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ANIMAL HUSBANDRY IN THE FOCUS

Fish welfare in aquaculture — Problems and approaches

TOPICS WINTER 2020

Editorial

Dear readers,

Fishes really are something special. With over 30,000 species, fishes are the largest and also a very diverse class of vertebrates that have inhabited almost all aquatic habitats for over 400 million years. They are found in lightless underwater caves, roam the high seas, inhabit coral reefs, survive in mud or—like mudskippers—live predominantly amphibiously out of the water, making the leap to land. Among fishes are giants like the whale shark and the basking shark. Greenland sharks can reach an age of over 500 years—an unimaginable period of time for us humans. Fishes have developed organs such as the lateral line organ or possess electrical organs for which there is no equivalent in mammals. They breathe not only with their gills, but also with their lungs, intestines, skin or their own labyrinth organ. Fishes also recognise individual conspecifics. Thus, male cichlids that have observed fights between different conspecifics almost certainly choose the loser when it is their own turn to fight. Evidence that this decision is not made based on external characteristics is provided by scientific studies in which male fighting fishes recognised winners and losers only when they had observed the territorial fights themselves. There are fishes that, like groupers, use tools in the form of shells/stones or form hunting communities with other species—abilities that for a long time were only attributed to primates.

Due to their completely different habitat, however, fishes are very alien to most people. They do not have facial expressions as mammals do and do not make sounds when they are in pain. Many vegetarians even eat fish. Furthermore, the appearance of a fishes does not quite evoke empathy—apart from, of course, the beloved clownfish Nemo and his friends from the film 'Finding Nemo'.

This is probably one of the reasons why fishes are among the most misunderstood and therefore mistreated creatures. Fishes cover a large part of the human protein supply worldwide. Fish farmed in aquaculture are 'harvested', their stocking density given in kilograms/litre of water. In deep-sea fishing, countless fishes suffocate or die from the difference in pressure or from being crushed against each other. But even in pond fisheries, stunning before killing is only mandatory in a few countries. Large sections of those involved in fishing or fish production, as well as specialists and a dwindling minority of scientists, still hold the view that fish suffer 'stress' but cannot feel pain.

It is not easy to prove that fish feel pain. The particular difficulty of scientific proof lies in the fact that the prerequisites for the perception of pain include an emotional component and a 'consciousness' and that these factors are difficult to objectify. Scientific research on this was therefore lacking for a long time. This changed at the beginning of the new millennium when a group of British researchers led by Lynne Sneddon published the results of their investigations on this question, in which they concluded that the question about whether fish feel pain must be answered with 'yes'. This triggered a heated and emotional debate that continues today. It is clear that the economic use of fish is considerably facilitated if one assumes that they do not feel pain. Furthermore, intensive research has been and continues to be carried out in this field by various working groups worldwide, and various institutions have issued statements on the subject. The evidence for a sense of pain, but also for intelligence and even a 'personality' is becoming more and more convincing.

I am therefore particularly pleased that the IGN is dedicating a separate issue to fishes. Billo Heinzpeter Studer, together with his colleagues in science and practice, has compiled a wealth of material on all aspects surrounding the use of fishes, which allows a completely new view of these hitherto very neglected animals.

I hope you enjoy discovering and marvelling at these fascinating creatures as you look at them with a fresh pair of eyes!

Johanna Moritz

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Introduction – Farmed fishes: Why so many? Fish welfare: why so late?

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Enlightenment is not a continuous process, at least not as long as the moral varnish of human civilisation is so thin and easily damaged. The relationship of humans towards (other) animals has not developed linearly from a mystical respect that is based on ethical considerations, which move more and more people today. From the veneration of certain animals in pre- and early agrarian societies, the path led through valleys of lamentation of increasing and religiously sanctioned instrumentalisation of animals. This was until in the course of the last century or two, when not only did individual intellectuals rebel against socially organised animal suffering, but gradually an animal protection movement arose, at first out of motives of compassion for the animals that were nevertheless used, then increasingly based on a more profound ethic, which today causes a growing number of people to massively restrict the consumption of products from animal husbandry or to stop it in principle.*[1]*

For a long time, care for the welfare of *'farm animals'* was left to the farming families, and they were increasingly alone in a society that was progressively based on the division of labour. It was only with the modern animal welfare movement that consumers alienated from primary production began to care about animal welfare in agriculture from the middle of the last century. This gave rise to protest movements, organisations and political initiatives that led to a partial improvement in the living conditions of animals in agricultural breeding and fattening, especially in Western Europe *[2]*, with minimum standards at the legal level, such as the phasing out of battery hens *[3]*.

For a long time, even the animal protection movement did not concern itself with the plight of fish, neither in fisheries nor in fish farming, neither in experimental laboratories nor in the numerous home aquaria. The first in modern times to start caring about fishes were fishermen and conservationists; but they were concerned with the preservation of fish species and their habitats, a compelling but not sufficient condition for individual fish.

Why did fish welfare become an issue so late?

How we relate to the world depends largely on our knowledge of that world. The popular argument that we know little about fishes because they live in an element foreign to our species is not entirely valid. Even before the emergence of the modern animal protection movement, individual scientists had been studying the biology and way of life of fishes, as Jonathan Balcombe reports. One of the fathers of behavioural research, Karl von Frisch, proved in an experiment as early as the mid-1930s that at least the dwarf catfish can hear and that, contrary to popular belief, fishes are not generally deaf. However, an online search conducted by Balcombe for his book *'What a Fish Knows'* published in 2014 also showed that of 71 scientific papers on the subject of fish welfare, 69 were published after 2001 *[4]*.

Apart from knowledge, there was above all a lack of moral compulsion to deal with the suffering of fishes. It was only a few centuries ago when it was considered quite normal in Europe to regard people of a different skin colour as inanimate and therefore without rights, therefore free to be abused, and only in the last century did the realisation gradually break through, in a society that had been patriarchally dominated for thousands of years, that women should in principle have the same rights as men. In both cases, it took the uprisings of slaves and women to promote such realisation. It is much more difficult for animals to protest audibly, but it is particularly difficult for us to perceive the protest of fishes and animals in general that live under the surface of the water. Where the protest of animals is not expressed by refusal to grow, by disease or death, and thus understood by the animal owner at best, it can only be expressed by humans. For animal species such as hens, pigs or cows, this has worked since the end of the Second World War with considerable partial success. For the welfare of fishes, on the other hand, a few organisations only began to get involved in the 1990s: the British Compassion in World Farming for the first time in 1992 for farmed salmon *[5]*, the Swiss association fair-fish from 1997 for edible fish from catch or farming *[6]*, and the Dutch foundation Vissenbescherming from 2000. And it was only in the last decade that many existing or new organisations began to join this commitment. The growing attention on the public's part simultaneously created the space for an exponential increase in research in the service of more fish welfare.

The fact that the suffering of fishes has only received attention at such a late stage is all the more astonishing when one realises that 93 to 98 percent of all vertebrates slaughtered each year are fishes. While about 70 billion land animals are slaughtered every year, including poultry *[8]*, according to a conservative estimate by the British initiative fishcount, between 1,000 and 3,000 billion fishes *[9]* are killed for us every year (not including other aquatic animals such as crabs, squid or mussels), and usually in even more brutal ways.

So why has humanity started to care about fish welfare so late? Is it because fishes are usually found in larger groups and are therefore hardly perceived as individuals? That can hardly be the reason; because in the industrialised countries of the Western world, campaigns for farm animal protection often began with laying hens, which also live in groups, usually in very large flocks not suited to their species, and are thus hardly perceived as individuals.

The main reason for society's late confrontation with the manmade suffering of so many fishes probably lies in the human peculiarity of having to reassure itself of a fundamental difference from the animal world *[10]*. The Enlightenment has wrested concessions from us time and again; in the meantime, it is recognised that vertebrates consciously experience pain, i.e. are sentient beings, which is why modern animal protection laws want to protect them *'as far as is reasonable'* from pain, suffering, overburdening, etc. As vertebrates, fishes were tacitly *'included'*, but without effective consequences; directly applicable regulations and enforcement principles only emerged in recent times *[11]*. For a long time, fishes were still assigned to a grey zone where the sentience remained debatable *[12]*. It is obviously difficult for humanity to assume that all living beings are evolutionarily related and to renounce a self-given special position in the cosmos.

Paradoxically, one reason for the late debate on the welfare of farmed fish may be the rapid growth of the aquaculture industry, which some environmental organisations had welcomed for years as an alternative to the threat of depleting the oceans. Consumers probably followed the recommendation to buy farmed fish all the more willingly because they could forget the images from documentaries about the nasty end of fishes in the fishing industry; in aquaculture on land, the fishes are gladly believed to be at least slaughtered *'humanely'*… The supposed ecological gain from aquaculture may have diverted attention from the suffering of the fishes. It was only when environmental organisations increasingly distanced themselves critically from aquaculture, which takes more fish out of the oceans to feed its farmed fish than it ultimately delivers to the Western market, characterised by its hunger for predator species *[13]*, that the varnish began to crack, thus also revealing the living conditions of the farmed fishes.

