ANIMAL WELFARE ASPECTS OF HUSBANDRY SYSTEMS FOR FARMED FISH: CARP[1]

Scientific Opinion of the Panel on Animal Health and Welfare

(Question N° EFSA-Q-2006-148)

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* A minority opinion was expressed by Prof. Donald Broom, member of the AHAW panel, based on the view that the accepted Report and adopted Opinion are incomplete. According to Prof. Broom introductory chapters on welfare, biological functioning and farming of fish should be included to the report in order to answer the mandate from the European Commission.

SUMMARY

Following a request from European Commission, the Panel on Animal Health and Welfare was asked to deliver a scientific opinion on animal welfare aspects of husbandry systems for farmed fish. Council Directive 98/58/EC concerning the protection of animals kept for farming purposes lays down minimum standards for the protection of animals, including fish. The Scientific Opinion on welfare of carp was adopted on 22 October 2008.

The common carp (*Cyprinus carpio*, Linnaeus 1758), which is by far the species farmed in largest numbers, is the scope of this opinion. Common carp is a domesticated species that has well adapted to the husbandry systems within which it is reared.

In Europe, only two major production systems (monoculture of carp and polyculture of carp) are commonly practised. There are numerous combinations of polyculture with common carp production. Since the species involved are all cyprinids and occupy only slightly different ecological niches in the pond system, they were subjected to the same risk and hazard assessments as carp in monoculture. Consequently, for the purpose of risk assessment, polyculture was considered as an intensive monoculture production system.

The various life stages of carp considered are: fertilised eggs and embryos, yolk sac fry, free swimming fry, nursed fry, fingerling, overwintering carp, on-growers, marketable fish, and broodstock.

A review of environmental conditions and factors that were identified as possibly affecting the welfare of common carp, *Cyprinus carpio*, at different life stages has been conducted. These factors are grouped as: abiotic and biotic factors (including behavioural interactions), food and feeding, husbandry and management, genetics, and the impact of disease and disease control measures. It is however important to realise that the environmental conditions are always defined by a range of inter-related factors. While each specific variable is described separately, there are very few occasions in reality where only a single factor is involved in any fish welfare issue relating to environmental conditions. For this reason, only ranges of acceptable levels for the various factors can be given and these should always be considered in the context of the other variables involved.

A semi-quantitative risk assessment was carried out to obtain a ranking of risk for different life stages under different production systems.

Light levels applied to embryos should be kept low to avoid over-stimulation leading to exhaustion of endogenous reserves.

The anatomy of carp may render them particularly vulnerable to excessive noise and vibration.

There are no water flow requirements under carp farming conditions (except for eggs). Cessation of water flow helps hatching. Excessive water flows may cause crowding of fry and wasted use of energy reserves leading to starvation. Too low water flow was found in the risk assessment to be a more highly ranked hazard (causing hypoxia) in early life stages. Carp are remarkably tolerant to low oxygen levels, except in the first few months of the life cycle when fry are more sensitive. Occasionaly severe oxygen depletion associated with collapse of algal blooms in late summer at high temperatures can affect welfare. However, the results of the risk assessment found low oxygen to be the most

important or second most important hazard for all life stages. Fry is a life stage particularly sensitive to low but also high O_2 levels. The risk assessment scoring found low oxygen to be an important cause of mortality at all life stages; but low oxygen levels are most important in the early stages.

Eggs exposed to levels of gas supersaturation can lead to long term effects on surviving individuals. Supersaturation of dissolved gases may lead to gas bubble formation inside the larvae causing disruption of swimming activity.

Carp can survive across a wide temperature range by adjustment of their level of activity. Carp larvae are very susceptible to temperature fluctuations: excessively high temperatures lead to increased rates of body deformities. Rapid temperature changes rather than absolute limits are normally a significant welfare issue for carp fry. Rapid temperature change was found in the risk assessment to be an important hazard for yolk and nursed fry and fingerlings.

During incubation high water pH can lead to incomplete embryonic development and deformities and was found in the risk assessment to be an important hazard. Carp larvae are particularly sensitive to acid stress. In later life stages, water pH *per se* has little importance in carp husbandry, it is only important in terms of its influence on other abiotic hazards (e.g. ammonia) should they be present.

Carp are not affected by suspended solid levels except at the very high concentrations that may occur during harvesting. High suspended solids can suffocate eggs and embryos (it was the third highest ranked hazard for this life stage) and the water supply to the hatchery water should be filtered to limit suspended solid and predatory invertebrates.

Unionised ammonia can be a serious welfare issue under conditions of intensive photosynthesis such as following collapse of algal blooms. This was reflected in the risk assessment tables where unionised ammonia was highly ranked in nearly all life stages. A great care and understanding is required in levels of fertiliser in ponds to avoid this hazard.

In the present culture systems in Europe, overwintering ponds do not present a particular welfare risk, compared with other life stages, although it is important that these overwintering ponds are sufficiently deep for the coldest weather. Catch pits in harvest ponds should be carefully designed to minimise the suspended solids problems. For larvae, bad design of the tank would prevent the swim bladder filling with air resulting in incomplete development of the swim bladder, impaired swimming ability, poor health and slow growth rates.

Unless ponds are managed carefully, anoxic layers producing toxic metabolites can develop. Algal blooms can be a significant welfare risk because of their effect on pH, because the algae may themselves be toxic, and because the collapse of algal blooms may cause severe and acute anoxia. The results of the risk assessment indicated that algal blooms were most important during the on-growing stage.

Predation is a very serious welfare issue particularly significant in the farm pond environment where cormorants in particular can induce significant stress to the fish manifested by behavioural modifications and associated reduction in feeding, and the birds may also inflict injury.

