequate stocking density shall be maintained to avoid intraspecific aggression (EFSA, 2008).
3. On-growing units (offshore culture):
    a. A typical stocking density in commercial sea cages is ranged from 5-20 kg/ m^{-3} for fish weighing 2.5-150 g and 10-20 kg/ m^{-3} for larger fish (>150 g) (EFSA, 2008).
4. Inappropriate stocking density shall be avoided because it can lead to fin erosion, injuries, decreased feed intake and increased disease susceptibility (Pavlidis M., et al., 2023).

DISINFECTION AND CLEANING

Good husbandry practices

1. Broodstock units (inshore culture):
    a. Since rearing water derives from installations outside the farms, usually via boreholes, particular attention must be paid to hygiene. Mechanical and antimicrobial filters shall be used for biosecurity and hence stock welfare (Pavlidis & Samaras, 2020).
2. Larval rearing units (inshore culture):
    a. In larval rearing tanks, the usage of a disinfected siphon once or twice a day is necessary to remove the settled debris (uneaten food and faeces) and dirt from the bottom of the tanks (EFSA, 2008).
    b. Mechanical and antimicrobial filters shall be used for biosecurity and hence stock welfare (Pavlidis & Samaras, 2020).
3. Juvenile – weaning units (inshore culture):
    a. Mechanical and antimicrobial filters shall be used for biosecurity and hence stock welfare (Pavlidis & Samaras, 2020).
4. On-growing units (offshore culture):
    a. In growth phases, frequent net changing is essential (up to every 15-20 days during summer), as well as weekly cleaning to remove fouling organisms (EFSA, 2008).
    b. Periodic anti-fouling treatment avoids net deterioration (EFSA, 2008).

Examples

- Greece implements GHP #1.a, #2.b, #3.a.

VACCINATION AND TREATMENTS

Good husbandry practices

[70] Commission Implementing Regulation (EU) 2020/464

1. Number of anti-parasiticide treatments allowed over the most recent production cycle, including the hatchery: only 1; while number of treatments of antibiotics over the most recent production cycle, including the hatchery: ≤3 (ASC, 2018).
2. Bath treatments are regularly used to control gill and skin ectoparasites (e.g., monogeneans, isopods, copepods). Treatments can be performed in the rearing tank or fish can be collected and treated in a separate tank, container, or recipient (Rigos, Padrós, Golomazou, & Zarza, 2023).
3. Freshwater or hyposalinity baths are considered therapeutic baths and are applied mainly at land-based facilities. An example with high efficacy hyposalinity scheme (8‰–10‰, for 1 h) is for Euplotes sp (Rigos, Padrós, Golomazou, & Zarza, 2023).
4. Baths in a formalin solution are undoubtedly the most commonly used therapy against ectoparasitic infections in aquaculture and currently the most popular antiparasitic approach in Mediterranean aquaculture. A dosing schedule for adults is 375 ppm against the ectoparasite *Diplectanum aequans* (Rigos, Padrós, Golomazou, & Zarza, 2023).

Examples

- Albania, Croatia, Italy, Germany, Greece, Turkey, Spain implement GHP #1.

ENVIRONMENTAL ENRICHMENT

Good husbandry practices

1. Increase the structural complexity (e.g., gravel, sand, pebbles, and plants) of fish captive environment as much as possible (EFSA, 2008).
2. Suspended vertical structures (U-shaped ropes) may positively affect the group behaviour of sea bass to stressful situations, which could correspond to better adaptation (Arechavala-López, Cabrera-Álvarez, Maia, & Saraiva, 2022).

SELECTIVE BREEDING

Good husbandry practices

1. There is an urgent need to broaden the genetic composition of the base populations from which selection programmes start. In this point, some measures include increasing the number of parents selected; conducting artificial fertilisation; applying single-pair rather than mass spawning; and, if possible, implementing optimal contribution selection to maximise genetic gain, while restricting the rate of inbreeding (Saura, 2021).
2. Selective breeding has been successfully applied to improve profitability and sustainability and for disease outbreaks, which is a major threat to the aquaculture industry (Griot, Allal, Phocas, & et al, 2021) (Boudry Pierre, 2021).
3. A new genomic tool, MedFish array, will accelerate selective breeding by selecting genes from efficient and exact genetic analysis (Peñaloza, et al., 2021).

FUNCTIONAL FEED

Good husbandry practices

1. Dietary inclusion of a mucilage extracts rich in galactomannan oligosaccharides (GMOS) and a mixture of garlic and labiatae-plants oils (PHYTO) in feeds of sea bass had beneficial effects on gut microbiota, such as the reduction of coliforms and Vibrionales bacteria, which include several potentially pathogenic species for fish, and the enrichment of gut microbiota composition with butyrate producer taxa (Rimoldi, et al., 2020).
2. The supplementation either with 0.5% galactomannan oligosaccharides (GMOS diet) or 0.02% of a mixture of essential oils (PHYTO diet) as functional additives entails a better capability of the animals to cope with infection in sea bass when fed low FM (fishmeal) and FO (fish oil) diets (Serradell, et al., 2020).
3. An innovative diet showed the successful partial replacement of FM by poultry meal (PM) and the total replacement of FO by a blend of poultry oil and an emergent microalgal oil (Montero, et al., 2023).

Examples

- Spain implements GHP #1.

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Gilthead sea bream (*Sparus aurata L.*)

Good husbandry practices

Topics addressed	General					Specific		
	Feeding	Handling	Mortality removal	Fallo-wing	Predator control	Environmental enrichment	Selective breeding	Functional feed
	☒	☒	☒	☒	☒			
	Mini-mising risk of escapes	Water quality	Stocking densities	Disin-fection and cleaning	Vaccina-tion and treat-ments	☒	☒	☒
	☐	☒	☒	☒	☒			

FEEDING

Good husbandry practices

1. Broodstock units (inshore culture):
    a. Two distinct feeding regimes are usually applied: a maintenance diet after spawning until the start of gametogenesis, and a boosted diet, enriched in n-3 PUFA and essential micronutrients during gametogenesis and spawning. Maintenance diet includes both dry feed (0.5 % biomass) and fresh feed (1.0 % biomass), using a combination of cuttlefish, sardines, hake/whiting, crustacea and molluscs (EFSA, 2008).
    b. During the breeding period, dry feed is integrated with commercial integrators and natural components, such as squid oil, to provide nutrients essential for ensuring proper gametogenesis and good quality eggs and larvae (EFSA, 2008).
    c. Distribution of dry feed during the maintenance period usually takes places six times per week, and for fresh feed twice a week. This is increased up to six times per week during vitellogenesis (EFSA, 2008).
    d. Feed is manually distributed to reduce waste and to prevent deterioration of water quality in tanks (EFSA, 2008).
2. Larval rearing units (inshore culture):
    a. Inappropriate provision of live feed (timing, distribution, quality) and feeding regime can lead to reduced welfare. Thus, it is necessary to give importance to food quality and feeding protocols (Pavlidis M., et al., 2023).
    b. Larval feeds contain enriched nauplii of *Artemia* sp., crustaceans and *Brachionus* sp. rotifers. There are also larval rearing protocols that include the additional provision of *Chlorella* sp. phytoplankton (the pseudo-green water method). To improve larval survival and growth, these feeds are enriched with polyunsaturated fatty acids, phospholipids, and amino acids (Pavlidis & Samaras, 2020).
3. Juvenile – weaning units (inshore culture):
    a. Feed shall be spread at regular intervals using automated feeders, as well as manual feeding or self-feeders (Pavlidis M., et al., 2023). Also, attention shall be given to feed quality and quantity (Pavlidis M., et al., 2023).

