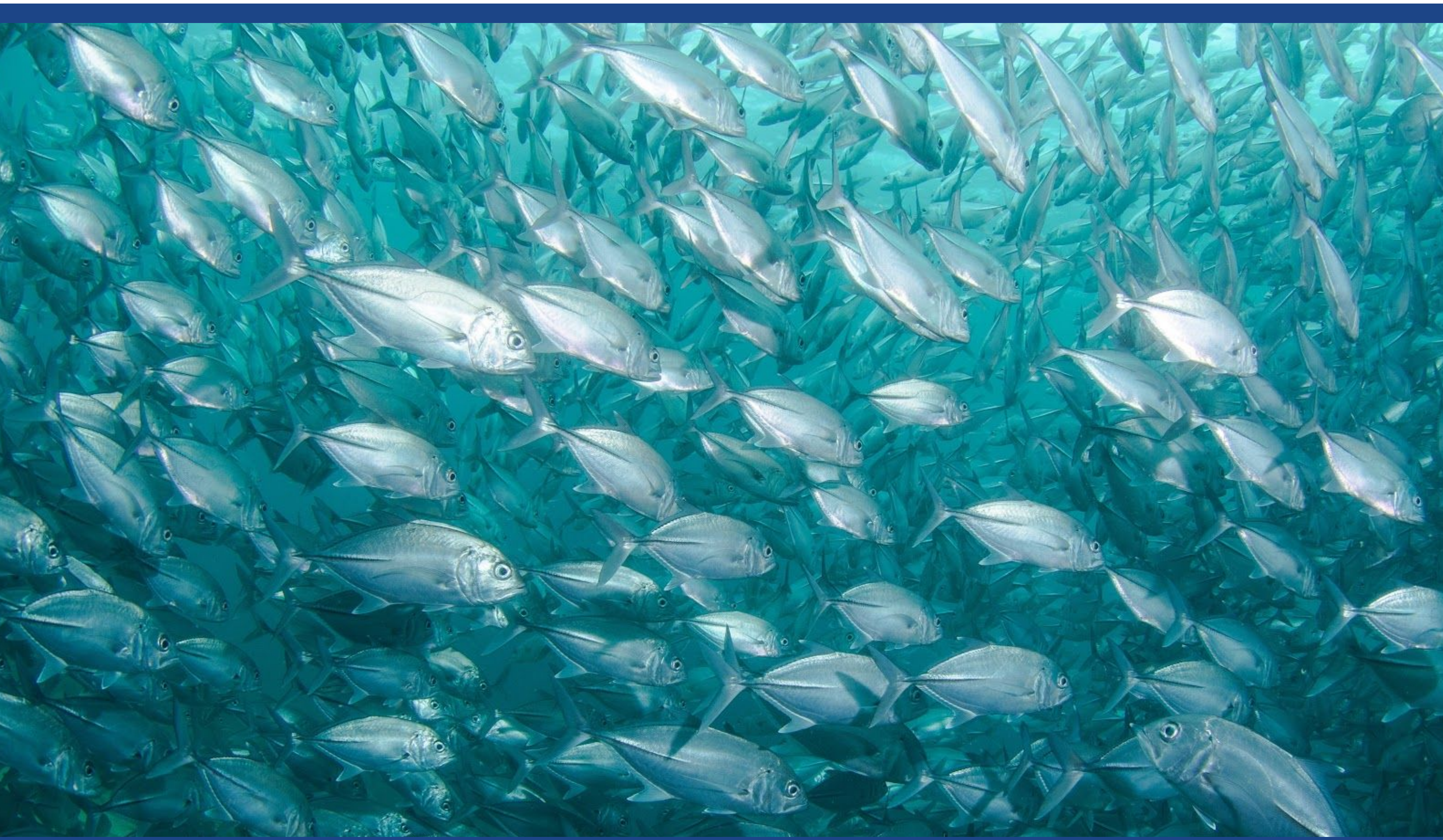
May 2020

Fish Welfare Initiative



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Prioritizing Fish Species for Effective Welfare Improvements

Prioritizing Fish Species for Effective Welfare Improvements

By Thomas Billington and Marco Cerqueira

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Summary

Humans farm an estimated 369 different species of finfish.[1] Members of these species live in different conditions, are raised at various scales, and have distinctive requirements for their welfare. Thus, effective welfare improvements must consider:

1.) Which fish groups should be prioritized (based on the opportunity for the largest positive effect)
2.) The welfare needs of the prioritized fish groups

This report will focus on these two considerations. We apply these within the context of Fish Welfare Initiative's work, highlighting six fish groups that we have prioritized: Catla (*Catla catla*), Striped Catfish (*Pangasianodon hypophthalmus*), Rohu (*Labeo rohita*), Nile Tilapia (*Oreochromis niloticus*), Milkfish (*Chanos chanos*), and Torpedo-Shaped Catfish (*Clarias spp.*).

Concerning the first point (which fish groups should be prioritized), we outline five criteria that we believe should be considered: sensitivity to negative stimuli, poor rearing conditions, number of fish raised, neglectedness, and tractability.

Concerning the second point (the specific welfare needs), we have conducted literature reviews on the welfare requirements of all of our priority fish groups. These are presented below, as well as a discussion of the limitations of such reviews.

Our aim within this report is to present Fish Welfare Initiative's current perspective on prioritizing fish groups, and help start dialogue around this important topic. We hope this report can be informative both directly for those interested in our priority fish groups, and as a reference point for those beginning to work on fish welfare improvements.

[1] FAO (2018). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals.

