FISH WELFARE IMPROVEMENTS IN AQUACULTURE

By Marco Cerqueira &
Thomas Billington
marco@fishwelfareinitiative.org
tom@fishwelfareinitiative.org

fishwelfareinitiative.org

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Author:
Fish Welfare Initiative

With contributions from:
Marco Cerqueira, Thomas Billington

With feedback from:
Rui Gonçalves, Sonia Rey, Jonatan Nilsson

Edited by:
Antonia Personette

We will continue to update this report with new advancements in fish welfare and stakeholder suggestions.

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We are grateful for assistance and feedback from Rui Gonçalves, Sonia Rey, and Jonatan Nilsson on this report. Their assistance does not necessarily imply that they agree with the conclusions we draw.

PREAMBLE

Awareness in fish welfare is growing globally, and many stakeholders across the NGO and food production spaces are taking interest. Fish Welfare Initiative expects this interest in fish wellbeing to continue to grow as more people realize that healthy and sustainable fish culture relies on adequate fish welfare. Fish welfare's benefits were internationally recognized when the OIE incorporated “guiding principles and policies for fish welfare” into their Aquatic Animal Health Code (recommendations without legal compulsory character that instead rely on voluntary compliance from its current 180 member countries).[1] The OIE’s actions speak to the clear evidence that fish are not passive within their environment but, rather, are conscious individuals who can feel pain.[2] The benefits of improving welfare standards in fish farming are no different from those in any other animal farming system and fish, in our understanding, deserve the same level of commitment. As research into aquaculture continues to develop, more and more people are realizing that the value of fish welfare extends far beyond the fish within the farming system. Fish welfare improvements are a gain for the environment, a boost for businesses, and an advancement for social welfare[3] (Fig. 1). These aspects improve global well-being in tandem, as exemplified by the costs of disregarding welfare standards:

Figure 1. Holistic view of Fish Welfare Initiative’s conception of welfare.

COSTS

Overcrowding fish decreases production efficiency and makes maintenance of water quality difficult, as keeping fish at too high a density increases the proportion of waste and pollutants in the water.[4] Over-stressed fish need more antimicrobials, and parasites in aquaculture systems can transmit to wild populations.[5]

PRODUCER COSTS

Chronically stressed fish have reduced growth rates,[6] increased mortality,[7] and inferior fillet quality.[8] Thus, poor welfare creates a worse product. We also believe that improving fish welfare increases worker satisfaction.

SOCIAL WELFARE COSTS

Stressed fish are more prone to diseases and need more antimicrobials, which can lead to antibiotic-resistant "superbugs."[9]

Additionally, the environmental impacts of aquaculture directly affect the local population's quality of life and can decrease tourism.[10]

Lastly, of course, improving fish welfare will safeguard the trillions of sentient beings that are slaughtered each year by the aquaculture and fishery sectors. Taken together, the costs of poor fish welfare ensure that better standards serve as a joint pursuit for many stakeholder groups. The extent of these costs also illustrates how fish welfare is an integral part of the United Nations Sustainable Development Goals (SDGs),[11] with ramifications for poverty, hunger, environmental sustainability, economic growth, and life below water (Fig. 2). Fish Welfare Initiative believes that the SDGs can only be attained if fish welfare is included as a fundamental principle of aquaculture operations worldwide.

Figure 2. How fish welfare contributes to the UN Sustainable Development Goals (SDGs).

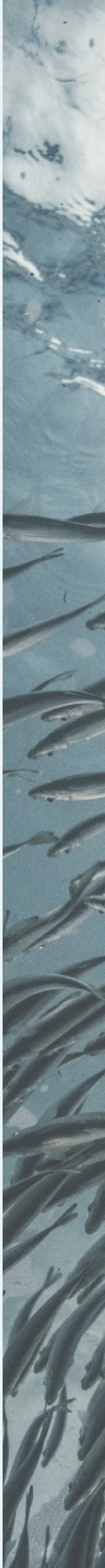
FISH WELFARE INITIATIVE'S DEFINITION OF WELFARE

The primary focus of Fish Welfare Initiative's work is addressing fish welfare in order to minimize the animal suffering associated with the way we rear and handle farmed fish. Therefore, Fish Welfare Initiative aims to use a definition of welfare that is practical, acceptable to most stakeholders, and takes into account the complexities of a fish's inner state - its individuality. The best available evidence (including the research of Victoria Braithwaite,[12] Lynne Sneddon,[13] Marco Cerqueira,[14] Jonathan Balcombe,[15] and Masanori Kohda,[16] alongside the review by Culum Brown[17] about fish intelligence, the Lisbon Treaty,[18] and the Cambridge declaration on consciousness[19]) converges in agreement on the fact that fish are sentient beings that can undergo both positive and negative experiences. That acknowledgement is necessary to increase their welfare and facilitate healthy development.

Taking all of the above into account, we define welfare as the freedom to adequately react to hunger and thirst, environmental challenges, pain, injury, disease, and mental challenges (such as fear and distress).[20] This allows fish to adapt and reach a state that they perceive as positive.[21] Ultimately, we believe that "animal welfare is the quality of life as perceived by the animal itself."[22]

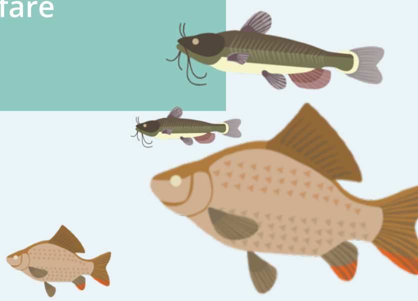
"ANIMAL WELFARE IS THE QUALITY OF LIFE AS PERCEIVED BY THE ANIMAL ITSELF."

Bracke et al. (1999)[22]



GOALS OF THIS REPORT

- **INFORM STAKEHOLDERS** about welfare issues across the farmed fish value chain.
- **INVESTIGATE BETTER PRACTICES** to be adopted by the sector through a commitment to fish welfare.
- **INFORM PRODUCERS, NGOS, GOVERNMENTS**, and other stake-holders about the disparity between the most advanced welfare practices available and common practice.
- **DISTINGUISH THE PROBLEMS TO BE ADDRESSED AND OPPORTUNITIES TO BE ASSESSED** in terms of fish welfare improvements, social welfare, and the environment.
- **PROMOTE TOOLS FOR BETTER** trained staff, better monitoring of fish environments, and better decision-making in the fish welfare sphere.



BROADLY SPEAKING,
FISH WELFARE INITIATIVE ENVISIONS

A GLOBAL PUSH TOWARDS SAFEGUARDING FISH, PLANET, AND PEOPLE.

SUMMARY

In recent years, fish welfare has been recognized as playing a crucial role in creating a more healthy, sustainable, and ethical world. Safeguarding fish welfare in global aquaculture helps preserve our oceans, buffer against disease risks, and improve the lives of billions of fish.[23] Therefore, the improvement of aquaculture management practices is a key element in making the current food system less damaging and more aligned with the UN's 2030 Development Goals.[24]

However, making welfare improvements on fish farms can be complicated, as fish welfare needs are often unintuitive. They vary depending on numerous factors, and it is often difficult to identify the precise welfare issues affecting fish. The aim of this report is to give stakeholders in a less damaging food system the tools for overcoming each of these obstacles, and thus start to make an actionable plan towards improving fish welfare.

1

Section One of the report identifies three conditions necessary for properly improving fish welfare in aquaculture: first, a **general understanding** of the welfare issues faced by fish in farms; second, **knowledge of the specifics** surrounding the fish species, farming system, and local context being targeted; and third, a **welfare assessment** of specifically targeted fish in the farm environment. We believe that all stakeholders in fish welfare should have access to knowledge of these conditions, and this report aims to provide information and applicable tools concerning each.

2

Section Two of the report focuses on the next step after obtaining the three conditions outlined above: making welfare improvements. This section outlines actionable welfare improvements available for different aquaculture systems, life stages, and stakeholders.

3

Section Three applies the information from previous sections to Fish Welfare Initiative's planned work for carp species (catla and rohu) in India. We outline contextual information on carp farming in India, assess welfare according to our farm visits and farm surveys, and review potential welfare improvements. From this analysis, we draw a preliminary conclusion as to which welfare improvements we should focus on to maximize our impact on fish, concluding that water quality is the most promising direction for our work.

Within India, our priority country used as a case study, traditional farming practices limit the farmers' ability to safeguard fish welfare, and there remains little information on the optimal conditions for the species they farm - Indian major carp. However, fairly affordable straightforward improvements to water quality can be made that drastically decrease the presence of stress responses in Indian major carp. This is not surprising, as poor water quality can impact fish for the entirety of their lives, leading to chronic stress.[25] Fish Welfare Initiative's preliminary conclusion is that water quality improvements seem to be the most promising direction for our operations (although they will likely need to be paired with training, better feeding management practices, or stocking density limits to safeguard benefits to fish welfare). The next step is to implement these water quality improvements on a small scale, where we will monitor how our improvements affect fish welfare outcomes.[26] This conclusion is based on the specifics of Fish Welfare Initiative's work, and so other stakeholders in fish welfare will need to apply their own context in order to properly address welfare for their targeted fish.

We hope that this report will help equip all stakeholders in fish welfare with the relevant knowledge to best address fish welfare in their context.

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CONTEXT

To satisfy the rising demand for fish worldwide, fish production is rapidly increasing.[27] Wild-caught fish production, however, reached a plateau in the late 1980s.[28] In 2018, for the first time ever, aquaculture overtook wild-caught production by tonnage.[29] As the global population continues to rise, people are becoming increasingly reliant on aquaculture production as a source of food. A somewhat controversial industry, aquaculture provides livelihoods and food security for many people, while at the same time raising concerns amongst the numerous stakeholders (Fig. 3). Issues such as the authenticity, quality, and traceability of seafood products, their sustainability, associated health outcomes, and the welfare conditions in which fishes are harvested continue to shape public and consumer opinion about aquaculture products. This has not, however, hindered aquaculture's current status as the fastest growing food production sector.[30]

As the institution of aquaculture becomes progressively more entrenched, the resulting increased competitiveness has prompted some industry leaders to employ drastic strategies, including intensification, in order to stay profitable.

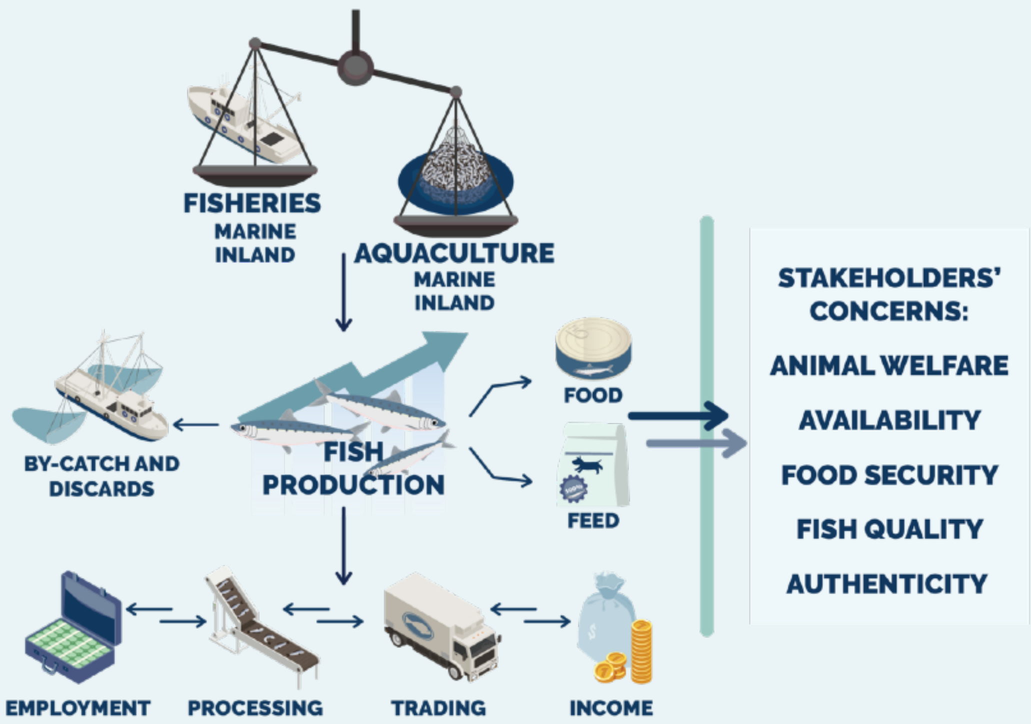


Figure 3. Conceptual representation of the fish production sector's impact on food supply: the pathway from production to food security (livelihoods, income, and employment) and nutrition (fish utilization); consumers' concerns (animal welfare, availability, food security, fish quality, and authenticity). Adapted from Magalhães, C. S. F. R., et al. 2018.

In 2015, the UN created the Sustainable Development Goals, which aim (among other things) to decrease malnutrition and increase sustainability in the food sector.[31] Fish welfare is commonly recognized as a requirement for mitigating the damage caused by the aquaculture industry's expansion. However, despite the increasing international interest in farmed fishes' welfare, few governments have shown interest in the issue. Even fewer have made significant investments in the safeguarding of fish welfare. Legislation still sometimes uses explicitly non-anthropocentric terms for animals, and often implies that fish well-being does not matter.[32] The practical implications of specifically considering welfare are likely to grow more important over time as the scientific methods of measuring fish welfare gradually improve.

> FISH RECEIVE **VERY LITTLE LEGAL PROTECTION,** ARE VERY **OFTEN FARMED IN POOR CONDITIONS,** AND ARE USUALLY **KILLED USING INHUMANE METHODS.** THESE ARE MAJOR WELFARE PROBLEMS FOR **TRILLIONS** OF FISH PRODUCED **EVERY YEAR.**

Despite the substantial scientific evidence that fish in captivity routinely suffer in various ways, guidelines for farmed fish production are still very basic, misunderstood, and often contradictory (as they may be more appropriate for terrestrially farmed animals). Fish suffer from poor water quality and management procedures (including during transport, feeding, and slaughter), low levels of environmental stimulation in barren environments, and a lack of opportunities to express their natural behavior.[33] Despite its substantial economic value, aquaculture regulation has been routinely neglected in the national legislation of many countries and, overall, only a few steps have been taken to develop criteria, methods, or practices to monitor and safeguard the welfare of cultured fish. This is particularly concerning as finfish production currently represents 67% of the fisheries industry's focus worldwide.[34]

Fish welfare in aquaculture is a global issue. Even in the European Union, where farmed fish welfare has become more of a priority, legislation still permits practices such as the selling of live fishes to untrained people, and cruel slaughter methods like asphyxiation or decapitation without prior stunning.[35] In most countries, food safety has primarily driven domestic regulations in aquaculture. However, the aquaculture industry's unregulated intensification has created issues beyond food security or environmental concerns. These include inconsistent regulatory practices, a lack of adequate aquaculture standards for small producers, the expense of certification for higher standards, and the difficulties of assessing welfare on farms. Each hurdle contributes to compromised fish welfare. Fig. 4 summarizes the main challenges to improving fish welfare.[36]

Non-governmental organizations (NGOs) and private certification bodies have played an important role in bettering aquaculture practices where governments fail.[37] Private certification bodies have become drivers for the early adoption of sustainable production practices.[38] This has led to a market-based governance movement to leverage supply chains, differentiate retailers, and solve the capacity gaps in public governance systems. However, many of these non-governmental groups have focused on organic production and environmental sustainability, not the fishes' species-specific welfare needs.[39] This means that welfare is often only a minor aspect of the advancements being made, and so the resulting welfare improvements are frequently circumstantial.[40]

For some farmed fish groups, such as salmon or trout, there is an established body of information that considers their welfare needs and proper production standards.[41] For others, like carp, catfish, and tilapia, a lack of accessible information has left the industry struggling to overcome significant fish welfare constraints such as widespread disease and parasite outbreaks, and high mortality rates.[42] The majority of production for these species with non-defined welfare parameters takes place in Asia, particularly in China. The support of prominent aquaculture researchers and producers in these regions is crucial to help solve farmed fish welfare issues, fulfill World Organisation for Animal Health guidelines, and match the progress that has been made for other fish groups like salmonids.

Globally, there is still an abundance of opportunities for improving fish welfare, as it is a young field with much research yet to be done. It is imperative that the relevant stakeholders in fish welfare be informed on how to conduct welfare improvements.

Figure 4. Challenges to improved fish welfare (illustrated by MSc Cláudia Raposo de Magalhães).

REFERENCES

1 World Organisation for Animal Health. (2019). Aquatic Animal Health Code.

2 For examples, see Brown, C. (2015). Fish Intelligence, Sentience, and Ethics; Cerqueira, M. et al. (2020). Cognitive appraisal in fish; and Sneddon L. et al. (2003). The evidence for pain in fish.

3 See references mentioned on our Why Fish Welfare webpage.

4 For a review about the impact of stocking densities on the welfare of farmed fish, see Baldwin, L. (2011). The effects of stocking density on fish welfare.

5 Peeler, E. J. & Murray, A. G. (2004). Disease interaction between farmed and wild fish populations, and Alves, M. T. & Taylor, N. (2020). Farmed fish pathogens risk to wild fish.

6 Van Weerd, J. H. & Komen, J. (1998). Effects of chronic stress on growth.

7 Wall, T. (2008) Disease and Medicines - the Welfare Implications.

8 Anders, N. et al. (2020). Effects of crowding stress on flesh quality.

9 For an example of "superbugs" in Chilean Salmon farms, see Miranda, C. D., Godoy, F. A., & Lee, M. R. (2018). Current Status of the Use of Antibiotics and the Antimicrobial Resistance in the Chilean Salmon Farms.

10 OneWelfare. (2020). About One Welfare.

11 Fish Welfare Initiative. (2020). Fish Welfare and the Sustainable Development Goals.

12 Braithwaite, V. (2010). Do fish feel pain?. OUP Oxford.

13 Sneddon, L. (2013). Do painful sensations and fear exist in fish?.

14 Cerqueira, M. et al. (2017). Cognitive appraisal in fish.

15 Balcombe, J. (2016). Cognitive evidence of fish sentience.

16 Kohda, M. (2018). Implications of consciousness and self-awareness in fish.

17 Brown, C. (2015). Fish intelligence, sentience and ethics.

18 European Commission. (n.d.). Animal welfare.

19 Low, P. (2012). The Cambridge Declaration of Consciousness.

20 We derive these criteria from the five freedoms model.

21 Cerqueira, M., & Billington, T. (2020). Defining Welfare For Fish.

22 Bracke, M. B. M., Spruijt, B. M., and Metz, J. H. M. (1999). Overall welfare reviewed. Part 3: Welfare assessment based on needs and supported by expert opinion.

23 For more information on the benefits of fish welfare, see our "Why Fish Welfare?" webpage.

24 United Nations. (2015). Sustainable Development Goals.

25 MacIntyre, C. (2008). The influence of water quality on farmed fish welfare.

26 Fish Welfare Initiative's 2021 focus is collaborating with livelihoods NGOs in order to implement improved welfare practices on the farms in which they work.

27 FAO. (2020). The State of World Fisheries and Aquaculture.

28 FAO. (2014). The State of World Fisheries and Aquaculture: Opportunities and Challenges.

29 FAO. (2020). The State of World Fisheries and Aquaculture.

30 FAO. (2018). The State of World Fisheries and Aquaculture 2018 Meeting the Sustainable Development Goals.

31 United Nations. (2015). Sustainable Development Goals.

32 Giménez-Candela, M., Saraiva, J. L., and Bauer, H. (2020). The legal protection of farmed fish in Europe.

33 A few reports summarize the different welfare issues in farmed fish production, some you can find here, here, here, and here. Certification schemes are adopting welfare guidelines, and reports have discussed the major issues related with fish welfare, for example see here.

34 FAO. (2020). The State of World Fisheries and Aquaculture.

35 Giménez-Candela, M., Saraiva, J. L., and Bauer, H. (2020). The legal protection of farmed fish in Europe.

36 These are a summary of the issues pointed out during our research concerning the topic of this report, from our visits in a few farms in India and from discussions with our stakeholders.

37 See more about the role of NGOs in fish welfare management here and here.

38 Amundsen, V. S. & Osmundsen, T. C. (2020). Becoming certified, becoming sustainable?.

39 Of the 5 main certifiers in Asia, 2 consider fish welfare, and most of this is either in early stages or only very lightly. See our report "Aquaculture in Asian Countries" for more information.

40 Learn more in the section Measuring Fish Welfare Needs below.

41 Noble, C. et al. (2018). Welfare Indicators for farmed Atlantic salmon: tools for assessing fish welare and Noble, C. et al. (2020). Welfare Indicators for farmed rainbow trout: tools for assessing fish welfare.

42 This was noted by the research made for the Global Aquaculture Alliance here: Rey, S., Little, D., & Ellis, M. (2019). Farmed fish welfare practices: salmon farming as a case study.

SECTION ONE

1. KNOWLEDGE BUILDING FOR FISH WELFARE

Securing the welfare of farmed fish is a difficult task. There is a broad range of species currently farmed, each with their own specificities and unique environmental requirements. To engage with this complexity, "a *modus operandi* that considers both the biodiversity of fish species and the peculiarity of each environmental context must be embraced."[43] In this report, we attempt to help systematize the assessment of fish welfare. This is informative for decision makers such as producers, advocates, and researchers who attempt to improve the conditions of fish kept in captivity. To our understanding and that of the scientific community, there are multiple conditions that must be met before welfare can be improved on each farm:

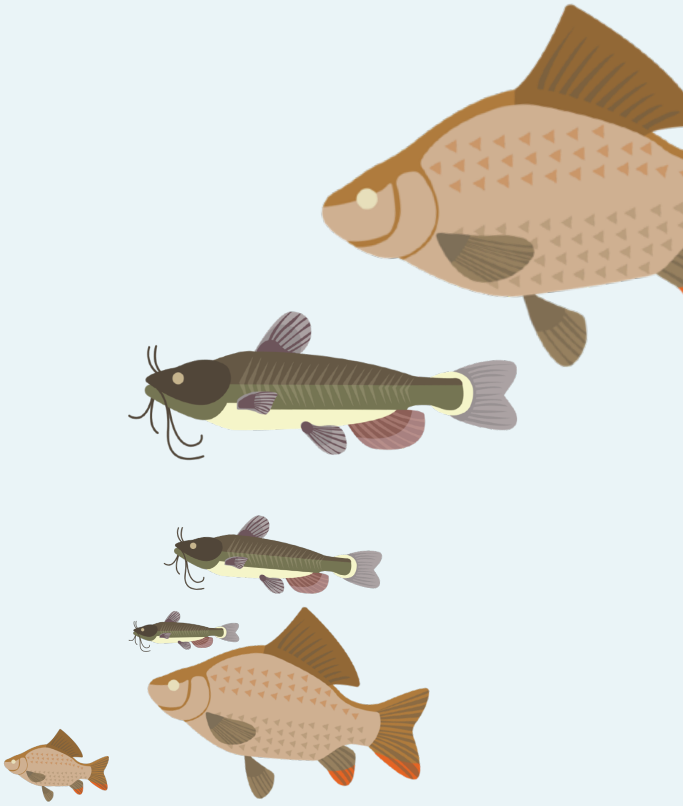
THE FIRST CONDITION is that there be an understanding of the potential welfare issues present on farms, and how these issues may impact the fish themselves. Fish farming is a complex operation, and many variables affect welfare. Therefore, a broad understanding of these issues is necessary in order to adequately prevent and treat them.

THE SECOND CONDITION is that farmers and advocates alike maintain a deep understanding of the specificities of the farm(s) under observation. Different species, culture systems, and life stages can each hold different requirements for the fish involved. For example, customized food pellets that sink quickly are appropriate for flatfish in recirculating aquaculture systems, but may be unsuitable for pelagic species cultured in net pens. Producers must consider the specifics of their farm when trying to introduce welfare improvements to their systems, and those who advocate for better welfare should be aware of how the differences in both systems and fishes may affect any attempted improvement's actual impact on fish welfare.

THE THIRD CONDITION is the provision of an accurate assessment of targeted individual fishes' welfare. This involves identifying which parameters are affecting the target fish's welfare, and to what extent, in order to pinpoint which issues to focus on. This condition can be hard to meet in some situations, such as when working on country-wide legislation, in which case the depth of the welfare assessment may need to be sacrificed for practicality.

Only when these three conditions are met can we move onto mitigating welfare issues within the aquaculture system. The first section of this report will focus on describing each condition and providing useful tools for meeting them.

1.1. CONDITION 1: UNDERSTANDING WELFARE ISSUES IN AQUACULTURE



1.1.1. Fish Welfare Infringements During Rearing

The first condition that stakeholders must meet before they can address welfare issues is that they maintain a broad understanding of common potential welfare issues. This is important because it ensures the contextual knowledge necessary for identifying and assessing detriments to the fishes' welfare. Often, the welfare issues that fish face are not intuitive to us, as they live in an environment that is both vastly different to ours and much more difficult to observe with the naked eye. In Table 1, we outline and briefly describe some of the main categories of welfare infringements that fish experience in aquaculture.[44]

Table 1. Summary of the main welfare constraints in aquaculture.

FEEDING AND NUTRITION	Correctly supplying the right amount of feed to farmed fishes is integral to safeguarding their survival and welfare. Feed content must be adequate for both the species and current life stage of the reared fish. Underfed fish are stressed and less resilient to infectious diseases.[45] Underfeeding might compromise swimming performance, prompt abnormal and aggressive behaviors, or even increase the rate of deformities, all of which negatively impact welfare.[46] Overfeeding, however, can also decrease welfare. High levels of feces and uneaten feed can result in poor water quality, which then decreases fishes' immunocompetence.[47] Proper management of feed needs to take into account species-specific behavioral requirements that do not restrict access to food.

WATER QUALITY AND FLOW

Fish are constantly in contact with their environment through their gills and skin. Therefore, water quality, water flow, and exchange rates are considered some of the most important factors affecting fish welfare.[48] Poor water quality is detrimental to both the ecosystem and to fish health, causing slower growth and higher mortality rates.[49]

The most important water quality parameters include temperature, suspended solids, dissolved oxygen, carbon dioxide, ammonia, nitrite, nitrate, pH, water flow, duration and intensity of light, noise, and vibration, all of which should be monitored regularly. This is a complex task, as optimal levels vary by species. Additionally, though any one factor may be safe at one time, it can become unsafe as other conditions change. Water quality and its variation over time is often a key factor that determines the welfare of fish in different rearing systems and practices.[50]

Other factors important to promoting good water quality include pond size and shape, the substrate of ponds, and environmental pollutants. Farm systems such as ponds, raceways, tanks, and pens are simple in design and tend to provide fairly uniform conditions throughout if properly sited to ensure optimal water flow.[51] However, it is questionable whether these systems allow sufficient variation suited to different fish species' needs and preferences. These factors often vary according to fish life stages.

STOCKING DENSITY AND CONFINEMENT

Defining and measuring stocking densities is more complex for fish than for land animals, as fish move in three-dimensional environments. However, stocking density commonly refers to the fish's weight per unit volume (as opposed to area).

Stocking density substantially affects fish welfare and is, hypothetically, the easiest variable for fish farmers to control and improve. Stocking density influences fish health and welfare at all life cycle stages, and it interacts with other aspects of fish welfare such as water quality.[52] Due to the wide variety of fishes raised in different aquaculture systems, optimal stocking density depends very much on their species-specific needs. An unsuitably high stocking density can impose significant welfare risks, including water quality deterioration, higher rates of injuries, increased aggression, changes in behavioral patterns such as reducing feed intake, and a greater susceptibility to infectious disease.[53] Species' space requirements depend on their life stage. For some fish groups, like salmon, maximum stocking densities have been set by assurance standards, industry codes of practice, and legislation, but these restrictions are infrequently enforced.[54]

Overcrowding and confinement during handling for management purposes such as transport or vaccination might be particularly stressful for non-social species. Such constraints should be imposed for the minimum feasible time.

