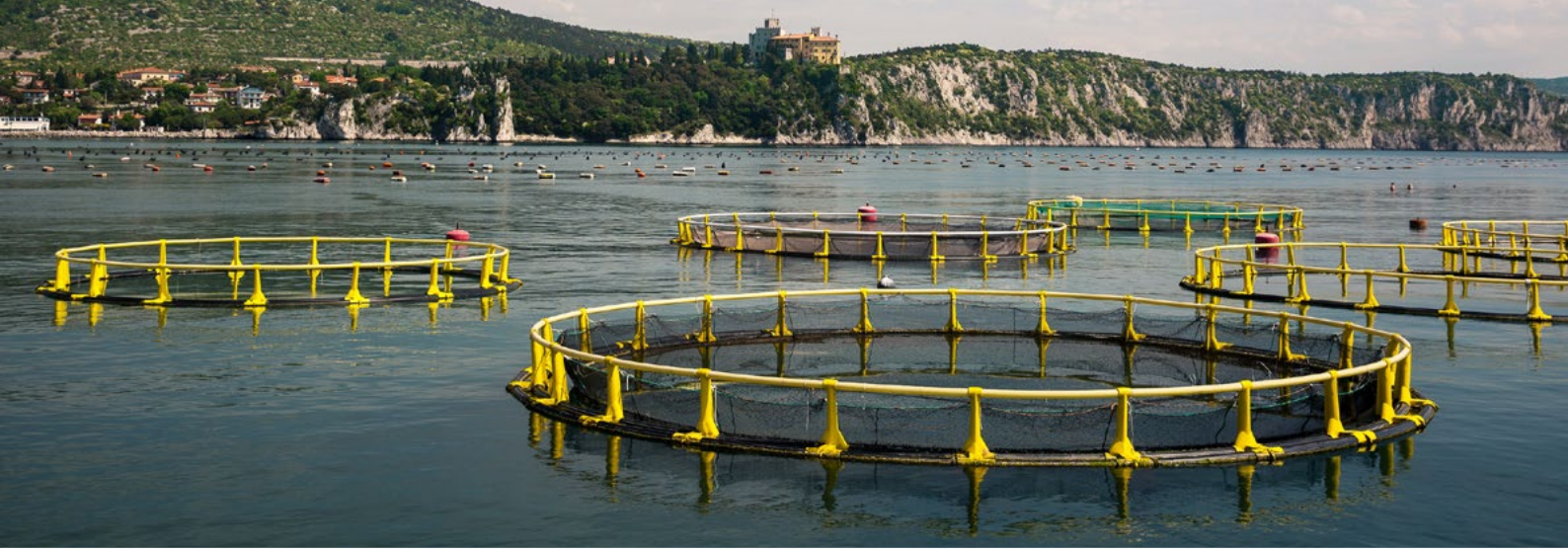

GUIDELINES ON WATER QUALITY AND HANDLING FOR THE WELFARE OF FARMED VERTEBRATE FISH

EU Platform on Animal Welfare
Own Initiative Group on Fish

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UNDERSTANDING THE GUIDELINES

The welfare of fish has been worked on less than that of other farmed animals in recent years. Nonetheless, understanding and meeting their needs is important for many aspects of good fish farming.

Farmed vertebrate fish (hereafter named "fish") are sentient beings and the keeping of fish carries with it an ethical responsibility to ensure their welfare. Fish should be cared for by appropriate preventive and enabling measures with full regard to the species-specific needs of the fish. Pain, distress, suffering, disease outbreaks, mortality, stress, aggression and behavioural disorders should be prevented and minimised, while natural behaviours and positive welfare should be maximised.

Water quality and handling are very important for the welfare of fish during all life stages and farming practices. Other factors are also important for the welfare of fish and for good fish farming, including transport, slaughter, feeding regimes, housing, and breeding regimes. These guidelines assume good welfare practices in areas not covered here.

These guidelines on water quality and on handling will be of use for aquaculture operators and the relevant competent authorities. They include factors and parameters that are common across species. Each includes:

- A section with related provisions[1] from the Council of Europe Recommendation concerning farmed fish. The recommendation was adopted on 5 December 2005 by the Standing Committee under the European Convention for the Protection of Animals kept for Farming Purposes, and it entered into force on 5 June 2006.
- A section with guidelines to good animal welfare practice developed by the voluntary own initiative group on fish.

The guidelines were produced in 2020 by the voluntary own initiative group on fish under the EU Platform on Animal Welfare which was established by the Commission Decision 2017/C 31/12 (Official Journal of the European Union C 31). The positions expressed in the guidelines do not necessarily represent in legal terms the official position of the European Commission.