Whilst carp generally feed on natural feed, above certain densities they should receive supplementation with a correctly balanced feed for a fish that already feed on natural feed. Stocking fry into ponds with insufficient supplies of suitable food will result in low survival rates, poor growth and significant deformities. Food supply is the main factor governing appropriate stocking density. This was reflected in the risk assessment results: a shortage of natural food was the highest ranked hazard for the free and nursed fry stage.

Disease is one of the major welfare issues in all fish husbandry. In the case of carp it is particularly related to environment. Most carp pathogens are facultative pathogens present in the environment. Those diseases with chronic, often sub-clinical effects are often of greatest welfare significance. In more acute conditions, control or treatment measures may have significant welfare impact in their own right. Good husbandry should be the major means of disease control. Currently very few of the treatments which are effective can be used due to the fact that they are not licensed. The risk assessment scored three selected diseases. These hazards affected mainly the earlier life stages (fry) and their importance varied between production systems.

Key words: **carp, animal welfare, risk assessment, fish farming, husbandry system, aquaculture, environmental conditions, biotic factors, feeding, husbandry, disease.**

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BACKGROUND AS PROVIDED BY EUROPEAN COMMISSION

Council Directive 98/58/EC concerning the protection of animals kept for farming purposes lays down minimum standards for the protection of animals bred or kept for farming purposes, including fish.

In recent years growing scientific evidence has accumulated on the sentience of fish and the Council of Europe has in 2005 issued a recommendation on the welfare of farmed fish[2]. Upon requests from the Commission, EFSA has already issued scientific opinions which consider the transport[3] and stunning-killing[4] of farmed fish.

TERMS OF REFERENCE AS PROVIDED BY EUROPEAN COMMISSION

In view of this and in order to receive an overview of the latest scientific developments in this area the Commission requests EFSA to issue a scientific opinion on the animal welfare aspects of husbandry systems for farmed fish. When relevant, animal health and food safety aspects should also be taken into account[5]. This scientific opinion should consider the main fish species farmed in the EU, including Atlantic salmon, gilthead sea bream, sea bass, rainbow trout, carp and European eel and aspects of husbandry systems such as water quality, stocking density, feeding, environmental structure and social behaviour.

Due to the great diversity of species it was proposed that separate scientific opinions on species or sets of similar species would be more adequate and effective. It was agreed to subdivide the initial mandate into 5 different questions in relation to Atlantic salmon, trout species, carp, sea bass and gilthead sea bream, and in relation to European eel

This Scientific Opinion refers only to carp.

ACKNOWLEDGEMENTS

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[2] Recommendation concerning farmed fish adopted by the Standing Committee of the European Convention for the protection of animals kept for farming purposes on 5 December 2005

[3] Opinion adopted by the AHAW Panel related to the welfare of animals during transport -30 March 2004

[4] Opinion of the AHAW Panel related to welfare aspects of the main systems of stunning and killing the main commercial species of animals- 15 June 2004

[5] Food Safety aspects of fish welfare are addressed by a Scientific Opinion of the BIOHAZ Panel (“Food Safety aspects of Animal welfare aspects of husbandry systems for farmed fish”, Question N° EFSA-Q-2008-297).

OUTCOMES FROM THE DATA PRESENTED IN THE SCIENTIFIC REPORT

1. Common carp, its importance to European aquaculture

The family Cyprinidae is the most important in numbers of species of all freshwater teleosts. The Common Carp (*Cyprinus carpio*, Linnaeus 1758) is one of the most widespread members of the Cyprinid family. In Europe, the common carp is by far the carp species farmed in largest numbers. However, due to socio-economical changes in Central and Eastern Europe, the production of common carp has declined sharply, between 1990 and 2004. Carp production in Europe is currently of about 225 000 metric tons and 90% of this is produced by aquaculture.

2. Overview of carp production systems in Europe

Carp are omnivorous fish with a strong tendency to eat animal food. Carp occur naturally in summer-warm lakes and slowly flowing rivers. Carp are rarely found in clear, cool, swift-flowing streams. They prefer muddy areas where they search for food organisms. Carp can tolerate winter temperatures below 2 °C. They can tolerate temperatures above 30 °C for short periods.

The scientific report, which was used as a basis for this opinion defines the systems used for culture of the common carp, and highlights areas where such systems may increase the likelihood of negative effects on the welfare of carp.

Three main production systems of common carp can be differentiated as: i) monoculture of carp, ii) polyculture of carp, and iii) integrated carp culture with other agricultural activities. There are very few intensive systems in the region despite existing technology. As a simplification, carp polyculture will be considered as an intensive monoculture production system, only considering the number of individuals not their species richness.

There is very little scientific literature that specifically addresses the welfare of carp under farming conditions.

3. Factors affecting the welfare of carp

The various life stages of carp considered are: fertilised eggs and embryos, yolk sac fry, free swimming fry, nursed fry, fingerling, overwintering carp, on-growers, marketable fish, and broodstock.

A review of environmental conditions and factors that were identified as possibly affecting the welfare of common carp at different life stages has been conducted. These factors are grouped as: abiotic and biotic factors (including behavioural interactions), food and feeding, husbandry and management, genetics, and the impact of disease and disease control measures. It is however important to realise that the environmental conditions are always defined by a range of inter-related factors. While each specific variable is described separately, there are very few occasions in reality where only a single factor is involved in any fish welfare issue relating to environmental conditions. For this reason, only ranges of acceptable levels for the various factors can be given and these should always be considered in the context of the other variables involved.