4. On-growing units (offshore culture):
    a. Regular feeding, in specific times (2-4 times per day) is important to reduce the risk of cannibalism and competition between fish, and to improve growth and production efficiency (Pavlidis & Samaras, 2020).
    b. Delivering food in a random fashion during the day shall be avoided because it may lead to an increase in blood cortisol concentrations and intense activity throughout the day when compared to fish fed at specific times (Pavlidis & Samaras, 2020).
    c. In small net pens systems, hand feeding achieves a better nutrition strategy, while in larger systems, automatic feeders are required to distribute and disperse better the food (EFSA, 2008).
5. Depending on developmental stage, physiological condition and environmental conditions, the digestion rate and feeding behaviour shall be borne in mind when estimating optimal feeding frequency – e.g. alterations in frequency and quantity in summer compared to winter (Pavlidis & Samaras, 2020).
6. It is important for feeding to take place according to a fixed timetable, as the fish will then know what time feed is delivered by following the innate biological rhythms in their physiology and behaviour that favour optimal feed utilisation (Pavlidis & Samaras, 2020).

Examples

- Greece implements GHPs #2.b, #4.a and 4.b, #5, #6.

HANDLING

Good husbandry practices

1. Broodstock units (inshore culture):
    a. Special attention shall be given in repeated handling procedures of broodstock fish such as tagging, sexing and ovarian biopsies (Pavlidis M., et al., 2023).
    b. Handling manipulations of the broodstock (DNA sample extraction, reproductive maturity audit, sex audit) must be done carefully and by specialised personnel (EFFAB, 2023).
    c. Whenever necessary, sex ratio monitoring can be carried out by checking the percentage of individuals that release milt during stripping. The technique shall be carried out under anaesthesia by a veterinarian (Pavlidis & Samaras, 2020).
    d. Special attention shall be given in changes to photoperiod and/or temperature, a technique which is commonly used to induce out-of-season egg laying. Both the method and intensity of photoperiod changes and the quality of lighting used can also affect animal welfare, e.g. due to growth and feed consumption (Pavlidis & Samaras, 2020).
2. Larval rearing units (inshore culture):
    a. Repeated sampling for estimation of growth rate and larvae quality (under anaesthesia) and cleaning of tanks shall be done properly (Pavlidis M., et al., 2023).
    b. Specialist handling, and transport necessary for transfer to the weaning installations (Pavlidis M., et al., 2023).
3. Juvenile – weaning units (inshore culture):
    a. When fish are transported to open sea pens for on-growing, delivery time usually varies from 1 to 2 hours up to 3 to 4 days for distant destinations. It is necessary to use closed containers equipped with aeriation-oxygenation systems, and with automated systems for recording the water quality and cooling systems (Pavlidis M., et al., 2023).
4. On-growing units (offshore culture):
    a. Husbandry operations, such as thinning down in bigger volumes of net pens, net changes, net pens 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, shall be carried out by trained operators (Pavlidis M., et al., 2023).
5. Fasting 24-48 hours before operations is needed to empty the gut and to reduce oxygen requirements (never exceed 48 hours of starvation), while, in warmer periods, the starvation time shall not exceed 24 hours (CIWF, 2018) (EU Platform on Animal Welfare Own Initiative Group on Fish, 2020).
6. In gilthead sea bream, even short-term (7-day) fasting may lead to weight loss. Furthermore, it is a species that does not show rapid weight recovery to the levels found in fish that have not undergone

fasting, thus it is essential to take this into account over the fasting procedure (Pavlidis & Samaras, 2020).

7. Once out of water, the fish shall be kept moist, handled using wet hands and for a maximum time of 15 sec, unless they are anaesthetised (CIWF, 2018) (EU Platform on Animal Welfare Own Initiative Group on Fish, 2020).
8. To minimise the negative effects on growth, fish quality and production, grading is typically done when fish weigh between 25-40 g and then again, when they weigh around 100 g (EFSA, 2008).
9. In every handling procedure, it is essential to remove dead fish to prevent the spread of possible diseases or the introduction of pathogens (Pavlidis M., et al., 2023).

Examples

- UK implements GHP #5, #7.
- Greece implements GHP #1.c and 1.d, #6.

MORTALITY REMOVAL

Good husbandry practices

1. Larval rearing units (inshore culture): Dead larvae shall be removed daily (EFSA, 2008).
2. Juvenile – weaning units (inshore culture): Co-habitation with dead or moribund fish shall be avoided (Pavlidis M., et al., 2023).
3. On-growing units (offshore culture): In marine net pens, divers shall remove dead and moribund fish on a weekly basis and examine for signs of disease. (EU Platform on Animal Welfare Own Initiative Group on Fish, 2020) (EFSA, 2008).
4. To mitigate against high mortality rates, especially in larvae and juvenile stages, it is proposed to reduce feed rations as temperatures drop and to use formulated feeds to mitigate the effects of thermal metabolic stress (EFSA, 2008) (CIWF, 2018).
5. In addition, to mitigate against high mortality rates, special attention should be paid to sea bream in order to avoid “winter” syndrome[71].This attention consists of proper management, focus on fish health during the winter months, reducing feed rations as temperatures drop, as well as the use of feed formulated to mitigates the effects of thermal metabolic stress. Winter diets rich in lipids, marine-derived ingredients, vitamins (especially C and E) and minerals have had positive effects on growth enhancement, reducing the metabolic effects of heat stress and improving immunity (CIWF, 2018).

Examples

- UK implements GHPs #4 and #5.

FALLOWING

Good husbandry practices

1. Fallowing may be considered if it is needed based on the renewal rate of the water, its carrying capacity, the depth of the establishment and the participation of aquaculture to the burden of the abiotic and biotic characteristics of the area (Greek legal bulletin, 2011).

Examples

- Greece implements GHP #1.

PREDATOR CONTROL

Mandatory requirements

Mandatory requirements for Gilthead Sea bream farmers related to predator control are inter alia foreseen in the following **EU legislation**:

[71] Seabream's loss of weight or even mortality in winter

- Council Directive 92/43/EEC of 21 May 1992[72]: Annex II and annex IV, Animal, and plant species of community interest in need of strict protection, for instance the Common Bottlenose Dolphin, *Tursiops truncatus*.

Good husbandry practices

1. In sea net pens, predation shall always be controlled (either by netting or other methods) and it is necessary to keep a record of potential predators (EFSA, 2008).
2. Especially in the case of on-growing units, special attention shall be given to predator control otherwise stress is increased (Pavlidis M., et al., 2023).
3. Cover sea net pens by nets or use double nets to avoid excess exposure to direct sunlight and predators (Pavlidis M., et al., 2023).