Table of Contents

Useful Resources for Researching Fish Welfare

Name and Hyperlink	Description
FishEthoBase	A database containing welfare assessments and needs of various species within aquaculture
FAOSTAT J	Up-to-date information on production from FAO
Fishcount	Estimated numbers of individual fish farmed per country
FAO cultured species fact sheet	Overviews of the predominant species farmed
CABI invasive species compendium	A database focused on invasive species, though has overlap with common aquaculture species. Full reports give water quality tolerances as well as other useful information.

Table 1: Useful resources when researching fish groups

Note: Throughout this report, we refer to 'fish groups'. This is used as a generic term for fish that share a taxonomic rank. Therefore, lists of fish groups may contain species, genera, and families in one list.

Introduction

Fish are often categorized as a homogenous group, all with similar capabilities and welfare needs.[2] The reality is that fish are an incredibly diverse group, with an array of genera and species, all with their own environmental needs and mechanisms to cope with stressors. To put this into perspective, consider that some fish (such as tuna) are evolutionarily more closely related to humans than they are to certain other fish (such as sharks).[3]

It would be incorrect to say, however, that there are no meaningful similarities between fish. Similar to how some needs are identifiable in virtually all mammals (such as suitable temperatures, water, and sleep), so too are some needs identifiable in virtually all fish (such as suitable temperatures, access to adequate oxygen, and specific pH levels).[4] This is especially true for Fish Welfare Initiative's work, which is aimed at bony fish.[5]

The motivation for considering which fish group to focus on, then, is two-fold:

[2] Balcombe, J. (2016). What a fish knows: The inner lives of our underwater cousins.
[3] Ibid.
[4] Towers, L. (2015). Water quality a priority for successful aquaculture.
[5] 'Bony fish' refers to fish whose skeleton is completely made of bone

Firstly, **because of the different levels of suffering fish groups experience in aquaculture.** Although all types of aquaculture have the potential to improve fish welfare, it seems that certain fish groups suffer significantly more than others under standard aquaculture practices. Numerous factors can affect a fish group's welfare in aquaculture, including the conditions they typically face, or simply different levels of suitability to the aquaculture environment[6] (such as Atlantic Halibut, an aggressive species 'sensitive to common farming procedures').[7] Thus, any effective welfare improvement for fish should take into account what fish groups should be prioritized.

Secondly, it is important to consider fish group distinctions because **different fish are affected differently by negative stimuli**.[8] For example, a given stocking density may be suitable for one species, but too low and negatively affect another species.[9] Thus, it is necessary to tailor welfare improvements to the needs of each fish group.

In the following sections, we will explore the concepts of prioritizing fish groups and defining their welfare needs. We will also discuss Fish Welfare Initiative's own work in this area.

Fish Welfare Initative's Priority Countries

Fish Welfare Initiative conducted secondary research into 26 countries to select the most promising for implementing welfare improvements in aquaculture. We assessed these countries based on multiple criteria:

- The Farming 'Landscape' (such as the typical conditions on farms and how dispersed farms were)
- Logistics (such as the ease of starting a new organization)
- Strategic viability (such as the viability of influencing government regulation)
- Attitudes towards fish welfare
- Potential flow-through effects (such as the information value for future fish welfare projects)
- Expert opinion

From this, we have narrowed our focus to six countries and regions, all of which are in Asia: India, Bangladesh, Vietnam, Indonesia, Taiwan, and the Philippines. These are referred to as our 'priority countries' below. We are now conducting country visits to all of these countries. More information on why we chose these countries will be released in future reports.

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[6] For an assessment of various species' current and potential welfare in aquaculture, see FishEthoBase.
[7] Saraiva, Joao L. 2020. Hippoglossus hippoglossus (Summary of Short Profile).
[8] Our focus is negative welfare effects in this report, as positive welfare effects have little data available for our priority fish groups.
[9] RSPCA (n.d.). Farmed Fish - Key Welfare Issues.

Despite its sizable aquaculture production (61.5% of global food fish production in 2016),[10] we have decided not to consider China within our priority species. This is due to several logistical and practical difficulties, such as the difficulty of establishing a non-profit organization.[11]

Our Priority Fish Groups

Due to the biological diversity of fish, we cannot thoroughly research all groups of fish farmed globally. Therefore, in this report, we have focused on the main fish groups raised in our priority countries: Catla (*Catla catla*), Striped Catfish (*Pangasianodon hypophthalmus*), Rohu (*Labeo rohita*), Nile Tilapia (*Oreochromis niloticus*), Milkfish (*Chanos chanos*), and Torpedo-Shaped Catfish (*Clarias spp.*). However, our criteria and methodology are cross-applicable to other fish groups.

Top genera/species in our priority countries[12]	**Production in priority countries (tonnes)[13]**
Catla (India)	2,981,932
Striped Catfish (Vietnam, India)	2,698,192
Rohu (India, Bangladesh)	1,398,568
Nile Tilapia (Indonesia)	1,344,229
Milkfish (Indonesia, the Philippines)	1,324,633
Torpedo-Shaped Catfish (Indonesia)	1,167,593

Table 2: The most produced genera/species within our priority countries

These fish groups are not only predominant in our priority countries: they also play a large part in global aquaculture production. Although not usually represented by western supermarket shelves, these six fish groups account for 27.13% of total global finfish aquaculture production.[14] In Asian aquaculture, they account for 31.60% (6.42% Catla, 5.96% Striped Catfish, 4.25% Rohu, 9.55% Nile Tilapia, 2.80% Milkfish, and 2.63% Torpedo-Shaped Catfish).[15]

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[10] FAO (2018). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals.
[11] Cox, V., and Sarek, K. (2019). Country Report: China.
[12] Bracketed are the priority countries which are the largest producers of each fish group. This data comes from: FAO. (2016). FishStatJ - Software for Fishery and Aquaculture Statistical Time Series - numbers from 2020.
[13] FAO. (2016). FishStatJ - Software for Fishery and Aquaculture Statistical Time Series - numbers from 2020.
[14] Ibid.
[15] Ibid.