3.1. Abiotic factors

3.1.1. Light period and intensity

Carp, like all cyprinid fish, react to changes in light. Change in photoperiod regime may affect carp growth rate, maturation and spawning alacrity, and respiration. During the main part of the production cycle, when the carp are held in extensive earth ponds, fish are exposed to a natural photoperiod, which is associated with other environmental features, such as temperature. For eggs and larvae, expert opinion suggests that light levels should be kept low to avoid stimulation of the embryo.

3.1.2. Noise and vibration

There is evidence that cyprinids are sensitive to noise and vibration. Carp physoclistous swim bladder makes this fish susceptible to major vibrations.

3.1.3. Water flow

Common carp do not require flowing water. In farming conditions carp are produced in ponds without water flow, except for replacement of water losses due to seepage or evaporation. For young stages, water flows in excess of these rates may cause shock and trauma, as well as exhaustion.

3.1.4. Water oxygen content

Carp are remarkably tolerant to low oxygen levels, except in the first few months of the life cycle when fry are more sensitive.

3.1.5. Total dissolved gases

Expert opinion indicates that above a 100% level of total dissolved gases, problems can occur with gas bubble formation leading to a loss of eggs and larvae.

3.1.6. Water temperature

Carp are able to survive across a wide temperature range (from ~2 °C to > 36 °C), although activity changes drastically with temperature. Decreases in water temperature below 20 °C and increases above 30 °C both lead to a decline in feeding. During the incubation of eggs, it is important that the temperature of the water be maintained as constant as possible within the optimal range. Carp larvae are very susceptible to temperature fluctuations.

3.1.7. Water pH

Adult carp can survive in waters with a wide range of pH 5.5-10, although extreme values reduce feeding activity and thus growth rates. The direct effect of pH is less important than the indirect effect of increased pH values have on the un-ionized ammonia content.

3.1.8. Suspended solids

Feeding activity of carp causes re-suspension of bottom sediments, resulting in high concentrations of suspended solids. In case of excessive suspended solids severe gill obstruction occurs and there is considerable reduction in respiratory capacity, limited gas exchange across the gills and temporary anoxia.

Water supplies to the egg incubation system, should be filtered to remove any particulate organic or inorganic material. This also ensures no predatory invertebrates such as cyclopoid copepods are present in the hatchery tanks.

3.1.9. Ammonia content

The toxicity caused by ammonia is related to the level of unionized ammonia (NH_3) and this varies depending on the pH of the water and also temperature, with lower temperatures resulting in lower levels of unionised ammonia. Under normal carp culture conditions, total ammonia nitrogen levels rarely exceed 1-2 mg/l so welfare issues rarely arise except in case of intensive photosynthesis by blooming algae.

3.1.10. Pond size and morphology

Since carp are grown in large to very large ponds or even small lakes, their conditions in many ways mirror those of their natural environment. Depending on pond size, depth and stocking density, ponds can vary in their complexity. Provision of a drainage chamber and catch pit and a controlled method of removing the water will reduce the stress associated with harvesting. Design of tanks is important to the swim up of larvae.

3.1.11. Substrate of ponds

The feeding activity of carp tends to remove all vegetation from the pond bottom and the constant stirring leads to the formation and deposition of a fine sediment. Silt can build up to a considerable depth and lower layers of this silt, if undisturbed, become anoxic. This favours the production of toxic substances. For over-wintering carp, the substrate should not have a high organic content as this may increase oxygen consumption within the substrate and production of toxic gases.

3.1.12. Environmental pollutants

Carp ponds are relatively stable and do not normally have any substantial water inflow, but there is some replacement water for evaporation and rain can bring terrestrial pollutants into the system.

3.2. Environmental conditions – biotic factors

3.2.1. Algal blooms

Algal blooms may affect welfare of fish in three different ways. First, because their photosynthesis levels are so high, their metabolites can cause dramatic increases in pond pH to levels that may be toxic either directly or through increases the proportion of unionized ammonia to toxic levels. Secondly, in many cases the algae involved may include toxigenic cyanobacterial species, which can on occasion cause mass mortality. Thirdly, when the bloom collapses, the oxygen may be extracted from the water column at a very rapid rate, and this can lead to significant mortality.

3.2.2. Behavioural interactions

In general, the senses of common carp are the same as for other fish. Common carp usually establish well-defined home ranges. During winter, over-wintering ponds may not offer the fish scope for movement and continued feeding. In polyculture interactions with other species include potential competition for food and, more importantly in a welfare context, predation.

3.2.3. Predation

Especially when small, carp fall prey to a wide variety of predators including mammals, birds, other fish and also invertebrates. Predation is a serious welfare issue and stress is manifested by behavioural modifications and associated reduction in feeding.

3.2.4. Stocking density

Stocking levels in carp pond vary depending on the farming system, the nature of the pond, whether it is winter or summer and whether there is to be auxiliary feeding.

3.3. Food and feeding

Because carp are almost exclusively produced in semi-intensive pond farms or under extensive conditions, feeding is only practised to complement the energy and protein requirements provided by pond primary production.

3.4. Husbandry and management

Stocking in outdoor ponds is a stressful experience for fish at all stages of development, but the early life stages are particularly sensitive and susceptible to environmental change. Newly-hatched larvae are extremely fragile and should never be removed from water. Transport to the pond should be done as quickly as possible and with the minimum of handling. Great care should be taken to ensure that the fish are not subjected to a rapid change in water parameters. Acclimation can be achieved by introducing the fish gradually to the environmental conditions present in the receiving tank or pond. Harvesting is another critical phase of carp culture.