WATER QUALITY

Good husbandry practices

1. Broodstock units (inshore culture):
    a. Because the rearing becomes in land-based installations with open or (during vitellogenesis/egg laying periods) closed water circulation systems (very often using boreholes), several of the water parameters may change more markedly than in the sea. For this reason, water temperature, oxygen concentration and pH must be monitored and adjusted where necessary to secure optimal conditions (Pavlidis & Samaras, 2020).
    b. The spawning season extends from January to May, under an increasing photoperiod (LD 9:15 to 14:10) and thermal cycle. Spawning has been observed over the temperature range of 14-20ºC, while optimal temperatures were 15-17ºC and spawning stops at temperatures above 24ºC (Cabrita, 2009).
2. Larval rearing units (inshore culture):
    a. The optimal range of temperature is 12-22 °C for eggs and larvae (Pavlidis & Samaras, 2020).
    b. Water temperature shall be maintained stabilised during incubation and early development stages (EFSA, 2008).
    c. Minimum saturation shall never drop below 70% for more than a few hours (CIWF, 2018).
3. Juvenile – weaning units (inshore culture):
    a. Weaning takes place in land-based tanks maintained in a continuous flow-through system 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 (Pavlidis M., et al., 2023). A recirculating system, to control water temperature may also be used either on a year-round basis or during winter/spring months (Pavlidis M., et al., 2023). Frequently, it is good to use deep well water ensuring low fluctuation of water temperature and a proper salinity (Pavlidis M., et al., 2023).
    b. Environmental parameters, such as temperature, oxygen, and lighting, can be regulated and determined by producers. On the other hand, salinity and pH must be monitored and adjusted being characteristics of the source water (e.g. sea or borehole) (Pavlidis & Samaras, 2020).
4. On-growing units (offshore culture):
    a. The optimal range of temperature is 8-30 °C (Pavlidis & Samaras, 2020).
    b. Prolonged exposure to high water temperatures and low oxygen saturation during summer - early autumn months shall be avoided (Pavlidis M., et al., 2023).
    c. During the on-growing phase, any rapid changes in temperature shall only occur within the recommended thermal ranges (5-34 °C) (Pavlidis & Samaras, 2020).
    d. Minimum saturation shall never drop below 40% for more than a few hours for adults (CIWF, 2018).
5. Temperature changes exceeding 5 °C /day shall be avoided. Especially for sea bream, acute temperature decreases (from 15 °C to 9 °C) shall be avoided due to the risk of winter syndrome (EFSA, 2008).

[72] Council Directive 92/43/EEC

6. Oxygen saturation shall be kept as close as 100% (optimal range 70-110%) and oxygen concentration above 5 mg/L (CIWF, 2018).
7. The optimal water pH range is 6.5 to 8.5; pH values below 5 and above 9 shall be avoided (Pavlidis & Samaras, 2020).
8. Optimal performance in terms of growth and feed consumption has been recorded at salinity 18-28‰ (Pavlidis & Samaras, 2020).

Examples

- UK implements GHP #2.c, #4.d, #6.d.
- Greece implements GHP #1.a, #2.a, #3.b, #4.a and 4.c, #7, #8

STOCKING DENSITIES

Mandatory requirements

The following production rule applies for organic certified products Commission Implementing Regulation (EU) 2020/464[73]: Annex II, Parts III and IV. Maximum stocking density 15 Kg/m^3 in sea net pens, 4 Kg/m^3 in earth ponds (traditional salt pans transformed into aquaculture production units).

Good husbandry practices

1. Broodstock units (RAS):
    a. Broodfish are usually kept in rectangular or circular indoor polyester tanks of 10 to 20 m^3 water volume at a density of 4-8 /Kg m^{-3} (Pavlidis & Mylonas, 2011).
    b. A male to female ratio of 3:1 shall be maintained in order to achieve a good fertilisation rate, since in gilthead sea bream sex reversal is socially determined (Pavlidis M., et al., 2023).
2. Larval rearing units (RAS):
    a. Larvae may be cultured under controlled conditions in circular – conical tanks of 3-6 m diameter (Pavlidis & Mylonas, 2011).
3. On-growing units (net pens):
    a. A typical stocking density in commercial sea net pens is ranged from 5-20 kg /m^{-3} for fish weighing 2.5-150 g and 10-20 kg/ m^{-3} for larger fish (>150 g) (EFSA, 2008).
4. Inappropriate stocking density shall be avoided because it can lead to fin erosion, injuries, decreased feed intake and increased disease susceptibility (Pavlidis M., et al., 2023).

DISINFECTION AND CLEANING

Good husbandry practices

1. Broodstock units (inshore culture):
    a. Since rearing water derives from installations outside the farms, usually via boreholes, particular attention must be paid to hygiene. Mechanical and antimicrobial filters shall be used for biosecurity and hence stock welfare (Pavlidis & Samaras, 2020).
2. Larval rearing units (inshore culture):
    a. In larval rearing tanks, the usage of a disinfected siphon once or twice a day is necessary to remove the settled debris (uneaten food and faeces) and dirt from the bottom of the tanks (EFSA, 2008).
    b. Mechanical and antimicrobial filters shall be used for biosecurity and hence stock welfare (Pavlidis & Samaras, 2020).
3. Juvenile – weaning units (inshore culture):
    a. Mechanical and antimicrobial filters shall be used for biosecurity and hence stock welfare (Pavlidis & Samaras, 2020).
4. On-growing units (offshore culture):
    a. In growth phases, frequent net changing is essential (up to every 15-20 days during summer), as well as weekly cleaning to remove fouling organisms (EFSA, 2008).

[73] Commission Implementing Regulation (EU) 2020/464

b. Periodic anti-fouling treatment avoids net deterioration (EFSA, 2008).

VACCINATION AND TREATMENTS

Good husbandry practices

1. Only 1 anti-parasite treatments are allowed over the most recent production cycle, including the hatchery. For antibiotics, ≤3 treatments over the most recent production cycle, including the hatchery are allowed (ASC, 2018).
2. Bath treatments are regularly used to control gill and skin ectoparasites (e.g., monogeneans, isopods, copepods). Treatments can be performed in the rearing tank or fish can be collected and treated in a separate tank, container, or recipient (Rigos, Padrós, Golomazou, & Zarza, 2023).
3. Freshwater or hyposalinity baths are considered therapeutic baths and are applied mainly at hatcheries (RAS facilities). An example with high efficacy hyposalinity scheme (10‰ for 3 h, four consecutive treatments, 3 days apart / 8‰–10‰ for 1–3 h) is for Cryprocaryon spp. and another with low efficacy hyposalinity scheme (0‰–2‰ for 1 h) is for *Amyloodinium ocellatum* (Rigos, Padrós, Golomazou, & Zarza, 2023).
4. Baths in a formalin solution are undoubtedly the most used therapy against ectoparasitic infections in aquaculture and currently the most popular antiparasitic approach in Mediterranean aquaculture. A dosing schedule for larvae is 25–200 ppm against the ectoparasite *A. ocellatum* and for juveniles is 150–200 ppm (1 h) against the ectoparasite *Sparicotyle chrysophrii* (Rigos, Padrós, Golomazou, & Zarza, 2023).

Examples

- Albania, Croatia, Italy, Germany, Greece, Turkey, Spain implement GHP #1.

ENVIRONMENTAL ENRICHMENT

Good husbandry practices

1. Increase the structural complexity (e.g., gravel, sand, pebbles, and plants) of the fish captive environment as much as possible (EFSA, 2008).
2. Juveniles (20.3 ± 0.22 g) reared with blue substrate (glass gravel 6-12 mm in size) displayed less aggression behaviour and had lower basal cortisol levels (Batzina & Karakatsouli, 2014). Additionally, blue, or red-brown gravel has been found to lower aggression (CIWF).
3. When comparing the effect of exposing juvenile (20.2 ± 0.26 g) to blue substrate (glass gravel 6-12 mm in size, structural enrichment) vs a photo of blue substrate, the fish exposed to blue substrate were less aggressive and were observed manipulating the substrate (Batzina & Karakatsouli, 2014).
4. A simple enrichment of adding vertical ropes in sea net pens could improve cognition, fin condition and behaviour for gilthead sea bream (Arechavala-Lopez, et al., 2019), (Arechavala-Lopez, et al., 2020), (Muñoz, Aspillaga, Palmer, & Arechavala-Lopez, 2020).