It is common in Asia to farm 'hardier' fish, which can withstand particularly poor environmental conditions.[16] This is the case with our six fish groups, which are often classified as resilient.[17] Their hardiness enables them to be raised in greater abundance, without the costly equipment required for more sensitive fish groups.

However, resilience to death does not necessarily equate to resilience to negative welfare effects. These six fish groups represent many billions of individual fish that regularly endure welfare issues within aquaculture.

European and North American Fish Groups

We recognize that many readers may be particularly interested in fish groups prominent within European and North American aquaculture. The predominant fish group in both of these regions are salmonids. In Europe, salmon and trout make up 78.68% of total production.[18] In North America, salmonids make up 51.79% of total production.[19]

To address these fish, our guest contributor Mark Borthwick has written a report Welfare Issues in Farmed Atlantic Salmon. This is the most comprehensive treatment of salmon welfare issues that we are currently aware of.

Criteria for Prioritizing Fish Groups

As addressed above, **effective improvements for fish welfare should consider what fish group is the most promising to prioritize**. To do so, we must consider what makes one fish group more promising than another. Below is a list of criteria that Fish Welfare Initiative believes are particularly valuable for determining the promise of a fish group.

The criteria considered below predominantly focus on 'fish-level' factors, such as fish biology and poor rearing conditions. Only light consideration has been given to factors external to the fish, which we have considered through the criteria of tractability. Within this report, tractability covers many important social and 'macro-level' considerations, such as which markets are the most influential, and which production systems are most changeable. These also have significant influence on which fish groups should be targeted and thus warrant further research and consideration by those implementing welfare improvements.

[16] This is based on our experience in the field, our impression through researching common species in Asia, and our conversations with experts.
[17] See our reports on each species, linked below.
[18] FAO. (2016). FishStatJ - Software for Fishery and Aquaculture Statistical Time Series - numbers from 2020.
[19] Ibid.

1. Sensitivity to Negative Stimuli

Some fish, such as salmon, are sensitive to the challenges that aquaculture poses and require significant, precise management of their environment to thrive.[20] Others can adapt better to the aquaculture environment, and their welfare seems less affected by adverse conditions, such as Striped Catfish.[21] Thus, there appears to be a distinction between fish groups that are more and less suited to aquaculture (at least, from a health and functional welfare perspective).[22] Therefore, it is important to prioritize those fish that are more sensitive to the negative stimuli commonly found within aquaculture (such as poor water quality and disease).

An important distinction to highlight when discussing sensitivity is that of general resilience to negative stimuli and resilience to dying from negative stimuli. Often, literature that refers to a fish group as 'hardy' or 'resilient' is only referring to resilience in terms of not dying from negative stimuli. Although mortality rates are a welfare indicator,[23] a lack of mortality does not mean positive welfare is present, and a much deeper analysis of secondary and tertiary stress responses is required to understand the welfare effects of a given stimulus fully.[24]

Comparing sensitivity between fish groups requires an in-depth review of their stress responses to various stimuli and the perspective of experts in the field. This can be difficult to achieve in an objective manner, and so we recommend reflecting this accordingly when weighting this criterion.

2. Poor Rearing Conditions

The previous criterion spoke to the capacity to suffer for each fish group. This criterion is needed to ground our consideration in what conditions are actually like for those fish groups. 'Poor rearing conditions' considers the conditions the average individual of a fish group experiences. Measuring this criterion involves considering the environment fish are kept in, and the husbandry practices they experience (for example, whether water quality is adequate, or whether fish are stunned pre-slaughter).

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[20] See Noble, C. et al. (Eds.) (2018). Welfare Indicators for farmed Atlantic salmon: tools for assessing fish welfare., and Fish Welfare Initiative's report Welfare Issues in Farmed Atlantic Salmon.
[21] See our review of Striped Catfish sensitivity: Striped Catfish - Priority Species Report.
[22] Functional welfare refers to definitions of welfare focused on an animal's ability to adapt to its present environment (good health, physiological systems functioning and so on).
[23] Ellis, T. et al. (2012). Mortality and Fish Welfare.
[24] Secondary stress responses are biological resistance to a stressor, such increased plasma glucose. Tertiary stress responses are whole-animal responses to secondary coping mechanisms being overwhelmed, such as reduced growth rates. To read more on stress responses in fish, see: Wedemeyer, G. A., et al. (1984). Assessing The Tolerance Of Fish And Fish Populations To Environmental Stress: The Problems And Methods Of Monitoring.

Information on the conditions a fish group experiences can be extremely challenging to obtain, especially for more neglected fish groups. The best way to find this data, generally, is to talk to those with first-hand experience of a broad range of farms or to gain this experience yourself. Both of these can be difficult, however, and so supplementation can be found in the form of government recommendations and regulations (though enforcement rates should also be considered),[25] reliable reports describing aquaculture in the region,[26] voluntary best practice groups,[27] and indexes such as World Animal Protection's index for 'Presence of animal welfare legislation - Protecting animals used in farming'.[28]

3. Number of Fish Raised

This criterion refers to the size of production in terms of individual fish raised. The number of fish raised is useful as an indicator of the size of positive impact achievable by increasing fish welfare. However, caution should be used when using total production as an indicator of potential impact. Total production is only useful insofar as it affects how many fish are helped (higher production rates are not better if a set number of fish will be helped regardless). We also recommend taking into account projected growth, not just current production.