3.4.1. Handling of broodstock

Spawners need to be separated by sex when water temperatures rise. After separation, feeding is increased. Spawners are moved into the hatchery. Fish are examined and the ripe developed specimens selected. Induced ovulation of spawners is done in tanks or in special small ponds. Fish are generally anaesthetized. Hypophysation is the traditional method of inducing fish to spawn and is widely practised in carp culture. The sexual products stripped from the fish are mixed and a fertilizing solution is added to prevent egg agglomerating. Spawners should be kept undisturbed between the treatments and ovulation.

3.4.2. On-farm movements

On-farm movements are movements of fish within the aquaculture facility tend to short term in nature usually lasting less than 30 min. Because of the temporary nature of the activity, welfare issues are generally limited to physical damage, dissolved oxygen content of the transport water, nature and levels of suspended solids and temperature shocks experienced when transferring the fish from one water body to another. Open tanks with aeration can be used. At temperatures above 15 C low doses of anaesthetic can be used to tranquilise the carp. During on farm transport operations, it is common practice to add low concentrations of NaCl to the transport water in order to minimise stress.

3.4.3. Sorting and Grading

Sorting and grading happen at different times in the production cycle. Polyculture is widely practised in European carp culture and, after being removed from the pond, the fish are placed onto sorting tables where the individual species and size groups can be separated. Most of this separating and sorting is done by hand although increasingly, the fish are graded using mechanical graders, which tend to cause less damage.

3.4.4. Monitoring

Frequent monitoring of the water quality is essential as there are a number of variables that affect the well-being of fish. In culture systems, the main factors that need to be monitored are temperature, dissolved oxygen, pH and the metabolic by-products NH_3 and NO_2. Depending on the culture system used, other parameters that need monitoring may include alkalinity, PO_4, total phosphorus, NO_3, CO_2, Biochemical and Chemical Oxygen Demand (BOD, COD), and turbidity. In addition to water quality, information is also needed on feed rates, growth, condition, mortalities, disease status and ultimately survival rates. These data enable the farmer to make informed husbandry decisions and ensure the continued health and welfare of the fish.

3.4.5. Staff training on welfare

To be successful and to maintain welfare standards in carp culture, it is important that staff at each unit is experienced and proficient. Failure to invest in the training and development of staff can lead to fish being subjected to avoidable stressors such as over-crowding, poor handling, underfeeding, sub-optimal culture conditions and inappropriate disease treatment.

3.5. Genetics

Quality breeding programs exist for common carp. Many varieties and strains of scaly or “mirror” carp (with some large shining scales), including hybrids, are available. Common carp is a domesticated species that well adapted to the husbandry systems within which it is reared.

3.6. Impact of diseases on welfare

Disease is one of the major welfare issues in all fish husbandry. In the case of carp it is particularly related to environment. Most carp pathogens are facultative pathogens present in the environment. Those diseases with chronic, often sub clinical effects are often of greatest welfare significance. In the case of more acute conditions, control or treatment measures may have significant welfare impact in their own right. Good husbandry should be the major means of disease control.

3.7. Diseases control measures

3.7.1. Biosecurity

Biosecurity covers implementation of a set of programmes and procedures preventing the entry, establishment or spread of unwanted pests and infectious disease agents whether they are a risk to humans, animals, plants or the environment. Biosecurity is the state of having applied appropriate measures to prevent or limit the possibility of pathogens entering populations from an exogenous source.

3.7.2. Monitoring mortalities / survival rates

Mortalities of fish during the production cycle can result from a variety of causes, including, disease, predation, damage, and adverse environmental conditions. Very poor welfare (e.g. disease, poor growth and mortalities) is not cost-effective for the farmer. At present many farms rely on the experience of the farm manager to decide when mortalities require additional action.

3.7.3. Drug usage

Carp diseases are a significant welfare hazard but currently very few of the treatments which are effective are used due to the fact that these veterinary medicinal products are not authorised.

3.7.4. Vaccination

As with any animal husbandry system, the intensification of fish farming has inevitably resulted in the emergence of disease problems, infectious diseases in particular. Carp farming is still to a large extent extensive, but in the case of Koi carp, for example, the value of the commercial product is now recognised as being worth treating with more expensive antibiotics or vaccines. Vaccines have made a significant contribution to controlling serious infectious diseases of fish. Future research on effective vaccination of carp against major infectious diseases is recommended as a means of improving carp welfare in this regard.

4. Risk assessment approach to welfare of common carp

The risk scores based on expert advice were used to compile a risk ranking by category such as abiotic or biotic to obtain an idea which hazards are the more important for each life stage in the various production systems considered, and also to enable the comparison of the different production systems.

4.1. Eggs

The important hazards for both Dubish ponds and jars were water quality parameters. The highest ranked hazards were low water oxygen content for jars and low water temperature in Dubish ponds. Too high or too low water flows were important in jars whilst only low water flow was important in Dubish ponds. High suspended solids ranked higher in jars (3) compared with Dubish ponds (8). The highest ranked hazards all lead to deformities which would persist through to later life stages. The top three ranked hazards also caused significant levels of mortality (greater than 40%). Water quality parameters score highly in part, because a high proportion of the population is affected (all the top hazards affected >40% of the populations and most affected greater than 60%). The most frequently occurring hazard was low water oxygen in Dubish ponds (low probability); all other highly ranked hazards occurred with very low or extremely low frequency.