SELECTIVE BREEDING

Good husbandry practices

1. To broaden the genetic composition of the base populations from which selection programmes start the following practices are reported: increase the number of parents selected; conduct artificial fertilisation; apply single-pair rather than mass spawning; and, if possible, implement optimal contribution selection to maximise genetic gain, while restricting the rate of inbreeding (Saura M., 2021).
2. Selective breeding has been successfully applied to improve profitability and sustainability and for disease outbreaks which is a major threat to the aquaculture industry (Griot, Allal, Phocas, & et al, 2021) (Boudry Pierre, 2021).
3. A new genomic tool, MedFish array, will accelerate selective breeding by selecting genes from efficient and exact genetic analysis (Peñaloza, et al., 2021) (Griot, Allal, Phocas, & et al, 2021) (Boudry Pierre, 2021).
4. Gilthead seabream broodstock selected on growth trait could have a positive role in the improvement of sperm and egg quality to produce viable progeny (Ferosekhan, 2021).

FUNCTIONAL FEED

Good husbandry practices

1. Current aquafeeds for farmed sea bream are designed to provide the fish with all the nutritional needs for maximum performance and sound growth. Microalgae-based products are suitable for improving feed efficiency and orchestrating significant changes in the intermediary metabolism in gilthead sea bream juveniles (Perera E., et al., 2020).
2. Feeds with elevated levels of chickpeas instead of soybean meal or sunflower meal could be considered efficient because of the high protein productive value and the tested legumes are ingredients that could be used in farmed sea bream diets up to 350 g/kg without negative effects replacing other carbohydrate sources and part of fish meal (Porcino & Genovese, 2022).
3. Carob seed germ meal might be substituted at levels up to 34% in diets without effects on fish growth and nutritive parameters for short-term feeding of sea bream (Martinez-Llorens, Baeza-Ariño, Nogales-Merida, Jover-Cerda, & Tomas-Vidal, 2012).
4. In feeds with orange peel (OP) as a feed additive in sea bream meals, growth performance and feed utilisation parameters were significantly improved by the elevation of dietary OP level, and the optimum level was 5 g kg^{-1} diet (Salem, Abdel-Ghany, Sallam, El-Feky, & Almisherfi, 2019).

Examples

- Spain implements GHP #1.

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Mussels

Good husbandry practices

Topics addressed	General					Specific		
	Feeding	Handling	Disease prevention	Fallowing	Predator control	Environmental enrichment	Selective breeding	Functional feed
	☐	☒	☒	☐	☒			
	Minimising risk of escapes	Water quality	Stocking densities	Depuration and cleaning	Treat-ments	☐	☒	☐
	☐	☒	☒	☒	☐			

HANDLING

Mandatory requirements

Mandatory requirements for mussels farmers related to harvesting and grading are *inter alia* foreseen in the following **EU legislation**:

- Regulation (EC) No 853/2004[74]: Annex III, Section VII.

In addition, the following production rules apply for organic certified products: Regulation (EU) 2018/848 on organic production and labelling of organic products[75]: article 15 and main provisions under points 3.1.3.2, 3.1.6.1, 3.1.6.2, 3.1.6.6 and 3.2 of Part 3 of Annex II; and specific rules under Commission Implementing Regulation 2020/464: Annex II part IX.

Good husbandry practices

1. Blue mussel (*Mytilus edulis*):
    a. Hatchery production: regardless of the rearing technique, mussel culture is currently dependent on settlement or capture of wild spat. This can be sporadic which leads to a break in the farmers' production cycles and income. Hatchery production would provide a dependable source of spat annually to the industry. However, there are currently no commercial mussel hatcheries in operation in Europe.
        i. As part of the EU-funded project Aquavitae, a protocol was developed for the hatchery production of blue mussel spat (Saurel, C. Et al, 2022)
        ii. Mature mussels shall be cleaned and hung as a group in larval tanks and the spawning is induced by thermal shock or by stripping (FAO, 2023).
        iii. Larvae shall be allowed to grow until they are ready to set onto ropes (13-15 days)

[74] Regulation (EC) No 853/2004

[75] Regulation (EU) 2018/848

(FAO, 2023).

iv. Deployed in setting tanks, mussels are transferred at a 1 mm size to a nursery, where they will remain until they reach 6-10 mm; then the spat is moved outdoors into grow-out systems (FAO, 2023).

b. On-bottom culture:

i. Mussel seeds (spat) shall be transferred from areas where they have settled in great abundance to culture plots where they can be re-laid at lower densities to obtain improved growth and fattening, and to control predation (FAO, 2023).

ii. Seeds are dredged from the bottom of the seabed and then re-laid into growing sites (tidal or subtidal plots), where carrying capacity is optimal (FAO, 2023).

c. Bouchot culture:

i. Spat settlement shall occur intensively in spring directly onto the horizontal coconut fibre ropes strung on the poles before settlement (FAO, 2023).

ii. The excess juveniles could be then transferred in summer to tubular nets that are reattached around the growing poles. Optimisation of stocking density encourages growth distribution and prevents drop-off from the mesh as the mussel grow. (FAO, 2023).

d. Longline culture:

i. In areas showing high tidal cycles and excessive current speed, it is better to develop subsurface longlines cultures to resist storm and wave effects. (FAO, 2023).

e. Mussels shall be harvested when they reach a marketable size (about 40 mm, which takes 12-24 months) (FAO, 2023). Meat content and mussel condition are crucial, being the Condition Index (CI) the main driver for harvesting. Best practices were carried out in 2013 in the MUSSELSALIVE project: reduce handling time during grading process, careful handling at harvest, use of modified grading barrel and correct settings of machinery such us declumper (MUSSELSALIVE project, 2010-2013).

f. Mussels grown on wooden poles shall be harvested by hand or by using a hydraulic powered system that removes all the mussels at once (FAO, 2023).

g. In The Netherlands, the four-steel dredge (1.9 m wide) system ran by a hydraulic or pneumatic 8-drum is used for on-bottom culture (FAO, 2023).

h. In Ireland, the “pneumatic or hydraulic 8 drums” is not required. Most plots are subtidal (comm personal BIM).

i. On hard bottoms, it is better to use round steel ground dredge bars that are provided with 2x2 cm steel blades (FAO, 2023).

2. Mediterranean mussel (*Mytilus galloprovincialis*):

a. Seed collection:

i. Farmers shall gather mussel seeds with mean length of 2 cm from natural beds every culture cycle (FAO, 2023b).

ii. To collect seed from the rafts, farmers should use special nets made from old fish nets and suspend them during March and April (FAO, 2023b).

b. Farmers can attach the seed to the ropes usually by hand, or with a machine which secures it with a special cotton or rayon mesh, which biodegrades within a few weeks (FAO, 2023b). Depending on growing conditions, seed mussels are shifted from intertidal plots to subtidal plots once reaching the refuge size (Capelle et al. 2017). (FAO, 2023b).

c. Farmers shall install the ropes mainly from November to March (FAO, 2023b). In Ireland collectors are installed around March - April. Thinning is performed in Autumn. (comm personal BIM).

d. Contamination of mussels during harvesting shall be avoided by, for instance, assignment of risk status (classification), detecting unpredicted additional sources of contamination affecting on the harvesting area, etc. (WHO, 2010).

e. The time to transport mussel seed from the collection site to the relaying site shall be as short as possible to avoid stressing the animals (Epsilon Aquaculture Limited, 2002). It is advisable to keep the seed moist (water spray or tarpaulin cover) during transfer, wherever possible (Epsilon Aquaculture Limited, 2002).

f. The ice is not the key management component for keeping blue mussels (*Mytilus edulis*) alive without stress. Survival and stress were reduced via depuration and rewatering (Barrento, S., Powell, A., 2015).

g. Immature seed mussels (15-30 mm shell length) shall be moved from the higher parts of

intertidal beds and offshore sub-littoral beds - where they do not grow well - to other areas of greater productivity (Epsilon Aquaculture Limited, 2002).

h. In some places, such as Castlemaine (Ireland), saller seed is up the shore and then transplanted in subtidal ground when they reach the refuge size from predation (comm personal BIM).