4. Neglectedness

'Neglectedness' considers how much work is already being done to improve the welfare of a fish group. This could refer to direct work towards improving their welfare, or work that is indirectly beneficial (such as efforts towards sustainable husbandry practices). Prioritizing fish groups whose welfare has gained less attention will help ensure that total resources towards better fish welfare are used more effectively, and increases the counterfactual value of an intervention.[29]

In Fish Welfare Initiative's research on neglectedness, we primarily focused on work from existing animal welfare organizations and work from government and academic institutions, which indirectly affects welfare (such as training programs for better husbandry practices).[30]

It should be noted that high levels of neglect for animal welfare issues can also be an indicator that it is particularly challenging to make any tractable difference in that region.

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[25] For an example of government recommendations for Indian aquaculture, see: The National Fisheries Development Board - Department of Fisheries (n.d.). Guidelines.
[26] For an example of an FAO report discussing aquaculture in Vietnam, see: Nguyen, T.P., and Truong, H.M. (2005). National Aquaculture Sector Overview - Viet Nam.
[27] For an example of a voluntary best practice group in Scotland, see: Code of Good Practice
[28] Animal Protection Index (2020). Republic of India: Ranking C.
[29] For a description of counterfactual value, see: EA Concepts (n.d.). Counterfactual considerations.
[30] For an example of a fisheries training program, see: Gias, U.A (2005). National Aquaculture Sector Overview - Bangladesh.

5. Tractability

This is perhaps the most important factor for prioritizing fish groups. A necessary property of a promising fish group is that a positive effect on their welfare is realistically achievable. It is important that any fish group targeted is not constrained by factors hindering the ability to improve their welfare. These are generally externalities to the actual fish, such as the species' research base, supply chain concerns, and the production systems utilized.[31]

In Fish Welfare Initiative's research on tractability, we primarily focused on social and legal factors. For example, law enforcement, attitudes towards animal welfare, and registered interest in improving aquaculture. However, we included any data we could find which updated our views on this topic.

Note: One criterion not included here is the likelihood or level of sentience for each fish group. We have decided to exclude this criterion from our investigations. This is because we are concerned about perpetuating the idea that each fish species must be 'checked' for sentience before having their welfare needs legitimized, as we believe part of the motivation for this is an internal bias against fish sentience. Thus, making this a standard could hurt fish welfare in the long run. There is currently strong scientific evidence and a clear scientific majority in favor of fish sentience.[32] Additionally, there is little work directly comparing the sentience of individual fish groups, and thus it would be difficult to draw any meaningful conclusions.

Generating a Weighted Factor Model

To complement the criteria above, we created a weighted factor model, applying the criteria to the top fish groups that we have outlined: Catla, Striped Catfish, Rohu, Nile Tilapia, Milkfish, and Torpedo-Shaped Catfish. A weighted factor model is a way of analyzing and discriminating between various options in a quantified way. The process involves generating criteria, giving these criteria unique weightings, and then giving a numerical assessment of each option (in this case, each fish group) based on its relationship to each criterion.[33]

Below is our weighted factor model considering our top fish groups. This is only a preliminary assessment based on existing Fish Welfare Initiative research. However, we believe it to be valuable to share our early work in this area. It should be noted that

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[31] For example, water quality is often considered impractical for producers to control in caged systems. See: Pérez, O. M., et al. (2003). Water quality requirements for marine fish cage site selection in Tenerife (Canary Islands): predictive modelling and analysis using GIS.

[32] Brown, Culum. 2015. Fish Intelligence, Sentience and Ethics.

[33] Charity Entrepreneurship (n.d.). Weighted Factor Model., and Business Analyst Learning (2014). Weighted Scoring Model: A Technique for Comparing Software Tools.

weighted factor models are imperfect,[34] and so readers are encouraged to take this as only one aspect of their consideration of these fish groups.

Weighting the Criteria

We added weights to each criterion above. The motivating question for choosing each weighting was: '**Would time spent researching this criterion bring us closer to the true value of assisting this fish group?'**

This question led us to assess these criteria on factors such as:
- The accessibility of information
- How objective the available information was
- Whether the criterion was acceptable to a broad range of ethical and philosophical stances
- If the criterion was peer-endorsed
- How unlikely the criterion was to produce false negatives or positives
- Whether they illustrate an important value for Fish Welfare Initiative

From this, weightings were assigned based on our intuition and experience researching fish welfare:

Criteria	**Percentage weighting**
Sensitivity to negative stimuli	15%
Poor rearing conditions	20%
Number of fish raised	20%
Neglectedness	20%
Tractability	25%

Table 3: Fish Welfare Initiative's percentage weightings for our criteria

To see a more in-depth review of the process of generating these weights, read the complementing document here.

Scoring Each Fish Group

We gave each criterion a score out of three for each fish group (where three always means high relative levels of the criterion). We then generate a z-score for each fish group, which is a statistical measurement where a score of 0 is equivalent to the mean average. The summary table can be seen below:

[34] Ibid.