Table 1: Welfare risk ranking: eggs

Jars	Dubish Pounds
water oxygen content too low	water temperature too low
water flow too low	water oxygen content too low
suspended solids too high	water flow too low
water temperature too low / unionised ammonia content	water oxygen content too high / water temperature rapid change / water pH too high
water flow too high	

4.2. Yolk sac fry

Water quality parameters remained important for yolk sac fry in both tanks/troughs and Dubish ponds, notably low water oxygen and low water temperature. There were some interesting differences between the 2 systems. White spot disease was the highest ranked risk in Dubish ponds and only the 8th ranked risk in tanks. Poor handling was important in jars but not Dubish ponds. The highest ranked hazards all resulted in deformities, have high severity scores and affect a high proportion of the population However, the probability of occurrence of hazards occurring was extremely or very low.

Table 2: Welfare risk ranking: yolk sac fry

Trough or Tank	Dubish ponds
water oxygen content too low	White Spot Disease
water flow too low	water oxygen content too low / water temperature too low
suspended solids too high	unionised ammonia content
water oxygen content too high / handling not in acorrdance with best practice	water oxygen content too high / water temperature rapid change
water temperature too low / unionised ammonia content	

4.3. Free living fry

The top ranked hazards in all three systems were similar. Whilst water parameters remain important, shortage of natural food is the most important hazard for all systems. This hazard results in deformities. The hazard attains a high score because its severity is high, and it affects a high proportion of the population. The dependence of the life stage on natural food means that intervention to mitigate the impact is limited. Water quality parameters and temperature (too high or too low), white spot and *Saprolegnia* are important in all three systems. Inappropriate design of the pond was considered an important hazard for all three systems. Too high a temperature was the hazard with the highest probability of occurrence which had a low probability.

Table 3: Welfare risk ranking: free living fry

Dubish ponds	Nursing ponds	Fingerling ponds
shortage of natural food long term	shortage of natural food long term	shortage of natural food long term
water temperature too high / water oxygen content too low / water temperature too low	water temperature too high / water oxygen content too low / water temperature too low	water temperature too high / water oxygen content too low / water temperature too low
pond size, morphology and substrate / water pH too low / water pH too high / White Spot Disease	pond size, morphology and substrate / White Spot Disease / Saprolegnia	pond size, morphology and substrate /White Spot Disease / Saprolegnia

4.4. Nursed fry

For both production systems, a lack of food supply continues as the most important hazard from the free living to the nursed fry stage. The hazards are very similar for both systems: low water oxygen, too low temperature and high unionised ammonia content. The main impact of the top ranked hazards remains deformities. The highest ranked hazards had high severity scores and affected a high proportion of the population, but occurred with very low or extremely low probability.

Table 4: Welfare risk ranking: nursed fry/nursing

Nursing Pond	Fingerling Pond
shortage of natural food long term	shortage of natural food long term
water oxygen content too low /water temperature too low	water oxygen content too low / water temperature too low
unionised amonia content	unionised amonia content
water temperature too high	water temperature too high
water flow too low / water temperature rapid change / water pH too low / water pH too high / suspended solids too high	water flow too low / water temperature rapid change / water pH too low / water pH too high / suspended solids too high

4.5. Fingerlings

At this life stage there is only one production system. The top three hazards remain the same as the previous life stage. A long term shortage of food is the 4th highest ranked hazards. At this life stage hazards result in reduced growth and poor condition (as well as mortality). The hazard which occurred with the highest probability was low oxygen (low probability). Predation also occurred with low frequency, and resulted in considerable mortality. Its severity at this life stage is low since mortality was the most common outcome, not injury. On some farms predation will occur with moderate or high frequency.

Table 5: Welfare risk ranking: fingerling

Fingerling Ponds
water oxygen content too low
water temperature too low
unionised amonia content to high
shortage of natural food long term

water temperature too high / water temperature rapid change

4.6. Over-wintering

Over-wintering carp may be kept in over-wintering or grow-out ponds but the most important hazards are the same: low water oxygen, predators and low water flow (leading to hypoxia). Hypoxia results in stress and mortalities. Predation can lead to mortalities but from a welfare point of view, stress and physical damage to survivors can also occur. Too low temperature or rapid changes in temperature were highly ranked because they may lead to stress. There are clearly interactions between some hazards. Stress may result in an increased risk of disease as well as directly affecting the carp's welfare.

Table 6: Welfare risk ranking: over wintering

Over wintering ponds	Grow out ponds
water oxygen content too low	water oxygen content too low
predators	water flow too low
water flow too low	predators
water temperature rapid change / water temperature too low / unionised ammonia content	water temperature rapid change / water temperature too low / unionised ammonia content

4.7. On-growers

On-growers may be kept under intensive or extensive conditions. Interestingly, a very similar ranking of hazards are found in both systems: low water oxygen, rapid change in temperature, low water temperature and low pH. Rapid changes in temperature stress carp, the other hazards result in reduced growth and more chronic low level stress. Pollution is an important hazard in extensive but not intensive systems, whist lack of natural food occurs in intensive but not to the same extent in extensive systems. Predation was the 8th highest ranked hazard. In some farms it is likely to be one of the most important welfare issues. At this, and later, life stage, predation is more likely to result in physical damage leading to a long duration of effect.

Table 7: Welfare risk ranking: on growing

Intensive on growing pond	Extensive on growing pond
water oxygen content too low	water temperature rapid change
water temperature rapid change	water oxygen content too low
water flow too low / water pH too high	water flow too low / water pH too low / water pH too high

unionised ammonia content h	pollution (sewage/industrial/agricultural run off)
water pH too low	

4.8. Marketable fish

Marketable fish are only kept in storage ponds. The hazards are very similar to on-growers: low water oxygen, rapid change in temperature and low temperature. This is the only life stage where the top three ranked hazards all occur with low probability. Thus the highest ranked hazards collectively occur more frequently at this life stage than any other.