HANDLING PRACTICES

During farming, there are a plethora of routine management procedures and practices that can inflict injury and distress. Sorting, size grading, vaccination, parasite monitoring, weighing, harvesting, and transferring fish are among those most potentially harmful. However, handling practices also hold the potential to ensure better welfare conditions for fish. For example, size grading, which may be carried out 3-5 times during rearing, is an important management tool that enables the detection of diseased or injured fish and prevents the development of aggression and cannibalism.[55] This practice can ensure correct stocking density through the separation of individuals according to their size, sex, or stage of maturity. Regardless, the physical damage (e.g., scale loss and abrasions) that grading systems can cause, as well as the amount of time that fish go unfed while being handled, remains a welfare infringement.

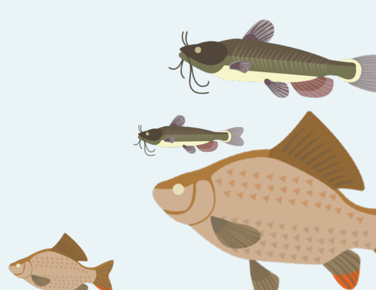
The foremost concern of correct management techniques should be to avoid any unnecessary handling of fish and, consequently, the related negative welfare outcomes, including poorer biosecurity,[56] health problems, external injuries, and the degradation of environmental conditions.

PARASITES AND DISEASES

Farmed finfish are vulnerable to a range of infectious and non-infectious diseases as determined by the features of the environment they live in. The impact of parasites and pathogens on fish health and welfare is determined by their abundance in the culture system. As aquaculture intensifies, it becomes increasingly important to maintain control and oversight of the fish's immunological health.

The impact of infections can be measured using a range of behavioral and physiological indicators. Fishes' continuous exposure to health-threatening situations such as poor water quality or nutritional imbalances increases their susceptibility to diseases, as stress compromises the immune system.[57] In instances where disease occurs, procedures for neutralizing the disease risk must be followed. Afflicted fish must be promptly and appropriately treated.

Many of the most prominent infectious finfish diseases can be controlled by vaccination. However, some diseases lack current treatments. Still others require treatments that are aversive, have significant side effects, or are limited in their use by environmental standards. Parallel to good terrestrial farming practices, all aquaculture facilities should be registered with a suitably experienced veterinarian and have a veterinary health plan covering major preventive procedures such as vaccinations.



BREEDING AND GENETIC SELECTION & ENGINEERING

Farmed fish undergo selective breeding and genetic manipulation to enhance favorable traits such as rapid growth rates, disease resistance, and improved harvest quality.[58] However, manipulating the animal's genetics often results in individuals with greater welfare constraints, so that more stringent standards, management, and nutrition are needed to achieve a level of welfare equivalent to that of wild species.

Animals genetically selected for high production efficiency seem to be more at risk for behavioral, physiological, immunological, and reproductive problems, e.g., having difficulties breathing and feeding, abnormal development, a lowered ability to cope with stress, and increased mortality.[59, 60] Factors affecting welfare include the incorrect timing of breeding and egg production, improper environmental conditions, and inbreeding, which increases the risk of development disorders and deformities in young fishes.[61] Artificial genetic selection by the aquaculture industry could confer genetic resistance to disease. This would be beneficial for individual fish, but could also enable farmers to intensify cultured systems beyond levels that allow for adequate welfare.

Escapees from fish farms are highly problematic for the aquaculture sector (especially as it continues to grow). A transgene introduced into a natural population by a small number of escaped transgenic fish may result in an enhanced mating advantage, but also reduce the viability of offspring.[62] This can eventually cause local extinction of both wild and farmed populations.

Artificial breeding can be stressful for fish and highly complex, containing multiple risk factors that are neglected by both industry and researchers.

SOCIAL STRESS - BEHAVIORAL LIMITATIONS

Under farming conditions, fish are often unable to express their natural behaviors. For instance, tilapia, a nesting species, are generally unable to form nests when raised in barren aquaculture tanks or ponds. Many fish species are naturally territorial and function in social hierarchies, which may not mesh well with the confined environments of aquaculture. Less dominant fish are often unable to escape from more dominant fish, resulting in increased aggression, injury, and stress.[63] Aggression can also lead to subordinate fish having limited access to feed, territories, and breeding opportunities.[64]

Highly standardized culture conditions can impede exploratory behavior and motivate frustration, boredom, and discomfort, which leads to abnormal or steroptic behaviors. Confinement drives fish to adjust their swimming behavior to the culture system's features, which can affect fishes' development, survival, and reproduction.[65]

It is still unclear as to what extent not being able to express natural behaviors is detrimental to the welfare of different species, but research has increasingly suggested that "positive welfare" opportunities are critical for fish to surpass behavioral restrictions and improve their lives in captivity.[66, 67]

PREDATORS

Finfish in farm pond environments and sea pens are particularly vulnerable to predation. Huge numbers of fish in one place attract wildlife such as fish-eating birds, seals, mink, and otters. Otters in freshwater systems and seabirds and seals in sea pens can have a devastating impact on fish welfare, causing fear, stress, trauma, and death.[68] In addition to these obvious effects of predation, the stress induced by the presence of birds or mammals in marine aquaculture can manifest in behavioral changes and a reduction in feeding.

Protection from predators can help to safeguard animal welfare and farm productivity. However, regard should also be given to the welfare of the predatory animals themselves. Some farmers may view the killing of wild animals as a legitimate part of predator control,[69] but the welfare of both fish and predator are of public concern.[70] Non-lethal control methods for predators include predator netting both above and under the water, visual devices (e.g., decoys and flares), and mesh nets. In some situations, lethal control is used to manage conflict. However, the shooting of predators is controversial and relatively ineffective. In many countries, these animals are themselves protected by law. The best way to protect fish from predators is through physical separation.

TRANSPORT

Transportation is as taxing for fish as for any other animal. It involves starvation prior to and during transport, physical handling, crowding, netting or pumping, and keeping fish in an artificial, ill-suited environment. A modified environment is inevitable during transport, but it is difficult to observe the fish and their conditions when they are underwater and overcrowded.

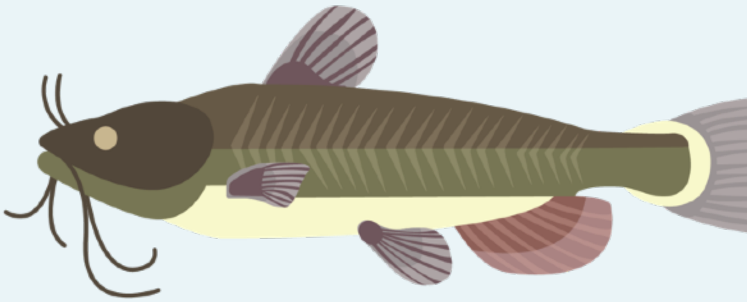
The main goal of transportation management should be to provide a safe environment for the fish and to minimize unnecessary stress and discomfort before, during, and after transport.[71] During transport, the principal concern should be the maintenance of satisfactory water quality appropriate for the species being transported. Deterioration of water quality is the most significant animal welfare issue present in the transportation of live fish, especially the depletion of oxygen and accumulation of carbon dioxide and ammonia.[72]

There are a variety of methods to safely transport fish. Chapter 7.2 of the OIE Aquatic Animal Health Code describes the general principles for ensuring the welfare of farmed finfish during transport by air, sea, or land.[73] The document covers the responsibilities of competent authorities (i.e., governments), farmers, and transporters to ensure suitable transport methods for the fish's species and life stage.

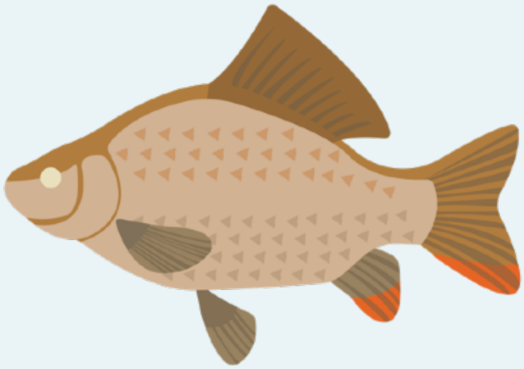
SLAUGHTER

The act of killing fish is often needlessly painful and stress inducing. Adherence to traditional slaughter techniques is still a reality in many farms and processing facilities.[74] The slaughter process includes a series of stressful operations before the actual killing, including fasting periods, crowding, removal and handling procedures, and transport to the place of slaughter (often processing facilities). These procedures are highly stressful if performed improperly, and "bruising, crushing, puncture and abrasion injuries from contact with other fishes, contact with the net and contact through the net with other hard surfaces" can occur.[75] Asphyxiation, another traditional slaughter process, is extremely harmful to fish.

Fishes are commercially killed in many ways, some of which may include prior stunning.[76] Despite the available knowledge regarding the least harmful methods of slaughtering fish, there is little evidence of improved slaughter methods on most of the fish farms around the world.[77]



Welfare issues often aggravate each other, causing even greater harm to the animals. For instance, fish subjected to unnaturally high stocking densities are more prone to reduced water quality and increased disease rates. Rough handling procedures are likely to remove part of the fishes' protective mucus layers, increasing their vulnerability to wounds, infections, and parasites. Thus, improvements to one aquaculture practice can have meaningful effects on other aspects of fish life. However, properly conducting these improvements requires knowledge of both the species-specific welfare needs according to the fish's life stage and the limitations of the farming systems in which fish are being cultured.




IMPROVEMENTS TO ONE AQUACULTURE PRACTICE CAN HAVE MEANINGFUL EFFECTS ON OTHER ASPECTS OF FISH LIFE.

1.1.2. Fish Welfare Needs During Rearing

There are approximately 30,000 fish species around the globe with a history of evolutionary success.[78] The natural behaviors of each of these species diverge based on their needs, coping abilities, and motivations. This variety complicates the process of making broad claims about specific fish welfare requirements. However, the predominantly farmed fish species share many general welfare needs. This section considers those broader requirements.

Like any other animal, fish must have access to numerous resources to guarantee their biological and physiological wellbeing. Fish also require challenges to help them learn and adapt to changing environments. Providing the right kind of environmental and cognitive stimulation alongside optimal environmental conditions appears to be key to reducing stress in farming contexts.[79] These conditions increase fishes' capacity to cope with the presence of threats and opportunities in their environment, influencing their biological success in terms of health and survival.

In fish farms, many situations associated with stress do not cause obvious physical harm. Inescapable, unpredictable, or chronic stressors lead to a loss of control, increased frustration, and allostatic overload. This can result in behavioral abnormalities leading to displaced aggression and stereotypical behavior.[80] Thus, it is necessary to know what a fish needs in order to safeguard their welfare.

WELFARE NEEDS ARE REQUIREMENTS THAT HAVE A NEGATIVE IMPACT ON WELL-BEING IF THEY ARE NOT MET OR ARE LESS FULLY MET, AND A POSITIVE ONE IF THEY ARE MET OR ARE MORE FULLY MET.[81]

Fish welfare needs can be classified as either ultimate or proximate.[82] Ultimate (i.e., adaptive) needs are those that are necessary for a fish's immediate survival.

These needs include, but are not limited to:

- respiration
- nutrition
- thermoregulation
- maintenance of osmotic balance
- body integrity

Proximate needs are those that improve a fish's ability to succeed in the long term.

Examples of proximate or behavioral needs are:

- behaviors that improve body control and strength (such as the ability to swim against the current or engage in reproductive behavior)
- exploratory behaviors that improve the chances of finding food or shelter
- social behaviors that increase the success of detecting or avoiding predators

For some species in European aquaculture, a reasonable amount of data on basic biological requirements is available. For instance, there is already a wealth of information available on the welfare requirements of Atlantic salmon (Fig. 5). These requirements are based on the five freedom domains, encompassing biological, environmental, health, and behavioral needs, which ultimately affect the psychological condition of the individual. These needs are specific to different life stages, culture systems, routines, and procedures, meaning that any assessments should be done case by case. Each species has different specificities, wherein some parameters may be more important than others. This information is essential in order to guarantee the safeguarding of the cultured species, as exemplified in Condition 2 below.

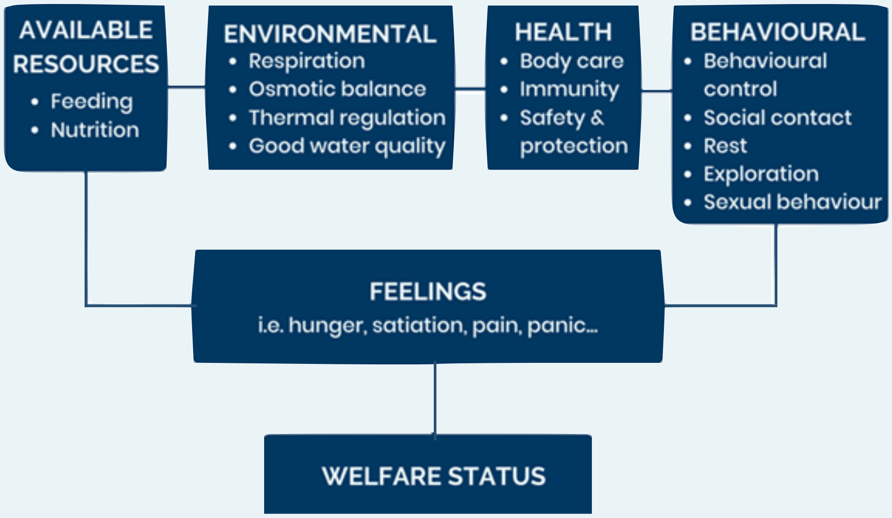


Figure 5. Broad overview of Atlantic salmon's environmental, health, behavioral, and available resources (A:R.) welfare needs (adapted from Noble et al., 2018).

Unfortunately, in comparison to salmon or trout, little information is available on the welfare needs of most of the top-produced farmed groups, including carp, catfish, and tilapia. This issue was raised by Rey et al.[83] in their research commissioned by Global Aquaculture Alliance. Within the scope of farmed fish welfare practices, it was noted that research pertaining to welfare indicators for both tilapia and catfish is almost non-existent. As an example, search results for the terms "parasites & disease & welfare" show a total of 74 citations for Salmon, 4 for catfish, and 3 for tilapia.

As illustrated in Fig. 6 below, the successful management of fish welfare is challenging, as numerous factors affect fish species differently. Furthermore, welfare needs also depend on whether fish are farmed under closed, re-circulated, or open water systems, and whether those systems are intensive or extensive. Additionally, many routine farming practices present a high risk of imposing stress, injury, and suffering on the individual fish. Fish in different life stages have different nutritional requisites in terms of protein and carbohydrates,[84] which can compromise health and welfare if not adapted to the stage of development. Therefore, to improve welfare on farms, there must be an assessment of the fishes' welfare conditions (Condition 3), and then farmers must be trained in improving the fish species' welfare according to the farming system, life stage, and routine practices at the farm (Condition 2).

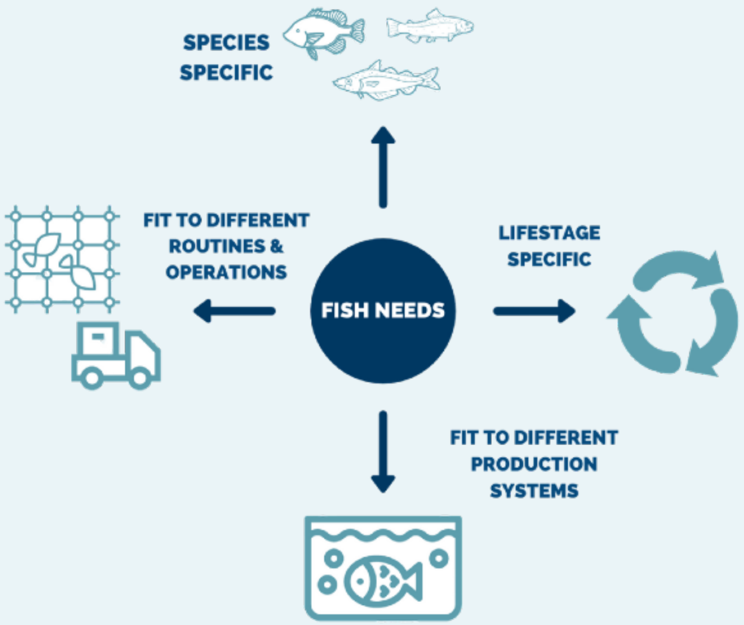


Figure 6. Overview of the different aquaculture-related factors affecting the welfare needs of fish, i.e., the fish specificities, the kind of farming systems, the life stages, and routine and operational procedures.

1.2. CONDITION 2: UNDERSTANDING THE SPECIFICS

The second condition necessary for stakeholders to address welfare issues is that they maintain a detailed understanding of the specifics surrounding the situation they aim to improve. The welfare needs of fish are not static, but are instead altered by many different factors, such as the fish's species and life stage, and the culture system used. Producers must adjust to the specifics of their fish. It is also important that decision-makers and NGOs who advocate for better fish welfare understand how differences between farms may affect the impact they have on fish lives.

1.2.1. Welfare Differences Between Species

In this section, we detail the specific welfare needs of two different species to provide an example of the subtle differences between fish (Table 2).

Table 2. The welfare needs of milkfish (Chanos chanos) and Atlantic salmon (Salmo salar).[85]

<table>
<tr><th>INDICATORS</th><th>MILKFISH (CHANOS CHANOS) NEEDS</th><th>ATLANTIC SALMON (SALMO SALAR) NEEDS</th></tr>
<tr><td>Temperature</td><td>28-29ºC may be optimal. Below 22.6 ºC affects performance. Above 32ºC affects growth</td><td>4-19ºC</td></tr>
<tr><td>Salinity</td><td>25 ppt is optimal. 29-34 ppt improves embryo development</td><td>Euryhaline: From egg to parr are freshwater tolerant; smolt in seawater</td></tr>
<tr><td>DO</td><td>Highly tolerant, but below 6.91 mg/L promotes myxozoans infestation in gills</td><td>>7 mg/L (research needed)</td></tr>
<tr><td>pH</td><td>7.5-8.5</td><td>6-8-7.9 (research needed)</td></tr>
<tr><td>Turbidity</td><td>0.5 m</td><td>N/A</td></tr>
<tr><td>Ammonia</td><td>Highly tolerant (20-21 ppm is toxic) but optimal <1 ppm</td><td>N/A</td></tr>
<tr><td>Nitrite</td><td>Freshwater <12 ppm; brackishwater <675 ppm</td><td>N/A</td></tr>
<tr><td>Depth</td><td>0-30 m. >1 meter for best performance.</td><td>N/A</td></tr>
<tr><td>Photoperiod</td><td>12L:12D is best.</td><td>Diurnal, occasionally nocturnal (smolt migrate at night to avoid predators)</td></tr>
<tr><td>Feeding score</td><td>Trophic level: 2.4. Herbivore/detritivore. Daytime feeder</td><td>Trophic level: 4.5. Herbivore/detritivore. Daytime feeder</td></tr>
<tr><td>Feeding style</td><td>Opportunistic generalists, substratum feeders but in captivity they feed from the surface, column and bottom</td><td>Carnivorous</td></tr>
<tr><td>Feeding frequency</td><td>Frequent feeding over a wider spread of time; Fry: 2-3 times a day, 3.5-5% feed rate. Fingerling: 3-4 times, 3-3.75% feed rate. Adult: 3-4 times a day, 2.5-3.25% feed rate. Brood stock: 3-4 times a day, 2-2.75% feed rate</td><td>Unpredictable schedules increase fin erosion. Predictable schedules increase aggression. The frequency of feeding is dependent on the water temperature and body size: 3–4 times a day for fingerlings and parr. above 20 g body mass and under standard environmental temperature conditions, a feeding frequency of twice a day to apparent satiation is sufficient for the species requirements</td></tr>
<tr><td>Particle size</td><td>Fingerling: 1.5-2 mm. For Growers at 20-100 g: 2.2-2.3 mm, at 101-400 g: 2.5-3.2 mm, and at >400: 2.8-4.0 mm</td><td>N/A</td></tr>
<tr><td>Feed delivery</td><td>Dispersed</td><td>Dispersed</td></tr>
<tr><td>Feeding content</td><td>Crude protein: adults = 25-40%; Juveniles: 30,6
Crude lipids: adults = 7-10%; juveniles: 8,8; fry: 9%
Energy: 10.4 -14.7Kj/g; juveniles:
Carbohydrates: adults = 25%</td><td><table>
<tr><td>Fry</td><td>Fingerling</td><td>Juvenile</td><td>Grower</td><td>Marine grower</td><td>Broodstock</td></tr>
<tr><td>50</td><td>45-50</td><td>45</td><td>42-45</td><td>40-45</td><td>45</td></tr>
<tr><td>16-18</td><td>20</td><td>20</td><td>20-24</td><td>24-30</td><td>24</td></tr>
<tr><td>19</td><td>19</td><td>19</td><td>20</td><td>20</td><td>19</td></tr>
<tr><td>10</td><td>10</td><td>12</td><td>12</td><td>12</td><td>12</td></tr>
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Stocking density	Holding capacity of intensive pond set below 5107 kg/ha. Mainly monoculture: 100-500,000 fry/ha. Larvae at first feeding is about 2–3 larvae/l. Grow-out systems: 1500 and 3000 ind/ha for extensive systems; 8000–30.000 ind/ha semi-intensive systems; intensive systems 20 to 60 ind/m3 for (smaller) marine coastal cages, up to 100 ind/m3 in large offshore cage.	In rivers, low density (<0.1 parr/m2). For better welfare, keep at <22 kg/m3, preferably even <10 kg/m3.
Transport	Broodstock should not be fed 2 days before transport/kept at 20-22ºC with 0.2L-1 of 2-phenoxyethanol. Change 50% of the water if transport is over 7h. 22 ppt salinity allows milkfish to recover faster. Eggs and fingerlings should not be transported for more than 12h. Should be transported in bags. Temperature should be maintained lower than 25ºC. Salinity of 5 ppt for freshwater/25 ppt for salt water.	Avoid confinement; more research needed; Follow OIE recommendations; no ethology-based recommendation definable so far.
Slaughter	No available stunning parameters or best method described. Follow OIE recommendations.	Preference percussive stunning and bleed immediately before conscious

LISTING THE SPECIFIC NEEDS FOR ALL SPECIES IS BEYOND THE SCOPE OF THIS REPORT, THOUGH IT IS AN INTEGRAL PART OF UNDERSTANDING HOW TO BEST IMPROVE FISH WELFARE IN A GIVEN SITUATION.

A welfare assessment of farmed fishes is publicly available at the FishEthoBase.[86] This database provides updated information on the welfare requirements of 45 cultured species, and intends to describe all fish species currently farmed. The database is aimed at stakeholders interested in comparing and safeguarding various commonly farmed aquatic species, and provides scientific recommendations to improve their welfare.

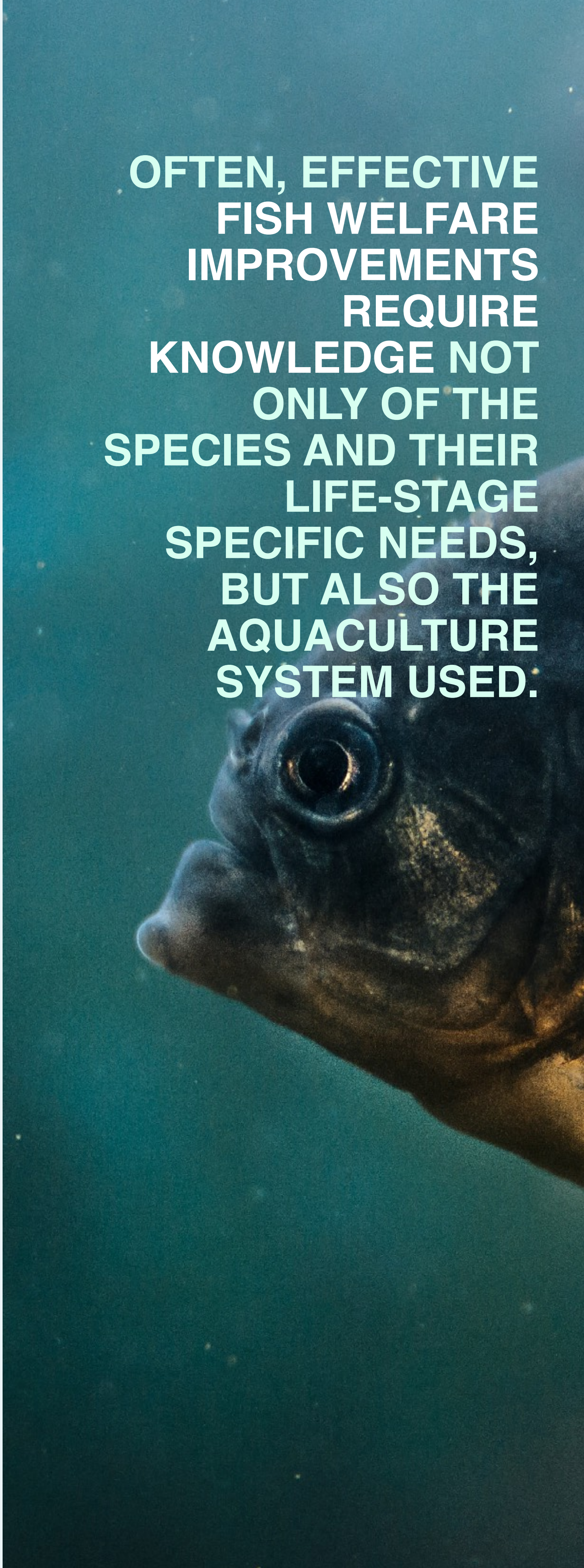
A critical analysis of the FishEthoBase was published[87] that presented some insights into species-specific welfare research, namely:

- Welfare conditions for farmed fishes are typically inadequate.
- There is a need for improved research into species-specific welfare requirements.
- There are many remaining knowledge gaps in aquaculture-related welfare, including proper and sustainable feeds, slaughter methods including suitable stunning parameters, disease and parasite prophylaxis, stocking densities specific to the farming systems and life stages, and optimal water parameters, among others.
- Current fish farming technologies do not seem to fully address welfare issues.

1.2.2. Welfare Issues in Different Farming Systems

Fish farmers use a broad range of farming systems, all with different inputs, technology, outputs, and common management practices (see Fig. 7 for details):[88]

- **RICE FIELDS**, where fish are raised in the flooded paddy as a supplementary crop. This farming system is predominantly developed in seasonally flooded deltas in Asia.
- **AQUACULTURE PONDS** are natural or artificial impoundments that form closed water bodies, primarily used for freshwater (rain-fed, irrigated, flow-through) or brackish water aquaculture.
- **RACEWAYS OR TANKS** are artificially constructed units, often with concrete sides and bottom, that use either running water or water flow systems.
- **CAGES OR NET PENS** are mostly floating or suspended enclosures located in natural aquatic systems such as lakes, rivers, and oceans. They can also be found in artificial water bodies.
- **RECIRCULATING AQUACULTURE SYSTEMS** (RASs) are typically land-based. Fish are contained in tanks or raceways with treated and recirculated water. The use of RASs is largely restricted to more high-value species or life stages (especially in hatcheries, where control over environmental conditions is critical and the unit values per individual fish are higher).