	Z-score	Overall Score
Catla	2.88	2.25
Striped Catfish	-0.51	1.85
Rohu	1.19	2.05
Nile Tilapia	-0.72	1.825
Milkfish	0.97	2.025
Torpedo-Shaped Catfish	-0.93	1.8

Table 4: Scores of our weighted factor model

To calculate these endline scores, we used the following score matrix:

	Sensitivity to negative stimuli	Poor rearing conditions	Number of fish raised	Neglect	Tractability
	15%	20%	20%	20%	25%
Catla	1.5	2.5	3	1.5	2.5
Striped Catfish	1	2	2.5	1.5	2
Rohu	1.5	2.5	2	1.5	2.5
Nile Tilapia	1	2	2.5	2	1.5
Milkfish	1	3	1.5	3	1.5
Torpedo-shaped catfish	1	3	1	3	1

Table 5: Weighted factor model score matrix. Details on the decisions for these numbers can be found in the individual species reports linked below.

The link to the spreadsheet can be found here.

Each score was estimated based on existing Fish Welfare Initiative research and a short literature review. These were then formed into reports for each fish group, which can be found at the links below:

- Catla
- Striped Catfish
- Rohu
- Nile Tilapia
- Milkfish
- Torpedo-Shaped Catfish

We created a tiered list based on the z-scores for each fish group (see below), the first tier being those fish groups with a z-score above one (and thus whose scores were above one standard deviation from the mean). We believe this gives a more accurate interpretation of our results, removing some of the noise between the scores. This will act as the conclusion to the weighted factor model:

Tier 1 *(z-score above 2.0)*	Catla
Tier 2 *(z-score between 0.0 and 2.0)*	Rohu
	Milkfish
Tier 3 *(z-score below 0.0)*	Striped Catfish
	Nile Tilapia
	Torpedo-Shaped Catfish

Table 6: Final tier list of the weighted factor model

From the weighted factor model, we can see that each fish group scored relatively close to each other (all being within a 15% range of the possible scores). This is partially due to this being a preliminary model on a topic with a general lack of data. It also shows, however, that these fish are all promising (all being resilient to death and farmed in lower welfare conditions). That being said, the weighted factor model found Catla to be the most promising, the reasons for which we shall discuss.

In 2018, 98% of global Catla production was within our priority countries and regions (India, Bangladesh, Vietnam, Indonesia, Taiwan, and the Philippines): 2,981,932 tonnes.[35] This is an

[35] FAO. (2016). FishStatJ - Software for Fishery and Aquaculture Statistical Time Series - numbers from 2020.

estimated 1.5 to 9.9 billion Catla slaughtered and sold[36] (presumably, many more fish either died during production or otherwise were hatched but not sold).[37] These estimates put Catla as the most numerous group of farmed fish considered in this report.[38]

The majority of Catla production is within India (94% of global production).[39] In India, small scale production seems to be prominent.[40] Smaller scale production has some welfare benefits,[41] but also often correlates with lower monitoring and control of the aquaculture environment.[42] This can lead to extended periods before producers are aware of negative environmental stimuli, and those stimuli being harder to resolve once identified.

Any environmental imperfections for Catla is likely to become a welfare issue. Catla were the most sensitive species within this review, even being referred to as 'highly sensitive to slight stress' (though they do not seem as sensitive as other species, such as salmon).[43] On multiple parameters, Catla seems significantly more sensitive than the other major Indian carp.[44]

These factors support the conclusion that Catla is a particularly promising fish group to focus on for welfare improvements. However, as stated above, all of these fish groups scored in a similar range, and we think all of these fish groups are promising as the subject of welfare improvements. We hope to see more work toward bettering their welfare. This weighted factor model serves mostly to discriminate what differences do exist between them and to help inform those making difficult distinctions between similarly promising fish groups.

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[36] FAO. (2016). FishStatJ - Software for Fishery and Aquaculture Statistical Time Series - numbers from 2020. This is using fishcount's estimated mean weight for species: Fishcount. (n.d.). Screen 2: Summary data for EMW-43.
[37] Survival rates for Catla in the nursery stage is only 30 to 40 percent: Towers, L. (2009). How to Farm Indian Carp (Catla catla).
[38] For numbers on the estimated individuals raised of all our priority fish groups, see the individual reports linked below.
[39] FAO. (2016). FishStatJ - Software for Fishery and Aquaculture Statistical Time Series - numbers from 2020.
[40] Dey, K. (2020). India's Blue Economy net getting bigger! Country ranks third in fisheries and second in aquaculture., and Certified Aquaculture (n.d.). Aquaculture in India. This also aligns with our findings from our country visit.
[41] For example, semi-intensive and extensive production tends to have lower stocking densities, according to: FAO (n.d.). AQUACULTURE METHODS AND PRACTICES: A SELECTED REVIEW.
[42] Extensive and semi-intensive systems are more challenging to control as they depend on natural conditions which vary over time. Without proper monitoring, water quality changes might not be detected. The lack of aerators and additional feed prevent extensive system operators from identifying and acting upon welfare concerns. For more information see: Chen, S. N. (1991). Environmental problems of aquaculture in Asia and their solutions. and AquaCultur. (2011). Aquaculture Systems of the World.
[43] Abhijitha, B.D., Ramesh, M., and Poopal, R.K. (2016). Responses of metabolic and antioxidant enzymatic activities in gill, liver and plasma of Catla catla during methyl parathion exposure.
[44] Latif, F., and Javed, M. (2019). Inter-Specific Differences in the Sensitivity, Accumulation and Antioxidant Capacities of Three Cyprinids Exposed to Heavy Metals Mixture., and Ashok K., et al. (2017). Assessment Of Water Quality And Fish Growth In Micro-water Sheds Of Banswara District In Southern Rajasthan., and Javid, A., Javed M., And Abdullah, S. (2007). Nickel Bio-accumulation in the Bodies of Catla catla, Labeo rohita and Cirrhina mrigala During 96-hr LC50 Exposures.