Suddenly so many fish – and fish species

In the meantime, however, aquaculture had already grown massively, by 7 to 9 percent annually since the 1950s *[14]*. Today, it is still the fastest-growing food industry. It is commonly assumed that this enormous growth is due to the motivation to create an alternative to overfishing of the oceans. However, the growth is not the result of collective, governmental decisions, but rather nothing more than the sum of the decisions of many individual entrepreneurs and investors, for whom the prospect of a good business was and still is the decisive factor. This has several consequences:

Firstly, many companies invested and developed when fish welfare was not yet a widely supported concern and science was only able to say a little about the behaviour and needs of fish – or more precisely: of many different fish species. For – secondly – in 2014 aquaculture already included 362 fish species, 104 mollusc species and 62 crustacean species *[15]*. Of the 340 aquatic species farmed in 2007, more than a quarter had only been kept in captivity since 1997, while only a dozen species had been farmed before 1900 *[14]*. Only a few species have been farmed for more than 1,000 years: Carp (China), Gilthead seabream (Mediterranean), and at best Eel and Trout (Europe) and Tilapia (Africa).

By comparison, terrestrial livestock farming has evolved over the last 6,000 to 10,000 years, depending on the species, and has focused on around 30 species, for good reasons not including a single predator. Why does the much younger aquaculture afford itself the luxury of keeping 18 times more species than the traditional livestock industry, when it knows little about the natural needs and behaviour of most of these species? Would it not be wiser, for economic reasons alone, to concentrate on a few (non-carnivorous) species in order to accumulate knowledge? *(see Fig. 1)*

Apart from traditional farms, many aquaculture industrialists – often career changers who are betting on a profitable business as demand grows – are behaving as if they were in a fast new market full of niches. The temptation to try something new seems to be so great that sometimes investments are even made without prior market research and production bypasses the market; the large marine fish farm in Völklingen in Saarland failed economically by a hair's breadth, and in the case of the large catfish farm in the Rhine Valley of St. Gallen, which had to close for other reasons, experts doubted whether the large quantity could have been sold. Why do entrepreneurs do this to themselves and to fishes?

Wild fish would be the smarter substitute for farmed fish

Another driver for the enormous number of species in aquaculture is apparently the retail sector. At a symposium on animal welfare in fish farming at the end of 2016 in Zurich *[16]*, industry representatives opposed the strategy propagated by **fair-fish** of concentrating aquaculture on a few species that are most likely to experience welfare in captivity according to the available

Table 1: Example of the summary of two FishEthoBase short profiles

Oreochromis niloticus	Li	Po	Ce
1 Home range	?	High	Medium
2 Depth range	Medium	High	High
3 Migration	High	High	High
4 Reproduction	High	High	High
5 Aggregation	?	High	Medium
6 Aggression	Low	Medium	Medium
7 Substrate	Low	High	High
8 Stress	Low	Medium	Medium
9 Malformation	High	High	High
10 Slaughter	Low	High	High
FishEthoScore	3	8	6

Clarias gariepinus	Li	Po	Ce
1 Home range	Low	High	Medium
2 Depth range	Low	High	High
3 Migration	Low	High	High
4 Reproduction	Low	High	High
5 Aggregation	?	Medium	Medium
6 Aggression	Low	Low	Low
7 Substrate	Low	High	High
8 Stress	Low	Medium	Medium
9 Malformation	Low	Medium	Medium
10 Slaughter	?	High	High
FishEthoScore	0	6	5

Li = Likelihood that the individuals of the species experience welfare under minimal farming conditions.
Po = Potential overall potential of the individuals of the species to experience welfare under improved farming conditions.
Ce = Certainty of our findings in Likelihood and Potential.

- High
- Medium *(not scored in Likelihood)*
- Low
- ? Unclear
- / No findings

FishEthoScore = Sum of criteria scoring "High" (max. 10)

Table 2: FishEthoScores, domestication level and number of farmed animals, basis: first 43 short profiles

Species	Li	Po	Ce	Do	Animals (in millions)
Nile tilapia *Oreochromis niloticus*	3	8	6	5	*4,900–15,700*
African catfish *Clarias gariepinus*	0	6	5	4	*160–500*
Yellowtail amberjack *Seriola lalandi*	4	4	4	2	*(20–66)*
Common carp *Clarias gariepinus*	1	4	2	5	*1,700–8,700*
Grayling *Thymallus thymallus*	2	3	0	3	*<1*
Greater Amberjack *Seriola dumerli*	1	3	2	2	*(20–66)*
European seabass *Dicentrachus labrax*	0	3	5	5	*320–400*
Atlantic cod *Gadus morhua*	1	2	4	4	*<1*
European perch *Perca fluvialtilis*	0	2	4	4	*<1–1*
Atlantic salmon *Salmo salar*	1	2	3	5	*282–659*
Southern bluefin tuna *Thunnus maccoyii*	1	2	3	3	*8–26*
Cherry salmon *Oncorhynchus masou*	0	2	3	4	*?*
Pacific whiteleg shrimp *Litopenaeus vannamei*	0	2	3	4	*?*
Russian sturgeon *Acipenser gueldenstadtii*	0	2	2	4	*<1–1*
Siberian sturgeon *Acipenser baerii*	0	2	0	5	*<1–1*
Grass carp *Ctenophayrynqodon idella*	0	2	0	5	*2,329–11,646*
Arctic char *Salvellinus alpinius alpinus*	1	1	2	5	*4–14*
Red porgy *Pagrus pagrus*	1	1	2	4	*1–3*
Cobia *Rachycentron canadum*	1	1	1	4	*5–7*
Rainbow trout *Oncorhynchus mykiss*	0	1	4	5	*152–3,627*
Gilthead seabream *Sparus aurata*	0	1	3	5	*417–556*
Meagre *Arayrosomus reqius*	0	1	3	4	*14–46*
Common octopus *Octopus vulgaris*	0	1	3	3	*?*
White sturgeon *Acipenser transmontanus*	0	1	2	4	*?*
Giant tiger prawn *Penaeus monodon*	0	1	2	4	*?*
Turbot *Scophthalmus maximus*	0	1	1	3	*33–93*
Pikeperch *Sander lucioperca*	0	1	1	4	*1–4*
Atlantic sturgeon *Acipenser naccarii*	0	1	0	4	*?*
Sterlet sturgeon *Acipenser ruthenus*	0	1	0	4	*<1*
Burbot *Lota lota*	0	1	0	3	*<1*
Atlantic halibut *Hippoglossus hippoglossus*	0	0	5	3	*<1*
Wreckfish *Polyprion americanus*	0	0	3	2	*?*
Barramundi *Lates calcarifer*	0	0	2	4	*38–255*
Brook trout *Salvelinus fontinalis*	0	0	1	5	*1–5*
Common dentex *Dentex dentex*	0	0	1	4	*<1*
Striped mullet *Muqil cephalus*	0	0	1	4	*10–30*
Pangasius *Pangasianodon hypopththalmus*	0	0	0	3	*280–839*
Hybrid sturgeon *BAEyNAC, NACxBAE*	0	0	0	5	*?*
Stellate sturgeon *Acipenser stellatus*	0	0	0	4	*<1*
Senegolese sole *Solea senegalensis*	0	0	0	3	*1–4*
Dover sole *Solea solea*	0	0	0	3	*<1*
Sharpsnout seabream *Diplodus puntazzo*	0	0	0	2	*<1–1*
Malabar grouper *Epinephelus malabaricus*	0	0	0	2	*<1*

omnivorous | mostly carnivorous | carnivorous knowledge collected in the FishEthoBase *[17]* *(see Fig. 2)*. A counterargument from the industry in the final discussion is: with a decreasing number of species that can still be sustainably gained from the oceans, aquaculture must ensure diversity in the fish supply. This is a remarkable statement from experts who know more about fish than most consumers. Over 34,000 wild fish species have been documented [18]; the number of commercially caught species is greater than the number of species farmed today. The diversity of supply will continue to come from the oceans, provided that their stocks are used wisely!

That aquaculture could replace fisheries is a popular argument. The Kiel fisheries biologist Rainer Froese, one of the fathers of the leading fish database FishBase *[18]*, dismantled this argument with regard to Europe's fish consumption at the aforementioned symposium: by fishing in a sustainable way, the yield could be increased by 57 percent, so conversely, it is fishing that could easily replace aquaculture *[19]*. This would spare the suffering of life in captivity for up to 150 million fish and up to 600 million shrimps per year *[20]*. The only thing that remains to be solved is the greatest possible reduction of suffering at the abrupt end of their lives in the fishing gear and on board, a question that **fair-fish** international and its research group will address in the future. After all, if you consider that the stocks of wild fish and aquatic animals are the last great wild resource for human food, it seems downright crazy to overexploit them through ruthless industrial exploitation and then want to replace them with farmed animals. But industrial fishing and aquaculture are subsidised to the tune of tens of billions per year – a sum that could be used to implement sustainable fisheries conversion.