Note that where specific detail is not given for a parameter, the people involved in fish farming should be monitoring for deviation from normal and/or expected outcomes in terms of fish welfare.

[1] Where the Recommendation uses the word "shall" or "must" it is a provision, which is legally binding for Contracting Parties (Article 9 of the European Convention for the Protection of Animals kept for Farming Purposes). Where the Recommendation uses the word "should" it is a guideline.

GUIDELINES ON WATER QUALITY

1. PROVISIONS FROM THE COUNCIL OF EUROPE RECOMMENDATION CONCERNING FARMED FISH

Water quality (at least turbidity, oxygen, temperature, pH and salinity) shall be assessed; visually or with an appropriate technical device according to the parameter to be considered, with a frequency appropriate to the species and the system involved in order to avoid poor welfare (Article 5,5).

Sites shall be carefully chosen or designed so as to ensure an adequate flow of clean water, of suitable quality, in the enclosures, according to the characteristics of the husbandry system and to the species' requirements (**Article 7.2, 1st bullet point**).

The parameters affecting water quality, such as oxygen, ammonia, CO_2, pH, temperature, salinity and water flow, are interrelated. Their variation will influence the water quality and therefore affect the welfare of fish. Water quality parameters shall at all times be within the adequate range that sustains normal activity and physiology for a given species unless certain parameters in exceptional situations cannot be managed by farmers provided that the site has been chosen in accordance with Article 7.[2] Water quality parameters shall also take into account the fact that the requirements of individual species may vary between different life-stages e.g. larvae, juveniles, adults or according to physiological status e.g. metamorphosis or spawning (**Article 12.1, 1st – 4th sentence**).

Fish show varying degrees of adaptability to changing water quality conditions. Some degree of acclimatisation may be necessary and this should be carried out for a period appropriate for the fish species in question. Appropriate measures shall be taken to minimise sudden changes in the different parameters affecting water quality (**Article 12.2**).

[2] of the Council of Europe Recommendation concerning farmed fish

Ammonia and nitrite are very toxic to fish and their accumulation to harmful levels shall be avoided. The toxic form of ammonia is unionised ammonia; the unionised portion of total ammoniac nitrogen concentration depends on pH, salinity and temperature. The accumulation of ammonia and nitrite can be avoided by different means according to the farming system used, such as increasing flow rate, reducing feeding, biofiltration, reducing density or temperature (**Article 12.4**).

Carbon dioxide is produced by fish during respiration and dissolves in water to form carbonic acid thus lowering pH. The carbon dioxide level may be affected by plant and bacterial metabolism as well as by the temperature, salinity and alkalinity of the water. Accumulation of carbon dioxide to harmful levels shall be avoided, for example by using aeration systems or by chemical means, according to the farming system used (**Article 12.5**).

pH depends on many water quality factors, among others the concentration of humic acids, CO_2 and dissolved calcium salts. Where possible, pH shall be kept stable, as all changes in pH initiate complex water quality changes, which may cause harm to the fish (**Article 12.6**).

2. GUIDES TO GOOD ANIMAL WELFARE PRACTICE

1. During all life and production stages, sufficient water supply and good water quality is essential for the welfare of fish. Fish prefer a stable water quality without changes of the different parameters. Poor water quality elicits a stress response in fish. Fish are able to tolerate poor conditions for a short period only, depending upon the species, life stage and history. When the conditions become too challenging or prolonged, fish cannot maintain homeostasis and experience chronic stress which in the long term can impair immune function, growth and reproductive function. Furthermore, chemical substances may have toxic effects at the level of cell and tissue but, in addition, elicit an integrated stress response.

2. Water quality refers to the physical and chemical environment that the fish are exposed to and comprises a complex set of interacting factors. All aquatic organisms have certain tolerance limits with regard to water quality, where they are able to maintain homeostasis. However, limits for good welfare may be narrower and more difficult to determine. In addition, fish have developed a range of compensatory mechanisms that may over time adjust the welfare limits by acclimatisation. The threats to fish welfare from physiological or pathological disturbances caused by water quality relate not only to its parameters' absolute levels but also to their rate of change. They also relate to the to the species, the size of the fish, their developmental stage, previous experience, health status, and different coping strategies and capacities. Other abiotic factors and a number of complex interactions are also important. Managing these interactions requires monitoring the behaviour and condition of the fish as well as controlling and monitoring specific water quality parameters.