Considering Welfare Needs

As addressed above, different fish groups will have different environmental welfare needs. Therefore, **effective welfare improvements should consider the welfare needs of the specific fish groups being targeted**. Below, we present the welfare needs of our top fish groups: Catla, Striped Catfish, Rohu, Nile Tilapia, Milkfish, and Torpedo-Shaped Catfish. We also discuss some of the limitations present in attempting to define the welfare needs of fish groups.

For some fish groups, their welfare needs are already collated into literature reviews, welfare standards, and guidelines, or on the FishEthoBase. However, for others, no such comprehensive review exists. Such reviews require considerable research, as well as frequent updating as new research is released.

Unfortunately, information on specific welfare needs (such as water quality or standards for pre-slaughter stunning) is often sparse to non-existent.[45] This is true even for top globally produced fish groups, as is shown by the average certainty given to species evaluations on the FishEthoBase being 1.93/10.[46] Information that does exist is regularly unscientific, and often from Africa and South America, bringing into question its relevance to Asian aquaculture (where the different substrate[47] and husbandry practices can be expected to alter the specific environmental needs of fish).

Identifying the welfare needs of fish is in the interest of the fish, the sustainability of aquatic environments, and the income of the farmers.[48] Thus, the gaps in research into welfare parameters for key species represents a major failure of the existing research. The implication for those invested in fish welfare is that we can only achieve an imperfect view of the needs of fish groups not already extensively researched and reviewed.

Polyculture (the farming of multiple fish species at the same time within one system) presents more challenges. Within polyculture systems, a compromise must be struck between the needs of multiple fish groups, meaning that understanding any one fish group's needs is not enough to ensure favorable conditions for all fish within the system. This is a significant constraint, with many of the top produced fish groups commonly farmed in polyculture systems (for example, Rohu and Catla are often farmed together).[49]

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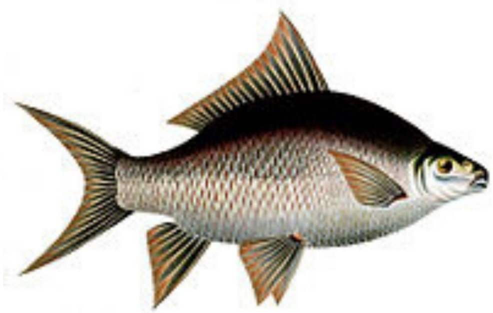
[45] For more information on knowledge gaps in fish welfare, see: EFSA (2009). Knowledge gaps and research needs for the welfare of farmed fish.
[46] Saravia, J. L., et al. (2019). A Global Assessment of Welfare in Farmed Fishes: The FishEthoBase.
[47] Substrate refers to the material at the bottom of a tank or pond.
[48] Higher fish welfare contributes to cleaner waterways (Miller & Semmens, 2002), minimises disease and parasite outbreaks (Arthur & Subasinghe, 2002), boosts business resilience (Conte, 2014), ensures food safety (EFSA, 2008), and protects wild fish stocks by improving feeding efficiency (Santos et al., 2010). For more information see our upcoming 'Why Fish Welfare?' webpage.
[49] Jena, J.K. (2006). Cultured Aquatic Species Information Programme. Catla catla.

Example Table

Below is an example of Fish Welfare Initiative collating data for one of our primary fish groups: Catla. This information is up-to-date as of May 2020.



Catla (*Catla catla*)

Scale: 2,981,932 tonnes (2018) (1,491 to 9,940 million fish)[50]

Primary producers: India (~94%)[51], Bangladesh (~6%)[52]

Age at Harvest: ~14 months[53]

Diet: Omnivorous[54]

Production System: Pond / Polyculture[55]

Photo source: Wikipedia

Temperature	Standard range: 25-33 °C.[56] Preferred temperature: 30-32ºC.[57]
Salinity	<6 ppt for better natural behaviour and growth. 20% feed protein increases resilience to saline environments. [58]
Dissolved oxygen	Sensitive to low O_2 levels. Best above 5mg/L, but fry show good performance in 3.9 mg/L to 5.3 mg/L.[59]
CO_2	2.0 - 5.6mg/L seems to be a suitable range.[60] More research required.
pH	6.5 - 8.5 is the acceptable interval, but levels between 7-8 are best since Catla is sensitive to pH changes.

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50 FAO. (2016). FishStatJ - Software for Fishery and Aquaculture Statistical Time Series - numbers from 2020., and Fishcount. (n.d.). Screen 2: Summary data for EMW-43.
51 FAO. (2016). FishStatJ - Software for Fishery and Aquaculture Statistical Time Series - numbers from 2020.
52 Ibid.
53 Jena, J.K. (2006). Cultured Aquatic Species Information Programme. Catla catla.
54 Lee, C. S. (2015). Dietary Nutrients, Additives and Fish Health.
55 Jena, J.K. (2006). Cultured Aquatic Species Information Programme. Catla catla.
56 Sharma, J.G., et al. (2016). Impact of Temperature Gradient on the Indian Major Carp Catla catla Larvae., and Das, T., et al. (2004) Thermal tolerance and oxygen consumption of Indian Major Carps acclimated to four temperatures.
57 Ahmad, M., et al. (2020). Effect of acclimated temperature on thermal tolerance, immune response and expression of HSP genes in Labeo rohita, Catla catla and their intergeneric hybrids.
58 Tripathi, S.D. (n.d.). Aquaculture Profile of Gibelion Catla: FishbaseAquaculture.
59 Tripathi, S.D. (n.d.). Aquaculture Profile of Gibelion Catla: FishbaseAquaculture., and Kadhar, A., et al. (2014). Studies on the Survival and Growth of Fry of Catla catla (Hamilton, 1922) Using Live Feed.
60 Das, P.C., Ayyappan, S., and Jena, J.K. (2006). Haematological changes in the three Indian major carps, Catla catla (Hamilton), Labeo rohita (Hamilton) and Cirrhinus mrigala (Hamilton) exposed to acidic and alkaline water pH.