Table 8: Welfare risk ranking: marketable fish

Storage ponds
water oxygen content too low
water temperature rapid change / water temperature too low
water flow too low / water pH too low
water depth too shallow / unionised ammonia contenth

4.9. Broodstock

Broodstock fish are only kept in storage ponds. The hazards are very similar to on-growers and marketable fish: low water oxygen, rapid change in temperature and low temperature. The top ranked hazards all occurred with a very low probability. The top 3 ranked hazards all affected between 60-80% of the population; low water oxygen was highest ranked due to its higher severity score (4) compared with other hazards. Again, predation was the 8th highest ranked hazard. In some farms it is likely to be one of the most important welfare issues.

Table 9: Welfare risk ranking: broodstock

Broodstock ponds
water oxygen content too low
water temperature rapid change / water temperature too low / water pH too high
water flow too low / water temperature too high

4.10. Uncertainty

All the highest ranking hazards had an uncertainty score of low or medium. Medium levels of uncertainty were for suspended solids (eggs, yolk sac fry) water pH (marketable, broodstock), dissolved oxygen (yolk sac fry), water flow (over-wintering, on-growers, marketable). Uncertainty was scored based on available information. For all hazards considerable variation will exist between farms, regions and over time. This has been captured to some extent by the ranges represented by each score; however, this has not been quantified (using confidence limits) in the final risk score. When assessing the risk scores, they should be viewed as the median value with a high standard deviation.

4.11. Mortality

Low oxygen is the most important cause of mortality, having a high score (>3) in every life stage. Low water flow is an important cause of mortality in the later life stages. This is due to the associated reduction in available oxygen. Three hazards cause high levels of mortality (score >3) for yolk sac fry and on-growers. Of the selected diseases assessed, white spot was noted as an important cause of mortality for yolk sac and free-swimming fry.

Table 10: Mortality scores >4 and 5 for the top 6 ranked hazards for each life stage.

Life stage	Hazard						
	Handling	Low O_2	White spot	pH	Low water flow	Pollution	Unionised ammonia
Fertilised eggs/embryo		5					
Yolk sac fry	4d	5	5a				
Free swimming fry		5	5b				
Nursed fry		4					
Fingerling[1]		5					
Over-wintering carp		4			4		
On-growers		4			4	5	4c
Marketable fish		4			4		
Broodstock		4					

a Dubish ponds, b nursing ponds, c intensive on-growing ponds, d tank/trough
[1]predation is also an important cause of mortality

4.12. General discussion

It is worth noting that the hazards were not distinguished by their duration of effect which generally was the same for all hazards within each life stage. The other main trend was that highly ranked risks generally affected a high proportion (≥60%) of the population and exerted severe effects (scores ≥3). However, the probability of occurrence was generally extremely low or very low.

A few water quality parameters occurred consistently across life stages: high or low water temperature (or rapid temperature change), low water flow, low water oxygen, high or low pH. These hazards occur relatively infrequently (extremely or very low frequency), however, when they do occur the impact is severe and affects a high proportion of the population. The risk assessment cannot assess interactions between hazards. Environmental and in particular climatic conditions may simultaneously cause more than one hazard. It is possible that the resultant impact of one or more hazards, occurring at the same time, is synergistic.

Oxygen paradoxically appears as an important welfare hazard in the risk assessment, although it is usually commonly accepted that carp are tolerant to low water oxygen concentration (as low as 0.9 mg/l). However, welfare issues arise before lethal limits are reached. Also, severe oxygen shortage (e.g. collapse of algal blooms) was identified as major welfare issues.

Apart from water quality issues, food shortage, disease and handling featured as highly ranked hazards. White spot was an important hazard for yolk sac fry in Dubish ponds but not other production systems. However, both white spot and *Saprolengia* were important at the next life stage (free living fry) in all 3 systems. Diseases did not rank highly for the older life stages. Handling only ranked in the top 6 hazards for yolk sac fry raised in tanks or troughs. Broodstock are handled for purposes of reproduction but the duration of the effect of handling is short-lived, resulting in a low score compared with other hazards. Long term food shortage was an issue at the fry and fingerling stages.

4.13. Risk mitigation / Recommendations

Monitoring water quality and the capacity to take remedial action would improve welfare in all life stages. In the early life stages, production in Dubish ponds may be less amenable to rapid and effective intervention compared with other production systems.

The farmer's ability to mitigate environmental factors affecting many water quality and temperature hazards is limited in most carp production systems. The most important hazards occur relatively infrequently (very or extremely low frequency) and for short periods. This reduces the intervention opportunities for aquaculturists as by the time the hazard has been noted, the damage may have occurred. Reducing the impact of these hazards probably depends on developing systems and management strategies that are less susceptible to environmental and climatic changes. As an example, high levels of stocking will clearly exacerbate the impact of adverse climatic conditions causing low levels of dissolved oxygen or high levels of unionised ammonia.

Of the hazards that can be described as management related only shortage of feed (during fry and fingerling stages) and handling, featured as highly ranked risks. Training and adoption of good codes of practice can reduce the impact of handling on the welfare of carp. Production systems which result, even relatively infrequently, in food shortages may be considered sub-optimal from a welfare point of view. Most carp production relies on natural productivity for some of the life stages. It is therefore inevitable that potentially, more vulnerability to shortages of feed exist compared with other types of finfish production. This is especially true for the early life stages of fish. Commercially available diets are either expensive and/or unsuitable for extensive carp farming. Pond preparation and the creation of optimal conditions for the development of natural food items are therefore vital. The design and construction of carp farms (location, size of pond, etc.) and management regime (e.g. stocking rate) should always consider continuous adequate feed supply a priority.