3. Water quality can show variations throughout the day depending on the fish's metabolism, feeding regime, and characteristics of the environment in which they live. For example, oxygen may fluctuate between day and night according to the load of micro-macroalgae, which may reflect natural conditions and in a closed or eutrophic environment may harm fish welfare. Certain species experience seasonal variations in their natural environment and such variation can be essential to induce reproduction.

4. All parties carrying out, supervising, and being responsible for the keeping of fish should ensure that consideration is given to the potential impact of water quality on the welfare of the fish.


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5. All parties carrying out, supervising, and responsible for the keeping of fish should have an appropriate knowledge and understanding to ensure that the welfare of the fish is maintained throughout the process. Aquaculture operators (farmers, transporters, service providers when the service provided affects fish management, etc.) have a responsibility to provide training for their staff and other personnel. Knowledge may include formal training and practical experience, including species-specific needs, on:
    a) Methods for inspection of fish
    b) Welfare indicators including fish behaviour and physiology, the environment, and general signs of disease and poor welfare
    c) Operation and maintenance of equipment relevant to fish welfare
    d) Systems for management of water supply and quality control
    e) Methods for the management of situations frequently encountered during the containment of fish
    f) Methods for the management of unforeseen events including the design and implementation of contingency plans

6. The water source and its quality should be analysed, including for seasonal changes, prior to the establishment of the holding, to ensure that it is possible to provide fish with an adequate water flow of an appropriate quality suited to the needs of the fish.

7. Water flow, water exchange and water treatment should ensure, according to the farming system used, the appropriate water quality and velocity for fish, once other factors, such as temperature and stocking density, have been taken into account, so that excretion and metabolism related products are kept below levels which negatively affect fish welfare.

8. Relevant procedures should be put in place to ensure that an adequate water supply and water quality is maintained at all times on farm, during transport and in holding pens at the abattoir. The plan should cover unforeseen events that may have an impact on water quality.

9. Water quality should be monitored at appropriate intervals. Wherever possible, water parameters may be monitored in an automated manner. Sensors for measuring water quality parameters should be integrated when possible, depending on the level of technical sophistication of the facility, into automated monitoring and alarm systems. Sensors and measuring equipment needs to be maintained and calibrated at appropriate intervals and taking into account any manufacturer's guidelines. It is recommended that all water quality parameters are recorded. The measurements or sampling should be carried out at appropriate points in each cycle in a risk-oriented manner.

10. Most important parameter monitoring:

    a) **Oxygen:** In pond culture and net pens, the oxygen level should be monitored closely in case of high density and warm water. In aquaculture systems with high degrees of recirculation, the oxygen level should be monitored continuously by way of a system, which accurately reflects the oxygen available to the fish, and an alarm system should be in place.

    b) **Ammonia:** Total ammonia concentration should be closely monitored, particularly in systems with restricted water exchange such as high-density fish tanks, in aquaculture systems with high degrees of recirculation, and during and after transport.

    c) **Carbon dioxide:** When the level of carbon dioxide dissolved in water is monitored, and as CO_2 is in equilibrium with the non-toxic bicarbonate ion, its concentration depends on pH, temperature and salinity of the water.

    d) **pH:** As the toxicity or occurrence of several water quality parameters is dependent of pH, this should be monitored at appropriate intervals and in aquaculture systems with high degrees of recirculation continuously.

    e) **Temperature:** In aquaculture systems with high degrees of recirculation, the temperature should be monitored continuously.

    All establishments where the maintenance of an adequate water quality and water exchange rate depends on automatic equipment or other mechanical systems, should have alarm systems and backup generators necessary to handle possible power, water supply or equipment failure.

11. Special attention on water quality should be given during breeding and the keeping of eggs and young fish. The development of larvae and young fish can be negatively affected by poor conditions, causing permanent harm such as malformations of organs and skeleton.

12. Dead and moribund fish should be removed regularly.

13. Transport vehicles and containers holding fish should have adequate oxygenation and control of CO2 and metabolic wastes, and the necessary equipment for monitoring relevant parameters and maintaining an adequate water quality. The system for water quality control and monitoring should be able to handle variations in the conditions for the whole journey, as required to meet the needs of the fish. Vehicles, containers and monitoring equipment should be maintained in good condition and be cleaned and disinfected after each use.

14. The optimal temperature varies by species and with the stage of development and tolerance to temperature, and depends on fish strain, adaptation, degree of acclimatisation, and interaction with other water quality factors such as oxygen, pH, and ammonia levels.

15. Oxygen concentration should be appropriate to the species, life stage and the context in which fish are held. It will vary depending on abiotic factors (temperature, salinity, atmospheric pressure, carbon dioxide concentration, etc.) and biotic factors (stocking density, phyto-/zooplankton, organic pollution, etc.). It is also affected by management practices (feeding, handling, etc.).