Examples

- The Netherlands implements GHP #1.g.
- UK implements GHPs #2.e and #2.g.

DISEASE PREVENTION

Mandatory requirements

Mandatory requirements for mussels' farmers related to mortality removal are *inter alia* foreseen in the following **EU legislation**:

- Regulation (EC) No 1069/2009[76]: Tittle I: chapter II
- Regulation (EU) 2016/429[77]: Article 10.4b.vi.
- Regulation (EC) No 853/2004[78]: Annex III, Section VII.
- Commission Delegated Regulation (EU) 2020/689[79]: Annex VI, Part II, Chapter 3.
- Commission Delegated Regulation (EU) 2020/691[80]: Part III Annex I.

In addition, the following production rule applies for organic certified products: Regulation (EU) 2018/848 on organic production and labelling of organic products[81]: the main provisions on disease prevention are set under point 3.1.4.1 of Part III of Annex II.

Good husbandry practices

1. Mussels' industry workers (professionals and professional organisations), with the help of specialised companies, are developing predictive alert systems (Davidson, et al., 2021) targeting the health risks that have the greatest impact on mussel farms, such as microbiological, viral and phycotoxin contaminations (AAC, 2023). With data collection and modelling, professionals can better predict the risk of contamination of their mussels and adapt their farming practices according to contaminants. Sheltering batches or long-term purification systems among other practices are considered (AAC, 2023). Having early warning systems (EWS) could help mitigate the impact of harmful algal blooms (HABs) and reduce the occurrence of HAB events. In this regard, FAO took the lead in the development of a technical guidance for the implementation of EWSs (Early warning system) for HABs. The document will guide competent authorities and relevant institutions involved in consumer protection or environmental monitoring to implement EWSs for HABs present in their areas (marine and brackish waters) (FAO, IOC and IAEA, 2023). Other example is the PRIMROSE project funded by the Interreg Atlantic Area that it'll deliver improved forecasts of HABs, microbial risks and climate impacts in aquaculture location the length of Europe's Atlantic Arc from Shetland Islands to the Canary Islands.
2. To gain a better understanding of mussels' contaminants in the environment and to develop management measures adapted to each territory, several professional organisations, in partnership with government departments and/or local authorities, shall monitor the environment for noroviruses, pesticides or micropollutants. This monitoring involves sampling and analyses of mussels at strategic points during targeted periods, such as the risk period for gastroenteritis (November to March) (AAC, 2023).
3. Some professional mussel farmers guarantee the continuity of their production by using their stocks on several concessions spread over different territories. In this way, they can protect their mussels in case of a suspected health or animal health problem and guarantee the healthy quality of their products (AAC, 2023).
4. A warning system to monitor the phytoplanktonic blooms and predict the "red tides" for production areas is available (INTECMAR, 2023).
5. In the absence of an established legislative limit for norovirus, the feasibility of regular testing for norovirus is limited. There can only be guidance limits set by Competent Authority's in the absence

[76] Regulation (EC) No 1069/2009

[77] Regulation (EU) 2016/429

[78] Regulation (EC) No 853/2004

[79] Commission Delegated Regulation (EU) 2020/689

[80] Commission Delegated Regulation (EU) 2020/691

[81] Regulation (EU) 2018/848

of legislation and by the operators themselves in their food safety management plans (comm personal BIM).

Examples

- France implements GHP #1, #2, #3.
- Spain implements GHP #4.
- Scotland implements GHP #1.

PREDATOR CONTROL

Mandatory requirements

Mandatory requirements for mussels' farmers related to predator control are *inter alia* foreseen in the following **EU legislation**:

- Council Directive 92/43/EEC of 21 May 1992[82]: Annex II and annex IV, Animal and plant species of community interest in need of strict protection.

For organic certified products, in addition to the above mentioned horizontal rules, the following production rule applies: Regulation (EU) 2018/848 on organic production and labelling of organic products[83]: points 1.7. and 3.2.2.c) of Part III of Annex II.

Good husbandry practices

1. Wherever possible, visual checks of stock on site permits to exclude and remove natural predators - such as crabs and starfish - and to maintain optimal conditions for growth through the regulation of stocking density (Epsilon Aquaculture Limited, 2002).
2. In small-scale mussel cultivation, it is possible to reduce predation by crabs by trapping them in pots or by erecting protective fences, while on an extensive scale one possibility is laying seed at high densities (Epsilon Aquaculture Limited, 2002).
3. To avoid predation from starfish, it is right to remove them from cultivation plots with dredges or mops, especially before seeds are relayed (Epsilon Aquaculture Limited, 2002), (Calderwood et al. 2016).
4. Application of chemicals that persist as toxins in the marine environment or on farms is not allowed. Only management and non-lethal management products are allowed (e.g., exclusion, deterrence, and elimination) of critical species that are pests or predators (ASC, 2019).

Examples

- UK implements GHP #1, #2, #3.
- Portugal and Italy implement GHP #4.

WATER QUALITY

Mandatory requirements

Mandatory requirements for mussels' farmers related to water quality are *inter alia* foreseen in the following **EU legislation**:

Regulation 853/2004[84]: Annex III, section VII.

In addition to the above mentioned horizontal rule, the following production rule applies for organic certified products: Regulation (EU) 2018/848 on organic production and labelling of organic products[85]: the main provisions concerning water quality practices are set under 1.1., 1.2, 1.5, 1.6, 3.1.3.2. of Part III of Annex II.

Good husbandry practices

1. Since mussels are growing in the open sea, any environmental change in water quality has an impact on their performance. Nevertheless, optimum cultivation temperatures for blue mussel are between 5-20 ºC and for Mediterranean mussel between 10-20 ºC (EUMOFA, 2019). Blue mussel has an upper sustained thermal tolerance limit of about 29 °C for adults (FAO, 2023).

[82] Council Directive 92/43/EEC

[83] Regulation (EU) 2018/848

[84] Regulation (EC) No 853/2004

[85] Regulation (EU) 2018/848

2. Blue mussel does not thrive in salinities of less than 15‰ and its growth rate is reduced below 18‰ (FAO 2023) and the optimum salinity for Mediterranean mussel is around 34%.

Examples

- Denmark, Germany and Italy implement GHPs #1, and #2.

STOCKING DENSITIES

Mandatory requirements

For organic certified products, the following production rules apply:

- Regulation (EU) 2018/848 on organic production and labelling of organic products points 3.2., 3.2.4.a of Part III of Annex II[86].
- Commission Implementing Regulation (EU) 2020/464[87]: Annex II, Part IX. The maximum drop-rope length must not exceed 20 m. Thinning-out of drop-ropes must not take place during the production cycle; however, drop ropes may be subdivided without increasing the stocking density.

Good husbandry practices

Some EU Member States have specific national laws for stocking densities for mussels. Below some general GHP related to good stocking densities for mussels are presented.