	Above 9 or below 5.5 mortality reaches 100%[61]
Turbidity	>30 cm improves behaviour and growth performance.[62]
Ammonia	15 mg/L increases mortality; optimal is below 1 mg/L. 0.01–0.02mg/L should be kept.[63]
Nitrite	<0.01 mg/L should be kept.[64]
Depth	Found to perform well in 1.5m depths.[65]
Hardness	122–136 mg CaCO3/L standard levels.[66]

Daily rhythm	Further investigation is needed, but it is known that 24h darkness is highly physiologically challenging, and possibly 12L:12D increases fish performance.[67] Environmental photothermal conditions should be followed if possible since reported data is inconclusive.
Light intensity	114±4 lux is optimal. Above 2672 lux shown to affect growth performance deeply.[68]
Light color	n/a

Feeding score	Trophic level = 2.8. Omnivorous (selective plankton feeding).[69]
Feeding style	Surface feeder. Maximum feeding activity of Catla occurs during the morning hours (6.00 to 9.00).[70]
Feeding frequency	Twice a day for all life stages. ~4% Body Weight/day for fingerlings and adults (see table 7).[71] Under field conditions, feeding once daily may be most promising (but more research is needed). [72]
Particle size	Larvae and fry are fed on finely powdered (<80 µ) feeds that are broadcasted over the water.[73] We don't know of any better alternative.

[61] Ibid.
[62] Bhatnagar, A., and Devy, P. (2013). Water quality guidelines for the management of pond fish culture.
Das, P.C., Ayyappan, S., and Jena, J.K. (2006). Haematological changes in the three Indian major carps, Catla catla (Hamilton), Labeo rohita (Hamilton) and Cirrhinus mrigala (Hamilton) exposed to acidic and alkaline water pH.
[63] Das, P.C., Ayyappan, S., and Jena, J.K. (2006). Haematological changes in the three Indian major carps, Catla catla (Hamilton), Labeo rohita (Hamilton) and Cirrhinus mrigala (Hamilton) exposed to acidic and alkaline water pH.
[64] Ibid.
[65] Hosen, M. H. A., et al. (2019). Effects of water depth on growth performance of Indian major carps at a poly culture system in Bangladesh.
[66] Das, P.C., Ayyappan, S., and Jena, J.K. (2006). Haematological changes in the three Indian major carps, Catla catla (Hamilton), Labeo rohita (Hamilton) and Cirrhinus mrigala (Hamilton) exposed to acidic and alkaline water pH.
[67] Rajiv, C., et al. (2016). Daily and Seasonal Expression Profile of Serum Melatonin and Its Biosynthesizing Enzyme Genes (tph1, aanat1, aanat2, and hiomt) in Pineal Organ and Retina: A Study under Natural Environmental Conditions in a Tropical Carp, Catla catla.
[68] Khan, N.A., and Moseki P. (2018). Investigating the role of heat shock proteins and melanophores during stress caused by high light intensity in Indian major carp, Catla catla.
[69] Froese, R., and Pauly D. (2019). FishBase.
[70] FAO (n.d.). Catla - Feeding methods.
[71] FAO (n.d.). Catla - Frequency Asked Questions.
[72] Biswas, G., et al. (2006). Effect of feeding frequency on growth, survival and feed utilization in fingerlings of Catla catla (Hamilton), Labeo rohita (Hamilton) and Cirrhinus mrigala (Hamilton) in outdoor rearing systems.
[73] FAO (n.d.). Catla - Feeding methods.

Feed delivery	Spread uniformly over the tanks.[74]
Feeding content	Crude protein: adults = 25-32% but 25% is enough for good performance.[75] larvae = 34-38%[76]
	Crude lipids: adults = 6-7% / larvae = ~5%[77]
	Energy: Broodstock = 20 KJ/g[78]
	Carbohydrates: adults = 20% / larvae = 26%[79]
	Inclusion of 1.57 to 1.58 of leucine is recommended.[80]

Stocking densities	Semi-intensive: Larvae - 3-5 million/ha, Fry - 0.2-0.3 million/ha.[81]
	Fingerling - 2000-3000/ha, 1kg/ha when fertilization is used.[82]
	Intensive: Larvae - 10 million/ha, Fry - >0.2-0.3 million/ha.[83]
	Fingerling - 5000-10000/ha, 1.5kg/ha when fertilization is used.[84]
	Proportion in polyculture: 10-35%[85]

Reproduction	Breed in T = 24-31ºC. It is the most difficult carp to breed and hormonal induction is required - all procedures should be standardized. Enrichment with oil n-3 PUFA in the broodfish diet enhanced the physiological response of broodfish to induced spawning (increased 96%) and improved the quality of eggs and larvae in terms of recovery and resilience to the environment. Spawning induction is usually performed using hypophysation.[86]

Transport	Transportation causes stress and reduction of immunity, with a bigger impact on fry than fingerlings.[87] This has implications for the grow out stages. Optimum fry packing is 100 fry/L (for 6h transport).[88] See here for more information.