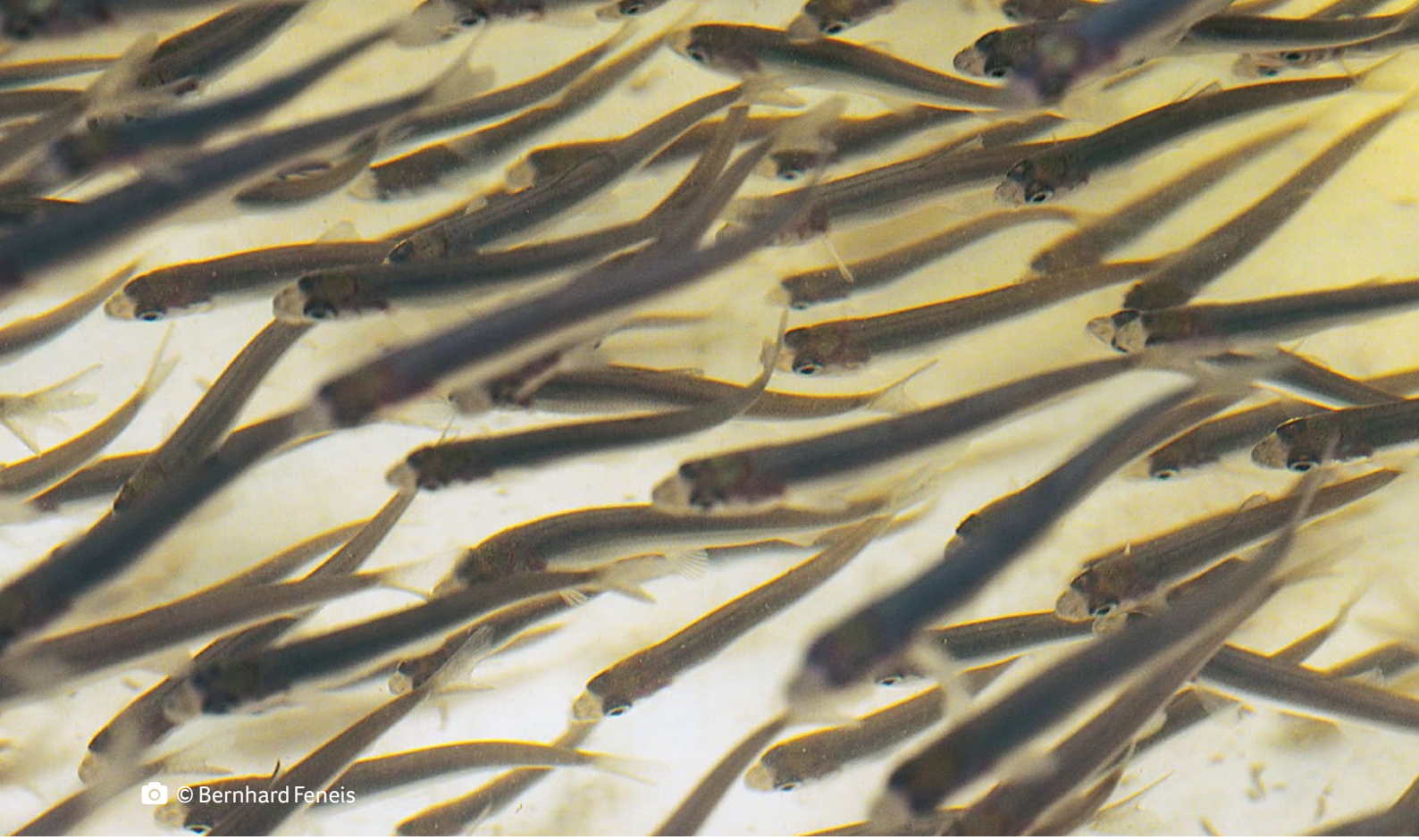
    At low levels of oxygen fish welfare is reduced and loss of appetite may be seen. Since the oxygen content of the water decreases when temperature increases, the oxygen levels should always be seen in conjunction with the water temperature. The fish's activity will also influence how much oxygen is needed or how quickly an oxygen deficiency ensues. Signs of low levels of oxygen include rapid gill movement and gasping.