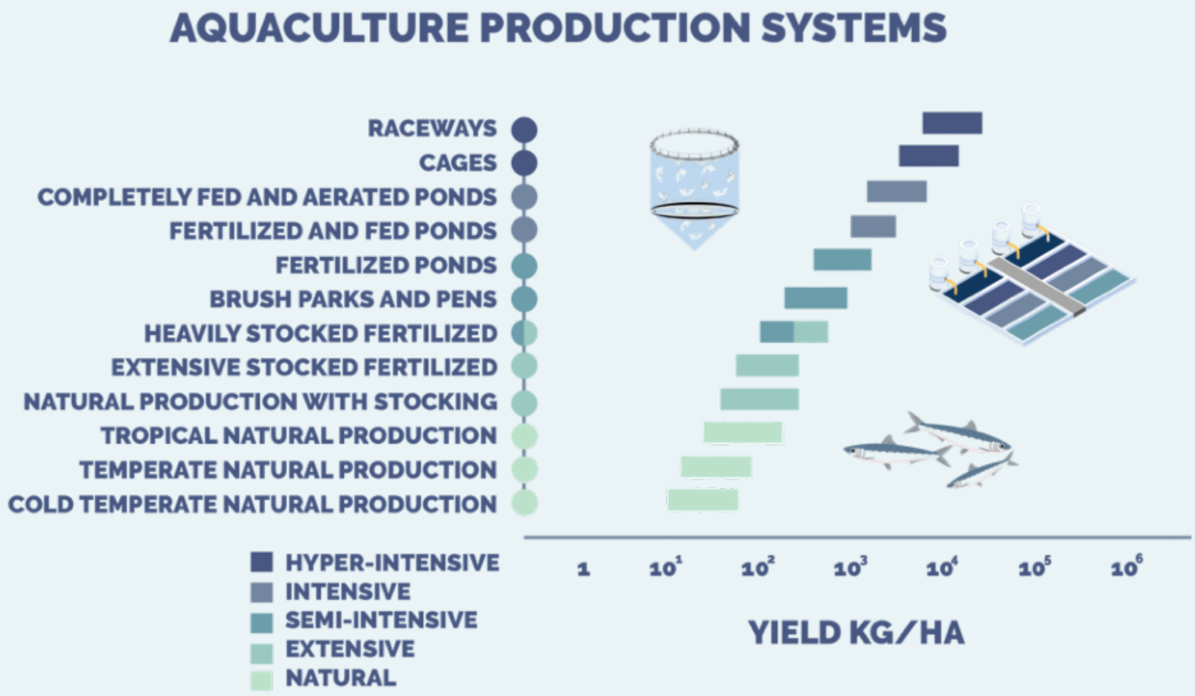


Figure 7: Fish production per hectare according to different aquaculture systems (Source: Information from Ottinger et al., 2016, illustrated by Fish Welfare Initiative).

The choice of culture system is influenced by both the farmer's objectives and by the circumstances and conditions available.

The final decision in any producer's choice of culture site is influenced by the culture sites available, infrastructure, environmental conditions (especially climate), socio-economic factors, technological knowledge, and market potential.

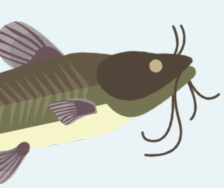
Often, effective fish welfare improvements require knowledge not only of the species and their life-stage specific needs, but also of the aquaculture system used. Each farming system creates unique welfare-related issues for the fish. We give a broad overview of these constraints for each aforementioned farming system in Table 3.[8]

Table 3. Aquaculture farming systems, their welfare-related issues, and possible mitigation procedures to improve the fitness of the system and the welfare of the cultured fish.

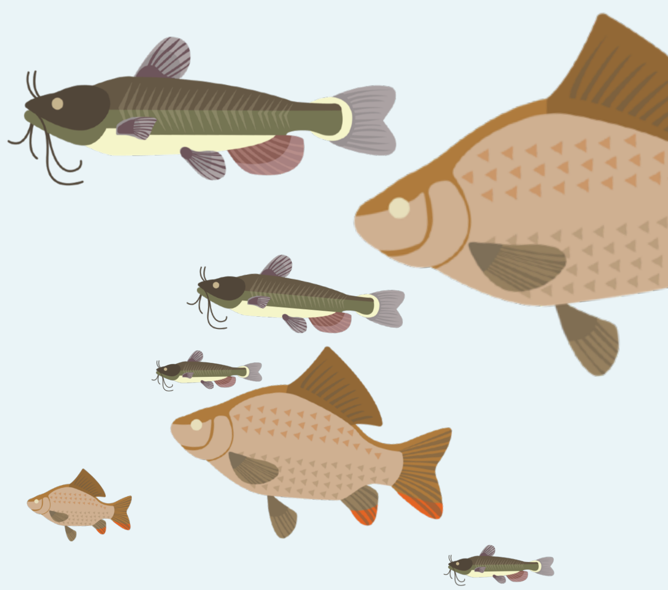
SYSTEM	WELFARE RELATED ISSUES
RICE PONDS	• The water supply to rice ponds is natural, and thus erratic. In dry seasons, low water levels may suppress normal fish behaviors. Conversely, high water levels may lead to fish escaping in field floods. Floods can also lead to fish entering nearby lakes or rivers, spreading diseases to the natural environment. Flood control is very difficult in this farming system. • The natural water source of rice ponds also means that there is high volatility in the water's quality. • Rice ponds have shallow water depths, meaning that fish are greatly affected by weather conditions (such as solar radiation, wind velocity, and temperature). • Pesticides and herbicides used for the plants can poison fish, leading to chronic stress and mortality. • Fish are exposed to predation and poaching.
PONDS	• Drugs like antibiotics can accumulate in the sediment, leading to increased bacterial resistance. This immunity can impact both the farmed fishes' welfare and that of the surrounding wild species. • Fish are often exposed to predation. • Improper stocking densities increase the prevalence of fin and tail injuries, disease outbreaks, cataracts, and deformities, as well as restrict normal behaviors. This can lead to high mortality rates. • Interactions with wild fish can occur when fish from natural water sources (more commonly larvae or juveniles) are pumped into the tank (within semi-intensive systems), ushered in by higher tides (within extensive systems), or enter due to problems with the gates that regulate the tank water level. This can lead to disease and parasite transfer. It can also lead to the dilution of wild population genetics. • Ponds are highly dependent on natural environmental conditions, where temperatures and dissolved oxygen content can be erratic. • Overfeeding or food waste impacts the sediment and fauna near the pond, increasing the organic matter and the primary productivity, and promoting oligotrophic conditions.[90] Accumulation of nitrogen-based waste due to fecal matter and uneaten feed can pollute the water, harming the farmed fish. • It is difficult to treat fish in ponds when they show signs of disease. Veterinary drugs provided in the fish's feed can be lost through leaching.[91] Drugs administered directly into the water can become diluted and less effective. • The use of systems that are less reliant on technology means that routine procedures such as handling and sorting are likely more stressful and have a higher chance of physical injury. • Phytoplankton blooms can cause large diurnal fluctuations in water quality, such as high pH and NH_3 concentrations.

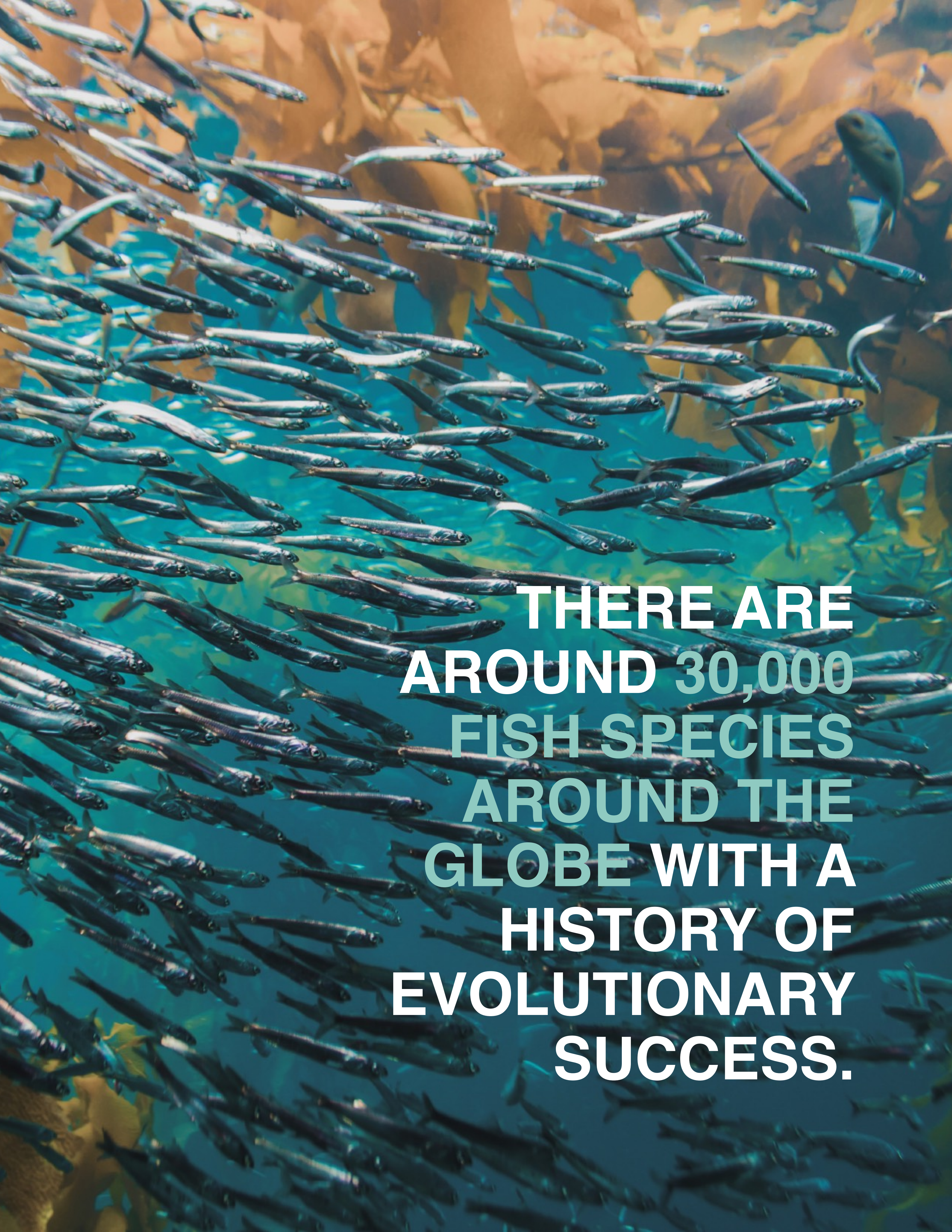
SEA CAGES	• Fish are kept in spaces much smaller than their territory or range in the wild. • The natural behaviors of bottom dwelling fish are restricted. • There is a high rate of encounters with predators attracted by the available food. • Stocking densities are often too high, which increases the prevalence of fin and tail injuries, disease outbreaks, cataracts, and deformities, as well as restricts behavior and leads to high rates of mortality. • There is little opportunity to improve water quality in fast-moving natural water streams. • It is difficult to administer veterinary drugs. Drugs administered by food incorporation can lose their effectiveness through both dilution and leaching. • Fish in sea cages often interact with wild fish populations, either due to escape or to wild fish being attracted to the sea cages. This damages wild populations by allowing farmed fish to mate with them, overwhelming gene pools with sub-optimal genetics for wild environments. It also promotes the spreading of diseases and parasites. • Food waste impacts the sediment and fauna around the cages, which creates negative welfare implications for wild fish. • The use of antifoulants/chemicals for nets and other submerged equipment can impact both fish welfare and the environment. • There are extra processes involved in sea cage maintenance that can lead to stress or physical damage for fish, e.g., cleaning or changing the nets.

FLOW-THROUGH SYSTEMS (TANKS, RACEWAYS)	• The quality of inflowing water may differ between seasons or days, and there are biosecurity issues associated with pathogens entering the system through the inflowing water. • Water flow exchange (volume of water in-water out) inappropriate for the target stocking density can lead to the accumulation of CO_2, a drop in pH levels, and increased metal toxicity. • Daily feeding, if not adjusted to the fish biomass within the tank, can deteriorate the water quality due to variations in the daily water parameters, allowing ammonia to accumulate. • Artificial oxygenation is often used to mitigate seasonal changes in water quality. Oxygen levels that are too low or too high can drive fish to respiratory alkalosis or acidosis, respectively.[92] During screening and transport, fluctuations in the water's oxygen levels are particularly likely to increase mortality. • Artificial hydrodynamics within the tank are affected by a few factors such as the water inlet, aeration, and fish biomass. This can undermine the tank's self-cleaning and oxygen availability. Unbalanced flow conditions (e.g., water velocity) can also impact swimming behavior, affecting osmotic balance and fish performance. • Accumulation of heavy metals in the water can increase toxicity and drop the pH levels. This, in turn, causes stress for fish and increases their susceptibility to some pathogens.



RASs: RE-CIRCULATING AQUA-CULTURE SYSTEMS (TANKS AND RACEWAYS)	• The system is limited to the feeding loads that it was designed for. As such, proper planning is required to ensure optimal production conditions, as well as to avoid health and welfare issues and/or unbalanced bacterial development in the biofilters. • RASs are highly reliant on technology, and any fault with the design or construction of the system can affect the water's physical-chemical properties and the welfare of the fish. • RASs use a biofilter to convert ammonia (which is toxic to most aquaculture species) into nitrate. Checking the biofilter capacity is crucial, as any disruption within the nitrification process can lead to an expanded concentration of possibly poisonous nitrogen compounds (ammonia and nitrites). • Despite more stable environmental conditions, the technological complexity of RASs can make it hard to address environmental issues. Thus, welfare issues can become chronic, inducing long-term exposure to stress and making fish more prone to health problems. • Unbalanced water exchange can promote the accumulation of heavy metals associated with high mortality rates. • Preventative biosecurity measures are needed, since veterinarians' products can compromise the stability of the biofilter. • Biosolids in RASs originate from fish feed, feces, and biofilms, and are one of the most important and difficult water quality parameters to control. • RASs use equipment such as aerators, air and water pumps, blowers, and filtration systems, all of which make noise that fish can hear. If left to become a chronic issue, this can affect their welfare as well as their behavior and physiology. • Mechanical failure of pumping systems and RAS equipment, power outages, hydrogen sulphite build-up and release, and operational accidents are all issues that can lead to sudden and catastrophic mortalities.





THERE ARE AROUND 30,000 FISH SPECIES AROUND THE GLOBE WITH A HISTORY OF EVOLUTIONARY SUCCESS.

1.2.3. Fish Life Stages, Value Chain, and Welfare Issues

Fish life stages are analogous between species, regardless of the farming system, and include both the hatching phase and the on-growing phase (Fig. 8).

In the **hatchery**, eggs collected from broodfish are raised in incubators. After hatching begins the **larval phase**, where fish remain in their incubators until they learn how to swim. The timeframe for learning to swim may differ between species. It can also vary within the same species (although it is usually around one week). After this period, the fish enter the **post-larval phase**, in which they are distributed to external hatcheries or intensive fingerling tanks. At this stage, fish run out of nutritional reserves and start to feed from external sources (plankton and microorganisms like benthos). When they reach the correct size, they are then moved to the second phase of breeding, **rearing**. In this stage, they become **juvenile fish** and are transferred to the grow-out farming systems, where they will remain until slaughter.

Welfare constraints exist throughout the value chain of any farmed fish species. The current focus on improving health and productivity outcomes has given researchers a broad understanding of the physiological needs of fish and, to some extent, the behavioral requirements for good fish welfare. However, more direct fish welfare research is essential

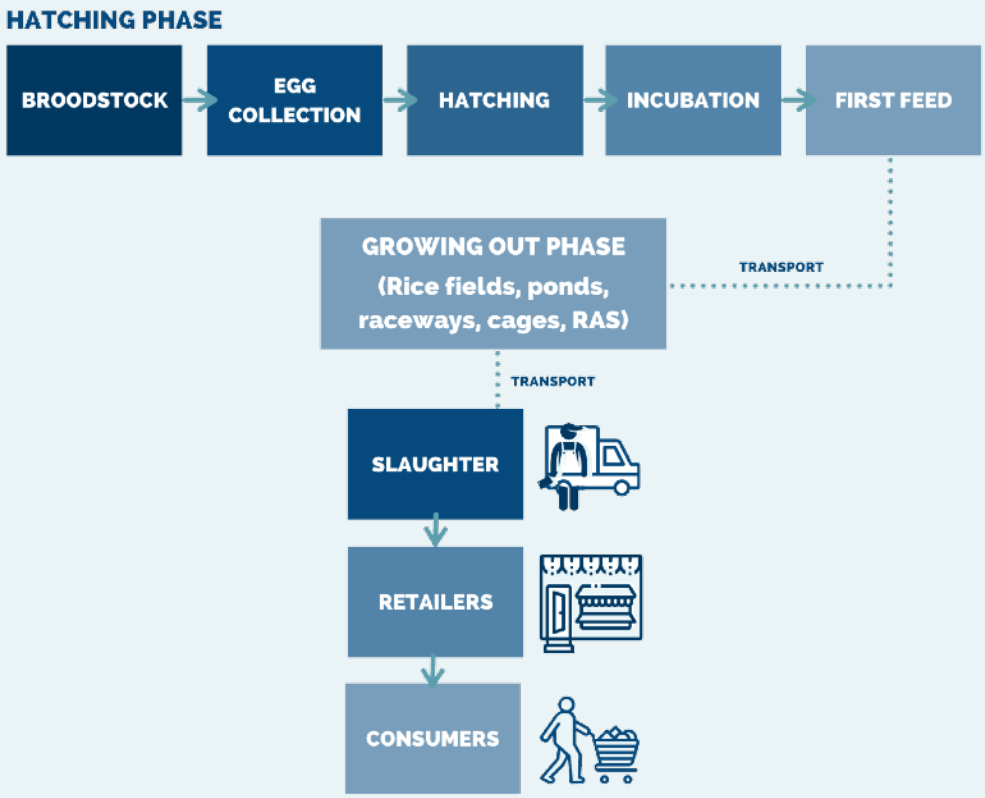


Figure 8. Broad and simplistic view of the life stages/value chain of farmed fish.

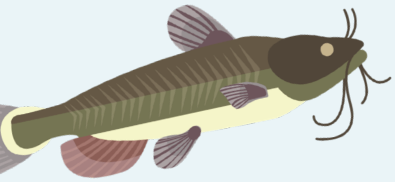
to identify the further improvements needed in each stage of the farmed fish value chain.[93] Such research will give producers the ability to provide fish with higher welfare, resulting in improved market access and reputation, as well as a price premium for niche markets.

Table 4 lists potential infringements to the welfare of cultured fish at each stage of the value chain.[94] Welfare issues are likely more numerous than those identified by current research, especially in the hatchery phase.

Table 4. Value chain stages of aquaculture, welfare-related constraints, and gaps that compromise the life of the cultured fish.[94]

VALUE CHAIN	WELFARE
BROOD-STOCK	• Poor management procedures for stripping and milking (and the egg collection of tilapia, which are mouth breeders), including improper anaesthetic concentrations and hormonal induction of spawning. • A lack of fish brood banks.[95] • Stress induced through selective breeding for growth, feed efficiency, health, and resilience (pushing these fish to their biological or physiological limit). • Unsuitable dietary content or lack of supplements to enhance egg quality. • Poor record-keeping and biosecurity. • Unsuitable slaughter methods. • A lack of environmental enrichment like shelters, gravel, etc.
HATCHERY	• A lack of adequate guidelines and protocols aimed at improving welfare. • Low immunity to diseases due to poor nutritional content in feeds and live food. • Poor feeding practices, including weaning procedures and fulfilling nutritional requirements. • Poor management practices, including stocking densities and handling (grading, and sorting) procedures. • Lack of behavioral, physiological, and molecular indicators for welfare. • Unbalanced Light : Dark hours cycle (L:D). • Unsuitable design of the aquaculture system and equipment (e.g., UV lights and filters). Poor maintenance and servicing of equipment. • A lack of environmental enrichment like shelters, gravel, background color, etc.

GROW-OUT	• Poor feeding practices, including a lack of feeds with incorporated plant-based ingredients and natural compounds to increase immunity to disease. • A lack of adequate guidelines and protocols aimed at improving welfare. • Poor water quality monitoring and management. • Poor management practices, including stocking densities, grading, and sorting procedures. • Poor biosecurity management with a lack of contingency plans. • A lack of prophylactic measures to control diseases, such as disinfestation and cleaning routines. • Few licensed anesthetics and pharmaceuticals. • A lack of environmental enrichment like shelter, pond bio-floating beds, etc. • Unbalanced stocking conditions for the species/culture system.
TRANSPORT	• Handling and crowding. • Transportation without suitable equipment to safeguard welfare (e.g., oxygenation and refrigeration equipment). • A lack of staff training for better welfare management and ability to recognize species-specific welfare indicators. • Poor implementation of OIE for transport standards. • The transport of live fish is not kept to an absolute minimum. • Unregulated use of anesthesia or sedation for transportation (e.g., clove oil for use as a stress reducer).
SLAUGHTER	• Poor implementation of OIE slaughter standards. • Poor pre-slaughter handling practices. • A lack of stunning and slaughter methods *in situ* that are species-specific. • A lack of established parameters required for effective stunning for each species (that are established in controlled lab conditions). • A lack of policy by external bodies, e.g., certification schemes. • Poor maintenance of stunning gears and monitoring procedures (e.g., checks to ensure that the electrical parameters are being properly delivered to each batch of fish). • A lack of coordination between research centers to improve stunning (e.g., setting up a standardized method to evaluate suitability of the method).
RETAILER	• A lack of plans to improve fish welfare (e.g., increasingly stringent fish welfare policies). • A lack of transparency of information (e.g., product labelling).
CONSUMER	• A lack of involvement in the process of instituting fish welfare requirements. • Poor awareness of fish welfare expectations. • Confusion surrounding product labelling and the perceived link between sustainability labelling and welfare standards. • A lack of demand for certified products and transparency.



1.3. CONDITION 3: WELFARE ASSESSMENT TOOLS

The third condition necessary for stakeholders to adequately address welfare issues is the assessment of the targeted fish's welfare. The first two conditions focus on important general and contextual knowledge. Here, we consider tools that allow the application of this general knowledge to the specific fish under consideration. Assessing welfare is important both to the identification of key welfare issues and as a step towards prioritizing these issues.

1.3.1. Measuring Fish Welfare Needs

Now that a broad consensus that fish can feel negative emotions such as pain, fear, and distress has been drawn, progressive producers should turn their attention towards how fish welfare can be measured. It is important that we develop and share tools to determine whether fishes are able to meet the demands of their environment, and whether those environments allow fishes to express their specific natural behaviors. To measure fish welfare, however, can be a complex undertaking.

"NO SINGLE MEASUREMENT SHOULD BE USED TO ASSESS FARMED FISH WELFARE. INSTEAD, DIFFERENT PROMISING INDICATORS SHOULD BE USED TO PROVIDE A MORE HOLISTIC ESTIMATE OF FARMED FISH WELFARE."

-ANIMAL CHARITY EVALUATORS[96]

As we cannot completely understand fishes' experiences or needs, we have to rely on indirect methods in order to measure their welfare. Welfare assessments currently used in the field include physiological functioning, productivity, health and pathology, and behavior. For example, measuring the disease resistance of fish can show whether a stressful stimulus has affected their immunity. However, fish have a variety of coping mechanisms for environmental challenges. Therefore, a cluster of welfare measurements will provide a more accurate assessment of welfare.[97] For example, fish who are showing a healthy growth rate and high feed intake are not necessarily experiencing good welfare. If their feed is not well balanced nutritionally, it can chronically compromise their immune system, leading to extended poor welfare by increasing susceptibility to diseases.

To assess fish welfare holistically, researchers and farmers commonly integrate multiple types of welfare indicators:[98]

WELFARE INDICATORS (WIs) are observations or measurements that provide information about the extent to which the animals' welfare needs are met:

- **OPERATIONAL WELFARE INDICATORS** (OWIs) are welfare indicators that can realistically be used on the farm by trained staff

- **LABORATORY WELFARE INDICATORS** (LABWIs) are welfare indicators that require laboratory or other analytical facilities to provide information or validate OWI observations.

ANIMAL-BASED – Direct measurements made through observation of the animal (both individual & group-based)

ENVIRONMENT-BASED – Indirect measurements made through the observation of the environment, infrastructure, and processes.

OWIs offer fish farmers a toolbox to use on-site, whereas LABWIs are off-site indicators that give a more precise and full assessment of welfare conditions. To make the best use of these tools, the assessment of OWIs must be done by farm staff properly trained to recognize and evaluate them. As most OWIs are based on routine husbandry procedures and production measurements, the consistency and correctness of data recording is key for their efficient use. The welfare indicators relevant in on-sight assessments are those that are science-based, realistically measurable on commercial farms, usable to support welfare decisions, and measure welfare over extended time periods (Fig. 9).[99]

- Take into account the **specificities of the species**
- Provide information on the **causes** of impaired welfare
- Provide information on **potential** welfare problems, as well as current issues
- **Fast** and **easy** to observe

Figure 9. Features of a relevant OWI within aquaculture welfare management (adopted from Noble C., 2019).

The importance of the Operational Welfare Indicators has been emphasized by the development and standardization of best management practices and routine health checks. These standards are essential to minimizing health problems and maintaining an adequate fish welfare status in the aquaculture sector.

1.3.2. Operational Welfare Indicators

OWIs incorporate both individual behavioral and individual physiological responses to environmental challenges or stressors. Behavioral responses are the animal's first line of defense against environmental changes, predators, or social conflicts. However, aquaculture systems are usually three-dimensional: fish do not only live side by side, but also below and above one another. This can make the observation of fish behavior particularly difficult. Farmers' experience and knowledge regarding the surrounding environment, the farming system, the fish species' biology, and the fishes' environmental requirements are, therefore, important for improving fish lives. Here, we introduce the most important and frequently used individual and group-based OWIs:[100]

- **FREEZING BEHAVIOR** is fishes' most common response to high-conflict situations. By remaining motionless on the bottom of their environment and suppressing fin movements, the fish can increase vigilance and arousal in order to monitor the stressor.

- **SWIMMING ACTIVITY** levels are typically highest under rewarding conditions, in contrast to freezing behavior.

This behavior is described as a measure of fish performance and is, therefore, an indicator of the fishes' ability to feed, evade predators, and maintain position in a water current.

- **SWIMMING SPEED** can be used to evaluate the physiological condition of fish. When swimming speed drops to levels seen during freezing behavior, this response can be interpreted in two directions: it either signals underfeeding, thus indicating poor welfare; or a foraging strategy, thus indicating good welfare.

- **FORAGING BEHAVIOR** is the search for and exploitation of food resources, and is one of the welfare indicators most commonly used by fish farmers. Low levels of foraging can indicate a reduced appetite, and therefore stress.

- **FEEDING INTAKE OR FEEDING MOTIVATION,** e.g., latency to resume feeding, are behaviors highly affected by feeding regimen: predictable feeding times were shown to positively affect behavior and physiology. Predictable feeding times also seem to help fish prepare themselves for the incoming events and optimize feed intake. These regimens tend to increase "anticipatory behavior" accompanied by increased swimming activity in the feeding area or increased schooling activity. A good anticipatory response and large feed intake can be signs of high feeding motivation and welfare.

- **LOWER LATENCY TO RESUME FEEDING** is sometimes indicative of good welfare, but it can also signal underfeeding. In that case, anticipatory responses lead to aggression and injuries, with high-stakes repercussions affecting even survival.

- **ANTAGONISTIC BEHAVIOR** refers to a set of fight-or-flight behaviors expressed between at least two social partners in which one exerts dominance over the other.

- **INTERACTIONS BETWEEN CONSPECIFICS** can indicate either good or poor fish welfare, dependent on the context. For example, if fish are underfed, they will become more aggressive in order to feed, which limits the weaker fishes' feed intake. Conspecifics often compete for resources, but interactions between fish can also allow them to engage in normal behaviors such as shoaling.

- **SHOALING OR GROUP SWIMMING BEHAVIOR** is another behavioral response that can be used to assess hunger, stress levels, and health status as indicated by the spatial distribution and swimming activity of the group. The motivational state of the individuals to explore the surrounding environment will vary with their internal affective and physiological states. For instance, stress increases collisions and erratic swimming, which will affect the coordinated collective swimming behavior of the shoal.