CONCLUSIONS AND RECOMMENDATIONS

Overall, common carp is a domesticated species that well adapted to the husbandry systems within which it is reared.

A review of environmental conditions and factors that may affect welfare of common carp, *Cyprinus carpio*, is given in the different sections of this report. It is important however to realise that the environmental conditions are always defined by a range of interrelated factors. While each specific variable is described separately, there are very few occasions in reality where only a single factor is involved in any fish welfare issue relating to environmental conditions. For this reason, only ranges of acceptable levels for the various factors can be given and always these should be considered in the context of the other variables involved.

From this review, the following conclusions and recommendations for specific hazards were drawn.

Conclusions

1. Over-stimulation of eggs and yolk sac fry with excessive light will result in smaller larvae that may have lower survival rates; compared with other hazards over-stimulation was not ranked as an important cause of mortality. In carp husbandry systems, natural light is normally used and therefore light levels seldom cause problems.
2. There are no particular water flow requirements for carp under farming conditions, except for eggs and fry. Cessation of water flow helps hatching. Excessive water flows may cause crowding of fry and wasted use of energy reserves leading to starvation. Too low water flow was found in the risk assessment to be a more highly ranked hazard (causing hypoxia) in early life stages.
3. The risk assessment scoring found low oxygen also to be an important cause of mortality at all life stages; but low oxygen levels are most important in the early stages. Fry is a particularly sensitive life stage to low but also high oxygen levels. Low levels of oxygen for extended periods can lead to poor welfare.
4. Eggs exposed to levels of gas supersaturation can lead to long term effects on surviving individuals. Supersaturation of dissolved gases may lead to gas bubble formation inside the larvae causing disruption of swimming activity.
5. The physoclistous swimbladder and auditory system of carp may render them particularly vulnerable to excessive noise and vibrations. However data on the level and significance of susceptibility are not available.
6. Carp are generally capable of surviving in waters of low oxygen levels, except in the first few months of the life cycle when fry are more sensitive. However, in terms of welfare, the results of the risk assessment found low oxygen to be the most important or second most important hazard for all life stages. In ponds, occasionally severe oxygen depletion associated with collapse of algal blooms in late summer at high temperatures can affect welfare of carp.

7. Carp can survive across a wide temperature range (from ~2 °C to > 36 °C) by adjustment of their level of activity. Carp larvae are however very susceptible to temperature fluctuations: temperatures high in excess of few degrees would lead to increased rates of body deformities. Rapid temperature change (close to 3 degrees per hour) rather than absolute limits is normally a significant welfare issue for carp fry. Rapid temperature change was found in the risk assessment to be an important hazard for yolk and nursed fry and also fingerlings.
8. During incubation, high water pH can lead to incomplete embryonic development and deformities and was found in the risk assessment to be an important hazard. Carp larvae are particularly sensitive to acid stress, though it was not generally highly ranked in the risk assessment. In later life stages, water pH *per se* has little importance in carp husbandry, it is only important in terms of its influence on other hazards (e.g. ammonia) should they be present.
9. Carp are not affected by suspended solids level except at the very high concentrations that may occur during harvesting. High suspended solids can also suffocate eggs and yolk sac fry (it was the third highest ranked hazard for these life stages).
10. Unionised ammonia can be a serious welfare issue under conditions of intensive photosynthesis such as following collapse of algal blooms. This was reflected in the risk assessment tables where unionised ammonia was highly ranked in nearly all life stages.
11. In the present carp culture systems in Europe, tank and pond design has been found related to some welfare issues as following: water temperature (most stages), suspended solids (most stages), swim bladder inflation (larvae), impaired swimming ability and poor health and slow growth rates.
12. With regards to substrate and pond bottom, unless ponds are managed carefully, anoxic layers producing toxic metabolites can develop.
13. Algal blooms can be a significant welfare risk because of their effect on pH, and because the algae may themselves be toxic to the fish; in addition, the collapse of the bloom may cause severe and acute anoxia. The results of the risk assessment indicated that algal blooms were most important during the on-growing stage. At latest stages, the hazard was considered to be less severe and to occur less frequently.
14. Carp husbandry systems in Europe allow normal social interactions between fish, and fish species in the case of polyculture.
15. Predation is a serious welfare issue particularly significant in the farm pond environment where predators such as cormorants can injure fish and induce significant stress manifested by behavioural modifications including reduction in feeding.
16. Stocking levels depend on the nature and condition of the pond. Traditionally on-growers are stocked at a biomass of about 300 kg/ha. However, carp are shoaling fish and this determines their own local biomass level, which has been found to have no welfare implications.

17. Carp generally feed on natural food. Above certain densities they receive supplementation with a correctly balanced feed for a fish that is already feeding on natural food. Shortage of natural food was identified as a welfare issue for fry and fingerlings. Stocking fry into ponds with insufficient supplies of suitable food will result in low survival rates, poor growth and significant deformities. Food supply is the main factor governing appropriate stocking density. This was reflected in the risk assessment results: a shortage of natural food was the highest ranked hazard for the free and nursed fry stage.
18. Diseases are one of the major welfare issues in all fish husbandry. In the case of carp it is particularly related to environment. Most carp pathogens are facultative pathogens present in the environment. Those diseases with chronic, often sub clinical effects are often of greatest welfare significance. In the case of the more acute conditions, control or treatment measures may have significant welfare impact in their own right.
19. Currently, very few of the treatments which are effective can be used due to the fact that these veterinary medicinal products are not authorised for use in carp. Absence of medicinal products may pose welfare problems. In practice treatment using unauthorised veterinary medicinal products may in itself represent a welfare concern.
20. The risk assessment scored three diseases selected to be used as working examples. These hazards affected mainly the earlier life stages (fry) and their welfare significance varied between production systems.
21. For yolk sac fry, risk assessment highlighted a difference between tanks/troughs and Dubish ponds, with white spot disease (*Ichthyophthirius multifiliis*) being the highest ranked risk in Dubish ponds.
22. Overall, the husbandry systems for each life stage did not differ considerably in their risk ranking.
23. The nets used during the harvest process induce stress and may also increase the risk of physical trauma and damage to the fish skin.