    Feeding must be adapted to the oxygen level. Oxygen levels can be increased by different means such as aeration, direct oxygen injection, increasing the flow rate, or reducing temperature. In the case of unavoidable sudden decrease in dissolved oxygen, handling should be stopped until the situation has been dealt with and fish should not be fed in such circumstances.
    For land-based facilities, efforts should be made to keep the oxygen level as stable as possible with the smallest oxygen drop between inlet and outlet water. To maintain homeostasis, fish need to adapt to any change in water quality and this process of adaptation is slow. Large fluctuations in oxygen saturation are therefore not ideal for fish.

    Oxygen supersaturation should be evaluated, as when water is oxygen saturated the fish's respiratory rate is slower and the excretion across the gills of CO_2 is affected. Consequently, CO_2 levels in the blood will increase. Even low levels of oxygen supersaturation also increase the number of radicals in the blood which is demanding for the fish to handle as they must use energy to detoxify their system. Bubbles of oxygen in the water can, if in contact with skin, cause damage in the form of erosion.

16. All farms, transporter vehicles, containers, and abattoirs where fish are kept in holding pens prior to slaughter, should have the capacity to supplement additional dissolved oxygen by aeration or oxygenation in case of critically low dissolved oxygen levels. Additionally, to avoid further stress for the fish, in such situations handling should be done only if urgently necessary.

17. Unionised ammonia is the toxic form of ammonia, and total ammonia nitrogen (TAN), pH and temperature should be monitored to indirectly monitor unionised ammonia. The toxicity of ammonia is pH dependent. In on-grow farms at sea, and in flow through systems using freshwater, ammonia is normally not a problem.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Any deviation from the advisable value of ammonia, should be considered as an indication that the situation needs assessment and appropriate corrective action may be necessary. It is important to be familiar with the exact situation in the farm, as all farms are different with regard to water chemistry, biofilter, pipelines, etc. In addition, life stage and fish's physiological status are likewise important. It is important to avoid rapid changes.

Chronic exposure to elevated levels of ammonia will increase metabolic rate and reduce growth rate, disease resistance and fecundity. Major symptoms of ammonia toxicity are, amongst others, lack of foraging, reduced swimming performance, erratic swimming, increased gill ventilation, gill damage, gasping, loss of equilibrium, and osmoregulatory disturbances.

For aquaculture systems with high degrees of recirculation it is especially important to maintain a low enough level of unionised ammonia, so if levels increase there is some margin before the levels get critical. Taking appropriate corrective measures without compromising welfare and maintaining a well-functioning biofilter is then possible. When taking action, abrupt changes of the water quality need to be avoided as fish homeostasis is slow to adapt to change. Abrupt changes may also impact on the proper functioning of the biofilter.

In the case of high nitrite levels in recirculating systems one or more of the following interventions should be considered:

a) feeding should be reduced,

b) the water exchange should be increased,

c) chloride should be added,

d) biofiltration should be increased,

e) temperature should be reduced.

The addition of chloride is usually the first choice of intervention. It is important to monitor the situation closely, and to consider elevated nitrite levels as well as the previous history for the production unit. Note that increasing water exchange too much will have a negative impact on the biofilter.

18. Elevated levels of nitrite may impact the uptake and transport of oxygen in the blood, which will reduce growth, swimming performance and eventually can be lethal.

19. Avoidance of accumulation of CO_2 to harmful levels by using aeration systems or by increasing the water flow rate are preferable to the use of chemical means. CO_2 may also build up due to inadequate removal in the aerators and therefore should be monitored in such systems. Changes in CO_2 level will also affect pH. Safe values of carbon dioxide vary depending on water chemistry, (e.g. higher values are acceptable in limestone areas). An increase in CO_2 will result in a decrease of pH-level which will keep TAN at a less toxic level. However, if in response to elevated CO_2, too much water is flushed through the system, the pH level increases rapidly and toxic levels of TAN ensue.

20. Elevated values of CO_2 will lead to reduced growth, changes in swimming behaviour, disturbances in homeostasis and kidney damage. Fish welfare is poor long before critical values are reached.

21. It should be borne in mind that CO_2 is not likely to be a problem in open production systems without addition of oxygen. Most farms nowadays use additional oxygen, and in land-based facilities with flow through systems problems with too high levels of CO_2 may therefore occur. Also, in recirculation systems CO_2 may build up due to inadequate removal in the aerators and thus should be monitored in such systems.

22. The pH levels should be appropriate to the species. The pH varies relating to levels of CO_2 and ammonia, the buffering capacity of the water, the temperature and interaction with other water quality factors such as aluminium and water hardness. Water with a low alkalinity will have little buffering capacity and measures will need to be taken to improve buffering capacity.

23. Special attention should be paid to systems where pH may drop acutely (e.g. before and during snow melting and during heavy downpour) and where it should be adjusted by addition of alkaline chemicals.