- **INCREASED VENTILATORY FREQUENCY,** or number of opercular movements, provides an index of ventilatory activity, thus offering evidence of physiological stress. Well-balanced ventilatory activity is fundamental to maintaining an adequate oxygen supply to blood and tissues. Increased ventilatory frequency is normally related to poor welfare, and can be a consequence of the several harmful aquaculture practices or stressors previously identified. Arousal caused by positive experiences can also trigger an increase in ventilatory frequency; hence, it should be interpreted with caution.

Fish use a myriad of adaptive behavioral responses to cope with environmental challenges. Many of these behaviors are homologous between farmed fish species, which make them relatively easy to characterize. However, as noted in the beginning of this section, a holistic framework should always be adopted in order to maintain a full overview of the cultured fishes' welfare conditions. In addition to the behavioral indicators presented above, farmers can also monitor the quality of their fishes' lives by assessing the environmental conditions in which they are being reared, as well as physiological indicators. Table 5 below lists applicable OWIs. These parameters are broadly practical under farm conditions for the daily, routine monitoring of fish welfare in different farming systems and life stages.

Much research has been devoted to the non-lethal and non-invasive reviewing of fishes' physiology and behavior, allowing for welfare to be outside the laboratory environment. Nevertheless, pre-validation of each of the OWIs is needed for each fish species before drawing conclusions concerning their condition. This pre-validation can be performed using molecular or physiological tools (e.g., genomic, metabolomic, and proteomic tools). Measures of the expression of stress related genes, metabolites, or proteins provide useful markers of the consequences of prolonged stress, which cannot be seen through other welfare indicators.[101] This can be particularly important when assessing whether a farming system is suitable for the given specific cultured species.

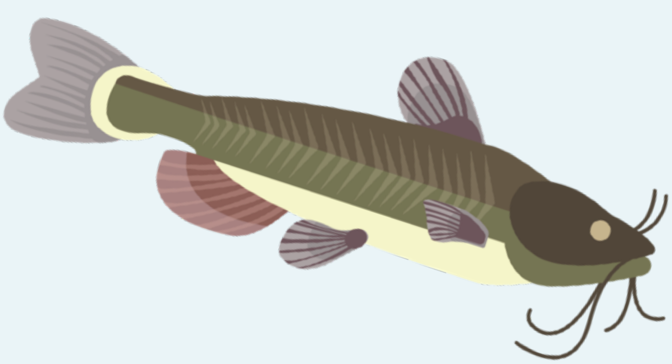


Table 5. Overview of OWIs that are fit for the purposes of different farming systems, fish life stages, and handling procedures (adapted from Noble et al. 2019).

	OWIs	Production systems	Life stage	Crowding	Pumping	Vaccination & medicinal treatments	Anaesthesia	Transport	Fasting	Underfeeding	Sanitation procedures	Grading	Fish examination	Slaughtering
Environmental	Temperature	x	x	x		x	x	x	x	x		x	x	x
	Salinity	x	x						x	x				
	Oxygen	x	x	x	x	x	x	x	x	x		x	x	x
	CO2	x	x			x	x	x	x	x			x	
	Total suspended solids	x	x											
	Turbidity	x	x											
	Light	x	x											
	pH and alkalinity	x	x			x	x						x	
	Total ammonia nitrogen	x	x			x		x						
	Water current speed	x	x	x	x									
	Stocking density	x	x			x		x				x		
	Time out of water	x	x			x						x	x	x
	Holding time	x	x			x								
Animal Group-based	Mortality	x	x	x	x	x	x	x			x	x	x	x
	Abnormal behaviour*	x	x	x	x	x	x	x	x	x	x	x	x	x
	Aggression	x	x						x	x				
	Loss of appetite	x	x	x	x	x	x	x	x	x	x	x	x	
	Growth	x	x	x	x	x			x	x	x	x	x	
	Disease & health status	x	x	x	x	x	x	x	x	x	x	x	x	x
	Change in skin color	x	x	x		x								
	Bulk oxygen uptake	x	x					x						
	Blood or scales in water	x	x	x	x	x	x	x					x	x
Animal individual-based	Trauma & haemorrhaging	x	x	x	x	x	x	x	x	x	x	x	x	x
	Opercular movements	x	x	x		x	x	x					x	x
	Eye status & haemorrhaging	x	x	x		x	x	x	x	x	x	x	x	x
	Opercula damage	x	x	x	x				x	x	x		x	
	Moribundness	x	x			x		x			x	x	x	x
	Pathology vaccine related	x	x			x								
	Condition factor	x	x						x	x			x	

* "Abnormal behaviors" includes the list of behaviors described in the beginning of this subsection

Other methods frequently used but not referred to in the table above are the measurement of cortisol, glucose, and lactate concentration in the bloodstream, the haematocrit, the osmolality, or the blood ionic composition. These measurements are costly to obtain,[102] but essential to ensure a reliable assessment of the fish's welfare condition when the first assessment is uncertain.

This section has focused on information for measuring welfare that is applicable across all fish species. However, diversity between species affects not only individual fish needs, but also the measurement of their welfare. For example, catfish are less sensitive to low oxygen levels and high stocking densities than catla.[103] Thus, monitoring freezing behavior in catfish is less useful for measuring their welfare related to oxygen levels or stocking density. Therefore, it is important to take the context of the species under evaluation into account when measuring fish welfare.

1.3.3. Welfare Assessments in a Farm Context

Welfare measures act as effective early-warning signals for problems that may occur on-site. To avoid welfare issues, farmers can identify these signals using the described welfare indicators for their cultured fish species, if available (if not, other species' welfare indicators can be adapted for use on a case-by-case basis). If these indicators are properly developed and the farmers have enough experience to recognize them, they can be used to prevent issues from occurring in the first place, benefitting the fish, the farmer, and the environment.

Figure 10. Example of an early warning signal assessment system for compromised welfare.

Although time consuming, the assessment of these welfare indicators can represent the success or the failure of the aquaculture sector in any country. A possible approach to the practical application of the aforementioned welfare indicators was reported by Noble et al. (2019), following a set of steps as detailed in Fig. 10 above.

For example, erratic circular swimming at the surface of a pond is a warning signal that something may be affecting fish welfare. Using general knowledge from **CONDITION 1**, it is apparent that there are a few plausible reasons for this behavior to occur. The farmer should first determine the source of the welfare issue (possibilities include unbalanced DO or pH levels, the presence of parasites, underfeeding, etc.) and, when identified, should then react with the appropriate improvements. To resolve these issues effectively, the farmer will need to be aware of the welfare needs of the cultured species - **CONDITION 2.** If the information in Conditions 1 and 2 concerning welfare issues and contextual specifics is not enough to determine the issue, the farmer will need to conduct a deeper analysis of the individual fish and the different water parameters using the welfare indicators from **CONDITION 3**. Individual analysis of the fish does not necessitate that the fish be killed. Instead, measuring water parameters or observing the skin and gills of the fish to detect disease and parasite signals is often enough. If this information is insufficient, fish and water must be sampled and sent to research or health centers for a more qualified analysis.

REFERENCES

43 Toni, M. et al. (2019). Review: Assessing fish welfare in research and aquaculture.

44 Poli, M. B. (2009). Farmed fish welfare-suffering assessment and impact on product quality.

45 Lall, S. P. & Lewis-McCrea L. M. (2007). Role of nutrients in skeletal metabolism and pathology in fish – an overview.

46 Ibid.

47 Oliva-Teles, A. (2012). Nutrition and health of aquaculture fish.

48 Farm Animal Welfare Committee. (2014). Opinion on the Welfare of Farmed Fish.

49 MacIntyre, C. M. et al. (2008). The Influences of Water Quality on the Welfare of Farmed Rainbow Trout: A Review.

50 See here for more detailed information.

51 MacIntyre, C. M. et al. (2008). The Influences of Water Quality on the Welfare of Farmed Rainbow Trout: A Review.

52 Farm Animal Welfare Committee. (2014). Opinion on the Welfare of Farmed Fish.

53 Animal Charity Evaluators. (2020). Farmed fish welfare report.

54 Cooke, M. (2016). Animal Welfare in Farmed Fish.

55 Gonçalves-de-Freitas, E., et al. (2019). Social Behavior and Welfare in Nile Tilapia.

56 Biosecurity is a set of actions taken at international, national, local, and farm levels to reduce risks of introduction of microbes and to reduce their spread between individuals, populations, farms, or ecosystems (Jia et al., 2017).

57 Raposo de Magalhães, C. S. F. et al. (2018). A Proteomics and other Omics approach in the context of farmed fish welfare and biomarker discovery.

58 Houston, R. et al. (2020). Harnessing genomics to fast-track genetic improvement in aquaculture.

59 Rauw, M. W., Noordhuizen-Stassen, E. N., & Grommers, F. J. (1998). Undesirable side effects of selection for high production efficiency in farm animals.

60 Lymbery, P. (2002). In Too Deep: The Welfare Of Intensively Farmed Fish.

61 Saraiva, J. L. et al. (2018). Domestication and welfare in farmed fish.

62 Muir, W. & Howard, R. (1999). Risks of transgenic organism release affect mating success.

63 Gonçalo-de-Freitas, E. et al. (2019). Social Behavior and Welfare in Nile Tilapia.

64 Martins, C. et al. (2012). Behavioural indicators of welfare in farmed fish.

65 Palstra, A. et al. (2015). The Implementation of Swimming Exercise in Aquaculture.

66 Fore, M. et al. (2017). Precision fish farming.

67 Fife-Cook, I. & Franks, B. (2019). Positive Welfare for Fishes: Rationale and Areas for Future Study.

68 Cooke, M. (2016). Animal welfare in farmed fish.

69 Lymbery, P. (2002). In Too Deep: The Welfare of Intensively Farmed Fish.

70 Nunny, L. (2020). Animal Welfare in Predator Control.

71 European Commission. (2017). Welfare of farmed fish: Common practices during transport and at slaughter.

72 Harmon, T. (2009). Methods for reducing stressors and maintaining water quality associated with live fish transport in tanks.

73 World Organisation for Animal Health. (2019). Aquatic Animal Health Code.

74 Giménez-Candela, T. et al. (2020). The legal protection of farmed fish in Europe.

75 Lines, J. A. & Spence, J. (2012). Safeguarding the welfare of farmed fish at harvest.

76 Compassion in World Farming (2018). The welfare of farmed fish during slaughter in the European Union.

77 Lines, J. A. & Spence, J. (2012). Safeguarding the welfare of farmed fish at harvest.

78 Rabosky, D. et al. (2013). Evolution is correlated across the largest vertebrate radiation.

79 Approaches to reducing fish stress: Cerqueira, M. et al. (2017). Cognitive appraisal of environmental stimuli induces emotion-like states in fish. and Arechavala-Lopez, P. et al. (2020). Enriched environments enhance cognition, exploratory behaviour and brain physiological functions of Sparus aurata.

80 Martins, C. I. M. et al. (2012). Behavioural indicators of welfare in farmed fish.

81 Dawkins, M.S. (1990). From an animal's point of view: Motivation, fitness, and animal welfare.

82 Noble, C. et al. (2018). Welfare Indicators for farmed Atlantic salmon: tools for assessing fish welfare.

83 Rey, S., Little, D., & Ellis, M. (2019). Farmed fish welfare practices: salmon farming as a case study.

84 The Fish Site. (2013). Principles of fish nutrition.

85 Milkfish Priority Species Report & Atlantic Salmon FishEthoBase Report

86 FairFish. (2020). FishEthoBase.

87 Saraiva, J. et al. (2019). A Global Assessment of Welfare in Farmed Fishes: The FishEthoBase.

88 Kirsch, J. & Cerqueira, M. (2020). Aquaculture in Asian Countries.

89 The table was created by web collected information and knowledge shared with stakeholders. We intended to broadly identify a few constraints that, to our understanding, are the commonly recognized issues. We are, though, available to discuss and do more research about welfare constraints in each of the farming systems. We can share all relevant references upon request.

90 Oligotrophic is an environment that offers very low levels of nutrients.

91 Leaching here concerns the loss of the veterinarian drugs from the pellet into the water, whether due to the water solubility of the chemical, the time during which the feed remains in the water before the fish eat the pellets, or the size of the pellets (the smaller the pellets, the higher the leaching losses). See here to learn more.

92 Respiratory alkalosis or acidosis are types of environmental diseases in fish prompted by the elevation and drop of the water's pH, respectively. It causes irritation on the skin and gills. Ammonia becomes more toxic in higher pH environments, which by itself can compromise water quality and thus fish welfare.

93 In Norway, the SMÅFISKVEL project is a good example of targeted research addressing welfare issues in hatcheries with a few recommendations for improvement.

94 Table 3 presents a broad overview of potential infringements for the welfare of farmed fish. We are available to discuss them and to perform deeper research on each of the stages mentioned. References upon request.

95 Farm Animal Welfare Committee (1996). Report on the welfare of farmed fish.

96 Animal Charity Evaluators. (2020). Farmed Fish Welfare Report.

97 Huntingford, F. A. & Adams, C. (2005). Behavioural syndromes in farmed fish: implications for production and welfare.

98 Noble, C. et al. (2018). Welfare Indicators for farmed Atlantic salmon: tools for assessing fish welfare.

99 Martins, C. et al. (2012). Behavioural indicators of welfare in farmed fish.

100 For an overview of behavioural welfare indicators, see Cerqueira, M. (2016). Linking personality and Appraisal modulators in fish.

101 Raposo de Magalhães, C. S. F. et al. (2018). A Proteomics and other Omics approach in the context of farmed fish welfare.

102 Ibid.

103 Striped Catfish Priority Species Report and Catla Priority Species Report.

SECTION TWO

2. MAKING WELFARE IMPROVEMENTS

Thus far we have reviewed the three conditions stakeholders must meet in order to properly address fish welfare issues. These are:

1) **BROAD CONTEXTUAL KNOWLEDGE OF FISH WELFARE NEEDS AND COMMON WELFARE ISSUES.**

2) **SPECIFIC KNOWLEDGE SURROUNDING THE TARGETED SPECIES, FARMING SYSTEMS, AND LIFE STAGES.**

3) **AN ASSESSMENT OF THE WELFARE (AND WELFARE ISSUES) OF THE FISH BEING TARGETED.**

The next step is to make welfare improvements. We will now apply the knowledge from Section 1 in order to outline the opportunities for welfare improvements in aquaculture. This section broadly describes the potential improvements[104] to fish farming concerning different farming systems (Table 6) and life stages (Table 7), pointing to opportunities that we believe different actors within the aquaculture value chain should address in order to safeguard fish welfare (Table 8).

2.1. WELFARE IMPROVEMENTS FOR DIFFERENT FARMING SYSTEMS

After reviewing the issues present in different farming systems, we can now move on to consider the appropriate welfare improvements. These suggested welfare improvements may change depending on the context of the species or farm.

Table 6. Aquaculture farming systems, their welfare-related issues, and possible mitigation procedures to improve the fitness of the system and the welfare of the cultured fish.

SYSTEMS	WELFARE-RELATED ISSUES AND MITIGATION PROCEDURES
RICE PONDS	• Rice ponds require careful management, especially when juvenile fish are introduced to the environment, as they can easily be overcrowded. Overcrowding compromises both water quality and growth performance. • There is a need to produce guidelines for best practice in this system. Farmers should connect with researchers so that they can benefit from technology and training, while also facilitating more research on sustainable fish welfare practices. • Increase the height of the dike to allow deeper water inside the field and/or to minimize the risk of it being flooded. • Provide weirs or screens to prevent the fish from escaping, as well as keeping predatory fish from coming in with the irrigation water. • Provide proper drains. • Provide deeper areas as a refuge for the fish. • Develop guidelines on the nutrient balance and carrying capacity of the integrated system.
PONDS	• The negative welfare effects of pond culture can be significantly reduced by the selection of a site with good soil and high-quality water, as well as by maintaining proper stocking densities. Features like the elevation of the pond bottom, a drainage canal, and an outlet should be included. • Inlet and discharge canals should be separated so that water supply and wastewater are not mixed. • Properly manage sludge and sediments after harvest and, if possible, use them for fertilization. • Include embankments to prevent flooding and erosion; consider environmental challenges such as the tidal amplitude, predominant wind direction, water current, and records of past flooding during cyclones/storms. • A minimum water depth of 100-150 cm should be maintained in the ponds. • The sluice gates should both seal the tank well and include net filters. • Periphyton-based aquaculture is a form of natural aquaculture in which the pond is shared with a collection of organisms (microbial, algal, and invertebrate community) growing in submerged objects (e.g., branches, bamboo, stone, plastic pipes, etc.). They help improve water quality by producing oxygen, trapping suspended solids, and taking up ammonia and nitrate. This technology is more important in polyculture. • It is important to use good feed formulation containing little FMFO content and to increase the stability of the pellets (e.g., using extruded pellets). Feed should be reduced at high and low water temperatures. Feeding fish after sundown should be avoided, as this is when dissolved oxygen levels normally decrease. Floating pellets should be used to allow for the observation of feeding activity. Excess mud at the site where food is dropped should be removed periodically.

PONDS (CONT.)

- Proper management is essential in pond culture. Adequate levels of water exchange are critical. When needed (typically after rain), lime can be added to ponds to increase the pH of the water. Aerators should be used to agitate the water, facilitating O2 distribution within the tank. Depending on species, structural environmental enrichment (e.g., shelters) can be beneficial.
- If possible, vegetative zones and habitat corridors should be provided.
- Guarantee good compaction of the tank dykes and the trench around the farm to reduce saline water intrusion.

SEA CAGES AND PENS

- The negative effects of sea cages on farmed fish welfare can be significantly reduced by careful site selection, stocking density control, improved feed formulation with less FMFO content, and integrated culture with macroalgae, filter feeders, and deposit feeders.
- Ensure prior environmental impact assessment and annual environmental audits.
- Keep proper records for relevant authorities.
- Clean nets to help maintain better water circulation, which can contribute to overall fish health.
- Regularly lift the cages/pens to replenish the fishes' swim bladders and avoid deformations and other welfare infringements.
- Net/pen raw materials should be suitable for the environmental conditions and strong enough to avoid breaking, which would allow fish to escape, creating potential welfare issues. (For instance, nylon has a greater breaking strength than polyester, but UV and abrasion can decrease its elongation and resistance to breaking more than polyester nets in the same conditions.)
- The species should be selected in order to properly safeguard welfare. For instance, Coho salmon are less susceptible to sea lice infections than Atlantic salmon.[105]
- Structural elements can also improve welfare through environmental enrichment (for example, plant fibre ropes or nets to prevent predation).
- Implement national and regional cage settlement guidelines to avoid issues like the introduction of exotic cultured species, disease and parasite invasions, insufficient maintenance of the cultured system, etc.
- With the increasing number of cages in protected areas, there is a need for policies and regulations to ensure environmental sustainability due to the high likelihood of water quality deterioration in cage culture sites.

FLOW-THROUGH SYSTEMS (TANKS, RACEWAYS)

- Monitoring the water's physical-chemical parameters (mainly temperature, oxygen, pH, and salinity) allows for the appropriate adjustments to feeding schedules and amounts in order to avoid increased susceptibility to diseases.
- Oxygenation equipment should be available as a backup for more demanding seasons. Stocking densities may need to be altered in seasons where water quality is a particularly pressing issue.
- The installation of CO2 stripping units prevents CO2 accumulation. As individual species' requirements affect the optimal water exchange and velocity, they must be taken into consideration. Airlift pumps can increase oxygenation and help establish good water circulation. Detailed biosecurity planning is also important.
- Proper handling management practices are essential to avoid distress, injuries, and susceptibility to infections.

RAS (TANKS AND RACE-WAYS)	• Any risks to fish welfare must be identified before production starts, and then risk mitigation plans must be incorporated into operational procedures: the number and species of fish to be produced, staff training, backup systems for emergencies, proper monitoring and operational routines, proper disinfestation procedures, and alarm technology all must be considered. • Denitrification reactors should be used to prevent ammonia accumulation issues. • Add dual-drain tanks, swirl separators, radial flow separators, depth and bead filters, and settling basins to the system to control settleable solids and prevent biosolid accumulation. • The system should integrate ozonation, bio clarification, foam fractionation, or a combination of these techniques for fine solids.

2.1.1. Future Advancements in Welfare Improvements

Environmental Enrichment

Environmental enrichments are modifications of the farmed environment aimed at providing physical or mental stimulation. Environmental enrichment is commonly recognized as a tool for increasing fish welfare, regardless of the farming system, life stage, or species. For instance, structures mimicking fishes' natural habitats have been shown to contribute to lower stress and aggression, improve growth and health, and boost development and metabolic performance.[106] However, until now, the benefits of environmental enrichment have been primarily demonstrated under laboratory conditions. There has been little work done to establish the utility of environmental enrichment in the farmed environment. There has also been little research into the species-specific environmental needs of most of the top farmed species, including catfish, carp, and tilapia.

We believe that more research into the specific requirements for environmental enrichment is needed. We also hope to see more research into requirements for the different life stages, as these can also differ greatly. For instance, fish are more vulnerable to stress at the earliest life stages, and therefore mortalities are usually higher. Enhancing the workability of environmental enrichment during these life stages might increase both the physiological and psychological performance of the individuals. Nevertheless, applying environmental enrichments without adequate testing can be detrimental to fish welfare. For instance, structures within a system can alter water dynamics, which can worsen the tank's self-cleaning, then leading to accumulated feed residues and even mortalities. Structures can also foster pathogens that decrease the biosecurity of the farming system.

Fish Welfare Initiative hopes to see more research into avoiding these welfare costs and building species-specific environmental enrichments. We believe that the benefits of providing environmental enrichment must outweigh the potential negative effects of increased maintenance, biosecurity issues, and its associated costs. We are not disregarding environmental enrichment as a potential tool for welfare improvements, but these cannot be generalized, and must instead be assessed case-by-case. For now, the extent to which environmental enrichment is easily transferred from laboratory settings to on-farm conditions is not clear, and does not allow us to strongly encourage its use.

Despite this caution, environmental enrichment should be considered for welfare improvements when information is available or made available, as in the “Sea Cages" subsection of Table 6.

TECHNOLOGY

As the industry advances, new technologies that can improve fish welfare throughout the farming systems continue to develop. These technologies include smart devices to individually monitor fish (such as SmartTags), drones to monitor offshore fish farm damage, and sensors to monitor water quality parameters (e.g., BiOceanOr, eFishery, Osmobot, or Sense-T). However, highly technological improvements need to be considered on a case-by-case basis, as in our understanding they are often not applicable to subsistence or small-scale commercial aquaculture due to their costs (both the upfront cost and maintenance). Table 6 has described some potential improvements for each of the farming systems. However, each improvement must be assessed with due caution on a case-by-case basis, as their effectiveness regarding fish welfare depends on factors such as the surrounding environment, the available infrastructure, the farmer’s well-being, public health, and environmental sustainability.

An emerging spectrum of farming system intensification has emerged, made up of “closed” super intensive systems such as RASs that are promoted by emphasizing biosecurity. These systems might be advantageous concerning the environmental impact of aquaculture, as they pose a much lower risk of causing environmental damage through genetic contamination and disease spread as compared to raceways and cages.[107] However, as explained above, mechanical failure and poor fail-safes are particularly damaging for fish welfare.[108] Despite the inevitable increase in these forms of farming in the coming years, research will need to assess the feasibility of the systems for the different cultured fish species’ requirements.

This information will be updated given future developments in the technology associated with the different farming systems and the farming systems themselves.

2.2. WELFARE IMPROVEMENTS AND THE VALUE CHAIN

Below, we broadly address the potential welfare-related mitigation procedures for each life stage of cultured fish (considering the welfare gaps in the value chain outlined in Condition 2 of Section 1). Additional specific improvements are given in our case study in Section 3.[109]

Table 7. Value chain stages of aquaculture and welfare-related potential improvements for each stage of cultured fish life.

VALUE CHAIN	WELFARE IMPROVEMENTS
BROOD-STOCK	• Introduce proper breeding techniques (such as stripping and milking) and related procedures such as proper anesthetic concentrations and hormonal induction of spawning. All staff involved should be trained. • Create fish brood banks to guarantee certified seeds supply. • Engineer genetic strains through selective breeding for survival, feed efficiency, health, and stress resistance. • Tailor dietary content or supplemented diets to enhance egg quality. • Improve record keeping and biosecurity. • Support and apply research on suitable stunning/slaughter methods. • Introduce environmental enrichment like shelters, gravel, spawning brush, etc.
HATCHERY	• Develop guidelines or protocols to improve welfare through the development of better feeding practices, including weaning procedures and the fulfillment of nutritional requirements • Ensure suitable stocking densities and the implementation of grading and sorting procedures. • Use tailored, functional feeds to enhance immunity to disease. • Guarantee a light : dark cycle (L:D) suitable for the species. • Adapt the culture system's design to the species' requirements, and properly maintain and service equipment like self-feeders. • Provide environmental enrichment like shelters, gravel, background color, etc. • Use certified healthy seeds to increase the prospect of better quality production and decrease welfare issues, e.g., susceptibility to disease and mortality. This will also improve the livelihoods of farming communities and mitigate the system's environmental impacts.

GROW-OUT	• Adjust feeding practices to increase feed efficiency (feed conversion ratio should be near 1). For example, use feeds with incorporated plant-based ingredients and natural compounds to increase immunity and resilience to stress. Additionally, guarantee the quality and stability of feeds to avoid pollution. • Add structures such as branches, bamboo, stone, plastic pipes, etc., to periphyton-based culture systems. This may improve water quality (see the section above on pond improvements). • Develop proper guidelines, protocols, and prophylactic measures to improve daily welfare (e.g., water quality checks, fish observation, system cleaning and maintenance, water replacement, etc.). • Ensure suitable stocking densities and the implementation of grading and sorting procedures. • Maintain detailed biosecurity and contingency plans, including disease treatment plans and collaborations with research and health centers for access to medicines and anesthetics. • Provide environmental enrichment like shelter, pond bio-floating beds, etc.
TRANSPORT	• Ensure handling and crowding best practices. • Ensure proper transport conditions with suitably designed equipment (such as oxygenation refrigeration systems). • Train staff in better welfare management and the ability to recognize species-specific welfare indicators. • Implement OIE transport standards. • Keep the transport of live fish at an absolute minimum. • Use anesthesia or sedatives for transport (e.g., clove oil as a stress reducer).
SLAUGHTER	• Implement OIE standards for slaughter. • Improve management pre-slaughter, such as handling practices. • Adopt stunning and slaughter methods suitable to each species; must be validated by research (collaboration should be encouraged). • Establish parameters required for the effective stunning of each species (to be established in controlled lab conditions). • Institute policy enforcement by external bodies, e.g., certification schemes. • Properly maintain stunning gear and monitoring procedures (e.g., check to ensure that the electrical parameters are being properly delivered to each batch of fish). • Encourage the coordination of dedicated research centers to improve stunning, i.e., creating a standard method to evaluate the method's suitability for each species.
RETAILER	• Lobby for rigorous fish welfare policies. • Lobby for best fish welfare management practices under farming conditions. • Encourage transparency of information (product labelling and food safety standards in order to avoid food fraud).
CONSUMER	• Educate consumers on fish welfare requirements and increase awareness of fish welfare expectations. • Encourage consumers to purchase certified products and understand what certain certifications mean. • Stimulate discussion surrounding certified products and transparency.

2.3. WELFARE IMPROVEMENTS FOR DIFFERENT ACTORS

Fish Welfare Initiative **sees four major opportunities for farmers to advance aquaculture management practices**, whether in India or in any other country relying on small to medium-scale aquaculture:

1) **Capacity building of welfare-specific skills and knowledge**. This is a necessary step in producing fish within welfare standards. Training is needed (and should be compulsory) for farmers to safeguard welfare. This can include on-farm practical demonstrations by experts; dissemination of information through posters, leaflets, booklets, or information sheets; and training workshops/ seminars.