Aquaculture is a reality – what can be done for the fish now?

Aquaculture is now a reality that must face up to the question of fish welfare. The following articles in this issue present possible solutions. Culum Brown and Cat Dorey start from the cognitive abilities of fish and formulate the consequences in caring for their welfare in aquaculture. Lynne Sneddon introduces research on pain perception in fish, while Becca Franks et al. add to the concern for avoiding pain and suffering the question of how to facilitate positive experiences for fishes in captivity. Leonor Galhardo then moves from stress avoidance to quality of life, while Maria Filipa Castanheira looks at the relationship between individual coping styles and fish welfare (her article appeared three years ago in the Fokus issue 18 on farm animal personality and has been updated for this issue). Lluis Tort and Joan Carles Balasch, on the other hand, argue for a ***'One Health'*** approach, which starts from health in the sense of healthy habits. Pablo Arechavala-Lopez presents three experiments in which solutions for environmental enrichment were tested in fish farms. Jenny Volstorf introduces the FishEthoBase database, which provides and interprets ethological knowledge about a growing number of fish species as a prerequisite for improving fish welfare. João L. Saraiva and Pablo Arechavala-Lopez conclude by showing that the welfare of farmed fish has finally become an issue that science and practice can no longer avoid today.

In the practical part, Billo Heinzpeter Studer et al. report on the development of fish welfare criteria and indicators for the **Friend of the Sea** (FOS) certification scheme, based on the FishEthoBase and observations on fish farms. Ruth Garcia Gomez presents parallel work by the **Aquaculture Stewardship Council** (ASC) label. Stefan-Andreas Johnigk explains how the German Aquaculture Welfare Standards Initiative intends to improve fish welfare, supplemented by a presentation of the planned coordination office for Swiss aquaculture. Finally, Georg O. Herriger shows the considerations on fish welfare from the point of view of a fish farming company.

The fundamental question remains unanswered so far: which aquaculture with which species? One possible answer seems obvious: focus on fish species with a high degree of domestication. However, an analysis of the first 41 species profiled in the FishEthoBase shows that the degree of domestication of a species does not correlate at all with its potential for high fish welfare *(Fig. 3)*. This is not surprising, however; the degree of domestication is primarily a measure of the closedness of the reproductive cycle in captivity. Many predatory and other wild animals can also be made to reproduce outside their natural habitat, and at best it is even possible to create relatively species-appropriate conditions for them in a zoo. Nevertheless, most of them, and predators in particular, are not found in farm animal husbandry.

This closes the circle we entered at the beginning. At the 3rd Summer Shoal *[22]* of **fair-fish** international, *Walter Sánchez-Suárez et al.* noted that knowledge

Table 3: Correlation matrix for selected variables of the FishEthoBase *[21]*.

Correlation matrix	Likelihood	Potential	Certainty	Domestication	Improvement Capacity
Likelihood	1				
Potential	0.60	1			
Certainty	0.21	0.56	1		
Domestication	0.02	0.11	0.14	1	
Improvement Capacity	0.08	0.80	0.49	0.18	1

First 41 species short profiles. Values are Spearman —›. Signifikant correlations are highlighted.

about fish welfare is still low compared to the rapid growth of aquaculture and the challenges it creates. While the focus is on fish health, the provision of husbandry environments that would provide positive experiences for the fish is neglected. The authors suggest using the science of terrestrial livestock welfare as a lens, and using its extensive expertise, errors, achievements and methods to better understand the challenges and opportunities in studying fish welfare and to develop strategies for filling knowledge gaps.

The FishEthoBase, or its FishEthoScore, suggests a different answer: shift towards the few species with high potential to live well in captivity under optimal conditions: As *Fig. 2* makes clear, the number of species thus considered is far smaller than the thirty species used in agriculture. The selection largely coincides with that based on ecological considerations, as presented by *Rainer Froese [19]*: aquaculture of species that can be farmed in a species-appropriate manner and without feed components from forage fisheries. All other fish species can exist in seas, lakes and rivers so long as we take care of them. Such a recommendation is still anything but popular with fish farmers; but as far as fish welfare is to become a weighty argument for the industry, the development of aquaculture will in the long run not be able to avoid delisting certain species.

Trout fattening in raceways, Northern Italy (Photo credit: © Studer / fair-fish)

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Pain and Emotion in Fishes—Fish Welfare Implications for Fisheries and Aquaculture

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Why should we care about fish welfare?

Humans interact with fishes in a variety of contexts and many of these have welfare implications *[1]*. Fishes are a major source of protein for a significant proportion of the world's human population. They remain the last animals that we largely capture from wild stocks; however, wild fish populations cannot cope with demand and many are now overfished *[3]*. In response, aquaculture is increasingly filling the gap. In terms of biodiversity, there are more fish species than the rest of the vertebrates combined, and freshwater fishes in particular are among the most endangered taxa in the world *[4]*. Each of these contexts brings unique fish welfare and ethical considerations, but to date fishes have largely remained off the animal welfare radar *[5]*.

During the 1970s, there was a considerable increase in advocacy for protecting the welfare of animals used in industrial agriculture (initially in the UK), but for some reason the movement never made it to the sea. To this day, and as we shall discuss, there are few animal welfare controls in aquaculture and none in commercial fishing operations. In many countries around the world fishes are not legally defined as 'animals' under existing animal welfare legislation or are specifically exempt. In Australia, for example, in two states (Western and South Australia) fishes are explicitly excluded from welfare legislation, while in the Northern Territory only captive fishes are protected. In the remaining states, while fishes are included in animal welfare legislation, fishing activities are exempt, although Tasmanian legislation does at least require that fishing is 'done in a usual and reasonable manner and without causing excess'. *[38]*

One wonders why it is that fishes should have such a poor representation in animal welfare legislation. Even the language associated with fishing (harvest, stocks, etc.) suggests that they do not qualify as animals, but rather are inanimate objects. One likely answer is that people generally view fishes as primitive animals with limited scope for intelligence. Scientific research in the last 20 years, however, has revealed that fishes are much more intelligent than the general public give them credit for [6]. In many domains they are as intelligent as most land animals *[7] [8]*. The following is a list of the traits reasonably associated with intelligence and, in the not too distant past, were once primarily assigned to humans: learning and memory, innovation, social learning, culture, cooperation, reconciliation, nest building, and tool use. Over the last decade or two, all of these behaviours have not only been shown in fishes, but fishes have often led the way as model species for understanding these phenomena in non-human animals (for comprehensive reviews of fish cognition see *[5] [6] [8] [9]*).

The gap between public perception of fish intelligence and scientific reality has serious implications for our interactions with fishes, not least of which is because public opinion can help drive changes in animal welfare policy and legislation. Intelligence, sentience and ethics are tied together *[5]*. People are far more likely to show empathy towards animals whom they believe are intelligent [10]. Moreover, animals who are intelligent have greater capacity to suffer *[11]*. This is largely due to their ability to learn from previous events and project their experience into the future *[11]*. For example, if a fish experiences a negative stimulus (for example, shock or a predator) in a given context, they rapidly learn from that experience and present signs of fear, stress and anxiety when later placed in that context in anticipation that the event will reoccur *[12] [13]*.

Fish pain

One of the reoccurring topics in fish welfare is whether fishes feel pain. Pain represents an emotional experience in response to harmful or potentially harmful stimuli and is intertwined with the nociception pathway, which is responsible for detecting harmful stimuli (for example heat). While there is ongoing debate in this area *[14]*, the overwhelming evidence suggests that fishes do feel pain much like humans *[15]*. Indeed, the reason humans feel pain at all is because we inherited our pain receptors and associated cognitive toolbox from a fish ancestor. Nociceptors date back to the annelids and emotional responses to pain simply act as behavioural motivators *[16]*. Given the primary role of pain is keeping animals safe from harm, it should come as no surprise that most animals have this capacity to varying degrees.