24. Super saturation can lead to gas bubble disease. Safe exposure limits vary by species and with fish size and environmental conditions. In cases of gas bubble disease, pumps and aeration systems should be checked for malfunctioning.

25. Toxic metals, such as iron, aluminium, copper and zinc pose a potential risk to the welfare of fish. The likelihood of exposure to toxic levels should be assessed for enclosures, bearing in mind the interrelationship between temperature, pH, oxygen concentration, salinity, alkalinity and hardness of the water and the potential toxicity of heavy metals. For example, the risk of precipitation of salts of iron and aluminium in water with low pH can result in reduction of oxygen transfer. If the risk is significant, measures should be taken to minimise the risk.

26. Both in freshwater and seawater, sulphur may under certain circumstances cause problems and may lead to hydrogen sulphide (H_2S) poisoning. H_2S is very toxic for the fish even in very small quantities, interfering with processes of respiration. The signs of poisoning are initially increased respiratory rates. In recirculation systems toxic levels of H_2S can build up in unintended sludge accumulation with areas of low oxygen. Due to dramatically higher levels (1,000 times more) of sulphur in seawater, the risk of build-up of toxic levels of H_2S is considered higher in seawater. It is particularly challenging to maintain a good water quality and a well-functioning biofilter in recirculation systems using high salinities or seawater. High salinities or seawater should therefore be used with caution and require good knowledge on the impact salinity has on the water chemistry and the different water quality parameters.

27. The physical characteristics (shape, size, properties, etc.) and total amounts of suspended solids in water are relevant in determining the extent of possible negative effects in gills and skin.

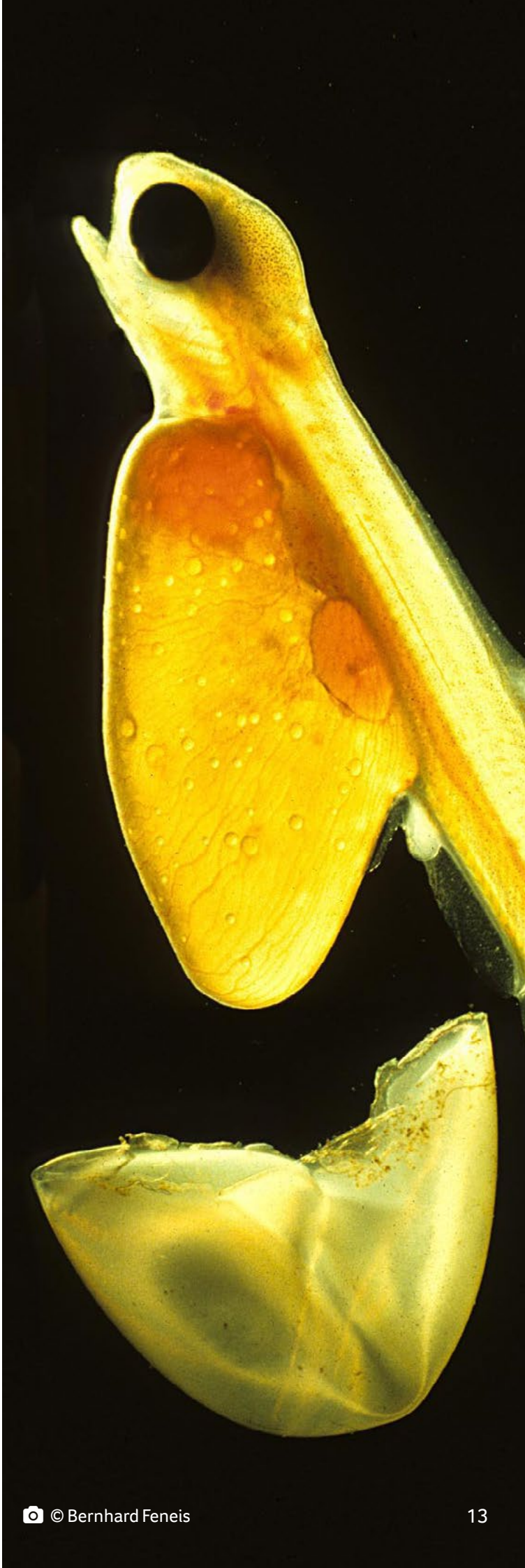
28. Different farming systems have different needs, and face different critical occurrences requiring extra measures.

    a) Special attention should be paid to recirculating aquaculture systems. The ammonium, nitrite and nitrate concentration should be determined in the start-up phase and then when using medications, in the event of an increase in mortality, or when changing feeding regime, on a daily basis. Otherwise, it is advisable to perform measurements of the ammonium, nitrite and nitrate concentrations on a system- and fish-type-dependent basis several times a week.

    b) In net pen aquaculture, oxygen and pH should be monitored during and after blooms of micro algae.

    c) Other farming systems and contexts may have other water quality challenges or specific situations that require attention or extra care.