2) **The formation of farm cooperatives.**[110] These are already commonplace in many sectors such as the shrimp industry. Promoting coalitions of finfish farmers would lead to technical improvements, better management practices, and increased knowledge-sharing. Coalitions "can be successful tools for improving aquaculture governance and management of small to medium-scale producers to work together, improve production, increase the welfare status in which fish are kept, develop sufficient economies of scale and enhance knowledge that allows participation in modern market chains and thus reduce vulnerability."[111] As such, the settlement of cooperatives can lead to the improvement of welfare in the aquaculture sector. Additionally, cooperatives would make it easier for farmers to acquire more expensive equipment that could be used by all participants, such as proper feeds and electrical or percussive stunners. Effective farming coalitions could even found fish pathology and diagnostic centers to help in the diagnosis of diseased fish.

3) **Stimulating the creation of platforms where large-scale industrial farmers can sell unused equipment** to small to medium-scale farmers at lower prices. Cooperatives can coordinate this transfer of equipment and acquire materials, equipment, reagents, anesthetics, chemicals, and other pharmaceuticals that would allow them to increase welfare and prophylactic measures on farms.

4) **Scale up the role of partners/stakeholders** to improve fish welfare. These partners and stakeholders include producers, governments, researchers, education and training institutes, NGOs and civil society organizations, aquaculture networks and associations, and donors. Potential steps towards welfare improvements include promoting the wider adoption of technologies, as well as continued research and information dissemination in order to increase the uptake and adoption of innovation in welfare improvements.

Other actors in the aquaculture value chain can have direct or indirect impacts on fish welfare. Below, we give some recommendations for each of these:

Table 8. Welfare improvements for different actors in the aquaculture value chain.

FEED PRODUCERS	• Use local feed ingredients to stimulate the local economy and improve the livelihoods of small farmers (this ultimately benefits fish welfare, as higher incomes would promote investments into improved fish culture conditions). • Develop and distribute feed tables to optimize ration sizes and feed management practices.[112] • Incorporate immunostimulants, probiotics, or other natural compounds to maximize immunity and welfare while reducing FMFO content in the fishes' diets. • Produce species-specific feeds to target a lower FCR (~1) that ensures better development, including ingredients with higher digestibility that ensure fish feces are more stable in the water and, therefore, avoid decreased water quality. • Adopt transparency in feed quality labels. • Establish efficient marketing networks and strategies to make products available at affordable prices.
POLICY MAKERS OR OTHER GOVERNANCE BODIES	• Encourage farmers to adopt proper tank preparation (e.g., liming, removing sludge and sediments) before a new harvest; this practice impacts the entire lives of fish. • Endorse the use of good management practices for chemical and medicine use. • Make the use of certified seeds and feeds (that promote improved development, FCR, and decrease pollution) compulsory. • Introduce guidelines for transport and slaughter. • Make the inclusion of FCR in the declarations of feed quality compulsory, and establish mechanisms for checking their proper use. • Create better policies for zoning aquaculture areas in order to avoid sensitive habitats (i.e., site selection) and those that might affect the culture system quality (with negative impacts on fish lives) and the surrounding ecosystem. • Give financial and logistical support for fish welfare improvements. • Promote shared-knowledge events (such as scholar programs) for building practical skills and learning best welfare practices. • Promote fish farm audits, including feed storage facilities, labelling processes, biosecurity, cleaning, transparency, etc. • Start government-led capacity-building initiatives such as facilitating partnerships between farms and research centers or certification schemes. • Develop a government-led certification program. • Establish and enforce science-based, fish welfare-orientated legislation. • Subsidize both farmers and farming interns to apply researched, learned skills,[113] and improve their decision-making capacity.[114]

RESEARCH	• Study the monitoring and subsequent mitigation of chronic stress to improve welfare and fish growth performance as well as financial returns. • Promote knowledge-sharing events such as conferences, workshops, and training with experts in aquaculture and fish welfare. • Conduct research in more sustainable and functional feeds with a balanced FMFO content and the incorporation of natural compounds (immunostimulants, probiotics, etc.) to mitigate stress levels and increase immunity to disease. • Conduct Research & Development to identify gaps in and new solutions for safeguarding fish welfare. • Conduct surveys on different actors from the aquaculture value chain, highlighting the welfare and health improvement opportunities according to different regions and farming systems.

2.3.1. Actionable Steps for NGOs

FISH WELFARE INITIATIVE BELIEVES THAT **COORDINATION BETWEEN MULTIPLE STRATEGIES AND ORGANIZATIONS IS LIKELY THE BEST WAY** TO INCREASE FISH WELFARE AWARENESS AND ENSURE THE ENFORCEMENT OF THE OIE ANIMAL WELFARE STANDARDS.

Some of the strategies available to NGOs for improving fish welfare include:

- Improving training around fish welfare.
- Encouraging other stakeholders, e.g., researchers and aquaculture associations, to participate in the welfare improvement process.
- Influencing improvements in legislation.
- Increasing the enforcement of existing legislation.
- Working with producers to implement direct improvements to animal welfare.
- Improving the welfare standards upheld by certification bodies (both national and private).
- Building interest and collaboration from all stakeholders, including shareholders, producers, and consumers, regarding fish welfare issues.
- Pressuring different parts of the value chain such as corporations.
- Encouraging research into fish welfare and distributing findings.

FISH WELFARE INITIATIVE HOPES TO CONTINUE TO SEE COLLABORATION AND STRATEGIC PLANNING BETWEEN ALL STAKEHOLDERS IN FISH WELFARE TOWARDS **IMPLEMENTING WELFARE IMPROVEMENTS AND BUILDING A PLAN FOR A MORE SUSTAINABLE AND ETHICAL FOOD SYSTEM.**

2.3.2. Actionable Steps for Researchers

Recent research by Buth S. R. et al. (2019)[115] effectively addresses the aquaculture value chain's emerging trends. Despite contextual differences, his conclusions likely converge with Fish Welfare Initiative's goals for future aquaculture welfare research. This future research "must be more rigorous, broader in geographical and theoretical scope, and more firmly grounded in the empirical realities of an increasingly complex and multi-polar world if it is to yield insights that can inform more effective policy and practice, and by doing so ultimately contribute to shaping a more sustainable and equitable global aquaculture industry."

We advocate moving beyond the simplifications and biases in research that have prioritized reporting on Northern species alone, North-South aquaculture differences, and the differences between small and large-scale production. These biases have created a blind spot in welfare research, as the leading Northern researchers have largely targeted their own cultured species rather than the most commonly farmed species worldwide. Asian countries such as China, India, and Indonesia are the top farmed fish producers, and their role in the aquaculture value chain and fishes' lives will only grow more important. This dearth of existing research presents a considerable opportunity for future projects to uncover the impacts that any of these countries have on the welfare of farmed fish, environmental sustainability, and social welfare.

REFERENCES

104 Improvements are according to research performed using technical reports, scientific material and stakeholders' opinions. We are available to go deeper in our analysis for any of the farming systems, life stages or for the role of the different actors within the aquaculture value chain. References are available upon request.

105 Drolet, J. (2015). Sea lice risk reduction program.

106 Näslund, J. & Johnsson, J. I. (2014). Environmental enrichment for fish in captive environments.

107 The Danish Government has stopped sea cage aquaculture development in September 2019 over environmental concerns. These concerns are tightly linked to welfare. (Phys.org, 2019).

108 Little, D. et al. (2017). Sustainable intensification of aquaculture value chains between Asia and Europe.

109 Improvements are according to research performed using technical reports, scientific material and stakeholders' opinions. We are available to go deeper in our analysis for any of the farming systems, life stages or for the role of the different actors within the aquaculture value chain. References are available upon request.

110 For information around success stories of coalitions of farmers in Asian countries, see White, P., Phillips, M. & Beveridge, M. (2010). Review of environmental impact, site selection and carrying capacity estimation for small scale aquaculture in Asia.

111 Ibid.

112 Feed tables permit farmers to standardize feed given on a daily basis according to different environmental conditions, i.e., temperature, salinity, etc..

113 Giving farmers the opportunity to learn skills can help both farmers through having access to new skills and technological knowledge and fish by promoting better culture conditions.

114 See the section titled "Aquaculture Field School" here: Samantaray, B. R., Bhuyan, S. K., & Ghadei, S. K. (2020). Small scale aquaculture – Boosting rural livelihoods.

115 Bush, S. R. et al. (2019). Emerging trends in aquaculture value chain research.

3. APPLYING OUR THREE CONDITIONS TO INDIAN CARP AQUACULTURE

Fish Welfare Initiative conducted a broad research effort to select the most promising country for implementing welfare improvements on aquaculture farms. We reviewed 26 countries based on multiple criteria. They were selected either because of their relatively high production levels, strategic viability, attitudes towards fish, logistics, potential flow-through effects, or recommendation from stakeholders. Through a process of country visits and secondary research, we decided to focus on India.

In this section, we use Fish Welfare Initiative's planned work in India as a case study for prioritizing welfare improvements. We apply the knowledge from preceding sections, alongside our preliminary research, to prioritize welfare improvements in the context of Indian carp aquaculture, namely for *Catla catla* and *Rohu labeo*.

Foundational to finding the most promising welfare improvements in any given country is having a deep understanding of existing welfare, culture, farming traditions, and infrastructure in that context. This information cannot be acquired through secondary research alone, and thus we instead hope to progressively understand these contextual variables through experience and the building of an in-country team.

Figure 11. Map of India showing the different states and 3 major finfish state producers: Andhra Pradesh, Gujarat, and West Bengal.

3.1. FISH WELFARE INITIATIVE'S PRIORITY COUNTRY: INDIA

India is a federal union comprising 29 States and 7 union territories. Figure 11 depicts the three states that generate 46% of finfish production: 24% in Andhra Pradesh, 14% in West Bengal, and 7% in Gujarat.[116]

Below are some of the defining features of Indian aquaculture (see Table 9 for an overview):[117]

- India possesses many different types of water resources including rivers, lakes, floodplains, canals, and thousands of small wetlands and ponds. The majority of these water bodies are suitable for freshwater fish culture.[118]

- India is the world's third largest aquaculture producer, after China and Indonesia. India's total aquaculture production comprised 6.2% of world aquaculture production in 2018 (15.62% of world aquaculture when excluding China).

- India is the world's second largest producer of food fish (finfish, crustaceans, and mollusks) with a share of 8.6% of world aquaculture. (Excluding China, India's food fish production represents 20.45% of world aquaculture.)

- India's share of farmed finfish production in 2018 was roughly 6.35 MT of the total 47.40 MT within Asian countries, making India the world's second largest finfish producer. (Excluding China, India comprises 31% of the total Asian finfish production.)

Table 9. Top 5 world aquaculture producers in 2018 (Source: FAO, 2020).[119]

Country	Total Aquaculture Production		Food fish Production		Finfish Production	
	tonnes	%	tonnes	%	tonnes	%
China (mainland)	66135059	57.8	47559074	57.9	26937843	49.6
Indonesia	14772104	12.9	5426943	6.6	4430578	8.2
India	**7071302**	**6.2**	**7066000**	**8.6**	**6356100**	**11.7**
Viet Nam	4153323	3.6	4134000	5.0	3009350	5.5
Bangladesh	2405416	2.1	2405416	2.9	2262708	4.2

Figure 12 below displays India's production for the top produced finfish species in 2018. India is the second largest producer of farmed freshwater fish, but has little diversification in terms of fish species, instead primarily farming carps and pangasius.

Freshwater fish farming predominantly (roughly 98%) uses traditional methods, which often include large ponds, little or no water exchange, poor draining, and no best management practices concerning tank bed sediment removal. This impacts water quality and can lead to the spread of diseases.[120]

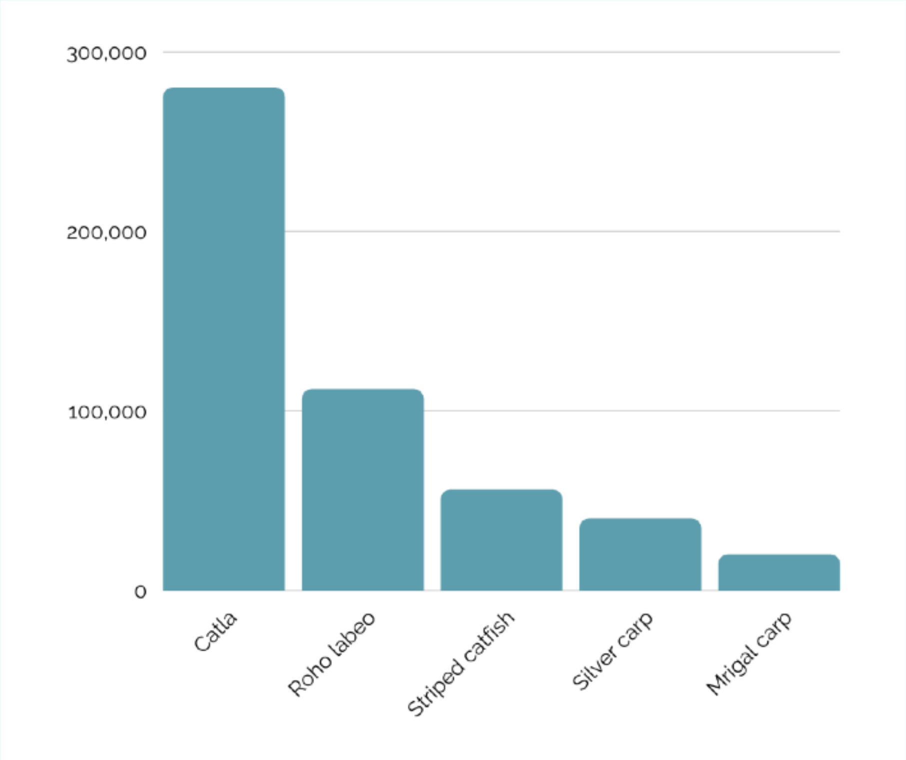


Figure 12. Top produced species in India (metric tons; data source: FAO[121]).

Most of the production is small to medium scale and semi-intensive.[122] This means that:

- The environment is often heterogeneous and there is little farmers can do to combat sudden events, e.g., an increase or drop in temperature, pH, or salinity.
- Health issues are harder to track.
- Fish may be difficult to observe, limiting behavioral observations.
- Records are limited to mortality or morbidity.

Fish welfare research is widespread for intensive aquaculture systems, where control over the cultured species is significant (such as for Atlantic salmon in Norway). Research is lacking, however, for extensive and semi-intensive farm operations.

THEREFORE, THE WELFARE IMPROVEMENTS RECOMMENDED IN THIS REPORT WILL CONSIDER SEMI-INTENSIVE FARMING IN INDIA.

3.1.1. India Aquaculture Survey

As of the time of writing, we have conducted roughly 60 farm visits across multiple Indian states. However, these visits have only been informal, and as such we cannot fully evaluate the conditions there. Thus, this is only a preliminary assessment, and we will continue to assess the welfare of fish in our work in order to ensure that we are properly safeguarding their wellbeing.

A field investigator from the Federation of Indian Animal Protection Organizations traveled with Fish Welfare Initiative's Director of Operations to visit farms in various states in India, namely Andhra Pradesh, Bihar, and West Bengal. Farms were found through google maps or by word of mouth. Upon arrival, we explained the goal of our visit and then asked the farmers if they would be willing to fill out our survey.

There were 17 successful surveys made from these farming visits.[123] From these 17, farmers were generally very open to talking, but difficulties with language often required the use of an interpreter, which made survey collection more difficult. As per our welfare improvement recommendations in Section 2, we will continue to conduct surveys throughout our work in India to more reliably assess the welfare of fish and ensure that we are properly safeguarding their wellbeing and that of the farmers.

Due to the unscientific nature of these surveys, Fish Welfare Initiative did not solely use survey data to draw conclusions regarding the most promising welfare improvements for aquaculture in India. Instead, the information below is used to outline and support our preliminary research on aquaculture welfare-related issues and possible mitigation procedures.

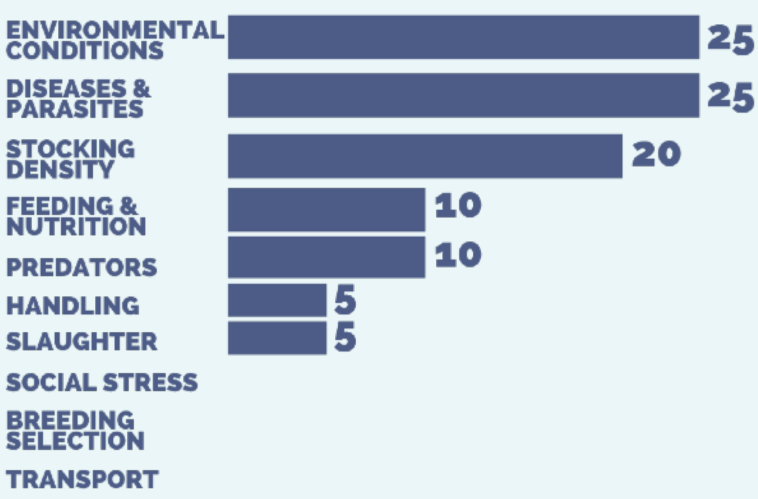


Figure 13. Main welfare issues pointed out by surveys from 12 out of 17 farmers in three different states from India, namely Andhra Pradesh, West Bengal and Bihar. Numbers are the % each welfare issue was mentioned by the surveyed farmers. Social stress, breeding selection, and transport were not mentioned by the farmers.

Survey Remarks

- Statistically speaking, our N (number of surveys) is fairly insignificant given the number of farms in India.
- The farms selected were chosen fairly randomly, and we believe they give an accurate broad overview of pond aquaculture in the three different states.
- Generally speaking, small-scale aquaculture is the most represented.[124] In such farming systems, there is a lack of government incentives, training, and access to medicines, as well as issues with water quality, diseases and parasites, and unbalanced stocking densities (Fig.13).[125]
- We observed a lack of enforcement of best management practices and animal welfare legislation, likely decreasing the sustainability of the sector.
- Language barriers can compromise our future work and, consequently, its impact on fishes' lives.
- Farmers seem willing to work with NGOs.

3.2. FISH WELFARE INITIATIVE'S PRIORITY FISH GROUPS: CATLA AND ROHU

To decide which species to prioritize, we reviewed species commonly found in Asia based on numerous criteria such as their sensitivity to negative stimuli, common conditions, tractability, neglectedness, and the estimated number of individuals produced. From this, we decided to focus on catla and rohu. These two species are the primary focus of Indian finfish aquaculture (making up 61.45% of India's total finfish aquaculture production), and their production in India accounts for 10.67% of the total finfish produced in Asia and 7.19% of the world's finfish production overall. More information on the process of researching and evaluating these fish groups can be found in our report on prioritizing species.[126]

Catla (*Catla catla*)

Image Source: Wikipedia

Rohu (*Labeo rohita*)

Image Source: Megafishingthailand

The literature on assessing farmed fish welfare is, as indicated above, incredibly vast and difficult to cover in detail. There are a variety of welfare indicators, but little research on determining which of these are the most important for our priority species. There is no single OWI or LABWI that gives a clear indication of compromised fish welfare. In most cases, it is the sum of welfare indicators that offers a holistic estimation of the true condition of the fish. In any case, a deep knowledge regarding the biology of the fish species (**Condition 2**) is needed before a proper assessment of welfare improvements can be made. An overview of the welfare needs for our priority species is reported below (Table 10).

Table 10. Welfare needs of catla[127] and rohu,[128] species produced in India.

INDICATOR	CATLA WELFARE NEEDS	ROHU WELFARE NEEDS
Temperature	Standard range: 25-33°C. Preferred temperature: 30-32ºC	Standard range: 25-33°C. Preferred temperature: 31-33ºC
Salinity	< 6 ppt	Tolerate salinity <5 ppt. 10-12 ppt increases the mortality in fingerlings by 100%
DO	Sensitivity to low O2 levels; best above 5 mg/L	>3.6 mg L-1. >6 mg L-1 is good against infestation
CO2	2.0 - 5.6 mg/L	<60 mg/L- more research needed, as this value is normally toxic for other fish species
pH	6.5 - 8.5 is acceptable but levels between 7-8 are best	6.5-8.5 is acceptable
Turbidity	>30 cm improves behavior and growth performance	N/A
Ammonia	Optimal is < 1 mg/L; 0.01–0.02 mg/L should be kept	Acceptable values are <0.82 mg/L (with pH = 6.95 and transportation densities of 134 g/L). 1.1 mg/L (with pH = 6.85 and densities of 201 g/L) causes mortality
Nitrite	<0.01 mg/L	<1 mg/L had no significant change either in hematology or enzymatic parameters. Optimal range is likely 0.02 to 0.2
Depth	Found to perform well in 1.5 m depths	1-1.5 m for fry & adults
Hardness	122–136 mg CaCO3/L standard levels	<100 mg CaCO3/L. 120 mg CaCO3/L increases fry mortality and stress
Daily rhythm	Further investigation is needed, but 12L:12D increases fish performance	12L:12D is optimal for following natural photoperiods
Light intensity	114±4 lux is optimal. Above 2672 lux affect growth performance	0.17 and 1.45 W/m2 improve performance
Light color	N/A	N/A
Feeding score	Trophic level = 2.8. Omnivorous (selective plankton feeding)	Trophic level = 2.2. Detritivorous, mainly herbivorous

Feeding style	Surface feeder. Maximum feeding from 6 to 9 am	Planktivorous surface feeder during fry stage, zooplankton column feeder from fingerling stage onwards at all depths. Can occasionally eat organic detritus from the bottom
Feeding frequency	Twice a day for all life stages. Feeding once may be most promising (but more research is needed)	Three times per day for fry and fingerling. Twice times per day for adults. One time per day for broodstock
Particle size	Larvae and fry are fed on finely powdered (<80 μ) feeds that are broadcasted over the water	Larvae are fed with particle feed size (< 50 um); larvae with 0.5 mm crumble pellet; fingerling, adult and broodfish with 1.5-2.0 mm, 2.5-3 mm and 5 mm dry pellet, respectively
Feed delivery	Spread uniformly over the tanks	Feeding provided either as dough on trays or feed baskets promote self-feeding, and are consumed after 1-2 hours
Feeding content	FAO guidelines: Crude protein: adults = 25% for good performance. larvae = 34-38%; Crude lipids: adults = 6-7% / larvae = 5%; Energy: Broodstock = 20 KJ/g; Carbohydrates: adults = 20% / larvae = 26%; Inclusion of 1.57 to 1.58 of leucine is recommended	FAO guidelines: Crude protein: adults = 25-30% / fingerlings = 30-40%; Crude lipids: adults = 3.5-16% / fingerling = 5-15%; Energy: adults = 2700-4000 Kcal7kg / fingerlings = <4000 Kcal/k; Carbohydrates: adults = 20% / larvae = 30-45%
Stocking densities	Semi-intensive: Larvae - 3-5 million/ha, Fry - 0.2-0.3 million/ha; Fingerling: 2000-3000/ha, 1 kg/ha when fertilization is used; Intensive: Larvae - 10 million/ha, Fry - >0.2-0.3 million/ha; Fingerling: 5000-10000/ha, 1.5 kg/ha when fertilization is used; Proportion in polyculture: 15-35%	3-5 million fry/ha; 0.2-0.3 million fingerling/ha; 5,000-10,000 adults/ha; 0.2-0.3 million fry/ha combined with catla and mrigal; Proportion in polyculture: 10-35% with catla and mrigal
Transport	Optimum fry packing is 100 fry/L (for 6 h transport)	Fingerlings optimal density is 134 g/L over 67 and 201 g/L for 2-3 h transport. Dropping water temperature is a common procedure for long periods of transport
Slaughter	Combination of percussive and electrical is promising	Combination of percussive and electrical is promising

Additional species information:[129, 130, 131]

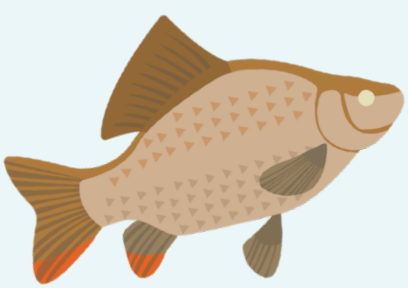
1. Both catla and rohu are raised in low input-based culture systems, primarily produced in ponds, and are not classified as invasive species.
2. Recent intensification of production (driven by selective breeding, organic fish farming, exports, and the development of processed value-added products) has led to welfare issues; catla is harder to breed than other carp species (as they need specific environmental conditions and hormonal induction) and presents low survival in the hatching stage, leading to shortages in seeds supply.
3. Both species exhibit high susceptibility to diseases and parasites (such as Argulus infection and Red Spot Disease), particularly under high stocking densities.
4. Rohu is a column feeder and needs deeper tanks (2-3 meters) for good growth performance, while catla eats from the surface.
5. There are few genetic advantages to hybrids.
6. Governmental regulation and control over the domestic marketing systems is almost non-existent; market price is determined primarily by demand and supply.
7. Post-harvest regulation is scarce.
8. For polyculture with only catla and rohu, proportions are set at 30:70, respectively. For polyculture with mrigal carp, proportions are usually equivalent between the three species.
9. Fish are largely sold to local markets.
10. Supplementary feed constitutes over 50% of the total input cost in carp polyculture.
11. Each species is frequently netted for grading and sorting.
12. Feed management is an issue for major carps.
13. Both species are "low-trophic" level organisms. Nevertheless, both are omnivorous and have animal-based protein requirements.
14. A significant amount of the aquafeeds are either produced on-farm or by small-scale, semi-commercial feed manufacturers comprising one or more ingredient sources.[132]
15. Organic and inorganic fertilizers are used to increase productivity, but a few conditions must be satisfied beforehand. Fertilizers should not be used if, for example, the water is too greenish, the weather is cloudy, the pH is too acidic, or the water too turbid. If these conditions are satisfied, the fertilizer must be well mixed and dissolved in water.[133]
16. A combination of natural and supplementary feeds in ponds is usually used (if natural productivity is not enough, supplemental feeds can satisfy the fishes' nutritional requisites). Supplemental feed should be lessened if water becomes too greenish.
17. Commercial FCRs have an average of 1.8 to 3.4, while the average for feed made on farms is 2.3 to 4.1 in semi-intensive ponds.
18. Feed typically comprises simple ingredients that, depending on the culture system, are fed as mixtures, doughs, or compressed pellets.
19. Formulations are not always supported by scientific research, may be poorly formulated, and are sold to farmers who are usually not familiar with the nutritional requirements of their farmed species.
20. Simple dry or moist mixtures, or moist mixed feeds, are usually dispersed in the water column, resulting in low ingestion rates and high feed conversion ratios.
21. Farmers are commonly unaware of the importance of applying appropriate standards for feed transport, handling, and storage.
22. It is difficult to assess the natural productivity of extensive and semi-intensive farming systems. It is also difficult to assess the impact of supplemental and farm-made feeds.

23. There is currently a lack of regulation for aquafeed and feed ingredient quality in carp aquaculture. The Coastal Aquaculture Authority (CAA) does not regulate feed mill registration due to limited power, and feed manufacturers are only subjected to voluntary codes of practice. Issues such as poor quality or adulterated ingredients, a lack of product labelling, the misrepresentation of products, and/or a lack of standard feed specifications are prevalent.

24. Farmer clusters/associations have proved an effective platform for advocating better feeds and feeding management information, as well as promoting farmer-to-farmer training in prawn aquaculture, but there is a lack of such groups in finfish aquaculture.

3.3. REVIEWING WELFARE IMPROVEMENTS FOR CATLA AND ROHU

A foundational aspect of evaluating welfare improvements is understanding their effects on the fish species involved. As with many topics related to fish welfare, there is a scarcity of information available on the welfare needs of catla and rohu.[134] Thus, we can only draw preliminary conclusions, and Fish Welfare Initiative will stay open to pivoting given more scientific data.