1. Blue mussel
    a. Bouchot culture:
        i. The rearing structures are 50-60 m long, with 120-130 poles in single or double lines for spat settlement and 80-90 poles for on-growing (FAO, 2023). Bouchots shall be spaced 25 m apart and mussel seed spreads to cover the entire pole (FAO, 2023). Each pole produces around 30-40 kg live weight of mussels (FAO, 2023). The FAO guidelines do not provide specific recommendations for the number of mussel seed pieces per meter of mesh in spat settlement and on-growing structures. Stocking density may vary based on local conditions and farming practices.
    b. Longline culture:
        i. This technique allows highly mechanised culture and yields 18-20 tonnes/ha/yr (FAO, 2023). A multi-longline system has also been developed in Norway and Sweden, using 7-9 headlines (FAO, 2023).
        ii. In Ireland, longline systems are typically used, where mussels are grown on ropes suspended from buoys or floats. This system makes the process of collection easier (McKindsey, C.W. et al 2006).
2. Mediterranean mussel
    a. In Galicia, where mussels are cultured in rafts, their size varies considerably from <100 m² to >500 m² (FAO, 2023b). Depending on the number of floats, which support the raft system, the usable culture area can go from 80 percent, when a central float is used, to 90 percent when four to six floats are used (FAO, 2023b).
    b. Farmers shall thin the mussels when they are half grown (shell length 4-5 cm) after 5-6 months of growth, usually from June to October (FAO, 2023b). This work shall be repeated once again before harvesting if the mussels grow rapidly (in which case their weight and density increases the risk that the mussel clusters will fall off). It is also necessary to repeat this operation to ensure that all mussels reach a comparable size at harvest time (FAO, 2023b).
    c. When high stock densities are required, the raft cultivation system is more effective especially in areas of high current (CEFAS, 2014).

Examples

- UK implements GHP #2.c.
- Ireland implements GHP #1.b.ii.
- Norway and Sweden implement all blue mussel's GHPs aforementioned.

[86] Regulation (EU) 2018/848

[87] Commission Implementing Regulation (EU) 2020/464

- Spain implements GHPs #2.a and #2.b.

DEPURATION AND CLEANING

Mandatory requirements

Mandatory requirements for mussels' farmers related to depuration and cleaning are *inter alia* foreseen in the following **EU legislation**:

- Regulation (EU) 2016/429[88]: Part IV, Title II.
- Regulation (EC) No 852/2004[89]: Annex I And II.
- Regulation (EC) No 853/2004[90]: Annex III, Section VII.
- Commission Delegated Regulation (EU) 2020/689[91]: Annex VI, Part 2, Chapter 3.
- Commission Delegated Regulation (EU) 2020/691[92]: Annex I

For organic certified products, in addition to the above mentioned horizontal rules, the following production rule applies: Regulation (EU) 2018/848 on organic production and labelling of organic products[93]: the main provisions concerning good practices for cleaning and depuration are set under Annex II , Part III, points 3.1.4.1 c) and 3.2.4.

Good husbandry practice

1. In unpolluted areas, dredged mussels can be cleaned and sorted by size directly on the decks of the boats with automatic equipment (FAO, 2023).
2. Mussels can be temporarily stored in rewatering plots where they remain for 2 weeks, during which they excrete mud, grit and sand and recover from dredging stress (FAO, 2023).
3. In the depuration process, the depth of the mussels in the tank shall not exceed 10 cm (Epsilon Aquaculture Limited, 2002).
4. Mechanical removal (e.g., scraping, brushing or power washing) and killing the fouling organisms (e.g. air drying or dipping in various caustic solutions such as brine, acetic acid, or lime) (ASC, 2019).
5. Farming operations shall have sufficient prevention and response plans in place and farm employees shall have the training necessary to properly dispose of waste and prevent and manage chemical and hydrocarbon spills (ASC, 2019).
6. The use of above-ground basins requires sea water, which is usually pumped near the operating sites. In this respect, professionals, either individually or collectively and in agreement with government departments, can equip themselves upstream with unsinkable basins, with controlled water inflows, which guarantee a reserve of water for purification and storage basins (AAC, 2023). These water reserves enable initial water treatment by decantation and UV action (AAC, 2023). Then, the water may pass through a filtration system (e.g. sand filter, bag filter, etc.) and, in some cases, UV lamps, before being fed into the basins (AAC, 2023). To achieve optimum water quality, professionals also invest in innovative filtration systems (micro bubbling), the performance of which is monitored and validated by government authorities (AAC, 2023).
7. Hatcheries and nurseries, by virtue of their production, are particularly sensitive to cleaning and must also provide their customers with animal health guarantees. For pumping water treatment, these structures are systematically equipped with settling basins, filters (e.g. sand, bags, cartridges, lamellae, etc.) and a UV steriliser, oversized by manufacturer standards, as seawater can retain residual turbidity despite filtration (AAC, 2023). Finally, bacteriological, and virological checks are carried out at every stage of the larval cycle, from broodstock management to micro-nursery, to control mortality and guarantee the absence of pathogens (AAC, 2023).
8. The use of UV lamps as a water disinfection system, especially in hatcheries and nurseries (AAC, 2023).

Examples

- UK implements GHP #3.

[88] Regulation (EU) 2016/429

[89] Regulation (EC) No 852/2004

[90] Regulation (EC) No 853/2004

[91] Commission Delegated Regulation (EU) 2020/689

[92] Commission Delegated Regulation (EU) 2020/691

[93] Regulation (EU) 2018/848

- France implements GHP #6, #7, #8.

SELECTIVE BREEDING

Mandatory requirements

For organic certified products, the following production rule applies: Regulation (EU) 2018/848 on organic production and labelling of organic products[94]: the main provisions concerning organic breeding are set under article 5.f) iii), 11 and points 3.1.2.2 and 3.2.1 of Part III of Annex II.

Good husbandry practices

1. In order to diminish the risk of genetic impacts of hatchery-based mussels aquaculture it is appropriate to use local broodstock, rotate broodstock within spawning seasons and between years, and avoid returning hatchery-propagated stock to the hatchery as broodstock (ASC, 2019).
2. The EFABAR aquatic code[95] is a voluntary good practice guide developed by the European Forum of Farm Animal Breeders (EFFAB) and plays a pivotal role towards sustainable and balanced aquaculture breeding. The code promotes breeding programmes that target: Better animal health and welfare (disease resistance and discarding genetic defects) using genomic information for selective breeding for improved disease resistance and preserving genetic diversity and monitor and limit inbreeding following the FAO recommendation (EFFAB, 2023).
3. Long-term selective breeding programs that mimic nature by amplifying the genetic tendencies for disease resistance are also showing promise in limiting the impacts of diseases that are already endemic (ASC, 2019).

Examples

- France implements GHP #2.