Since the discovery of nociceptors in trout in the early 2000s *[17]*, the debate over whether fishes feel pain has been repeatedly repositioned *[18]*. The issue is no longer about whether fishes can detect noxious stimuli, but rather how they respond on an emotional level. That is: are they cognitively engaged with pain? Rather than concentrating on how the human brain processes painful stimuli and whether fishes do something similar *[19]*, let us stop and think about why we feel pain at all. That is: what is the evolutionary significance of pain perception? What is its function? Pain perception and the associated emotional response is an ancient, highly conserved evolutionary trait *[20]*. There are two main components. The first is a simple reflex—an emergency move away from a painful stimulus. No cognition is required as the nociception pathway carries the message from the injured limb to the spinal cord before the withdrawal order is sent directly back to the offending limb. In many cases, there is no awareness of pain before the withdraw reflex is complete—the brain receives this information afterwards. The second component is about long-term consolidation of that experience. That is, to remember that object X or context Y is dangerous and to

[1] First published under the title *'Pain and Emotion in Fishes—Fish Welfare Implications for Fisheries and Aquaculture'* (2019) in: *Animal Studies Journal*, Vol. 8, No. 2, https://ro.uow.edu.au/asj/vol8/iss2/12/. Translation by Billo Heinzpeter Studer (omitting the sections on fisheries). Courtesy of the publisher and authors.

stay away. There is little value in detecting painful stimuli without remembering to avoid them again in future *[20]*. There must be cognitive engagement for the system to work. Without cognitive engagement, having just been burnt, you could turn around and walk straight back into the fire. The emotional response to painful stimuli is a reinforcer to ensure that we learn from these experiences.

Since the discovery of nociceptors in fishes there have been considerable research efforts into studying fish pain in great detail. Table 1 shows the accepted criteria for measuring the capacity of animals to feel pain (modified from *[21]* and *[22]*), and reveals that the evidence for fishes feeling pain is just as good as it is for non-human mammals. Further, it is better than that for birds, reptiles and amphibians. It is interesting to note that the evidence for pain in decapod crustaceans and cephalopods is also comprehensive, and it is unsurprising that these taxa are finding their way into animal welfare legislation around the world. While many of these criteria could arguably be influenced by aspects of the nociception system only, the last three categories shown in Table 1 definitely involve higher level cognitive processing. Animals who are in pain show changes in behavioural preferences and the choices that they make by, for example, avoiding contexts previously associated with noxious events. Animals who can experience pain are also willing to pay fitness costs to avoid pain by trading off pain with other fundamental requirements (for example, access to food or social companionship). This behaviour reveals an ability to titrate the potential damage caused by noxious stimuli with other competing motivators *[21] [22]*.

The following case studies serve to illustrate the types of experimental evidence that have contributed to populating *table 1* for fishes.

Case study 1: Pain responses

When animals are experiencing pain their normal pattern of behaviour changes and pain often takes priority over, or interferes with, other motivators. Researchers injected trout in the lips with a noxious substance (acetic acid or bee venom) and found that the fishes avoided eating for about three hours *[17]*. In contrast, control fishes and those injected with saline (procedural control) return to feeding after 80 minutes. Clearly the painful stimuli reduced the motivation to feed.

Case study 2: Pain killers restore behaviour

Having shown that fish behaviour changes in response to pain, the next obvious question is to what extent can it be restored if pain relief is applied. A study *[23]* examined the change in activity and opercular (gill covering) beat rate in rainbow trout 30 minutes after they were injected subcutaneously with saline, acetic acid, or acetic acid combined with pain relief. Injection of acid caused a reduction in activity levels and increased breathing rate relative to controls. Trout injected at the same site as the acid with the local anaesthetic lidocaine were no different from the control trout, suggesting that the pain relief worked and returned behaviour and physiology back to normal. These experiments also illustrate the highly conservative nature of vertebrate physiology, such that many of the drugs designed for humans also work on fishes.

Case study 3: Trade-offs between pain and other motivators

Trout were introduced to an aquarium which was divided into three sections. After acclimation to the tank they showed no preferences for any particular sector. When a mild shock was introduced as the trout entered a sector, they rapidly learned to avoid that location after just a few exposures. Similarly, when a positive reward was added to the end of the aquarium (food or conspecifics) the trout shifted their space use to access the food or be near their friends. But what happened when the shock and the reward (food or friends) are placed in conflict? That is: were fishes willing to risk shock exposure to access food or friends? When deprived of food for three days *[24]*, or if a companion fish was in an adjacent compartment *[25]*, fishes traded-off the risk of shock with the competing motivator. They were willing to pay a pain cost to access important resources.

The key result in the second experiment *[25]* was from the treatment when a companion fish was present in the end compartment. Before the shock, there was a greater preference for the shock zone closest to the companion. Even though the fishes learnt that they would be shocked in this zone, they still entered the sector to get closer to their companion. Even more compelling is that they spent more time in this zone while a shock was being administered and they remained after the shock, perhaps even further increasing their preference for this sector. This is primarily due to the social behaviour of fishes which tend to increase their schooling behaviour when threatened *[26]*. Companionship can also buffer emotional stress *[27]*.

Collectively these case studies illustrate that the response to painful stimuli by fishes is not simply reflexive; rather it involves long-term cognitive engagement with pain. The responses made by fishes in these contexts are not fundamentally different from those of mammals, and therefore our own.

Animal emotions

In *The Expression of the Emotions in Man and Animals*, Charles Darwin *[28]* makes close connections between human emotions and their evolutionary precursors in animals. Darwin proposed that emotions are adaptive. They serve to motivate behaviour and also act as a form of communication: a means to outwardly express an animal's current inner state. At the most fundamental level, emotions likely guide animal behaviour by motivating rewarding behaviour and discouraging behaviour that results in punishment. *Fraser and Duncan [29]* propose that motivational affective states evolved to serve two fundamental functions: what an animal needs (survival) and what an animal wants (opportunism). In both cases, the net outcome results in fitness benefits *[30]*. Objects or contexts vary in emotional salience. In this way, emotions can help guide animals through the minefield that is the complex world in which they live. By assigning emotions to animals we assume that they are conscious and are aware of their internal state *[31]*.

Emotions affect the way we interact with the world. They affect our perception and decision-making processes. Because of this, animal emotions play an important role in assessing animal welfare *[32]*. Emotions are subjective experiences and humans rely heavily on verbal reporting of internal states or feelings. Of course, there are also behavioural and physiological indices of emotions which we can measure *[33]*. Cognitive bias is one such example *[34]* that has been used as a tool to assess animal emotions and welfare *[35]*.

Table 1: Pain Criteria for Animals. Source: adapted from *Walters, 'Defining Pain and Painful Sentience in Animals' [21]*; and *Sneddon et al.* 'Defining and Assessing Animal Pain' *[22]*.

Criteria	Mammals	Birds	Reptiles/ Amphibians	Fishes	Cephalopods	Decapods	Insects
Nociceptors, CNS pathways & processing							
Analgesic receptor							
Physiological responses							
Learned avoidance							
Change in behaviour							
Protective behaviour							
Drugs reduce response							
Selbstverabreichung von Medikamenten							
Pain takes priority							
Change in behavioural preferences/Choices							
Pay cost to avoid pain							
Trade off pain with other requirements							

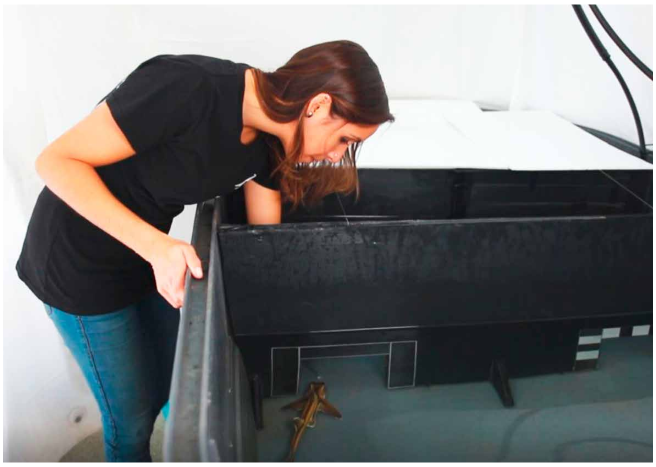

Figure 1 and 2: Shark fingerlings solving cognition tasks (photo: © Culum Brown)

Pessimists will look at a half glass of water and say it is half empty, while optimists will say it is half full. Animals suffering from poor welfare, for example, tend to demonstrate pessimistic behaviours, such as reduced learning ability *[36] [37]*. We can use our knowledge of how emotions interact with cognition to test the welfare status of individual animals. However, this has rarely been done in fishes (but see *[38] [39] [40]*). This means that we should not only focus on preventing poor welfare in fishes but must actively encourage positive welfare. There is increased awareness among animal welfare researchers that just attending to poor welfare does not lead to a lack of suffering *[41][42]* and there is a growing movement towards encouraging positive welfare states *[43]*.

Implications for aquaculture

Fisheries and aquaculture are by far the greatest human source of suffering and painful deaths of fishes, in terms of both the duration and intensity of suffering inflicted and the vast scale of these industries, and hence the number of fishes affected. There are also significant implications in how we address fish welfare in terms of their importance to humans as a source of food and employment.