Below we describe the potential welfare improvements for our priority species, catla and rohu.[135] This assessment is done according to the welfare constraints described in Section 1 (**Condition 1**), the species-specific welfare needs described in detail above, and information on these species' production from our secondary research and farm visits (**Condition 2**). Fish Welfare Initiative acknowledges that fish welfare outputs are the summation of many interrelated interventions, but considers each welfare issue in isolation in order to assess which is the most promising and impactful. This is done with the intention of focusing our efforts on the most cost-effective welfare improvements available.

See below in Table 11 a list of potential improvements[136] for each of the main welfare issues summarized in Condition 1, with remarks on each and an outline of their weaknesses and strengths as possible interventions.

WELFARE IMPROVEMENTS

Table 11. Potential welfare improvements for catla and rohu considering the recognized aquaculture welfare constraints as described in Condition 1 from Section 1.

FEEDING & NUTRITION

PROMOTE THE DEVELOPMENT OF FARMERS ASSOCIATIONS, EXTENDED NETWORKS, AND MEDIA INVOLVEMENT

- Improve access to information (such as information on formulations, ingredient suppliers, and costs).
- Improve farmer-to-farmer training around best management practices.
- Create field schools to help farmers develop better feed formulations, adjusted to the different life stages of fish, and learn about proper storage and handling.
- Associations can increase farmers' buying power, granting access to production technologies and management developments that can improve fishes' welfare status.
- Open proper channels for the acquisition of pelleted feeds at affordable prices.

PROMOTE PUBLIC/PRIVATE PARTNERSHIPS BETWEEN SMALL-SCALE FEED MANUFACTURERS AND FARMERS/FARMERS ASSOCIATIONS

- We expect this to improve access to cost-effective quality feeds (though this needs further investigation).
- Increase access to small-scale commercial feed manufacturers who are available to produce smaller feed batches.
- Introduce the possibility of collaborative agreements (such as single source purchasing).

CREATE APPROPRIATE FEED REGULATIONS FOR FRESHWATER AQUACULTURE, WITH SPECIFIC GUIDELINES AND A LEGALLY BINDING FRAMEWORK

- Poor regulatory control and a lack of standards along the aquafeed value chain is a constraint to feed quality and therefore to fish welfare.
- There is a need for the institutional capacity to enforce these regulations and ensure compliance. For better monitoring and enforcement of feed production and quality, make use of non-government actors such as the national feed industry associations.[137]

IMPROVE NATURAL FISH FOOD PRODUCTION IN POND WATER

- Manuring, organic fertilizers (e.g., from cattle, poultry, rabbits, sheep, etc., and decaying plant matter, such as cut grasses), inorganic fertilizers (e.g., Di-Ammonium Phosphate (DAP) and Urea), and periphyton-based aquaculture all promote the growth of bacterioplankton and phytoplankton, on which zooplankton and other animals feed. Zooplankton is food for many fish species, including carps. This compensates for any lack of supplemental feed, but might not fulfill the species' requirements.[138]
- Train farmers to measure the levels of natural productivity in their ponds and to provide fish with a well balanced environment concerning phytoplankton, zooplankton, benthos, and periphyton production.
- Determine the role that natural productivity, feed, and fertilizer use have on nutrient recycling and retention in extensive and semi-intensive farming systems.
- Determine the qualitative and quantitative relationships between natural productivity and the addition of supplemental and farm-made feeds.
- Develop appropriate feed formulations, accounting for natural productivity, to safeguard high nutritional standards for the cultured fish.
- Develop monitoring protocols to assist farmers in optimizing natural productivity in their extensive and semi-intensive farming systems.

INFORM FARMERS, FEED SUPPLIERS, AND UNREGULATED FEED MANUFACTURERS ABOUT THE IMPORTANCE OF SELECTING APPROPRIATE INGREDIENTS AND SIZE-SPECIFIC FORMULATIONS

- While a significant amount of research has been undertaken to establish the nutritional requirements of many species (though still scarce for both catla and rohu), much of this knowledge has not been communicated to the farmers producing farm-made feeds or to small-scale feed manufacturers.
- Provide farmers and small-scale feed manufacturers with species and life-stage specific feed formulations (which consider the quality of the ingredients, seasonal availability, processing technologies available, and the welfare effects).
- Fish welfare can be improved through using simple extruders and compressing feed ingredients into dry pellets. Alongside this, improving pelletization and feed's binding features reduces the amount of dust and leaching,[139] improves pellet hardness and water stability, improves FCR, and, thus, results in better welfare for the fish.[140]

STORE FEED IN APPROPRIATE ROOMS WITH COOL VENTILATED AREAS PROTECTED FROM PESTS

- Feed should be used on a first in: first out basis.[141]
- Develop better feed storage and handling management guidelines. Avoid exposure to the elements, extremes of temperature and humidity, and control the exposure to pests like rodents.
- Best management practices need to be communicated to the farmers.
- Better enforcement of best management practices regarding storage.

INCORPORATE APPROPRIATE ADDITIVES (E.G., IMMUNOSTIMULANTS, PROBIOTICS, PREBIOTICS, ETC.) TO FEED IN ORDER TO INCREASE IMMUNITY AND STRESS RESILIENCE[142]

- Require farmer education in better management practices, such as how to top dress their feed, and the legal status of the incorporated compounds (e.g., veterinarian drugs or food additives).
- Improve regulatory controls and enforcement.
- Establish targeted research to test the welfare efficacy and cost-effectiveness of the various additives available.
- Establish the dosage, efficacy, impact on fish welfare, and cost-effectiveness of the chemical compounds and materials used.
- Study the environmental impacts associated with their use.

OTHER DIETARY IMPROVEMENTS

- Promote nutritionally balanced feeds that are water stable, palatable, target a specific developmental stage, and take into consideration the natural productivity of the culture system.
- Reduce FMFO content balanced with the proper incorporation of essential amino acids such as tryptophan, lysine, or methionine to improve immunity and welfare, as well as to decrease aggression and strain on wild fish populations.
- Increase digestibility and nutrient availability, e.g., use selected mash feed ingredients high in starch to promote the binding properties of the different ingredients (or use gelatinization instead).[143]
- Choose the appropriate pellet type (for both catla and rohu, floating pellets are best).[144]
- Promote commercial feeds over farm-made feeds for better FCR and to decrease feed dust.[145] If commercial feed is not available, promote the on-farm pelleting and drying of feeds using mixed ingredients to reduce fish energy expenditure and wastage.

OTHER FEED MANAGEMENT IMPROVEMENTS

- Give farmers tools to monitor productivity indicators (e.g., sampling procedures, FCR analysis, etc.) and make available corrective actions for different scenarios.
- Maintain appropriate timing of feeding, e.g., split feed rations into two, delayed by 20 min, in which proactive and dominant fish eat during the first round and the subordinate reach satiation during the second round.[146] (For catla, feeding is more promising between 6 to 9 am.)
- Use structures for feed enclosure and use floating feeds to prevent feed wastage and water quality deterioration.[147]
- Alternate between higher and lower protein diets or restricted feeding regimes, e.g., alternate day feeding, where fertilizers need to be used to fulfill nutritional requirements of fish.
- Use feed tables from suppliers or researchers when possible.
- Employ mixed feeding schedules if no automatic or demand feeders are available.
- Prioritize demand feeders since they account for the daily rhythms and needs of the species, as well as the nutritional quality of the diet (dominance should be investigated to understand if monopolization of the feed exists).
- Use automated feeders over hand feeding, as they permit for larger volumes of feed to be dispersed efficiently. In hatcheries, simple belt feeders are promising, whereas for grow-out, other feeders can be more welfare effective. (For catla, movable mechanical systems based on compressed air should be encouraged for dispersing feed. For rohu, static demand feeders should be used. Another simple and cost effective option is the use of dough on trays or feed baskets that endorse self-feeding.)

- Delay onset of external feeding (e.g., extend weaning between live feed and inert feed).
- Optimize feed administration through automatic or demand feeders.
- Keep adequate feed management records.
- Reducing mortality is of primary importance to improve feed efficiencies and welfare, as well as to maintain water quality.

OTHER INDIRECT IMPROVEMENTS FOR WELFARE

- Provide farmers with information about small-scale feed manufacturers and other farmers producing farm-made feeds, investing in the labelling and transparency of such feeds, including their proven quality, feed ingredient rates, and formulation processes.
- Promote awareness and assist farmers with understanding the implications of their feed choices and optimizing their feed management strategies.

REMARKS

Feeding and nutrition is a critical welfare issue that should be taken into consideration from the beginning. In India, like in many other countries, it is often difficult for smaller producers to access good-quality feed. Often, channels do not exist to purchase feed that is well suited for the species of fish and affordable for farmers. Feed can constitute up to 54% of the total aquaculture farm production costs in India, and so this is not something that Fish Welfare Initiative can subsidize on a long-term basis. We acknowledge, however, that better feed and feed management improves fish health and water quality, as well as decreases the environmental impact of aquaculture. Despite the increased investment in technological innovation and knowledge transfer after government involvement, there are still water pollution, fish health, and welfare constraints associated with fish nutrition, feeding practices, and feed storage.

We see most of the work for improving feed in the hands of feed manufacturers and researchers, as part of the global push towards creating a less damaging food system. Farmers already use some strategies to improve daily feed management in India, and the “low-trophic” profile of both catla and rohu helps to reduce this issue.

Despite how important feed management practices can be in maximizing fish welfare, Fish Welfare Initiative does not plan to prioritize them directly. We see our main role as creating awareness for best feeding management practices, and promoting the bridge between farmers and research centers. By promoting better feed and feed management, we hope to encourage farmers to join local communities and source better feed for themselves. We expect building channels to access better feed to take a long time. We encourage you to read the FAO report about feeding and feed management for Major carps in Andhra Pradesh, India, to learn more about this issue, as it gives a few recommendations for improvement that, despite targeting fish production efficiency, would indirectly improve fish welfare.

SPECIFIC FOR PONDS[148]

SITES MUST BE CAREFULLY SELECTED OR DESIGNED TO ENSURE AN ADEQUATE FLOW OF CLEAN WATER.

- Supply water needs to have a quality suitable to the species and the characteristics of the culture system.

ALL WATER NEEDS TO BE DRAINED AND THE TANK DRIED FOR A PERIOD OF FOURTEEN DAYS.[149]

- Drying the pond helps to inactivate potentially harmful microorganisms.
- This promotes the breakdown of organic matter and allows excess mud to be removed.

APPLY LIME TO THE POND BOTTOM AND DYKE SLOPES TO GUARANTEE A SAFE ENVIRONMENT.[150]

- Use agricultural limestone ($CaCO_3$) to create a buffer system for pH and alkalinity correction in the fish pond.[151] If limestone is not available, the use of other liming materials (such as quicklime or slaked lime, dolomite, gypsum iron and silica, zeolite, bacterial inocula, or humic acid products) may be necessary. Recommended amounts, though normally tabled, are often 500 kg/ha (which could increase with lower pH levels). See the use and effectiveness of different limes below.

LIMESTONE Kills germs, parasites, and bacteria, clarifies water, increases the effectiveness of fertilizers, increases the supply of CO_2 necessary for photosynthesis, and mitigates ulcers in fish.

QUICKLIME (CaO) Extremely alkaline to increase pH rapidly. Removes germs and is safe to use in dry ponds.

DOLOMITE ($CaMg(CO_3)_2$) Can be used in ponds rich in organic matter.

GYPSUM ($CaSO_4{,}2H_2O$) Clears water turbidity caused by mud and helps balance the pH.

- Should be spread over the tank and the slope of the dykes using a shovel.
- Promotes mineralization and reduces oxygen depletion.
- Acts as a disinfectant and improves the sanitary conditions of the tank.

APPLY FERTILIZERS AND PERIPHYTON-BASED FRAMEWORK AS EXPLAINED IN THE "FEEDING AND NUTRITION" SECTION ABOVE.

- Besides improving natural productivity within the tank, this also improves water quality by contributing to the DO balance and taking up ammonia and nitrate.
- Inorganic fertilizers should not be applied directly to the tank, rather, they should be dissolved in water and dropped over the tank. Otherwise, they can be absorbed by the mud and fail to benefit the water quality.
- Adjust the use of fertilizers to standard rates. However, too much fertilizer can be harmful to the water quality. Rates are normally given by suppliers. FAO describes rates of fertilizers to be applied to ponds depending on the level of productivity expected.
- Use the color of the pond water - light green, brownish green, or light brown - as an indicator to monitor phytoplankton density using a Secchi disk and adjust fertilization accordingly.

HARROW THE POND BED TO TURN OVER THE MUD.

- A rope with a tied brick should be enough to cover the width of the water body and touch the bottom.
- The harrowing helps to release accumulated toxic gases from the bottom to the surface of water. This must be done at least every two weeks or 15 days. If needed, this dredging can be done more frequently.

WATER QUALITY NOTES FOR CARP PRODUCTION IN INDIA

- Monitor water quality parameters on a daily basis through aquaculture sensors and probes, e.g., portable meters or multiparameter sondes. Online monitors are advised. There are four major categories of water quality concerns that affect aquaculture finfish production, namely, (1) physical parameters, e.g., pH, temperature, dissolved oxygen, and salinity, (2) organic contaminants, (3) biochemical hazards, e.g., cyanotoxins, and (4) biological contaminants, i.e., pathogens.
- Careful data collection will likely help to influence decisions regarding water management (include environmental parameters alongside feeding and growth performance).
- The populations of phytoplankton and microorganisms are major determinants of oxygen and metabolite levels in pond systems. Dissolved oxygen and pH need to be monitored before the start and at the peak of photosynthesis, 5-6 AM and 2-3 PM, respectively. The other parameters can be monitored once a day.
- Aquaponics is a practical technology that allows for the integrated multi-trophic production of fish and plants in a semi-closed synergetic recirculating system. The water waste from fish excretion and the microbial breakdown of fish feed provide nutrients for plant growth. The plants remove undesirable nutrient wastes from the water, which fish then reuse.[152]
- Acceptable water quality can be achieved using the following pond management techniques:
    - Most water quality problems can be solved with controlled water exchange (though it must not lead to the instability of the ecosystem): it adjusts salinity, oxygen, and temperature to remove excess metabolites and to keep algae healthy. Maintaining a healthy and stable natural productivity in the system is essential to promoting the balance of pH, alkalinity, and water hardness. The exchange rate should vary with the production period, natural productivity, stocking density and total biomass, turbidity, water source, and water volume. Decrease the water level by 25-50 cm daily.
    - Balance the water exchange and fertilization to maintain natural productivity.
    - Avoid overfeeding through proper feed management (see "Feeding and Nutrition" above).
    - Aerate the water to increase dissolved oxygen and avoid depletion during the night, which helps in the diffusion of oxygen and carbon dioxide, facilitates the volatilization of toxic gases such as N2, NH3, and H2S, helps to create a dynamic flow within the pond to decrease the stratification of temperature, DO, pH, and salinity, helps with the decomposition of organic matter in water and soil, improves the nutritive value of fertilizers, and decreases pollution.
    - Remove accumulated organic material from the pond bottom.
    - Oversee the maintenance of a high density bacterial population, e.g., probiotics, combined with water circulation and aeration.
    - Prevent mortalities and the respective increase of organic matter in the tank bottom through vaccination or proper veterinarian medicines.
    - Apply biofloc technology to help the uptake of nitrogen and increase competition with pathogens.[153, 154]

GENERAL WATER QUALITY CONCERNS

DISSOLVED OXYGEN (DO)

- Fish must be stocked according to the recommended rates (see the "Stocking Density" section below) within the production capacity of the tank.
- Avoid overfeeding and follow the recommended daily feeding rates.
- Reduce feeding rates during periods of slow growth (e.g., winter, periods of higher temperature, after handling, etc.).
- Increase water inflow if possible to reduce challenging environmental conditions such as eutrophication.
- In ponds, promote and maintain a good phytoplankton bloom through fertilization. Follow regulatory measures for chemical fertilizer use.
- Use periphyton-based aquaculture tools (bamboo, roots, etc.) if possible.
- Maintain a good rate of water exchange, as physical conditions such as temperature, pH, and salinity can deeply affect oxygen levels.
- Use mechanical aeration, e.g., paddle wheels, agitators, vertical sprayers, impellers, airlift pumps, air diffusers, liquid oxygen injection, etc., to guarantee water agitation and DO exchange.[155]
- In general, a saturation level of at least 5 mg/L is required for the best welfare performance in both catla and rohu.
- Monitor feed quality and waste to avoid a drop in oxygen levels.
- Maintain a good and balanced quality and quantity of natural production in the tank, since bacteria, phytoplankton, and zooplankton compete for dissolved oxygen with fishes.
- Avoid higher plankton densities, as they create a shading effect that limits the penetration of sunlight in water, thereby reducing photosynthetic oxygen production in the bottom of the water column.

WATER TEMPERATURE

- Ensure water temperature is within the species' tolerance (between 25 to 33ºC).
- Increase the water exchange and avoid stagnated water.
- Increase the depth (water volume) of the tanks and use paddle aerators to promote water agitation and avoid temperature/oxygen stratification, which negatively influences primary production.
- In situations where temperature maintenance is too difficult, ensure improvements in other parameters more easy to control, such as oxygen (see above).
- Install groundwater pumps to maintain the pond level and keep the water temperature stable.
- If sources of water with different temperatures are available, prioritize cooler water for the water exchange.
- Guarantee proper stocking densities to avoid the depletion of oxygen when temperature varies abruptly.

SALINITY

- Salinity plays an important role in the growth of both catla and rohu through the osmoregulation of minerals from the surrounding water. Levels should be kept below 5 ppt.
- Ensure proper selection of the production area to avoid mixture with brackish or salt water.
- Ensure good quality selection of fry, fingerlings, and seeds to prevent swim bladder issues when the salinity changes abruptly.

pH, ALKALINITY, AND HARDNESS

- Ensure soil pH and acidity are within acceptable limits in order to manage the alkalinity, hardness, and pH of the water. pH is lowest at sunrise and peaks in the late afternoon. Monitor and keep soil pH at 6.5 or above.
    - Dry the pond for at least 15 days before a new production cycle.[156]
    - If the pH is below 6.5, apply lime prior to filling the pond or spread uniformly over the water's surface when full. If the soil's alkalinity and hardness are high, lime application is not necessary, but acid fertilizers may be recommended depending on need.
- Maintain alkalinity at or above 40-100 mg $CaCO_3$/L so that pH and hardness do not fluctuate widely.
- If possible, flush the ponds daily to reduce the pH (advisable when the magnitude of diurnal pH fluctuation is great), or guarantee a proper water exchange.
- Measure the pH after rain, as it can make water acidic and toxic for fish. After rain, 75-80 g of burnt lime/dolomite per decimal should be applied.[157]

AMMONIA

- Un-ionized ammonia (NH_3) concentrations in pond water should be kept below 0.5 mg/L. Concentrations of this form of ammonia are toxic to fish and are influenced by DO, pH, and alkalinity. It is essential to manage these parameters as explained above, including:
    - Maintain pH near neutral, at least between 6.5 and 8.5; ammonia is converted from toxic ammonia (NH_3) to a nontoxic ammonium ion (NH_4^+) at pH below 8.0.
    - Keep DO concentrations high - near saturation.
    - Maintain water alkalinity at 40 mg to 100 mg $CaCO_3$/L.
- Monitor feeding and avoid overfeeding, since excess feed decays and facilitates toxic ammonia buildup.
- Guarantee a proper water exchange and dynamic within the system.

CARBON DIOXIDE

- Maintain an adequate algae culture for proper CO_2 levels and water color.
- The consumption of CO_2 during photosynthesis causes an pH increase in the afternoon, and the accumulation of CO_2 during the night causes pH to be at its minimum before dawn.
    - Monitor plankton productivity and ensure optimal levels for the system's capacity.
    - Act accordingly to keep pH, alkalinity, and hardness at optimal levels, which is essential to minimize CO_2 toxicity.

TURBIDITY

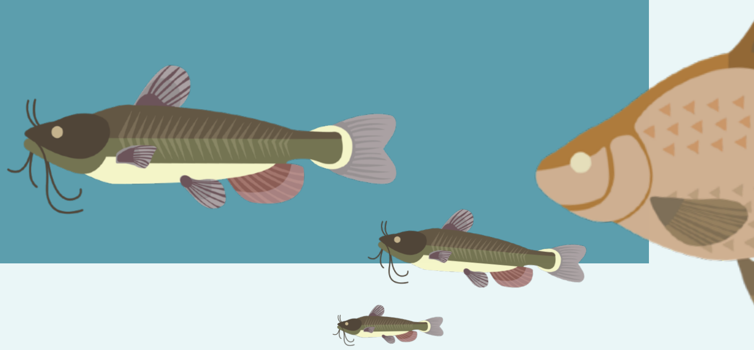
- Turbidity limits light penetration, thereby limiting photosynthesis in the bottom layer. Higher turbidity can cause temperature and DO stratification, as well as increase gill obstruction and tissue injuries.
    - Periphyton-based strategies can reduce turbidity if needed.
    - Maintain a proper range of pH and alkalinity through the liming of the system.
    - Keep a proper water supply to remove muddy water.
    - Use a proper stocking density, and include fewer species that might stir up the bottom layer of the pond (catla is a surface feeder and rohu a column feeder. If cultured with mrigal, however, use a smaller proportion of rohu).
    - Pond visibility with the right plankton density should be about 30 cm (for catla). Use proper water exchange to help maintain this level.
    - Assess the water turbidity daily using the pond water color as an indicator: light green, brownish green, or light brown.
    - Use lime and gypsum concentrations, according to the supplier, to clear water turbidity.

REMARKS

There appears to be a broad consensus that water quality is one of the most important factors influencing fish welfare, as it affects their entire lives. The parameters affecting water quality, such as oxygen, ammonia, CO2, pH, temperature, salinity, and water flow, are interrelated. Each of these parameters' variations will influence the water quality and, therefore, affect the welfare of fish. Water quality parameters must remain at all times within the adequate ranges that sustain normal activity and physiology for these species. Water quality dramatically affects welfare indicators such as growth. Water quality can also help alleviate other welfare issues, including those involved with “Feeding and Nutrition,” “Diseases and Parasites,” “Stocking Density,” “Social Stress,” “Handling,” and “Transportation.” Prioritizing water quality will, therefore, can help protect against a diverse range of welfare issues. To preserve water quality, proper monitoring (of both the water quality and the fish) should be a daily routine, which, from our surveys in India, appears to be uncommon.

Water quality is a prevalent issue within India. Fairly simple improvements to water quality can be made that would likely drastically improve the fishes’ welfare. For example, installing aerators, adding bio-floating beds in ponds, adopting periphyton-based strategies, preparing ponds with lime, and fertilization can all improve water quality without requiring highly specialized equipment or skills. Each of these improvements results in high return on investment.

There is a concern that water quality improvements could be exploited to put more fish into a system to increase yield, potentially decreasing welfare overall. As such, groups advocating water quality improvements should be careful to do so in a way that also ensures the fishes’ welfare. The aim should be to show farmers that welfare has holistic value both to themselves and the globe, and that the long-term benefits of better welfare are larger than the short-term gains of increased production. Farmers who wish to intensify their production should note that increasing the number of fish increases the complexity of the technology and managerial skill required for successful farming. This increases the costs of production, presents financial risk, and puts more strain on the environment and fish. Thus, successful intensification is a long and difficult process that increases risk and costs.



STOCKING DENSITIES AND CONFINEMENT

STOCKING DENSITIES SHOULD BE DECREASED TO LEVELS THAT DO NOT COMPROMISE THE FISHES' SOCIAL BEHAVIOR OR PHYSIOLOGICAL CONDITIONS

- Stocking density becomes a welfare issue when farmers make productivity their goal without giving regard to the welfare of their fish.

- Stocking density has been reported to affect fish survival, growth, health, and yield, as well as water quality, parasites and diseases, handling, social stress, and transport.[158]
- The selection of proper stocking densities should be science-based.
- Use gates and filters to avoid other fish species' larvae entering the system through water in-flow.
- Stocking density at the beginning of the production cycle must account for the growth of the fish up until commercial weight.
- Under standard stocking densities (usually 10000 fish/ha), use biofloc technology to adjust the ratio of carbon:nitrogen, increase feed availability, and improve water quality.
- Stock fish with similar sizes. Disparate sizes affect their social hierarchy, increasing social stress and decreasing food availability for smaller fish.
- Prepare tanks in advance according to proper biosecurity management standards. Clean ponds before stocking to avoid loss of space due to structures inside the system and calculate the density accordingly.
- Overcrowding and confinement during handling for management purposes such as transport or vaccination are stressful (perhaps especially so for non-social species). Such constraints should be imposed for the minimum feasible time.
- If possible, ensure the stocking of certified seeds/fingerlings to avoid diseases, mortality, and water quality deterioration (see information about good/poor seeds below[159]).

GOOD QUALITY SEEDS	POOR QUALITY SEEDS
Normal anatomy structure with no marks on body and gills	Abnormal body structure
Agile in movement	Erratic movements and moves with current
Head moves quickly when the tail is pinched	Head moves slowly when the tail is pinched
The color of the body is bright and glossy, and the scales are slippery	Dull body color and rough scales
No marks on body and gills	Red marks on body and gills

USE AVAILABLE RESEARCH ABOUT STOCKING DENSITIES THAT ENSURE GOOD WELFARE

- Information concerning the correct stocking densities for both catla and rohu lacks a consensus. There is no proven scientific data that has determined the best stocking densities to avoid compromising welfare, but some additional information has been reported:
    - In pens, it was demonstrated that stocking densities of 11.5 fry/m2 were better for growth, survival, and yield in a polyculture of catla and rohu in the ratio of 1:1.[160]
    - In Andhra Pradesh, farmers culture catla and rohu fingerlings stocked at 8,000-10,000/ha at a ratio of 1 catla:10 rohu. Sometimes snakeheads (*Channa striata*) are stocked together at 500 fish/ha to decrease the impact of dead fish and insect pests in ponds,[161] but no information is available concerning the welfare of this species.
    - From our farm visits, it seems that 5000 to 7500 fish per hectare are normal stocking densities for catla and rohu.
    - In West Bengal and few other states, six-species stocking is normal. The ratio comprises 30-40% surface feeders, silver carp, and catla; 30-35% column feeders, rohu, and grass carp; and 30-40% bottom feeders, common carp, and mrigal. This ratio is also used to more efficiently use different niches in the pond ecosystem.
    - Stunt fingerlings in their first year, if restocked at lower densities in grow-out ponds, may exhibit remarkable compensatory growth and grow to market size within a year.[162]

REMARKS

Stocking density influences fish health and welfare at all lifecycle stages and interacts with other welfare parameters such as “Water Quality,” “Parasites and Diseases,” and “Feeding and Nutrition.” The stress of high stocking density and confinement can manifest in increased susceptibility to disease. Due to the wide variety of fishes raised in different aquaculture systems, optimal stocking density depends very much on their species-specific needs. Excessive stocking density can impose significant welfare risks, including the deterioration of water quality, higher rates of fin damage and other injuries, increased aggression, changes in behavioral patterns such as reducing feed intake, and a greater susceptibility to infectious disease.

Fish Welfare Initiative believes stocking density to be a middlingly promising ask. This is because stocking density is one welfare constraint that, theoretically, farmers can more easily mitigate. We advocate that the chosen stocking density remain below the maximum carrying capacity of the farming system, as the primary concern **should always be keeping an acceptable density regarding fish welfare**. It is acknowledged that species’ space requirements depend on the life stage. Within this framework, we understand that proper regulation and enforcement policies should be created to limit the densities used in different farming systems and life stages.[163]

HANDLING PRACTICES

ALL STAFF RESPONSIBLE FOR THE HANDLING OF FISH MUST CONSIDER ITS IMPACT ON THE WELFARE OF THE FISH

- Prior to handling, the health and welfare status of the fish should be assessed to ensure that they can withstand the rigors and stress of handling.
- The operator needs to be aware of critical points in the handling procedure, as well as apply corrective measures and indicate when to discontinue handling in order to safeguard fish welfare.
- The procedures should include contingency planning for unforeseen events that may have an impact on handling.
- All staff and operators need to be trained for the procedures, as well as given proper knowledge and practical experience, including information about the specificities of the species.