[74] Ibid.
[75] Ishtiaq, A., and Naeem, M. (2019). Effect of different dietary protein levels on growth performance of Catla catla (Hamilton) reared under polyculture system.
[76] FAO (n.d.). Catla - Nutritional requirements.
[77] Biswas, G., et al. (2006). Effect of feeding frequency on growth, survival and feed utilization in fingerlings of Catla catla (Hamilton), Labeo rohita (Hamilton) and Cirrhinus mrigala (Hamilton) in outdoor rearing systems.
[78] FAO (n.d.). Catla - Nutritional requirements (table 2).
[79] Ibid.
[80] Zehra, S. and Khan, M.A. (2014). Dietary leucine requirement of fingerling Catla catla (Hamilton) based on growth, feed conversion ratio, RNA/DNA ratio, leucine gain, blood indices and carcass composition.
[81] FAO (n.d.). Table 16 - Feeding tables for Indian major carp aquaculture using formulated feed under experimental conditions.
[82] Ibid.
[83] Ibid.
[84] Ibid.
[85] Tripathi, S.D. (n.d.). Aquaculture Profile of Gibelion Catla: FishbaseAquaculture.
[86] Ibid.
[87] Ahmed, I., and Shenoy, K.B. (2012). Effect of transportation stress on the humoral immunity of Catla fry and fingerlings.
[88] Chatterjee, M., et al. (2006). Secondary stress responses in Indian major carps Labeo rohita (Hamilton), Catla catla (Hamilton) and Cirrhinus mrigala (Hamilton) fry to increase packing densities.

Slaughter	In Common carp, and most likely in Catla as well, percussive (applied manually) and electrical stunning are poor inducers of unconsciousness before slaughter, while a combination of these is more promising. In order to improve electrical stunning, further investigations into the current density is required to induce prolonged insensibility in carp during electrical stunning.[89]

A table such as the one above was produced for each of our priority fish groups. These were then added to the individual report for each fish group, which to reiterate can be found at the following links:

- Catla
- Striped Catfish
- Rohu
- Nile Tilapia
- Milkfish
- Torpedo-Shaped Catfish

Ultimately, the literature reviews above aim to showcase the ideal conditions, according to current literature. They should not be enforced as required standards, as the data available is often too inconclusive to derive firm standards for welfare upon. Also, practical standards must take into account that environmental conditions are not entirely within the control of the producer (for example, it has been argued that ‘It is impractical to try [to] control water quality parameters in cage culture systems’).[90]

These reviews are a step towards better understanding the welfare needs of these fish groups. There are still many gaps within the literature, and data is often focused on fish health, growth, and survival, as opposed to welfare.[91] The information above is also very general, often not taking into account the life stage or production systems. There is still much work to be done in identifying the welfare needs of many of the most common species within aquaculture.

As stated above, the FishEthoBase has done similar reviews for many species, such as European seabass[92] and common carp.[93] We recommend reviewing its database before researching.

[89] Retter, K., et al. (2018). Stunning of common carp: Results from a field and a laboratory study.
[90] Pérez, O. M., et al. (2003). Water quality requirements for marine fish cage site selection in Tenerife (Canary Islands): predictive modelling and analysis using GIS.
[91] Though complimentary, standards for health and standards for welfare are distinct.
[92] Saraiva, J. L. and Volstorf, J. 2020. Dicentrarchus labrax (Summary of Short Profile, Version 1.30) .
[93] Castanheira, M. F. 2020. Cyprinus carpio (Summary of Short Profile, Version 1.72).

Conclusion

Humans farm an estimated 369 different species of finfish.[94] Any effective welfare improvements should account for:

1.) Which fish groups should be prioritized (based on the opportunity for the largest positive effect)
2.) The welfare needs of the prioritized fish groups

Concerning the first point, it is apparent that some fish groups are more promising as the subjects of welfare improvements than others. This conclusion is the product of multiple criteria, such as their sensitivity to negative stimuli, typical rearing conditions, the number of fish being raised, neglectedness, and tractability . Effective welfare improvements should target those fish that are most promising. Fish Welfare Initiative has highlighted six fish groups: Catla, Striped Catfish, Rohu, Nile Tilapia, Milkfish, and Torpedo-Shaped Catfish. We have also provided criteria that we believe are important to identify which fish groups are the most promising, and have applied this to a weighted factor model of these six fish groups. From the results, all the fish groups considered were fairly promising, with Catla performing the best due to its combination of poor conditions, high production, and being the most sensitive fish reviewed.

Concerning the second point, the diversity between fish groups requires effective welfare improvements to be tailored to the specific needs of the fish group it aims to help. Unfortunately, a lack of data exists on the specific needs of fish groups. It is possible to build a starting point for better understanding fish needs through a literature review. Accordingly, Fish Welfare Initiative has generated literature reviews of our priority species. However, more research and verification is required.

We hope that this assessment of fish groups can inform others that aim to improve fish welfare. Ultimately, prioritizing fish groups for welfare improvements is a practice still in its infancy.[95] This report aims to be a step forward for the practice, and Fish Welfare Initiative will continue to explore species prioritization. This could either be through giving a deeper analysis of the fish groups assessed here or by assessing more fish groups. We hope to see more organizations exploring this important topic in the future.

[94] FAO (2018). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals.
[95] The only major project we are aware of within this space is the FishEthoBase.