The scale of the impact of fisheries and farming on fishes

The *Food and Agriculture Organization of the United Nations* (FAO) collects fishing and aquaculture data from member countries and produces official statistics on the production and use of fishes. In its biennial report, *The State of World Fisheries and Aquaculture [44]*, FAO estimated that in 2018 the global production of *'fish'* (fishes, crustaceans, molluscs and other aquatic animals, but excluding aquatic mammals, reptiles, and plants) peaked at about 178.5 million tonnes. Of the 96.4 tonnes of wild-caught fish, 77% were for direct human consumption. The remaining 23% of fish caught, 22.2 million tonnes, were for non-food uses. In 2016, 15 million tonnes were processed into fishmeal and fish oil for feeding farmed fish and other livestock like pigs and chickens, while the remainder was utilised as material for direct feeding in aquaculture and raising of livestock and fur animals (like mink), to be cultured (wild juveniles and small adults caught for on-growing in farms), as bait, in pharmaceutical uses, and for ornamental purposes *[45]*.

A recent study from the University of British Columbia *[46]* showed that the FAO fisheries landing figures do not reflect the amount of fish actually caught and killed because reporting nations often significantly underestimate the landings of small-scale and subsistence fishers, while recreational catch, discarded bycatch, and catches from illegal fishing operations are often not counted. When catch data was reconstructed from a wider variety of sources to estimate the numbers missing from official reports, the authors concluded that global catches between 1950 and 2010 were 50% higher than those reported to the FAO.

As populations of fishes have declined globally due to overfishing, and catches began to decline after the peak in 1996 *[45]*, aquaculture grew rapidly to fill the gap in demand, with a 5.8% annual growth rate during the period 2001 – 2016. Aquaculture took over from fisheries in 2013 as the main supplier of fish for human consumption and in 2018 represented 47% of total fish production and 53% if non-food uses are excluded *[44]*.

Since 1961, the 3.2% average annual increase in global fish consumption has outpaced annual human population growth (1.6%) and exceeded the annual increase in consumption of meat from all terrestrial animals, combined (2.8%) and individually, except poultry (4.9%) *[45]*

Moreover, according to the FAO, the increasing demand for fish and improvements in technology mean that world fish production is expected to expand from 171 million tonnes in 2016, to 201 million tonnes by 2030. Aquaculture is projected to grow 37% above 2016 levels to reach 109 million tonnes. *[45]*

Fishes as a source of food and employment

In 2015, fish accounted for about 17% of animal protein consumed, and provided 3.2 billion people with almost 20% of their average per capita intake of animal protein *[45]*. The populations of some countries eat a lot of fish, in terms of both volume and diversity, because they are a readily available cultural favourite, while in other countries people eat a lot because they have little choice. In coastal regions of developing countries, fish is often the only affordable and available source of animal protein. In Sierra Leone, for example, which has a very low overall food security, fish makes up 50% of the animal protein consumed. Inhabitants of some island nations, such as Kiribati and Micronesia in the Pacific and the Maldives in the Indian Ocean, depend almost exclusively on fish as a protein source, with consumption rates more than double the global average.

A 150-gram portion of fish provides 50-60% of an adult's daily protein needs and contains important fatty acids, vitamins and other essential elements such as iodine and selenium, which do not occur in such quantity and diversity in plant crops or land-based meat. Thus, fishes are a very important source of nutrition for those with few other options. In terms of employment, 59.6 million people were engaged in the primary sectors of fisheries and aquaculture in 2016: 19.3 million of these in aquaculture and 40.3 million people in fisheries. Many millions more are employed in fish processing, trade, retail and food services *[45]*.

How we farm and kill fishes

Fish capture and farm production are reported in weight, a fact that significantly devalues the lives of individual fishes, especially juveniles and smaller species, as well as the vast impact of human activities on fishes. Estimates based on the FAO's (under)reported catch data are that 0.79 to 2.3 trillion fishes are killed each year by fisheries and another 48 to 160 billion by aquaculture *[2]*.

The primary concern with regard to wild fishes is how we catch and kill them.

When it comes to farming – on which we are concentrating here –, fishes can suffer throughout their whole life cycle. Fishes are farmed in almost as many ways as they are fished, from low-intensity backyard ponds that feed Asian households, to high-intensity salmon farms in sea cages feeding a global demand by the growing middle classes for salmon.

We know very little of the ideal requirements for most fishes to live a life where they can freely express natural behaviour and live positive lives, but few farming methods provide fishes with a situation close to their natural environments to ensure this. This is especially true for highly migratory fishes like salmons, eels, and tunas.

Freshwater species are farmed in a range of natural or manmade ponds, channels or raceways that are fed by rivers or lakes, in cages or pens within rivers, or on land-based, closed- system tanks with recirculated treated water. Marine species are farmed in coastal ponds, and in open cages within lochs, bays, fjords, or the open ocean, and in land-based recirculating tanks. Fishes may be farmed throughout the whole life cycle, with eggs produced in hatcheries, or maybe taken from the wild as eggs, juveniles (like eels) or young adults (most 'farmed' bluefin tuna) and grown to the required harvest size.

Farms fall into three broad categories—extensive, semi-intensive, and intensive. Extensive systems tend to be the more traditional and sustainable systems which farm under more natural conditions, with low stocking densities. Fishes take their nutritional requirements from the environment, although nutrient rich material may be added to encourage algae growth for the fishes to feed on. In semi-intensive systems, natural food sources are supplemented with fertilisers and additional food, such as agricultural byproducts, manures, and fishmeal produced from wild fish, which allows higher stocking density. In intensive systems, almost all nutrition is from processed commercial feeds and stocking densities are high. Most of the carnivorous species, like salmon, are farmed this way, and there is a general trend towards more intensification of aquaculture systems. It is the high-intensity, high-output farms that have the greatest environmental and human rights concerns *[47]* and cause the most suffering to fishes, particularly through overcrowding, handling, transport, starvation, and slaughter *[48] [49]*.

In intensive fish farms, fishes' physical and mental well-being, and freedom to express their natural behaviour can be severely compromised by overcrowding in poor conditions. Overcrowded fishes, like any animals, suffer greater levels of stress and injury, and have a higher susceptibility to disease *[48] [49]*. Under these conditions the water quality is often poor, with low oxygen content, and contaminated with uneaten food, fish waste products including ammonia and carbon dioxide, and a variety of chemicals and antibiotics used to combat disease. Fishes in captivity have no way to avoid stressful situations or environmental changes. They cannot escape from other stressed and aggressive fishes, parasites, or predators, and cannot seek out cooler or warmer waters, or shelter when required.

Intensive farming practices require significant handling of fishes throughout their lives, and their delicate skin and fins are often injured when they are transported, during size sorting, vaccination and other veterinary treatments, and harvesting. Transportation of fishes from hatcheries to grow-out ponds, pens or cages, or between these for cleaning or restocking, is an especially traumatic experience with high loss of life from injury and stress *[49] [50] [51]*. For example, fishes can be pumped from a pond, into a large transport tanker, driven to the next facility, and then pumped back out again.

It is common on salmon farms to find as many as a quarter of individuals with stunted growth and abnormal behaviour, often floating lifelessly at the surface of the tank. They are described as 'losers' or 'drop-outs', and until recently the cause was unknown. A recent study showed that the behaviours and brain chemistry of these salmon was similar to those seen in stressed and depressed mammals *[52]*. They are unable to cope with the level of constant and inescapable stress, and essentially give up on life.

When it comes to harvest time, often after a stressful period of starvation to clear out their guts, farmed fishes suffer similar inhumane slaughter methods to wild fishes. Farmed fishes are commonly killed by asphyxiation in air or in an ice slurry, gill-cutting, and carbon dioxide narcosis *[48] [53] [54]* all of which cause considerable suffering. Some may be gutted while alive. The more humane methods of percussive stunning (a blow to the head) and electric stunning methods to render fishes unconscious are increasingly being used, but only by a minority of farms. These methods still have some problems (such as inappropriate electrical field strength, and poor staff training or conditions) and need further development at a species level to ensure humane killing *[48] [49] [54]*.

Conclusions and a way forward

Fishes are intelligent, social creatures. The evolutionary function of pain is ancient and highly conserved across all vertebrates and likely some invertebrates, and the evidence for pain in fishes is as good as for mammals. Fishes have neurones for nociception and the necessary brain parts for 'emotional' responses to pain. Fishes engage cognitively in pain perception which has important fitness functions. Fishes experience positive and negative emotions which provide insights into their welfare status. We are likely in a position not only to prevent negative welfare in fishes, but also to move towards actively encouraging positive welfare.

Despite our knowledge that fishes can suffer, trillions of fishes [2] are subjected to inhumane fishing and farming practices annually. Many of these practices would not be acceptable to the public if they were applied to animals used within land-based animal agriculture. While there is increasing awareness of the capacity for fishes to suffer, and the inhumane practices of fishing and farming, there has been little action to date to remedy this.

Various organisations have produced guidelines for fish welfare in aquaculture (for example, Humane Slaughter Association), but these often do not address the full range of welfare issues. Where they are applied on farms, it is primarily to reduce fish deaths to increase profits, rather than though concern for the full extent of welfare issues. There is little in the way of national legislation addressing fish welfare.