PREVENT STRESSFUL CONDITIONS AND CONSIDER THE HETEROGENEOUS ABILITY OF INDIVIDUALS TO COPE WITH STRESS[164]

- Monitor abnormal behaviors like erratic swimming, rubbing lips on the tank wall, rocking from side to side, or swimming off-balance, and act accordingly, i.e., deploy them in the stock or recovery tank.
- Handle with care and maximum efficiency to decrease the impact of any routine procedure.

USE BEST MANAGEMENT PROCEDURES TO AVOID INJURIES, DISEASES, AND MORTALITY

- Clean fish handling equipment thoroughly after each use. Rinse the equipment in clean water or use disinfectant, wash afterwards, and briefly dry it in the sun. This preserves the equipment and minimizes the spread of fish diseases.
- Avoid handling fish out of the species' lower and upper temperature limits.
- The water quality, especially oxygen levels, should be monitored and kept within acceptable limits.
- Avoid the re-use of materials and equipment from one culture area to another, e.g., nets used for fingerlings should not be used for adults and vice versa.
- Use proper nets and equipment. For example, use seines and dip nets manufactured from the softest netting material possible to minimize abrasion, or nets with canvas appropriate for broodstock fish handling.[165]
- Check the tubs, buckets, dip nets, and any other handling equipment periodically to ensure that there are no sharp edges or corners that may injure fish.
- Efforts should be made to keep fish in water during all moving stages (e.g., using pipes and pumps).
- Use proper stocking densities according to the handling equipment/material, e.g., tubs or transport tanks, to avoid lesions that can later become infections.
- De-water the tank (to levels that do not increase density to harmful levels) to improve the effectiveness of the fish capture and handling.[166]
- Avoid loud noises during handling.
- Grading should be executed by skilled personnel, taking welfare parameters into account.

AVOID LIVE TRANSPORT

- Always avoid the transport of live fish. If avoidance is impossible, allow the fish enough time to recover after transport.
- Move fish to their next location as quickly as possible; store tubs and buckets in good conditions. The period in which fish are kept crowded should be as short as possible.
- Acclimatize fish after transportation for approximately 15 minutes prior to releasing them in the destination tank. When putting the fish into a pond, equalize the water temperature in the transfer container (plastic bag, bucket, etc.) with that of the pond water by mixing the water of the tank and container. This procedure also equalizes any existing water chemistry differences.

USE PROPHYLACTIC MEASURES TO REDUCE STRESS AND IMPROVE WELFARE

- Use supplemented feeds with stress inhibitors (e.g., tryptophan or/and natural immunostimulants).[167] More research is needed for both catla and rohu, but promising results in other species have been found.[168]
- Do not feed fish 24-48 h prior to moving them.[169] 48 hours should be long enough for fish to empty their gut. Any longer can constitute its own welfare concern.
- Apply anesthetics or analgesics after handling to reduce stress on a case-by-case basis. Apply analgesics only upon a veterinarian's recommendation that they will significantly reduce the pain and stress caused by handling.

REMARKS

Handling procedures are part of the daily routine on a carp farm. Sampling, grading, sorting, inducing reproduction, and vaccination are a few routine handling procedures. If not properly planned and managed, these routines can significantly affect welfare (even leading to mortalities). Similar to stocking densities, better handling management is theoretically easy to enforce and requires relatively low investment. Examples include cleaning and disinfecting equipment, adjusting equipment to the life stage of the fish, planning for handling to occur during lower temperatures, and ensuring that handling takes the minimum time possible. These procedures reduce the daily impact on fish welfare by preventing cross-contamination and avoiding the unnecessary handling or crowding of fish. Following procedure safeguards against biosecurity issues, health problems and external injuries, and the degradation of the environment, ultimately improving fish welfare.

Apart from anesthetics or immunostimulant feeds (which are more expensive) to increase stress resilience, training for best handling practices is the best option for reducing handling welfare infringements. Improvements in handling will reduce the acute stress that fish are subjected to on a daily basis, but handling affects fish for smaller amounts of time than other welfare constraints. We see ourselves, therefore, working towards knowledge sharing rather than operating directly in enforcement, as other welfare asks are more promising for impacting fish lives.

DISEASE & PARASITES

ENSURE THE USE OF OPERATIONAL WELFARE INDICATORS TO AVOID DISEASE OUTBREAKS AND TREAT FISH AS SOON AS POSSIBLE

- Regularly monitor the system and fish to identify potential problems early and prevent the development of full-scale disease or parasite outbreaks.
- Make a proper assessment of fish stock through analysis of behavioral or visual alterations (examples below):[170]
    - loss of balance, swims in erratic manner
    - feeding is reduced or even stopped
    - swims alongside the current
    - ulcerations
    - abdominal distension
    - inflammation
    - operculum covered by white spores
    - shoaling at the surface
    - gill color changes
    - red/black/white marks on body of fish
    - body becomes rough and loses shine due to mucus over-secretion
    - fish rubs its body against the walls or bottom of the tank/pond, cages, or nets
    - exophthalmia
- Monitor for mortality. Remove and examine dead fish as soon as possible.
- Remove disease vectors and intermediate hosts using best management practices.
- Develop and improve channels to services for disease identification and treatment.

ADOPT PREVENTATIVE PRACTICES

- Preventive measures are necessary to maintain fish health. These measures include the maintenance of good water quality, vaccination, proper feeds, and the adjusting of stocking densities to the carrying capacity of the system.
- Dry and disinfect the pond or tank after each culture cycle.
- Maintain good farming system sanitation.
- Safeguard the water's physical and chemical composition, e.g., DO, temperature, salinity, pH, ammonia, turbidity, etc.
- Apply lime to the pond soil as a disease preventive, even if it is not needed to correct soil pH or water alkalinity.
- In ponds, increase the fertilization if natural productivity is low, or decrease if signaled as responsible for the disease.
- In cages, the site selection for housing the system is important to avoid stagnated waters and ensure adequate currents to permit a good water exchange.
- Keep the pond clean and free of weeds.
- Quarantine fish that exhibit erratic behavior or unusual appearances.
- Always handle fish carefully and only when necessary.
- Maintain a regular, nutritionally balanced feeding schedule and avoid overfeeding.
- Supply fish with proper feeds and, if possible, supplement with additives (see "Feeding and Nutrition").[174]
- Properly quarantine new fish before stocking,[175] as their health status is unknown.

- Aerate the system water to improve DO, remove ammonia, and release toxic gas from the mud at the pond's bottom.
- Avoid feeding fish with spoiled feed or low-level feed quality.
- When possible, adjust stocking density to provide fish adequate space, as densely packed groups of fish might be more easily detected by parasites. Alternatively, give fish the option to access divergent spatial environmental conditions,[171] such as temperature, to avoid parasites, infected conspecifics, or sick prey.[172]

ACT APPROPRIATELY AT THE FIRST SIGNS OF PATHOLOGY

- In the case of a disease outbreak, either use a properly isolated facility for disease diagnosis, or remove affected fish and transfer them to a disease diagnostic laboratory.[173]
- Enforce strong biosecurity and integrated disease outbreak management protocols.
- Bacterial, fungal, viral, and parasitic diseases must be treated if the fish is already affected. Apart from best management practices, drugs and medicines such as NaCl, Formalin baths, or KMnO4 can be used. The list of approved medicines (antimicrobials, disinfectants, and anti-parasitic drugs) is given here, along with recommended dose and dosage.
- Follow guidelines and regulatory measures for the use of chemical therapeutics, drugs, and chemicals.
- Avoid indiscriminate use of medicines during disease outbreaks. Access to expert opinion may be necessary.
- Drain the tank when the disease is too severe (e.g., Argulosis).

ADDITIONAL MEASURES THAT IMPROVE HEALTH AND WELFARE SECURITY

- Develop and follow appropriate biosecurity plans.
- Develop guidelines and regulatory measures for the use of therapeutics, drugs, and chemicals.
- Build farmers' coalitions to increase access to proper medicines and vaccines at lower prices (as discussed above in Section 2).
- It is recommended that the fish farm operatives who are responsible for farmed fish are trained in best management practices.[176]
- Provide vaccination to avoid further diseases at a later stage.
- Use only certified fry or fingerlings obtained from a reputable source, and safeguard the fish and the system.
- Ensure a good broodstock quality and secure quality fry by using only "certified" eggs.

REMARKS

Pathogens and parasites are a prevalent welfare issue for fish. They are responsible for around 50% of production loss, which is more severe in low or middle income countries due to a lack of diagnosis centers.[177] Fish diseases usually result from exposure to excessive stress (either due to their environment or to poor management practices), which leads to allostatic overload and chronically stressed fish. Constant challenges to health and welfare alongside an abundance of pathogens and parasites present in the culture system make fish more prone to infection.

Fish Welfare Initiative acknowledges that to overcome this prevalent issue, it is necessary to react to health constraints in ways that are scientifically proven and recommended, as well as locally applicable. The unavailability of approved vaccines as immunoprophylactic measures[178, 179] and approved veterinary medicines remains an issue.[180] We therefore prioritize other preventive measures. We advise focusing on preventing pathologies rather than treating them (as well as preventing the use of chemotherapeutants). This requires holistic improvements in welfare and management practice. Any single change will be unsuccessful alone.

Improvements in water quality can play a major role in mitigating disease and parasite risk, but only in combination with improved husbandry/management practices, biosecurity measures, and feed enhancement will they reduce chronic stress. Fish Welfare Initiative will continue to shed light on the important connection between fish welfare and biosecurity.

BREEDING & GENETIC SELECTION

SAFEGUARD THE WELFARE OF “IMPROVED” SPECIES

- The domestication of breeding species must be supported by scientific research.
- A long-term assessment of the suitability of the selected/hybrid fish needs to be set forth (including during the different life stages and farming systems).
- Genetic “improvements” for desired traits (e.g., fast and efficient growth, enhanced nutritive value, disease resistance, and product quality) must be researched in the context of each species’ specificities. (Normally, traits of interest are not tested on individual species, and thus genetic relationships have not yet been determined. This can lead to unintended negative welfare effects, such as increased growth speeds that make a species more prone to disease.)
- "Improvements” need to safeguard the welfare of both fish and environment.
- Train local staff in quantitative genetics and animal breeding.

AFTER SPECIES SELECTION, BREEDING PROGRAMS MUST BE WELL STRUCTURED

- Keep proper records of stocks to avoid inbreeding and the consequent development of disorders and deformities in young fish.
- Optimize breeding designs and genomic tools for improving the accuracy of selection.
- Disseminate the improved stock to other farmers to ensure better welfare for future fish stocks.

IMPROVE LEGAL AND/OR BIOLOGICAL PROTECTION MEASURES AND ENSURE FURTHER RESEARCH AND DEVELOPMENT WORK

- The production of all-female populations to decrease intra-specific aggression and avoid cross-breeding between farmed and wild populations must undergo more targeted research into its welfare implications, as it infringes the principles of the five freedoms of animal welfare.[181]
- Similarly, the production of all-male populations using triploid, i.e., functionally sterile, fishes should be avoided, as evidence that they are more prone to development disorders and sensitive to challenging environments has emerged.

REMARKS

Genetic selection programs are becoming more common in aquaculture. This technology may create a welfare gap, as it pushes the animals to their biological limits.[182] Although genetically altered fish are able to tolerate harsh conditions, this does not necessarily mean that they are less sensitive to negative welfare effects. Researchers and industry still fail to recognize and adequately address the welfare gaps for genetically and biologically modified fish. This cautioning is not to imply, however, that this technology should be abandoned, or that we should revert back to historic farming methods. Rather, Fish Welfare Initiative wants to see stakeholders use science and technology for the betterment of the animals' welfare and, moving forward, to develop systems that enable the fish to reach higher levels of welfare instead of a resilience to mortality alone.

Nevertheless, more research on Indian major carp is needed before genetic selection can fall within the scope of Fish Welfare Initiative's work. Breeding selection is not yet, in our understanding, a promising welfare intervention, despite its success in increasing fishes' ability to deal with the stressors of aquaculture. To become a promising ask for our work, there must be rigorous research and increased access to technology that is not currently available on most farms.[183] This would require collaboration with universities or research institutes, which is difficult for small to mid-scale farmers to achieve and for Fish Welfare Initiative to scale up.

SOCIAL STRESS

ADOPT MEASURES TO MITIGATE SOCIAL STRESS

- Include environmental enrichment, e.g., shelters, bottom layers, substrate, ropes, etc., whenever possible to increase the fishes' feelings of control over their environment and their facilitate places to escape from social group dynamics.
- Ensure that the selection of polyculture species accounts for their trophic level.[184]
- Feed pellets should float for catla and sink slowly for rohu. Alternatively, use self-feeders.
- Carry out proper size screenings and grading management procedures.[185]
- Provide enough food to ensure feeding opportunities for all fish.
- When supplying feed, split into two rations delayed by 20 min. The proactive and dominant fish eat during the first round, and the subordinate and reactive fish eat during the second round. (Feeding catla between 6 to 9 am seems the most promising.)
- Decrease stocking density to allow fish to exhibit their behavioral repertoire and avoid changing the group dynamic.
- After handling (often accompanied by anesthetics or vaccination), give fish time to recover in an isolated tank (in order to avoid aggression towards the debilitated fish).
- Avoid the presence and proximity of predators that can greatly stress the fish.
- Provide adequate resources to avoid the establishment of social hierarchies.

REMARKS

Fish have a complex relationships between stress and social behaviors. Social activities such as fight and flight, aggression, shoaling cohesion, and food intake can give farmers insight about the condition of their cultured fish. The relationship between stress coping and sociality is, therefore, of interest here.

The establishment of a social hierarchy, wherein the dominant fish have control over both the environment and the subordinate's behavior, has welfare repercussions. Two distinct stress response patterns (reflected in both behavioral and neuro-endocrine profiles)[186] have been widely described in the literature: proactive (active and dominant traits) and reactive (passive and submissive traits). Behaviorally, proactive individuals are more aggressive, more bold when facing potential danger or exploring novel environments, and have a tendency to develop rigid learned routines. Hence, they have a lower sensitivity to environmental stressors. They also often recover faster from stressful situations, and have higher growth rates and higher reproductive success. Reactive coping (shy fish) relates to submissive behavior and lower reactivity to social confrontation. They are, however, more flexible to changes in the environment due to lower noradrenaline and adrenaline releases under challenging situations. Reactive individuals have higher neural plasticity, longer life spans, and more robust hormonal regulation. Understanding such traits allows farmers to understand the social behavior of their fish and the strategies to decrease the impact of the established social hierarchy. Social stress is, however, usually hard to identify in fish ponds or cages (if not using video tracking, which is highly costly and ineffective in murky waters). Still, using simple preventative strategies like better feeding management, more space, and environmental enrichment may decrease the social stress of the fish population.

Fish Welfare Initiative aims to work with the polyculture of catla and rohu, which have different ecological niches. Since catla eat from the surface and rohu from the water column, competition is not a prevalent issue for these species.[187] Available research concerning the social welfare of these species is scarce, but the few indications we do have suggest that intra-specific competition is low and does not affect growth performance,[188] leaving us with little to say concerning social stress in these species. Promoting awareness for better feeding strategies, stocking densities, and predator fences will likely reduce social stress, and is something that we can advocate for through knowledge-sharing.

PREDATORS

DESIGN MANAGEMENT PRACTICES TO PREVENT THE PRESENCE OF PREDATORS

- Use non-lethal control methods for predators, such as physical separation.
- Add a netting system both above and under the water for land predators.
- Adopt visual devices (e.g., decoys and flares) to deceive predators.
- Stretch nets over ponds to keep birds out.
- Keep grass on watercourse ditches and cut the grass around tanks/ponds.
- Install covered hapas in the ponds for rearing smaller fish such as catla and rohu fry.
- Construct a low barrier around ponds to keep small land animals out.
- Fish ponds used for fry production should be kept dry while not in use to prevent predatory insects.
- When possible, the water should be filtered through a strong sieve/screen to prevent the entering of unwanted fish species, i.e., potential predators.

REMARKS

Fish in pond environments and sea pens are vulnerable to predation. However, carp have been found to be “able to detect the scent of predators and, from the scent of their faeces, to recognise what species of fish the predator has… eaten, and therefore how much of a risk it poses.”[189] This suite of anti-predator responses is extremely valuable for wild carp. However, for their farmed counterparts, experiencing a barrage of predators in confined conditions can easily lead to allostatic overload. On-growing catla and rohu are especially vulnerable to predation due to their large size. The presence of fish-eating birds, seals, mink, and otters can cause fear, stress, trauma, and death.

Protection from predators can help to safeguard animal welfare and farm productivity. As stated previously, the primary means of protecting fish should be through physical exclusion, e.g., nets, seal curtains, and screens, where the welfare of both fish and predator can be safeguarded. For instance, net mesh should be sized to ensure that birds do not get trapped. Fish Welfare Initiative sees preventing predation as a moderately promising welfare improvement, as there are simple methods to reduce its impact. However, predation ultimately impacts far fewer fish than other welfare issues. We encourage producers to use physical separation to prevent predation, and we will continue to promote that both fish and predators deserve protection.

TRANSPORT

CONDUCT AN INSPECTION OF THE FISH PRIOR TO TRANSPORTING

- Assess signals of diseases (e.g., red spot disease, skin parasites), abnormal behavior (e.g., abnormal swimming), and significant injuries (e.g., skin lesions). Avoid transportation in any of these cases.

ENSURE PROPER FASTING AND STARVATION PRIOR TO AND DURING TRANSPORTATION

- Adjust fasting and starvation to the species' biological needs to empty the gut. (Cold water species tend to need three days, and warm water species such as catla and rohu need 1-2 days.[190])
- After fasting, feed should be returned only after a recovery period in the new stocking tanks. Levels of feed should be adjusted considering the level of stress, increasing as stress levels reduce, until the tabled baseline is reached.
- Use scientifically tested dietary supplements to enhance the immune system and improve stress tolerance (e.g., glucan, probiotics, ascorbic acid, carotenoids, herbal supplements, and tryptophan).[191] Give preference to natural compounds.

FOLLOW PROPER HANDLING PROCEDURES DURING LOADING, TRANSPORT, AND UNLOADING

- Please see the improvements for "Handling."
- Transport is a multiphase operation: collection, capture, transferring, and stocking in the transport containers, all of which must be done following best management practices to avoid acute or chronic stress.
- Use certified companies for live fish transport.
- Use proper containers for fish transport and follow all biosecurity measures (for a list of possible customized solutions to maintain fish welfare, see here).
- Keep transport time to a minimum, whether by plane, boat, truck, or train.
- Ensure vehicles have the proper systems in place, e.g., systems for oxygenation and compressed air.
- Guarantee that the handling, transport, and water parameters are adjusted to the species' specificities, the number of individuals transported, and the length of transport.
- Ensure the proper monitoring of conditions during transport, including water quality, adverse weather conditions, and emergencies.
- Use nets and tanks designed to minimize physical injury, and ensure that they are well maintained.
- Avoid handling without water. Use brail wet nets instead of brail dry nets.
- If using pumps for removing fish, e.g., using air lift, venturi, and vacuum pumps: maintain the pumps by checking for sharp bends and adjusting the pressure of the pump to ensure a smooth water flow inside. Avoid pumping fish for long periods.[192]
- Article 7.3.5 of OIE considers the conditions under which fishes should be unloaded, transferred, and loaded in order to minimize injury and stress.[193]

PROVIDE PROPER WATER QUALITY

- Ensure oxygen near saturation in the transport containers and avoid over-oxygenation due to CO_2 toxicity.
- Use reasonable stocking densities to avoid ammonia, organic matter and CO_2 issues, lesions, and wounds.

- Provide adequate water exchange whenever available.
- Ensure proper handling prior to transport to avoid increased metabolic activity, mucus production, and concomitant water deterioration.
- A variety of products can be added to the water to maintain water quality or alleviate the problems caused by waste (e.g., pH buffers, zeolites, AmQuel®, nitrifying bacteria, water conditioners, or anesthetics such as clove oil).[194]

ENSURE STANDARD BEST PRACTICES ARE FOLLOWED

- Transport issues such as vibration and noise should be kept to a minimum.
- Use lower temperatures to decrease fishes' metabolisms and avoid water deterioration.
- Light intensity and water flow must be administered according to the species' needs and stocking density.
- Personnel should be properly trained for the transportation of live fish.
- Reduce the transport of live fish to a minimum, as it negatively affects their welfare.
- Prepare emergency plans regarding fish welfare.
- Prepare transport according to the route plan, sea conditions, weather forecast, and the nature and duration of transport.
- Secure proper record-keeping, including all information for proper tracking.
- Enforce the OIE transport guidelines if this does not happen at a national level.
- If doubts about best practices during transport exist, read OIE recommendations for transport.[195]

RESEARCH AND DISSEMINATE SPECIFIC INFORMATION THAT MIGHT IMPROVE CATLA AND ROHU WELFARE PERFORMANCE

- Optimum packing density for Indian major carp fry is 100 fry L^{-1} during transport for up to 6 h.[196]
- Optimum packing density for rohu fingerlings for the duration of 2.5 h of transport would be 134 g L^{-1}, which keeps stress at low levels.[197]

REMARKS

OIE produced standards for the transportation of fish with the aim of reducing the effect of transport on their wellbeing. It defines responsibilities for the different parties involved and recommends trained staff, proper records, proper planning, and contingency plans. However, these are not mandatory guidelines, and there is a lack of proper national legislation/enforcement for the transport of live fish. In India, as with other Asian countries we have visited, fish are often sold live, meaning that these fish need to be transported to market. Fish are also transported between farms and farming systems as they grow. Fish can be transported by land, sea/lake/river, and air. Regardless of means, the transportation of fish can drastically impair welfare due to water quality deterioration and high stocking densities, which, ultimately, leads to high rates of mortality. The European Commission gathered information on current animal welfare practices in European aquaculture with regards to transport (and slaughter). Likely due to its resilience to mortality, common carp transport was found to have many shortcomings.[198]

In countries like India, where small to medium-scale farming is prevalent, most of the farmed fish are sold in local markets. When fish transported, it is often by land, whether by motorized land vehicle, train, or animal cart.[199] Almost any clean, waterproof container is used. Containers such as "cans of different sizes, pots of ceramic or metal, wooden or metal buckets, vats, barrels, plastic bags, styrofoam boxes, bottles, jugs, animal skins and bamboo sections[200]" are used for transport, some of which are not sealed or waterproof. This is a major welfare issue, as water loss means dropping oxygen levels, increased organic matter, and increased stocking density.

Juvenile fish may be successfully transported in oxygen-enriched sealed plastic bags (partly filled with water and atmospheric oxygen), which in turn are stored in insulated containers. This method, by itself, is not stress-free for fish. However, aligned with procedures like using optimum packing, decreasing temperature, reducing transport time to its minimum, following proper management practices during pre-transport stages, and proper fasting and starvation, it can be a practical way to transport fish. Similarly, these improvements can safeguard fish welfare for slaughter or when bringing breeding fish to new hatcheries. In this case, the continuous monitoring of dissolved oxygen and adding proper mechanisms for air and oxygen injection should also be included.

Improvements in transport do not appear cost-effective, as they will improve the fishes' lives for only a few minutes to hours, and the enforcement for better management practices is almost nonexistent.[201] This makes it difficult even for certification schemes, corporations, or retailers to enforce transportation requirements. We will passively promote better transportation through knowledge-sharing, but do not plan to enforce better practices.

SLAUGHTER

GUARANTEE FISH WELFARE DURING PRE-SLAUGHTER OPERATIONS

- See both the "Handling" and "Transport" tables for potential improvements during pre-slaughter operations that include both handling and transport of the fish.

APPLY IMPROVED SLAUGHTER AND STUNNING

- Develop proper standardized protocols with guidelines for the entire process of humane slaughter, including steps to check for consciousness and instructions for monitoring equipment compliance.
- Operations should be conducted with minimal injury and stress to the fish (for example, rendering fish unconscious and killing them before they regain consciousness).
- Avoid inhumane slaughter methods such as asphyxiation by air, being sold alive for home slaughter, live chilling in ice slurries without previous stunning, and carbon dioxide in water or ice slurry.[202]

- Operate the described humane slaughter, i.e., proper percussive and electrical stunning. If not available, consider the promotion of a coalition between farmers to acquire equipment to be shared.[203] Signs of correct stunning include:[204]

Loss of of opercular activity
Loss of visual evoked response
Loss of vestibulo-ocular reflex

- Ensure fish are killed before consciousness can be recovered through a suitable killing method, such as a gill cut, decapitation, or mechanical spiking or coring.
- Whenever possible, the handling system should be adjusted to the slaughter equipment, e.g., pumps and pipes for fish removal and transport.
- Ensure proper staff training regarding the equipment to be used.
- From time to time, veterinary authorities/certification bodies should ensure that fish are being stunned effectively through audits or inspections.
- Promote enforcement of OIE slaughter standards.

STAY UPDATED ABOUT ADVANCES IN HUMANE SLAUGHTER METHODS

- Be aware of newly-established stunning parameters, newly-developed equipment adjusted to the target species, new potential implementation and monitoring procedures, and the efficacy of the method (to be determined on-farm after laboratory environment validation). This involves different intervenients, manufactures, researchers, authorities, and producers.
    - As suggested for Europe, a reference center dedicated to developing humane fish slaughter, set up by the different stakeholders and using the OIE slaughter standards as template, could greatly facilitate this process.

USE CURRENT KNOWLEDGE AVAILABLE FOR THE TARGET SPECIES

- From the available research, and as recently described by Compassion in World Farming research, the most humane slaughter method for carp is:
    - An electrical stun, followed by a percussive blow, followed by a killing method such as decapitation.[205]
- An electrical stun followed directly by decapitation has also been reccomended.[206]
    - After decapitation, it is likely that brain activity continues. Thus, it may also be necessary to spike the head immediately after.[207]

REMARKS

Each fish species differs in morphology, and may therefore respond differently to any given slaughter method. Therefore, each species needs its own best practice to be established. While essential for good fish welfare, a rapid and humane death can also benefit producers, as lower stress is associated with better product quality. For both catla and rohu, there are not yet scientifically established humane slaughter procedures.

Improved on-farm slaughter is desperately needed to avoid substantial suffering for millions of fish produced every year. Governments and corporations should enforce the OIE guidelines for slaughter (after making them legally binding), and incentives should be given to farmers, as both percussive and electrical slaughter equipment is expensive. Especially in India, we hope to see clusters of farmers developing associations with nearby businesses to allow them to acquire second-hand equipment that can then be moved between farms, with research centers assisting by producing standards and reviewing practices. This is being done in the north of Italy, where small farmers from the Astro Association are actively searching for more humane trout slaughter methods as part of an ongoing project in collaboration with the Mach Institute research center.[208]

Stunning is perhaps the most important improvement for preventing acute suffering. It also likely has significant consumer support. However, there is a current lack of species-specific stunning parameters for both catla and rohu. Researching and validating the effective stunning parameters and systems could take a long time, and efforts may not produce usable results. There are also high up-front costs for electrical and percussive stunning equipment, which makes it difficult for small-scale farmers to invest without financial help (which would be very costly to provide at scale).

Adequate handling equipment for the effective stunning would increase the cost even more, and increase the duration of slaughter. Ultimately, we believe that the suffering involved, though extreme, is outweighed by the chronic suffering induced by other issues such as water quality. This, at least in part, comes down to individual epistemology, and so may be a point of difference between groups.