29. The World Organisation for Animal Health (OIE) recommendations of the Aquatic Animal Health Code on welfare of farmed fish during transport and welfare aspects of stunning and killing of farmed fish for human consumption and when killing for disease control purposes should be applied as appropriate.



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GUIDELINES ON HANDLING

1. PROVISIONS FROM THE COUNCIL OF EUROPE RECOMMENDATION CONCERNING FARMED FISH

Every person engaged in the keeping of farmed fish shall, according to their responsibilities, ensure that every reasonable step is taken to safeguard the welfare, including health of such fish (**Article 3.1, second sentence**).

A substantial period of training appropriate to their responsibilities, including practical experience, as well as continued training, are considered essential for those engaged in the keeping of fish (**Article 3.2**).

Where handling is necessary, it shall be carried out with a minimum of stress and disturbance for the fish handled and to the other fish and for the shortest time possible. Sedation or anaesthesia may be appropriate (**Article 14.1**).

Procedures and equipment used in handling fish shall be maintained and operated to minimise stress and injury. When handled, the body of the fish shall be adequately supported and fish shall not be lifted by individual body parts only, such as the gill covers. The most preferable way is to handle fish without taking them out of the water (e. g. size grading by machines carrying water along the run). If fish have to be taken out of the water for handling, this shall be done in the shortest time possible and all equipment in direct contact with fish should be moistened (**Article 14.2**).

All equipment must be free of rough surfaces liable to cause injury (**Article 14.3, 3rd sentence**).

If fish show sign of undue stress during crowding, immediate action must be taken as appropriate, for example, by increasing the volume available to fish or by addition of supplementary oxygen (**Article 14.4, last sentence**).

During treatments in an enclosure, water quality parameters shall be monitored and maintained at levels acceptable to the species concerned (**Article 14.5**).

In the breeding of farmed fish, the stripping and milking process shall be carried out by trained and competent persons. During the monitoring of fish prior to stripping and milking, sedation may be necessary. The number of times a fish is handled and exposed to sedation shall be minimised to limit injury and stress. If live fish are to be stripped or milked, anaesthesia or sedation should be used as necessary for the species concerned. Where compressed air is used to assist stripping and milking in live fish they must be fully anaesthetised. If gonads are removed from fish, the animal shall be killed prior to their removal (**Article 13**).

Packing live fish in ice as an on-farm handling practice shall not be allowed (**Article 14.6**).

2. GUIDES TO GOOD ANIMAL WELFARE PRACTICE

1. Handling causes stress, raising activity as well as oxygen demand. A brief period of stress may bring long lasting effects. Various genetic, developmental and environmental factors can have a modifying effect on the magnitude and duration of the stress response.

2. Inappropriate handling procedures can lead to injury, pain, distress, and suffering. As a result, increased disease incidence, increased mortality, reduced appetite, impaired development, and deformities in fish may ensue.

3. All parties carrying out, supervising, and being responsible for the handling of fish should ensure that consideration is given to the potential impact on the welfare of the fish.

4. All parties carrying out, supervising, and being responsible for the handling of fish should have an appropriate knowledge and understanding to ensure that the welfare of the fish is maintained throughout the process. Aquaculture operators (farmers, transporters, service providers when the service provided affects fish management, etc.) have a responsibility to provide training for their staff and other personnel. Knowledge may include formal training and practical experience, including species-specific needs, on:
   a) Methods for inspection of fish
   b) Welfare indicators including fish behaviour, physiology, the environment, and general signs of disease and poor welfare
   c) Operation and maintenance of equipment relevant to fish welfare
   d) Methods of live fish handling
   e) Methods for the management of situations frequently encountered during handling
   f) Methods for the management of unforeseen events including the design and implementation of contingency plans

5. Handling should be kept at an absolute minimum level and only be conducted when necessary. In order to minimise handling throughout the lifetime of farmed fish, the production cycle should be scheduled and procedures optimised for the least amount of handling possible.

6. Handling procedures should be gentle. Those procedures that are successful with one species may be ineffective or dangerous for another species. If fish during handling show signs of oxygen deficiency or signs of avoidable stress, measures should be put in place so that fish can recover. This can be done, for example, by increasing water turnover or by adding extra oxygen.