With growing production in aquaculture, however, there are distinct opportunities to have much greater control over the choice of species farmed, and housing conditions and slaughter methods used, and bring them into line with the ethics and welfare requirements for terrestrial agriculture to align more strongly with public expectation. However, the drive to increase production could also increase the use of problematic practices, such as high stocking densities, that will prevent a shift to positive welfare outcomes.

In order to identify priority areas, it may be helpful to consider the issue of fish welfare in terms of the formula used by fishcount.org.uk [2]:

Magnitude of welfare problem
= Severity × Duration × Numbers.

Given the immense numbers of fishes killed by fishing and farming, we need to begin the process that shifts these industries towards a better outcome for as many fishes as possible. This would imply that we must reduce the demand for fish by addressing the overconsumption by those who do not need to eat more animal-based protein. Industrialised fish production is primarily feeding the expanding seafood consumption of developed and developing countries. As the FAO report highlights, China is the world's largest fish consumer (55.9 million tonnes, 38% of global consumption in 2015 *[45]* with per capita consumption twice the global average, fuelled by growing domestic wealth. The other top importers and consumers of fish, the USA, Japan, and the EU when combined accounted for approximately 64% of the total value of world imports of fish and fish products in 2016, or approximately 56% if trade within the EU is excluded.

Farmed fishes must be kept in more natural environments at lower densities, and we must find ways to reduce the impacts of handling and transport *[49]*. We must choose species that cope better with farming and that require little in the way of wild fishes in their aquaculture feed. Humane slaughtering practices must be developed for both industries, aquaculture and fisheries.

Despite the overwhelming nature of the problem, there is some room for hope. The rise of campaigns like *'Meatless Monday'* and the growing vegetarian and vegan movements, fuelled by a range of health and ethical concerns around meat production, are helpful avenues for reducing fish consumption. We are seeing a rapid growth in the development of plant-based meat alternatives, and lab-cultured meat, with some companies specialising in alternatives to seafood (for example, *sophies kitchen.com*, *finlessfoods.com)*.

Awareness about the environmental and human rights concerns of fish production continues to rise, as does the demand by fish traders and retailers for ethically sourced products. For example, Thai Union, one of the largest fish traders in the world, recently made significant commitments to address unsustainable, illegal, and unethical practices throughout its global supply chains *[55]*. Addressing fish welfare concerns is another way that fish producers can differentiate themselves in the marketplace. There is already some common ground between fish welfare and industry concerns in that fishes which are reared and killed humanely are less stressed, and therefore produce a better fillet quality and a longer shelf life *[56] [57]*.

Fish behaviour and welfare experts will benefit from collaborating with the people and systems that are driving equitable and sustainable practices in fisheries and farming. Together we can drive improvements that will benefit individual fishes, and the broader marine environment, as well as the lives of those working in the industry. We must reduce our consumption of fish, and ensure that where we do need to farm and capture fishes it is done humanely, fairly and without unnecessary waste of trillions of lives. We recommend reading the substantial recommendations on this issue provided by fishcount.org.uk *[2]*.

Take Home Message

Scientists have built a significant body of research that shows that fishes display all the features commonly associated with intelligence in mammals, and that they experience stress, fear and pain. These findings have significant ramifications for animal welfare legislation, an area from which fishes have been traditionally excluded. Our most detrimental interaction with fishes is through commercial fisheries and aquaculture, an industry that feeds billions of humans and employs millions more.

Farmed fishes are under our control for their entire lives, and while there are welfare guidelines available, where these are applied, the goal is primarily to maximise production and reduce losses, rather than ensure good welfare. These industries are important to many of us; however, we need to change these systems to address both welfare and sustainability. For aquaculture this means keeping fishes in more natural environments at lower densities, reducing transport and handling impacts, and choosing species that cope better with farming. Aquaculture as well as fisheries need to develop humane slaughtering practices.

Fish behaviour and welfare experts will benefit from working with the people and systems that are driving more ethical and sustainable practices in fisheries and farming, to help initiate improvements that will benefit individual fishes and the broader marine environment, as well as the lives of those working in the industry. We must ensure that where we do need to farm and capture fishes it is done humanely, fairly and without unnecessary waste of trillions of lives. A simple way forward would be to reduce our reliance on fish as a primary source of protein, particularly in wealthy countries where alternatives abound.

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Sentience in Fishes

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Introduction

Fishes are used in a variety of contexts and in incredibly large numbers. Trillions of fish are caught or farmed each year to provide a foodstuff for humans or other animals. Millions are employed as models for experimental studies. Fishes are also used for recreational purposes in sport or as a hobby. Numerous species are held in public aquaria and fishes are the most numerous pet held in home aquaria or ponds. Recent empirical studies have demonstrated the capacity for pain and sentience in fishes which may lead to suffering. This review presents the evidence and biology of pain and sentience in fishes that make a compelling case for the capacity to experience negative affective states. From the neuroanatomy of the nervous system, physiological responses and through to whole animal behavioural changes, pain is highly conserved and comparable with mammals. This has important implications for how we treat fish which suggests a more ethical and humane management should be adopted.

Defining Sentience

According to *Broom's definition [7]* a sentient being has some ability to:

- Evaluate the actions of others in relation to itself and third parties. I would interpret this as being able to form relationships within and between species.
- Remember some if its own actions. Here fishes should have the cognitive ability to learn and remember past experiences.
- Assess risks and benefits. Thus fishes must be able to assess the pros and cons of a situation and make decisions based upon this assessment.
- Have some feelings. The ability to experience positive and negative affective states and be influenced by the state of others.
- Have some degree of awareness. Thus fishes should have some form of consciousness such that they can differentiate and recognise themselves distinct from others.

Recent empirical evidence has shown that fishes do indeed have some ability within each criterion which shall be reviewed below. Quoting Redouan Bshary *'Behaviourally speaking, fish can do anything a mammal can do' [1]*. Yet we treat fish quite differently to mammals which is curious?

Forming relationships

Fishes are capable of having complicated relationships both intra- and inter-specifically. For example, ***coral reef rabbitfishes*** *(Siganus)* form pairs where they use subtle communication signals to perfectly match their partner's behaviour *[2]*. Whilst one fish forages in the coral crevices of their environment, the other fish remains vigilant looking out for predators *(Fig. 1)*. They regularly change roles and this matching of behaviour requires the ability to understand the intentions of each other. This coordinated vigilance is termed direct reciprocity and was thought to exist only birds and mammals. The benefits of engaging in this behaviour are obvious; rabbitfish pairs have increased foraging success by penetrating deeper into the coral crevices and reduced predation. This is an excellent example of a complex relationship within species but what about between species.

Figure 1: Direct reciprocity is rarely seen in birds and mammals but here are photographs depicting this complex behavior in rabbitfishes. The foraging individual (in the head-down position) feeds in cracks and crevices in the substratum, while the vigilant individual is positioned in the water column with its head up. Note the obstructions to the visual field of the forager, suggesting high vulnerability to predation and the unobstructed field of perception of the vigilant fish. (a) Siganus corallinus, (b) S. vulpinus, (c) S. doliatus, (d) S. puellus. (Taken from [2], photographs taken and owned by Jordan M. Casey, reproduced under a Creative Commons License CC BY [2].)

It has been well documented that giant moray eels *(Gymnothorax javanicus)* and grouper fish *(Epinephelidae)* form a cooperative hunting partnership *[1]*. These associations are non-random since individuals choose specific partners so must remember these individuals. The groupers use signals to initiate joint searching and show moray eels to prey hiding places so they can chase them out from small crevices the bulkier grouper cannot. This signalling is dependent on how hungry the grouper is but both partners benefit from the association foraging at a greater rate together than when alone. These two species use their complementary hunting skills to enable them to catch more prey fish. Again the use of a signalling system demonstrates that the two species can communicate and decipher intent and embark on a joint venture together to the benefit of both individuals.

Cognitive ability

To dispel the myth that fishes, goldfish in particular, have a three second memory a plethora of studies have investigated the cognitive ability of fishes and not found it lacking. Goldfish *(Carassius auratus)* can navigate mazes and can remember the location of spatial cues to reach a target area *[3]*. Furthermore, this species has a concept of time and learned to press a lever at a specific time of day to get a reward in an operant learning paradigm *[4]*. After training, guppies have been shown to possess numerical skills and can recognise the number of dots on test cards always choosing the larger number no matter the size, distribution or combination of dots *[5] (Fig. 2)*. These are just a small number of examples demonstrating how well developed fishes' cognitive ability is (*review in [6]*).