OTHER

INDIRECT MEASURES SHOULD BE ENDORSED

- Having trained staff and operators is a key requisite for ensuring fish welfare. They should maintain an extensive knowledge of the species' specificities, including:[209]
    - Methods for the inspection of fish.
    - Welfare indicators including fish behavior, physiology, the environment, and general signs of disease and poor welfare.
    - The operation and maintenance of equipment relevant to fish welfare.
    - Methods of live fish handling.
    - Methods for managing day-to-day situations (e.g., those frequently encountered during handling).
    - Methods for managing unpredicted events, including the design and implementation of contingency plans.
- The government needs to be active in promoting, regulating, and supporting aquaculture development, and suggest specific support and facilitating activities for the development and adoption of best management practices in aquaculture.[210]
- New bridges between farmers and research centers or non-governmental organizations need to be created for access to qualified and effective services (e.g., for water quality analysis).
- Proper electricity supply (which is commonly unavailable and charged at industrial rates).
- Feed companies need to establish efficient networks and strategies to make their products available at affordable prices to distant farmers.
- Climate change will threaten fish welfare. Use preventative measures to mitigate the impacts e.g., better use of feeding resources such as better feed efficiency, achievable only through adopting feed pellets instead of the conventionally used feed in India.[211]
- Certification schemes need to develop affordable certification for small-scale farmers.
- Researchers will need to continue to develop easy and validated methods to assess fish welfare, and make them available to all farmers through proper dissemination.
- There is a need for certified services that provide proper training in best aquaculture practices.
- New legislation with legally binding character needs to be created, nationally and internationally (using OIE standards as template).
- The enforcement of legislation should be endorsed.
- Measures should be adopted to secure the well-being of farmers (economically and socially) so they are able to also improve fish welfare (e.g., ensuring access to proper markets). Farmer wellbeing is directly correlated with animal welfare.
- The integration of animal welfare as part of general livelihood improvement programs is an important part of reducing poverty and increasing local community support.

REMARKS

Only a concerted effort between all the carp aquaculture value chain actors can safeguard fish welfare and the sustainability of the environment. The gap between research outputs and common practice is still large, and closing it will require a broad array of projects, from dispersing information, to training, to enforcing current standards. There is also a need for more research aimed at understanding fish welfare needs, rather than focusing solely on productivity.

3.4. PROMISING WELFARE IMPROVEMENT FOR CATLA AND ROHU IN INDIA

Fish Welfare Initiative works to achieve the most it can for fish welfare. To do so, it is necessary for us to prioritize some welfare improvements in order to focus our resources toward those with the largest positive impact for fish. Having considered the specific context of our work within India for Indian major carp, we believe that water quality is the most important improvement for us to focus on and test. This is largely due to its large impact on fish wellbeing and tractability. This, however, is specific to our planned work in India for our priority species. A large factor in considering water quality as a welfare ask is the current water quality standards in the country of implementation.

Water quality is frequently cited as crucial for farmed fish welfare.[212, 213, 214, 215] Data from our survey indicates that this is also true for Indian major carp. This is, in part, due to how water quality improvements synergize with other welfare asks, such as "Feeding and Nutrition," "Diseases and Parasites," "Stocking Density," "Social Stress," "Handling," and "Transportation" (Fig. 14). As such, water quality provides holistic benefits, improving multiple facets of farmed fish life.

Behavioral, biological, and immunological stress responses are all dramatically affected by water quality. Intuitively, this makes sense, as fish are in constant contact with water through their skin and gills. Poor water quality affects fish similarly to how a less hospitable atmosphere would affect humans.

Water quality improvements are also fairly tractable relative to other welfare asks. An aerator for a fish pond costs, on average, 280 USD. A water quality parameter sensor costs, on average, 1500 USD. These two pieces of equipment would allow both an improvement in water quality and the proper monitoring of water quality, respectively, without needing any qualifications or technical skills. This is also something that aligns well with producers' wants, as it is understood that adequate water quality decreases mortalities and stimulates fish growth.

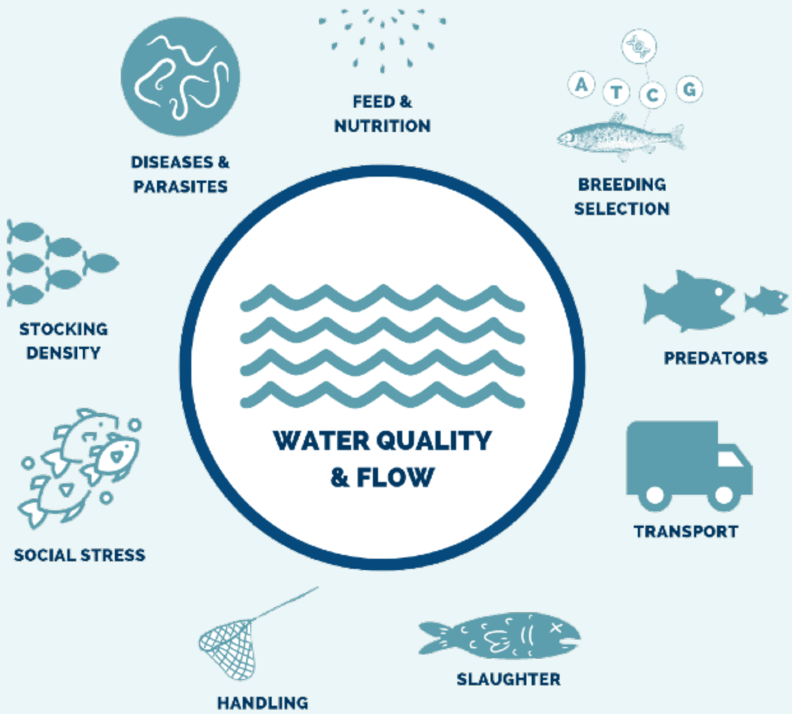


Figure 14. Synergies between water quality and flow with other welfare issues.

However, water quality improvements will need to be addressed case-by-case, as what is optimal for one species, production site, or farming system may not be for others, and proper research will need to be done in the local context to determine the optimal conditions. Apart from that, other challenges may arise during the intervention. For example, increasing water quality will also increase the carrying capacity of a farming system.

Farmers can exploit this increase and input more fish into the system, returning water quality to its previous levels, but with more fish now experiencing these poor conditions. To prevent this, Fish Welfare Initiative will likely need to build its broad strategy with this in mind. For example, we may need to incorporate a stocking density ask, or focus on a certification scheme that we believe adequately addresses this issue. We hope that farmers will understand that improving the carrying capacity of their system should not prompt an increase in the number of fish to be produced. Producing more fish also requires upgrading the complexity of technology and managerial skill, which not only increases the costs of production but also the risks for farmers, the fish, and the environment. It should also be noted that increasing carrying capacity is an issue for many welfare improvements.

Water quality, as such, stands as our preliminary conclusion. However, it is impossible to fully appreciate the reality of production through secondary research and informal country visits. As a result, much of our early field-work will act as a test into the viability and impact of water quality as our long-term focus. We will carefully monitor our effect on fish welfare, stocking densities, and farmer wellbeing, and we will stay open to pivoting if we believe water quality to no longer be promising. However, for its large direct impact on fish welfare and relative tractability, we believe that water quality stands as the most promising candidate for a cost-effective welfare ask for Indian major carp.

REFERENCES

116 Department of Animal Husbandry and Dairying. (2017). Annual Report 2016-2017.

117 FAO. (2016). FishStatJ.

118 Cerqueira, M., King-Nobles, H., Kirsch, J., & Raghavan, K. (2020). Fish Welfare Scoping Report: India.

119 FAO. (2016). FishStatJ.

120 More information below in Table 11.

121 FAO. (2016). FishStatJ.

122 Cerqueira, M., King-Nobles, H., Kirsch, J., & Raghavan, K. (2020). Fish Welfare Scoping Report: India.

123 Successful means that farmers were available to answer our survey. Unsuccessful means that the visit occurred without guidance or farmers available to answer the survey.

124 Our categorization of the surveyed farms is based on both the low stocking densities and low value chain reported, e.g., selling fish to local markets. (Oswald & Milolasek, 2016). The fish farming sector in sub-Saharan Africa.

125 Cerqueira, M., King-Nobles, H., Kirsch, J., & Raghavan, K. (2020). Fish Welfare Scoping Report: India.

126 Billington, T. & Cerqueira, M. (2020). Prioritizing Fish Species for Effective Welfare Improvements.

127 Catla Priority Species Report.

128 Rohu Priority Species Report.

129 Bias, B. (2018). Fish scenario in India with emphasis on Indian major carps.

130 Hasan, M. & New, M. (2013). On-farm feeding and feed management in aquaculture.

131 Ramakrishna, R. et al. (2013). Feeding and feed management of Indian major carps in Andhra Pradesh, India.

132 De Silva, S. and Hasan, M. (2007). Feeds and fertilizers: the key to long-term sustainability of Asian Aquaculture.

133 Hecht, T. (2007). Review of feeds and fertilizers for sustainable aquaculture development in sub-Saharan Africa.

134 Billington, T. & Cerqueira, M. (2020). Prioritizing Fish Species for Effective Welfare Improvements.

135 These species are usually produced in polyculture, and improvements consider both species' welfare specificities.

136 References are presented when given examples. Comprehensive references are given upon request.

137 Tacon, A. & Hasan, M. (2007). Global synthesis of feed and nutrients for sustainable aquaculture.

138 More information about commonly used manures or fertilizers here.

139 Top coating the feed pellets with a special binder such as TOPGEL® (PROVIMI-VETCARE) has interesting applications in fish medicated feeds.

140 Hasan, M. & New, M. (2013). On-farm feeding and feed management in aquaculture.

141 On many farms, limited access to extruded feeds means these are stored for long periods. This period should be reduced to minimize nutrient loss, feed spoilage and environmental impact.

142 See this recent review about the inclusion of beneficial additives in the daily meal in order to mitigate the stress response to typical aquaculture stressors by (Herrera, Mancera, & Costas, 2019).

143 Nandeesha, M. C. et al. (2013). Feed management of major carps in India.

144 Ramakrishna, R., Shipton, T. A., & Hasan, M. R. (2013). Feeding and feed management of Indian major carps in Andhra Pradesh, India.

145 Between rice bran, Miracle, and Tokyo commercial feeds, the latter has shown to improve growth performance and most likely welfare (though more research is needed) (Ahmed et al., 2012).

146 For successful examples developed by farmers in Andhra Pradesh, see Ramakrishna, R., Shipton, T. A., & Hasan, M. R. (2013). Feeding and feed management of Indian major carps in Andhra Pradesh, India.

147 Farmers use demand bag feeding in Andhra Pradesh with some advantages of its use. See Ramakrishna, R., Shipton, T. A., & Hasan, M. R. (2013). Feeding and feed management of Indian major carps in Andhra Pradesh, India.

148 For a list of chemicals and their formulations for water quality maintenance, see: Mishra, S. S. et al. (2017). Status Of Aqua-Medicines, Drugs And Chemicals Use In India: A Survey Report.

149 Ngugi, C. C. et al. (2007). A new guide to fish farming in Kenya.

150 FAO (1992). Fish Production With Polyculture.

151 Woynarovich, A. et al. (2011). Better Management Practices For Carp Production In Central And Eastern Europe, The Caucasus And Central Asia.

152 Maucieri, C. et al. (2019). Effect of stocking density of fish on water quality and growth performance.

153 Emerenciano, M. et al. (2017). Biofloc Technology (BFT): A Tool for Water Quality Management in Aquaculture.

154 In Odisha, India, the government provides a 40% entrepreneurial subsidy to set up biofloc systems (The Fish Site, 2020).

155 It was suggested here that a paddle wheel aerator is capable of elevating the dissolved oxygen

level from 0.05 to 4.9 mg/l within 4 hours in 0.5 ha.

156 For more information on pond management, see Kerala Agricultural University's infotech portal.

157 Collis, W. J. et al. (2011). Training Manual on Improved Carp/Carp-Shing Poly Culture in Pond and Dyke Cropping.

158 Baldwin, L. (2011). The effects of stocking density on fish welfare.

159 Collis, W. J. et al. (2011). Training Manual on Improved Carp/Carp-Shing Poly Culture in Pond and Dyke Cropping.

160 Mane, A. et al. (2017). Effect of Stocking Density on the Growth, Survival and Yield of Carp.

161 Mohanakumaran Nair, C. & Salin, K.R. (2007). Carp polyculture in India.

162 Shivananda, M. H. (2002). A review of Indian major carp species.

163 For salmon, maximum stocking densities have been set by assurance standards, industry codes of practice, and legislation that may potentially benefit welfare, but there are few policies for these standards' enforcement.

164 Volstorf, J. (2019). Cyprinus carpio (Recommendations).

165 In broodstock handling for milking, for instance, using a net with canvas allows fish to maintain water during transportation and the sperm collection process.

166 Fish can be trained to associate lower water levels to an aversive event giving the possibility to prepare themselves behaviorally and physiologically to reduce their stress response (see here, here and here).

167 This can be sourced from companies like Sparos I&D.

168 In seabream, tryptophan was shown to decrease stress and immunity and in common carp, fructo-oligosaccharide increased stress resistance (Cerqueira et al., 2020 & (Hoseinifar et al., 2014).

169 Fish should be starved to empty the gut prior to harvest to ensure proper hygiene in further processing, i.e., good water quality with less ammonia; and starvation decreases physical activity, hierarchy formation, and stress (Waagbø et al., 2017).

170 Islam, M. M. et al. (2011). Training Manual On Household Based Pond Aquaculture, Homestead Gardening And Nutrition Awareness.

171 Environmental enrichment promotes different salinities or temperatures to modulate the development of parasites or pathogens (Cerqueira et al., 2016).

172 Bui, S. et al., (2017). Behaviour in the toolbox to outsmart parasites and improve fish welfare.

173 The following are examples of suppliers of pathology expertise: Central Institute of Freshwater Aquaculture, India; Central Institute of Fisheries Education, Mumbai, India; College of Fisheries, Mangalore, India.

174 The list of certified, antibiotic-free aquaculture inputs was updated on 25th July 2020 by the Coastal Aquaculture Authority. See here.

175 Quarantine may range between 15 days to 3 months. (Jia et al., 2017).

176 FAO (n.d.). Code of Conduct for Responsible Fisheries - Article 9: Aquaculture Development.

177 Assefa, A. & Abunna, F. (2017). Maintenance of Fish Health in Aquaculture.

178 Ibid.

179 For a list of available vaccines for carp and other species diseases, see Assefa, A. & Abunna, F. (2017). Maintenance of Fish Health in Aquaculture.

180 Associations of farmers can overcome this issue to some extent by creating the proper channels to increase access to them.

181 Cerqueira, M., & Billington, T. (2020). Defining Welfare For Fish.

182 Welfare gap refers to the gap between a fish's sensitivity to negative stimuli and their resilience to dying from that stimuli.

183 Genomic information of the fish species and equipment to assess the viability of the crossed fish species' biological material is needed.

184 The general recommendation is to use 4:2:3:1 ratios of surface feeders, columnar feeders, bottom feeders, and macrophyte feeders, respectively (Murthy, 2002).

185 Screening for coping styles is a tool to advance welfare and refine fish population resilience. There is not yet research on our species concerning group-based screening methods. For examples of screening for the number of dominant and subordinate fish in a given population see here and here.

186 Cerqueira, M. (2016). Linking Personality And Appraisal Modulators In Fish.

187 Siddiquee, M. M. R. et al. (2012). Impact of Exotic Carps in the Polyculture with Indigenous Carps: Competition for Food.

188 Alim, M. A., Wahab, M. A., & Milstein, A. (2005). Effects of increasing the stocking density of large carps by 20% on 'cash' carp–small fish polyculture of Bangladesh.

189 European Food Safety Authority. (2008). Animal Welfare Aspects Of Husbandry Systems For Farmed Fish: Carp.

190 Kondera, E. et al. (2015). Haematological and haematopoietic effects of feeding different diets and starvation in common carp.

191 Ibid.

192 Lines, J. & Spence, J. (2012). Safeguarding the welfare of farmed fish at harvest.

193 World Organisation for Animal Health (2019). Aquatic Animal Health Code - Chapter 7.3. Welfare Aspects Of Stunning And Killing Of Farmed Fish For Human Consumption.

194 Vanderzwalmen, M. et al. (2018). The use of feed and water additives for live fish transport.

195 World Organisation for Animal Health. (2019). Aquatic Animal Health Code Chapter 7.2 for welfare recommendations and Chapter 5.5 for health risks.

196 Chatterjee, N. et al. (2006). Secondary stress responses in Indian major carps Labeo rohita (Hamilton), Catla catla (Hamilton) and Cirrhinus mrigala (Hamilton) fry to increasing packing densities.

197 Pakhira, C. et al. (2015). Stress responses in rohu, Labeo rohita transported at different densities.

198 Shortcomings were found regarding the OIE standards for transport of fish, see (European Commission, 2017).

199 We are not disregarding other transportation means since all have inherent welfare-related issues for fish, but in the scope of this report we address land transportation in more detail. Nevertheless, much of what is discussed here also applies to transportation by air or boat.

200 The Fish Site. (2006). Transporting Fish.

201 Giménez-Candela, T. & Saraiva, J. L. (2020). The legal protection of farmed fish in Europe.

202 Boyland, N. (2018). The Welfare of Farmed Fish During Slaughter in the European Union.

203 Effective stunning needs to be established in controlled laboratory settings, e.g., the voltage and current required in electrical stunning according to the species shape, age, size.

204 According to the OIE Aquatic Animal Health Code.

205 Retter, K. et al. (2018). Stunning of common carp: Results from a field and a laboratory study.

206 European Commission. (2017). Welfare of farmed fish: Common practices during transport and at slaughter.

207 Lines, J. & Spence, J. (2014). Humane harvesting and slaughter of farmed fish.

208 The project is limited by the Coronavirus pandemic, but forecasted to commence in November 2020.

209 EU Platform on Animal Welfare Own-Initiative Group on Fish. (2020). Guidelines on Water Quality and Handling for the Welfare of Farmed Vertebrate Fish.

210 Giménez-Candela, T. & Saraiva, J. L. (2020). The legal protection of farmed fish in Europe.

211 Kirsch, J. (2020). Climate Change, Aquaculture, and Fish Welfare.

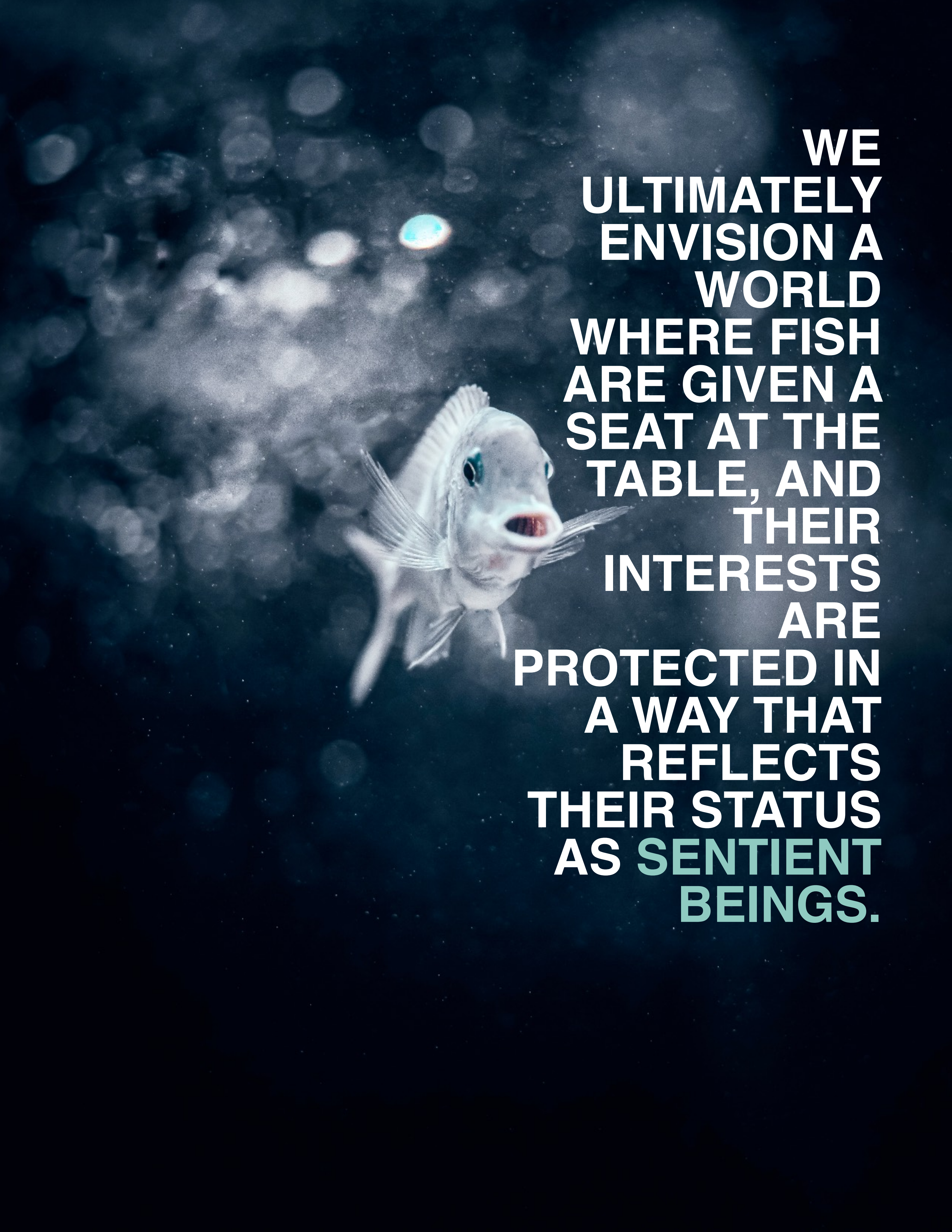
212 Sarek, K., Savoie, J., & Moss, D. (2019). Improving Environmental Conditions - A Summary.

213 Cooke, M. (2016). Animal Welfare in Farmed Fish.

214 Shoko, A. et al. (2014). A comparison of diurnal dynamics of water quality parameters in Nile tilapia.

215 Farm Animal Welfare Committee. (2014). Opinion on the Welfare of Farmed Fish.

216 Sen, A. (1987). The Standard of Living: The Tanner Lectures on Human Values.


WE ULTIMATELY ENVISION A WORLD WHERE FISH ARE GIVEN A SEAT AT THE TABLE, AND THEIR INTERESTS ARE PROTECTED IN A WAY THAT REFLECTS THEIR STATUS AS SENTIENT BEINGS.

4. CONCLUSION

FAO data shows a dramatic increase in aquaculture production over the last few decades. It also shows a heavy increase forecasted in the following decade. As such, fish welfare will continue to becoming an increasingly important global topic. The presence of diverse cultures, religions, and languages means that welfare improvements cannot be made homogenously across the globe. Instead, to achieve the UN Sustainable Development Goals in 2030, there must be further concerted efforts from each of these nations to establish better fish welfare practices. There have been many advances in fish welfare, whether through farming systems technology, increased knowledge of how to measure welfare with state-of-the-art tools, or a better understanding of fish welfare needs. These strategies must be made available to each country.

We have outlined three conditions necessary for stakeholders to properly address fish welfare:

1. **Broad contextual knowledge of fish welfare needs and common welfare issues.**

2. **Specific knowledge of the targeted species, farming systems, and life stages.**

3. **An assessment of the welfare (and welfare issues) of the fish being targeted.**

As the global population rises and aquaculture becomes progressively more entrenched, utilizing information on fish welfare will become increasingly more important.

Currently, much of the industry's focus is on fast profit growth and high yield.

IT IS IMPERATIVE THAT WE RECOGNIZE THE NEED FOR INCORPORATING WELFARE INTO AQUACULTURE MANAGEMENT, NOT ONLY FOR THE FISH INVOLVED, BUT ALSO TO SAFEGUARD THE ENVIRONMENT AND SOCIAL WELFARE.

The aquaculture sector is still in its infancy compared to other food sectors. This provides opportunities to positively direct its growth. Fish Welfare Initiative believes that there should be a multi-stakeholder effort to address fish welfare challenges in aquaculture production (including NGOs, producers, corporations, and governments). To ensure that the welfare of the fish is properly being addressed, these stakeholders must have access to each of the three conditions above (either by gaining information themselves or by involving groups who have expertise into their decision-making processes).

For Fish Welfare Initiative, meeting these conditions will mean a continued assessment of how our interventions are affecting welfare outcomes for fish in India. It will also mean using a combination of academic knowledge and the experience of producers to ensure that the context we work with is properly being accounted for. As of now, we believe that the most promising welfare improvement to focus on for our work is water quality.

The specific needs of our target species were addressed, and despite many water quality parameters being relevant to aquaculture production, only a few are essential for producers to control, due to their higher impact on fish welfare (and because they are interconnected with all the other related water quality parameters). These include dissolved oxygen, salinity, and pH. Issues such as a lack of outflow systems, high stocking densities, chemical and antibiotic misuse, and inadequate feed quality, among others, are the main concerns for such water quality parameters. There are various management practices that can significantly improve water quality, such as pond preparation and treatment (including disinfection or adding lime), proper aeration, feed quality control, proper chemical treatments, pond water treatment, and reduced stocking densities. Other procedures less costly from an economic standpoint, like water exchange and proper selection of the pond location, can also increase water quality. When possible, improvements in the farming systems alongside the use of proven technology should be enforced. This includes biofloc or aquaponic technology. However, these alterations are often challenging for farmers, as they may demand a major change in the adopted system. As such, incentives should be made available by the government to allow for these changes.

An integrated, systematic, and ongoing process to promote fish welfare in the aquatic food system impacts positive social and environmental change, and ensures better lives for billions of animals. Within this framework, we believe that the foundational questions and improvements described here are not only a moral and ethical obligation, but are also needed to decrease the pressure on our environment and support undernourished communities with new opportunities for social wealth.

We envision a world where fish are given a seat at the table, and their interests are protected in a way that reflects their status as sentient beings. Discussing fish sentience is beyond the scope of this report, but the fact that we do not fully understand fishes' welfare needs is not in itself a valid argument for neglecting such pressing issues. As once rhetorically asked by Amartya Sen in a different, but related, context: **"Why must we reject being vaguely right in favour of being precisely wrong?"**[216]

Every day, research is unlocking the mysteries of fishes true capabilities and how they are defying aquatic stereotypes. For many researchers, the question is no longer whether fish feel pain, fear, or sadness, but rather, which commonalities are shared by fish. This is an important change for fish welfare, and we hope it contributes to fish being given the same welfare considerations currently given to mammals.

4. FINAL NOTES

This report contains many resources that are intended to be useful for stakeholders to reference periodically, as and when they need to make decisions for the welfare of fish.

Here are some of the sections we would like to highlight:

SECTION 1

SECTION 2

SECTION 3

We hope that this report shows the promising opportunities to improve the welfare of fish in aquaculture, and that it will further demonstrate how improved welfare is a necessary component of a healthier, more sustainable, and more humane society.

We encourage any organization or industry interested in engaging with fish welfare to contact us. We are available to provide consulting and training in fish welfare improvements.

For a more comprehensive review of fish welfare, see "The Welfare of Fish" (edited by Tore S. Kristiansen, Anders Fernö, Michail A. Pavlidis, and Hans van de Vis).

Lastly, we would like to thank the countless people who made this report possible.

4.1. FURTHER QUESTIONS OF INTEREST

- Which specific measures do aquaculture farmers in India use for water quality management?
- What is the best approach to improving water quality in India?
- What is the economic impact of applying these water quality management measures to a subsistence-level industry or other small-holders?
- Which variables might affect the application or selection of water quality management measures in small-holder farmers?
- Will farmers accept the importance of fish welfare?