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7. Most fish are ectothermic organisms that derive the required heat from the environment. The sensitivity of the fish to handling is thus temperature-dependent. Handling should be avoided when water or air temperatures reach the lower and upper optimal limits respectively, in relation to the ontogenetic and physiological state. Fish should not be handled at the outer limits of the temperature ranges that they can tolerate.

8. The operator should have relevant procedures that identify critical points in the handling procedure, propose corrective measures and indicate when to discontinue handling in order to maintain adequate fish welfare. The procedures should include contingency planning for unforeseen events that may have an impact on handling. The personnel involved in fish handling procedures, their roles, the approximate number of fish handled, health and welfare issues observed, as well as mortality rate and cause should be evaluated.

9. Prior to any handling procedure, the health and welfare status of the fish should be assessed to ensure that they are fit and able to withstand the rigors and stress of handling without risking adverse welfare and health implications.

10. Some species may need to be physiologically prepared prior to entering a new environment, such as using feed withdrawal or osmotic or temperature acclimatisation. This should be done in a way which minimises negative welfare consequences.

11. Fish may be deprived of feed prior to certain management procedures, transport or slaughter for as short a period as necessary to ensure gut clearance for welfare purposes. Feed is withdrawn in order to prevent pollution of the transport water through excrement. The duration of feed withdrawal should always be adjusted to fish size and to temperature, and kept as short as possible.

12. Fish should be inspected during and after handling for signs of external injury or excessive time to resume feeding that might be due to the procedures or equipment used. In case of injury or excessive mortality, the handling procedure should be evaluated to identify pitfalls in order to avoid similar occurrences in the future.

13. If fish have to be removed from water for handling, the time should be limited to the minimum and they should be kept moistened at all times. Fish should not be allowed to asphyxiate under any circumstances.

14. Fish should never be thrown onto solid objects or onto each other or hit solid objects including when exiting pipes and pumps. Fish should not be allowed to fall from a height that would compromise welfare.

15. During crowding and removal of fish from water, which occur as part of husbandry and handling procedures, measures should be taken to avoid invoking a maximal stress response in fish. Fish should be crowded at the lowest density possible that is appropriate for the required handling procedure. The impact of crowding should be reduced primarily by carrying it out in several steps. Periods of critically high density, and the number of crowding events, should be minimised. The water quality and especially levels of oxygen should be monitored and kept within acceptable limits. The period in which fish are kept crowded should be as short as possible.

16. Grading is a husbandry practice that is beneficial for fish welfare when it is executed by skilled personnel taking into account welfare parameters. Grading prevents the development of aggressive behaviours and cannibalism due to big size differences. Furthermore, it offers better access to feed to all fish by breaking hierarchies in farmed populations. Instances of grading should be carefully planned and kept to a minimum. Grading is more difficult in sea floating net pens than in other systems.

17. Vibrations and noise caused by some equipment may have an impact on fish welfare and should be kept to a minimum.

18. Procedures involving pumping should minimise pain, distress and suffering including the risk of injury. In particular, it should be ensured that pumps' or pipes' height, pressure and speed, as well as the height from which fish fall when they emerge, are adjusted to this aim. Pumps should have an appropriate piping size, and this should be adjustable when it will be used for different sizes of fish. The design of the pipes and pumping system should be such that sharp bends, rough surfaces, and protrusions are avoided in order to minimise injuries. An appropriate procedure should be in place to ensure that all fish have been removed from the system at the end of the operation.

19. Nets and landing nets should be designed to avoid physical injury, and they should not be overloaded so as not to crush or injure the fish.

20. Equipment including nets, pumping devices, pipes, brailing devices, vaccination equipment, grading devices etc. should be appropriate to the species, size, weight and number of fish to be handled, and be maintained in good condition. Equipment should be cleaned and disinfected between each use to reduce the risk of disease transmission.

21. Fish should be given anaesthesia if this is considered to significantly reduce the pain and stress during handling, and only upon a veterinarian's recommendation.

22. The World Organisation for Animal Health (OIE) recommendations of the Aquatic Animal Health Code on welfare of farmed fish during transport and welfare aspects of stunning and killing of farmed fish for human consumption and when killing for disease control purposes should be applied as appropriate.

CONCLUSIONS

These guidelines concerning water quality and handling of farmed fish will contribute to the increase of awareness of all sectors involved regarding both quality of production processes, the final product and the dissemination of best practices.

The respect of fish as sentient beings along with that of the environment and the consumer necessitates the need for further research to be performed in the coming period to achieve increased fish welfare.