Recommendations

1. For eggs and yolk sac fry, light levels should be kept low to avoid over-stimulation leading to exhaustion of endogenous reserves.
2. The water flow for egg incubation should not exceed 1.5 l/min during the first hours of development and 3 litres per min thereafter.
3. For fry, excessive water flows should be avoided to prevent crowding of and wasted use of energy reserves leading to starvation.
4. Carp larvae are particularly sensitive life stages to low and high oxygen levels and levels should be maintained between 6 and 8 mg/l during this phase of culture.
5. Eggs and larvae should not be exposed to levels of gas supersaturation, which can lead to short and long term effects on individuals, including swimming capacity.

6. Carp larvae are very susceptible to temperature fluctuations; fluctuations over 1 °C should be avoided during transfer from incubation system to hatching system.
7. During incubation, water pH should be maintained between 6.0 and 8.5.
8. The water supply to the hatchery water should be filtered to limit suspended solids as high suspended solids can suffocate eggs and embryos. This will also limit entry of predatory invertebrates.
9. Unionised ammonia can be a serious welfare issue under conditions of intensive photosynthesis such as following collapse of algal blooms and great care and understanding are required in levels of fertiliser utilised in pond management to avoid this hazard.
10. Over-wintering ponds should be properly designed and sufficiently deep for the coldest weather.
11. Catch pits in harvest ponds should be carefully designed to minimise the suspended solids problems.
12. Harvesting the ponds should occur when water temperatures have dropped below 14 °C, when carp have a significantly reduced metabolic activity and their requirement for oxygen is diminished.
13. During harvesting operations, efforts should be made to maintain the fish in water of sufficient oxygen content, either by removing the fish as quickly as possible or by introducing fresh, oxygen-rich water into the catchpit. Efforts should be made to crowd fish carefully to reduce the possible effect of net damage.
14. For larvae, tank design should enable swim bladder to fill with air in order to prevent its incomplete development, and subsequent impaired swimming ability and poor health and slow growth rates.
15. Grow-out ponds should be carefully managed to prevent anoxic layers producing toxic metabolites can develop.
16. Algal blooms can be a significant welfare risk at on-growing stage because of their effect on pH, oxygen, and possible direct toxicity. The levels of algae in ponds should be monitored and maintained at levels to avoid the development of blooms and the harmful effects following bloom collapse. On farm reliable emergency backup is also recommended.
17. When stocking ponds, there should be minimal disturbance of the fish and sudden changes in temperature should be avoided. During the early rearing, stocking levels should be matched to the plankton availability.
18. Larval feed should contain 40-50% protein. The size of food particles is extremely important since first feeding fry can consume food of only a few hundred microns in size. In the later part of the nursing period fry may consume feed up to 1 mm in size. The quantity of artificial feed is to be defined based on the abundance of zooplankton, survival rate and age of the fry. Initially fry require 1 – 1.5 kg food/100 000 fish.
19. Ponds populated mostly or only with herbivorous species require 20-40% less fertilisers than common carp in monoculture since the herbivorous fish feed on water plants and recycle nutrients back into the pond after digestion.

20. Fry require good quality supplementary feed with a digestible crude protein content of 25-30%. Mixtures of cereals or legumes, or industrial by-products are used. If the natural feed (protein) supply runs out during the growing season a high protein diet based on fish or meat meal should be given.
21. Larvae should never be removed from the water.
22. Research should determine if genetic selection could affect traits that have a negative welfare impact.
23. Disease is one of the major welfare issues in all fish husbandry. Good husbandry should be the major means of disease control.
24. Rearing ponds for carp fry should range between 500 and 10 000 m^2 in size with an average depth of 1-1.5 m and sheltered from excessive wind.
25. Storage ponds should be around 2 m deep in order to reduce the effect of changes in ambient air temperatures. Shape and slope of the bottom and the design of the catch pit should ensure rapid and efficient fish crowding. Concrete bottoms should be avoided as they may result in traumatic skin lesions. When a pond is partially emptied, suitable equipment should be used to prevent physical damage to the remaining stocks as well as to the harvested fish.
26. Over-wintering carp ponds should be 1.5-2.5 m deep. They should have a soft bottom with a low proportion of organic matter. The pond should be supplied with appropriate inflow of clean well aerated water and it is important that over-wintering ponds are sufficiently deep for the coldest weather.
27. Disinfection and husbandry discipline are key component of biosecurity. A particular attention should be given to transportation equipment both before and after transportation of fish.
28. In view of the risks associated with the movement of live fish, including Koi carp, improvement in biosecurity is needed, at national and farm level. There is a need for training and establishment of robust biosecurity arrangements that will be both applied and monitored.
29. Vaccines have made a significant contribution to controlling serious infectious diseases of fish. Future research on effective vaccination of carp against major infectious diseases is recommended as a means of improving carp welfare in this regard.
30. There is a need for authorised veterinary medicinal products for carp disease treatments.