Decision making

Being able to assess the risks and benefits of a situation and then make a decision based upon that assessment indicates sentience since this involves reasoning *[7]*. Intraspecific variation in behavioural phenotype, often termed the bold and shy continuum, affects decision making in a consistent manner in many fish species. For example, rainbow trout *(Oncorhynchus mykiss)* display disparate personalities where active, aggressive dominant individuals take risks and are classified as bold. In contrast shy trout are risk averse, less active and submissive *[8] [9]*. In some opinions fish were believed to be automatons only capable of reflexive behaviours (e.g. *[10]*) but numerous studies on personality and risk taking in fish including rainbow trout demonstrate that these individual characteristics influence decision making and thus each fish assesses risk in a different way. Assessment of risk can also be influenced by external factors and behaviour altered accordingly. Cleaner wrasses *(Labridae)* set up cleaning stations on reefs where client fish, often predatory, arrive and are cleaned of parasites *[11]*. If the service is good then the clients will return and the cleaner wrasse gets repeat business. The parasites are nutritious but the client's skin and mucus are more so. Therefore, sometimes the cleaner wrasse will nibble the client. This is a risky strategy when cleaning a predator and expecting they will return. *Pinto et al. [11]* observed the number of client bites when cleaner wrasse were unobserved or observed by a potential client and found that bites were dramatically reduced when a client was watching. These results demonstrate the cleaner is aware of being watched and that its own

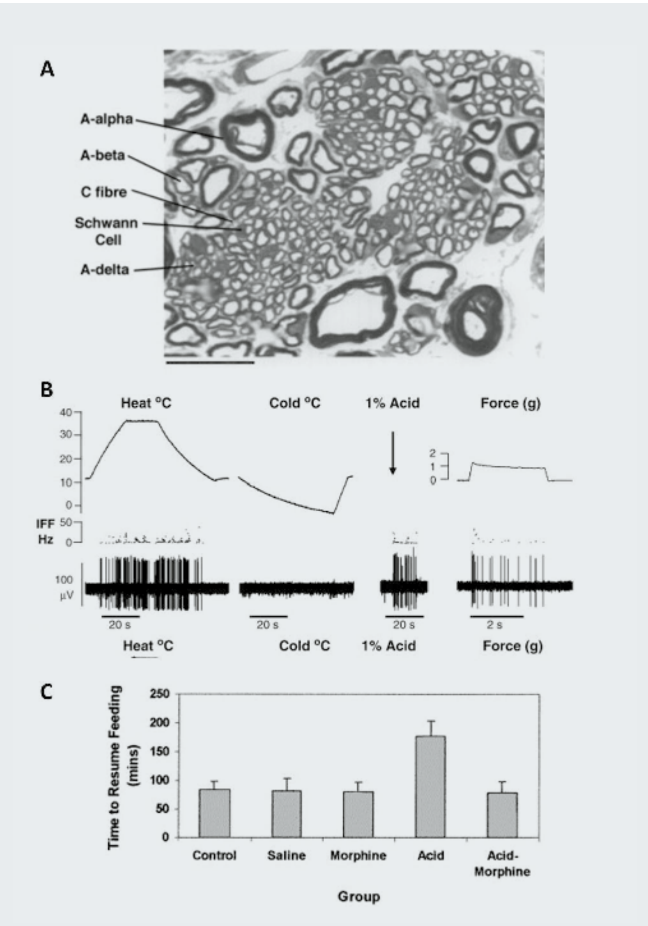

Figure 2: (A) Test apparatus for the abstract numerical discrimination test. Subjects were required to choose the stimulus with the greatest number of orange dots. (B) Stimuli used in numerical discrimination training consisted in two groups of dots differing in numerosity. Here, we depicted two examples of 3 vs. 4 contrast, with cumulative surface area controlled (I) and not controlled for (II).

(Taken from [5] under the terms of the Creative Commons Attribution License CC BY).

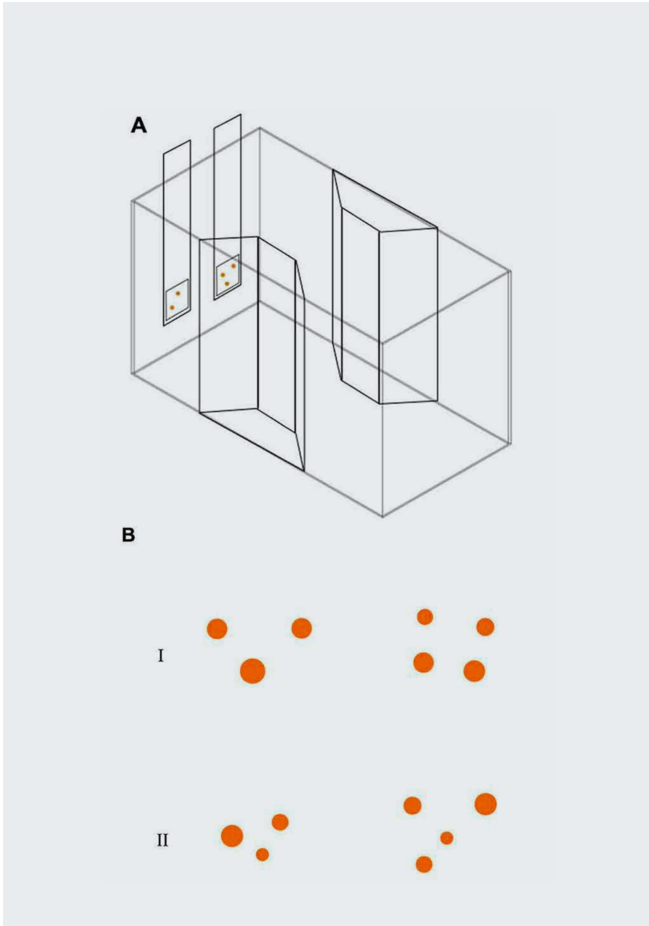

Figure 3: (A) Section of the maxillary branch of the trigeminal nerve of rainbow trout showing the presence of A-delta and C fibres (×1000, scale bar=2 μm; [20]). (B) Responses of trigeminal receptors on the head of rainbow trout. Recordings show responses to heat, cold, chemical (1% acetic acid applied topically) and mechanical stimuli. For each recording, upper trace indicates stimulus applied to the skin, middle plots instantaneous firing frequency (IFF, calculated from intervals between successive action potentials), and bottom shows extracellular, single unit recording from the trigeminal ganglion. This example is from a polymodal nociceptor showing slowly adapting responses to heat, chemical and mechanical stimulation but not to cold stimulation [19]. (C) Mean time (+S.E.) taken for the treatment groups to begin ingesting food (n=5 rainbow trout per group). There was a significant difference in the time taken to resume feeding between the groups ($F_{4,20}$=7.29, P=0.003; [27]). (All figures reproduced by kind permission of Elsevier.)

behaviour will have an impact upon the potential new client. Thus, it does not bite its client and assesses the risk and benefits of this behavioural strategy and how it may influence another individual.

Positive and negative affective state

Studies have sought to understand the nature of positive and negative 'feelings' in fishes. Surgeon fish (*Acanthuridae*) when exposed to a moving model of a cleaner wrasse with brushes voluntarily swim parallel to the model and receive what could be called a massage *[12]*. They do not engage in this behaviour if the model cleaner wrasse is stationary. Those surgeon fish that engaged with the model had lower circulating cortisol levels compared to individuals that did not have a massage and the researchers concluded this had a calming, positive effect on the fish. Therefore, this can be considered as an example of positive affective state in fish. There has been a focus on negative affective states in fish since most legislation suggests the ability to suffer is the main driver behind protecting a particular species.

Current scientific evidence proves that fish possess nociceptors, receptors that preferentially detect painful, damaging stimuli; adverse physiological and behavioural responses to painful treatment that are prevented when pain-killing drugs are administered; and that when experiencing pain fishes do not show appropriate fear or anti-predator behaviour (reviews in *[13] [14] [15] [16]*; *Fig. 3*). Therefore, there is ample evidence of pain in fish. Furthermore, the responses to pain are not reflexive and are influenced by the presence of others. In zebrafish *(Danio rerio)*, individuals subject to fin clipping where a portion of tail fin is removed for genotyping, recovered more quickly in a group compared with isolated and paired zebrafish *[17]*. This phenomenon is termed social buffering where the social environment can modulate affective state, thus, in a familiar group of conspecific the individual may be less affected by a negative welfare state. Emotional contagion, where an observer mirrors the behaviour of an affected individual, has also been investigated in fishes *[18]*. This is linked to empathy where humans show sympathy and human affective state is influenced by the mental state of another thus the emotion is contagious. In zebrafish, individuals who observed conspecifics reacting to a predator cue performed an increase in freezing behaviour even though they were not exposed to the predator cue *[18]*. Thus the fear response in the exposed fish was recognised by the observer fish and the observer exhibited a similar anti-predator response even there was no cue to signal danger demonstrating emotional contagion.