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Ballan wrasse (*Labrus bergylta A.*)

Good husbandry practices

Topics addressed	General					Specific		
	Feeding	Handling	Mortality removal	Fallo-wing	Predator control	Environmental enrichment	Selective breeding	Functional feed
	☒	☐	☒	☐	☐	☒	☐	☒
	Mini-mising risk of escapes	Water quality	Stocking densities	Disinfec-tion and cleaning	Vaccina-tion and treatments			
	☐	☒	☒	☒	☒			

FEEDING

Good husbandry practices

1. Ballan Wrasse will only be an effective cleaner fish if the availability of alternative feed is low. Therefore, they should be fed about twice a week when the lice load on the salmon are low (LeppeProd project, 2014).
2. Feeding in salmon net pens: feed stations must be located close to the hides/refuges and must be available all year round (RSPCA, 2021) (Norwegian Seafood Research Fund, 2017).
3. An aqua-feed prepared by mixing a manufactured ground ingredient with a 20 g/L agar solution at a 1/1.6 (w/v) ratio is proposed as the basis for a novel cleaner fish feed adapted to the grazing behaviour of ballan wrasse within the salmon sea-pen environment. The proposed aquafeed combines the complete nutrient profile of a manufactured diet with high water stability to minimise feed loss and facilitate supplemental feeding of cleaner fish stocked in salmon from weekly interventions (Leclercq, Graham, & Migaud, 2015).
4. Hatchery: High-quality live feed must be used for ballan wrasse larvae from 4 - 5 days after hatching, prior to weaning onto dry food. Weaning on formulated feed takes 1-10 days and may be completed by 50-80 days of age. Commercial diets are available (RSPCA, 2021) (European Union Reference Laboratory for Fish Diseases, 2016).
5. Hatchery: Larvae fed on copepods are more efficient predators and show fewer skeletal abnormalities than those fed on rotifers (LeppeProd project, 2014).
6. The optimum dietary macronutrient composition for juvenile ballan wrasse is 65% protein, 12% lipid and 16% carbohydrate, based on maximum lengthwise growth (Hamre, Nordgreen, Grotan, & Breck, 2014).

Examples

- UK implements GHP #1 and #4.
- Norway implements GHP #1 and #5.

MORTALITY REMOVAL

Good husbandry practices

1. Dead fish must be retrieved daily. Mortalities are registered by number (of dead fish) and species. Cause(s) of death(s) should also be noted in a diary or journal system. To avoid the spread of infection, the sick or dead fish must be dealt with according to the same methods as applied to the salmon (slaughter/conversion to ensilage) (Norwegian Seafood Research Fund, 2017) (RSPCA, 2021).

Examples

- UK and Norway implement GHP #1.

WATER QUALITY

Good husbandry practices

1. Optimum water temperatures: ≤ 14ºC (eggs), ≤ 17ºC (larvae), 7-17ºC (on growers); oxygen: 95 - 100 % (eggs, larvae and ongrowers); pH: 7.3-8.0 (eggs, larvae and ongrowers) (RSPCA, 2021).

Examples

- UK implements GHP #1.

STOCKING DENSITIES

Good husbandry practices

1. The first stocking density of ballan wrasse in the pen must not exceed 10% of the salmon biomass. Stocking densities for ballan wrasse over 10 grams must be less than 40kg/m3 (RSPCA, 2021).

Examples

- UK implements GHP #1.

DISINFECTION AND CLEANING

Good husbandry practices

1. Cleaning of nets, refuges and other equipment is decisive for successful ballan wrasse husbandry. If cleaning is inadequate, the ballan wrasse will prefer to eat the slimy fouling instead of the lice. With the use of ballan wrasse during the winter the refuges must be cleaned before temperatures go below 6-8ºC (Norwegian Seafood Research Fund, 2017).

Examples

- Norway implements GHP #1.

VACCINATION AND TREATMENTS

Good husbandry practices

1. Vaccination against bacterial pathogens has been shown to be effective for ballan wrasse. For on-site vaccination, cleaner fish must be transferred into bins containing both oxygenated seawater and kelp, post-vaccination (European Union Reference Laboratory for Fish Diseases, 2016) (Norwegian Seafood Research Fund, 2017).

Examples

- Norway implements GHP #1.

ENVIRONMENTAL ENRICHMENT

Good husbandry practices

1. Installation of refuges (e.g., mimicking kelp forests) in salmon pens holding cleaner fish is essential for the reduction of cleaner fish stress and predation by salmon. When ballan wrasse live in salmon net pens, they need to have a place to hide and rest. Artificial kelp (made of plastic) works fine in that regard (Haugland, Imsland, Reynolds, & Treasurer, 2020) (Leclercq, Graham, & Migaud, 2015) Refuges must be in position in the pen before the wrasse are released there. Place the shelters 2-3 metres below the surface - to avoid the fouling zone - and vertically to allow the fish to find a suitable depth depending on the seasonal changes of the marine environment (Norwegian Seafood Research Fund, 2017).
2. Plan for refuges to function as cleaning stations, i.e. a place where the salmon go to be relieved of lice. Curtain refuges are often used, as these offer salmon many opportunities to encounter the cleaner fish. The refuge curtains are hung out in parallel lines, as experience shows that 2-4 metres between each curtain and 1-1.5m between each kelp ribbon provides a spacious area where the salmon and cleaner fish can meet (Norwegian Seafood Research Fund, 2017) (MOWI, 2022).

Examples

- Norway implements GHPs #1, and #2.

FUNCTIONAL FEED

Good husbandry practices

1. The benefit of feeding ballan wrasse larvae with copepods compared to other live preys (i.e., rotifers, Artemia) has been reported. Results clearly demonstrate that even short periods of feeding with cultivated copepods had a clear positive long-term effect on the growth, survival, and stress tolerance of ballan wrasse larvae. Early larval nutrition is very important (Oie G., et al., 2017).
2. Producing copepods is very difficult and the availability of wild copepods for marine fish is very limited. So, it is crucial to develop sound enrichment strategies for live preys such as Artemia resulting in EFA-rich polar and lipid fraction (PL). When this enrichment is further boosted with either marine or soya lecithin products, the polar lipid fraction is notably increased in the enriched Artemia. In addition, some results point out that plant-based protein ingredients can successfully replace fish meal in the diet of ballan wrasse juveniles (Cavrois-Rogacki T. Leeming, Muñoz, & Davie, 2022).

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Lumpfish (*Cyclopterus lumpus L*)

Good husbandry practices

Topics addressed	General					Specific		
	Feeding	Handling	Mortality removal	Fallow-ing	Predator control	Environmental enrichment	Selective breeding	Functional feed
	☒	☐	☐	☐	☐	☒	☒	☒
	Minimis-ing risk of es-capes	Water quality	Stocking densities	Disinfec-tion and cleaning	Vaccination and treatments			
	☐	☒	☒	☒	☒			

FEEDING

Good husbandry practices

1. Hatchery: Feed must be introduced when at least 90% of the lumpfish in the tank have absorbed their yolk sacs post hatch (RSPCA, 2021). Lumpfish larvae do not require live feed, so commercially formulated dry feeds with high energy content are usually used during this stage (European Union Reference Laboratory for Fish Diseases, 2016).
2. Feeding in salmon net pens: Finmark producers have reported that the ratio for daily feeding routines is a maximum of 2% with a sea temperature over 10˚C, and a maximum of 1% in winter. If feeding is skipped for one or two days, the lumpfish will seek alternative food such as fouling growth, salmon feed or nip at sores and fins. To hand feed a small amount during the workday for observation/assessment of the lumpfish. The timing of lumpfish feeding must coincide with the end of salmon feeding (Norwegian Seafood Research Fund, 2017). A combination of manual and automated feeding is better to disperse the feed (Johannesen, Joensen, & Magnussen, 2018).
3. The feed used throughout production has been shown to be sufficient to support lumpfish growth. However, it is also potentially deficient in terms of dietary requirements (Jolley, Wan, Davies, & Bolton-Warberg, 2021).

Examples

- UK implements GHP #1.
- Norway (Finmark producers) implements GHP #2.

WATER QUALITY

Good husbandry practices

1. Temperature: farmed lumpfish water temperature ranging 2-16ºC depending on seasonal changes and the life stage of the fish (eggs ≤ 10ºC, larvae ≤ 14ºC, on growers 7-12ºC) (RSPCA, 2021) (European Union Reference Laboratory for Fish Diseases, 2016).

2. Oxygen: 95 - 100 % (eggs, larvae and on growers); pH: 7.3-8.3 (eggs, larvae and on growers) (RSPCA, 2021).

Examples

- Denmark and Norway implement GHP #1.
- UK implements GHPs #1, and #2.

STOCKING DENSITIES

Good husbandry practices

1. The stocking density of the first feeder must not exceed 25kg/m3; while the stocking density in the outgrowing tank must not be higher than 60kg/m3. At sea, lumpfish must be stocked at no more than 20% of the salmon biomass (RSPCA, 2021).
2. There is a negative correlation between the density of lumpfish and floating seaweed clump weight. Some authors have speculated whether the latter might indicate some form of territorialism in lumpfish or cannibalism. The type of substrate offered is critical to the welfare of the fish that have access to some form of the substrate, due to the need to rest and attach overnight (Imsland, Reynolds, & Eliassen, 2015).

Examples

- UK implements GHP #1.
- Norway implements GHP #2.

DISINFECTION AND CLEANING

Good husbandry practices

1. Cleaning of nets and refuges must be planned and carried out every 7-14 days in summer, depending on environmental conditions and temperature at the installation site. There is less fouling of nets and refuges in winter, so the cleaning routines must be adjusted accordingly. Good routines for drying/washing refuges must be planned to prevent build-up of fouling (Norwegian Seafood Research Fund, 2017).

Examples

- Norway implements GHP #1.

VACCINATION AND TREATMENTS

Good husbandry practices

1. For on-site vaccination, cleaner fish must be transferred into bins containing both oxygenated seawater and kelp, post vaccination (RSPCA, 2021).
2. Vaccination against bacterial pathogens has been shown to be effective for lumpfish (European Union Reference Laboratory for Fish Diseases, 2016). Lumpfish are vaccinated according to minimum size of 8-10 g and released after 500 days after vaccination (Norwegian Seafood Research Fund, 2017).
3. One of the most important considerations for commercial lumpfish production is to reduce the risk of disease transfer between cleaner fish and salmon, for example of the infectious pancreatic necrosis virus (IPNV), the amoebic gill disease (AGD) and Vibrosis (Breiland, Mikalsen, & Johansen, 2016) (Haugland, Olsen, Ronneseth, & Andersen, 2016) (Murray, 2016).

Examples

- Norway implements GHP #2.
- UK implements GHP #1.

ENVIRONMENTAL ENRICHMENT

Good husbandry practices

1. Installation of refuges (e.g. mimicking kelp forests) (Haugland, Imsland, Reynolds, & Treasurer, 2020) (Imsland, Reynolds, & Eliassen, 2015) in salmon pens holding cleaner fish is essential for the reduction of cleaner fish stress and predation from salmon. These should be custom designed for the respective species in use (European Union Reference Laboratory for Fish Diseases, 2016).
2. Experienced producers say that the amount of kelp ribbon should be enough to cover the needs of refuges/resting spots for 50 lumpfish. Furthermore, refuges should not be placed alongside the net wall, by salmon feeding stations, resting close to the bottom of the net in a cone-shaped net or in the middle of the net. Producers have found that lumpfish prefer shade and smooth, rigid surfaces to attach themselves to (by suction) in the pen (Haugland, Imsland, Reynolds, & Treasurer, 2020) (Imsland, Reynolds, & Eliassen, 2015). One way of creating shade is to have horizontal kelp ribbons the length of the curtained area on the (water) surface (Norwegian Seafood Research Fund, 2017) (MOWI, 2022).
3. There must be sufficient substrate/refuges/hides for all the lumpfish to adhere to in the sea pen. Hides/refuges must be free of algal growth and stinging marine life and easy to clean (RSPCA, 2021).

Examples

- UK implements GHP #3.
- Norway implements #2.

FUNCTIONAL FEED

Good husbandry practices

1. Feed blocks (water-stable agar-based diet on PVC pipes or trays) specially designed for lumpfish - which quickly accepted and grazed on them - and successfully reduced the prevalence of cataracts compared to supplementary pelleted commercial feed (Imsland, A., et al. 2019), (Imsland, A., et al, 2018).
2. Increased inclusion of vitamin C in the diet has been shown to be beneficial for growing in studies (Jolley, M., et al, 2021).
3. The presence of cataracts is considered an indicator of poor animal welfare. It seems that the addition of antioxidants can help reduce the severity of cataracts in lumpfish (Lein, et al., 2021).

Examples

- Faroe Islands (Denmark), Ireland, Norway and UK implement GHP #2.

SELECTIVE BREEDING

Good husbandry practices

1. As lumpfish are not farmed for human consumption, but rather to remove sea-lice from salmon, the targets of artificial selection differ from those applied to most other cultured fish, which are usually selected for fast growth and high conversion efficiency. Strains showing slow growth may also be advantageous, as lumpfish stop eating sea-lice when they reach a size of 300-400 g. The species spawns over a relatively prolonged period, and it may be possible - perhaps in combination with photoperiod manipulation - to select lumpfish lines that reproduce throughout the year to achieve year-round juvenile production (Powell A. et al, 2018).

Examples

- Norway, UK and Iceland implement GHP #1.

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ANNEX III - EU LEGALISATION RELATED TO HEALTH AND WELFARE OF FARMED FISH

- Council Directive 98/58/EC f 20 July 1998 concerning the protection of animals kept for farming purposes.
- Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.
- Regulation (EC) No 178/2002 of the European Parliament and of 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.
- Regulation (EC) No 1831/2003 of the European Parliament and of the Council of 22 September 2003 on additives for use in animal nutrition.
- Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs.
- Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin.
- Council Regulation (EC) No 708/2007 of 11 June 2007 concerning use of alien and locally absent species in aquaculture.
- Regulation (EC) No 767/2009 of the European Parliament and of the Council of 13 July 2009 on the placing on the market and use of feed.
- Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002.
- Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (codified version).
- Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC.
- Regulation (EU) 2016/429 of the European Parliament and of the Council of 9 March 2016 on transmissible animal diseases and amending and repealing certain acts in the area of animal health (Animal Health Law).
- 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.
- 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.

- 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 Delegated Regulation (EU).
- Commission Delegated Regulation (EU) 2020/689 of 17 December 2019 supplementing Regulation (EU) 2016/429 of the European Parliament and of the Council as regards rules for surveillance, eradication programmes, and disease-free status for certain listed and emerging diseases.
- Commission Delegated Regulation (EU) 2020/691 of 30 January 2020 supplementing Regulation (EU) 2016/429 of the European Parliament and of Council as regards rules for aquaculture establishments and transporters of aquatic animals.
- Commission Implementing Regulation (EU) 2020/464 of 26 March 2020 laying down certain rules for the application of Regulation (EU) 2018/848 of the European Parliament and of the Council.
- Commission Delegated Regulation (EU) 2021/578 of 29 January 2021 supplementing Regulation (EU) 2019/6 of the European Parliament and of the Council with regard to requirements for the collection of data on the volume of sales and on the use of antimicrobial medicinal products in animals.
- Commission Implementing Regulation (EU) 2021/1165 of July 2021 authorising certain products and substances for use in organic production and establishing their lists.
- Recommendations from the council of Europe for the implementation of its Convention for the protection of animals kept for farming purposes. [96]

[96] https://www.coe.int/t/e/legal_affairs/legal_co%2Doperation/biological_safety_and_use_of_animals/farming/Rec%20fish%20E.asp#TopOfPage

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