Self-awareness and consciousness

Can fish recognise themselves as distinct from other individuals? Are they self-aware and show some degree of consciousness? A study *[21]* clearly demonstrated cichlid fish can recognise their own odour and distinguish it from others in a choice test. Mirror self-recognition tests were recently thought to be the gold standard of proving consciousness if an animal could recognise itself in a mirror *[7]*. When presented with a mirror, Manta rays *(Mabula)* perform self-directed behaviours waving at the mirror and blowing bubbles *[22]*. Cleaner wrasse pass the mirror self-recognition test with flying colours. Indeed when a coloured dot was put on the wrasse and they saw themselves in a mirror they sought to rub off the dot by rubbing that part of the body on the substrate *[23]* *(Fig. 4)*; this behaviour has only been recorded in birds and mammals previously and is considered evidence of consciousness. Thus there is evidence in some species of fish for the capacity for self-recognition and awareness.

Conclusion

This review provides compelling evidence that fishes meet the criteria for animal sentience where they possess some ability to form relationships, possess complex learning and memory abilities, can make decisions based on risks and benefits, can experience positive and negative affective states including being affected by the affective state of others, and show self-awareness. Only a few examples are given here but there are many more including tool use and building of complicated structures (*review in [6]*).

If fishes are sentient then this has implications for the way we treat them. In animal experimentation juvenile and adult fishes are protected by legislation and regulations in Europe *(EC Directive 2010/63)*. Given fish are now the second most popular experimental across Europe it is vital we treat experimental fish in a humane and ethical manner. This not only ensures they remain healthy but will also lead to more robust data and valid scientific outcomes. Fishes are used as an important source of protein. Large scale fisheries catch vast numbers of fishes and improving their welfare during the capture and slaughter process would enhance food security. The Farm Animal Welfare Council *(FAWC, UK)* have stated that fish should be treated in farming and aquaculture humanely since they experience pain *[24]*. Improving welfare means fish are healthy and that could improve economical return for the farming industry.

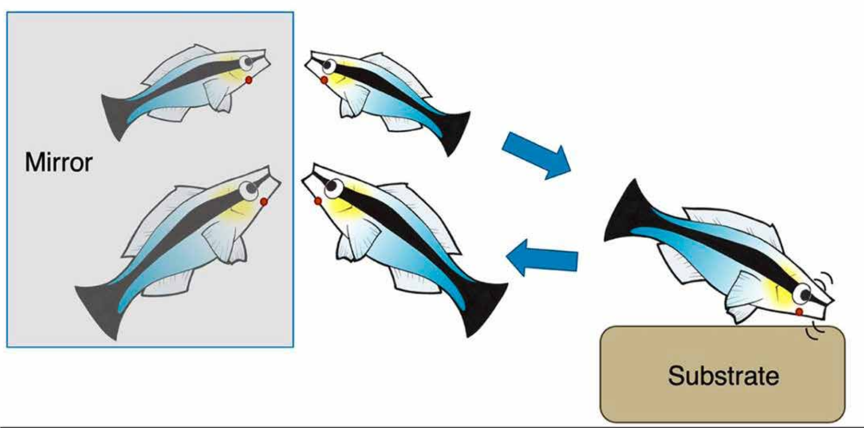

Figure 4: Schematic sequence of posturing, throat-scraping behaviour, and then posturing again in positions that reflect the throat when a coloured dot is present on cleaner wrasse presented with a mirror (from [23], reproduced under the terms of the Creative Commons Attribution License CC BY).

Recreational fishing involves capture of fish for food or in the practice of catch and release.

Catching and killing fish quickly and humanely *[25]* thereby treating them in a humane manner means any suffering is reduced. However, the practice of catch and release does involve releasing fish with hooking injuries after what may be a stressful event. Therefore, welfare improvements should be investigated to ensure the released fish have the best chance of survival.[1] Finally, fishes are also used as a companion animal and are probably the most numerous pet with large numbers kept in home aquaria and ponds *[26]*. Thus legislation and protection should be reviewed to improve and maintain high welfare standards in the ornamental fish industry.

To conclude it is not only in the fish's interest to treat them ethically but it's also in our best interests that fish are healthy and in a good state if we are to use them as research models, as a foodstuff, as a pet or we wish to maintain sustainable populations for fishing.

Take Home Message

Recent research shows that at least some, if not all, fish species are sentient. They can form relationships with conspecifics or with individuals of other species, can solve complex learning and memory tasks and make decisions based on the assessment of risks and benefits, are able to experience positive and negative affective states, show self-confidence, use tools and are able to build complicated structures.

Fish are by far the most widely used animals. For human consumption, several trillion fish are obtained annually from aquaculture or fisheries. Millions of fish are used for animal experiments, and fish are probably the most commonly kept pets. In view of this large number of animals involved, questions about improving animal welfare in fish are even more important. A considerate handling of fish not only improves their welfare, but also the benefit for humans. A more careful catch increases the food safety of the fish meat, a more species-appropriate farming increases the product quality as well as the profitability of the farm. Existing animal welfare legislation should be reviewed to determine what measures are needed to improve fish welfare and keep it on a high level. (Ed.)

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Fishes are smart and feel pain: What about joy?*

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Sneddon et al. [1] write that *"more funding is needed in the area of fish welfare to provide robust empirical evidence we can use to inform the humane and ethical treatment of fish."* We ask: What sort of additional empirical evidence is required?

Thus far, the debate over fish sentience has focused almost entirely on whether fish can feel pain (e. g., *[2]*). Pain is a complicated concept that cannot be proven or disproven in a species through a single, standalone experiment *[3]*. The body of evidence as a whole provides strong reason to accept that fish have experiences that we can plausibly describe as pain: Fish pay to avoid potentially painful stimuli, forfeit good outcomes for the sake of avoiding such stimuli, and seek out analgesics after potentially painful procedures *[4]*. These behaviors require active decision making and are thus easier to explain by accepting that fish can experience pain rather than assuming that they cannot.

Pain, however, is not the sum-total of sentience. Sentience is a complicated concept, but most scholars agree that it involves the ability to experience pain and pleasure *[5] [6]*. While scientific studies over the past several years have indicated that fish have the cognitive equipment necessary for rich mental lives *[7]*, the scientific study of fish pleasure has been relatively neglected. Thus, focusing future research on fish pleasure is likely to generate a wealth of theoretically and practically useful information, including answers to questions about what kinds of positive experiences fish may have and under what circumstances they might have them.

Several decades ago, the positive psychology movement sought to correct a similar bias in the human literature, arguing that beyond being a luxury, positive psychology is at the very core of human experience *[8]*. More recently, the field of animal welfare also began to consider ways to promote positive welfare beyond simply trying to alleviate poor welfare *[9] [10] [11]*. Even though fish have yet to benefit directly from these correctives, both fields – positive psychology and animal welfare – contain insights about ways forward for research on fish pleasure.

In positive psychology, Fredrickson *[12]* has identified ten core positive emotions: joy, gratitude, serenity, interest, hope, pride, amusement, inspiration, awe, and love. While these might seem like strange words to apply to a fish (at least from a behaviorist perspective), the field of animal welfare is beginning to develop methodologies for identifying similar experiences in ***nonhuman animals***. For example, studies on cognitive biases in nonhuman animals (Peter Singer) suggest that animals with better welfare have more optimistic interpretations of ambiguous cues *[13] [14]*. In other words, they are hopeful. In addition, behavioral research with many species has provided evidence of curiosity (e.g., *[15] [16] [17]*), which is defined as the motivation to gain information. In other words, they display interest.

The existing literature on fish pleasure is slim, but promising. Studies dating back to the early twentieth century have examined spontaneous leaping and somersaulting behavior in fish, as well as voluntary and nonfunctional object manipulation and social interaction that fulfill the criteria of play *[18] [19]*. As a naturally occurring behavior, play may provide the best example of a behavior that is widely observed across the animal kingdom *[20]*. And, in humans at least, play is associated with intensely positive emotional experiences like joy and amusement. Studies of participation in play may be the most fruitful way to develop theoretical and empirical markers of positive emotional experiences in nonhuman animals, including fish.

Other promising lines of research include preferential attachment (aka friendships) in guppies *[21]*, social motivation in cichlids *[22]*, and free-choice exploration in zebrafish *[23]*. Most recently, research with zebrafish suggests that when they are housed in naturalistic environments, they engage in heightened shoaling behavior – protracted bouts of tight group cohesion and increased behavioral synchrony – another behavior that may yield insights for future work on positive emotion in fish *[23]*. Further developing operational definitions of positive emotions such as joy, gratitude, and serenity will allow us to test whether such terms should continue to be reserved to a single species (i. e., ourselves).

The human impact on fish is increasing at an alarming rate: Aquaculture and the use of fish in science is expanding rapidly, as are habitat degradation and threats to wild populations from overfishing. The pressures to understand fish sentience are more urgent than ever, yet both academics and the general public remain focused primarily on pain, where the evidence is already compelling. We need a more complete picture of fish sentience. To ground decision-making about humane and ethical treatment, the biggest need going forward is for research on positive emotional experience in fish, including joy.

Take Home Message

The evidence for fishes feeling pain is now so strong and comprehensive that arguments against it are increasingly difficult to defend in a balanced academic discourse. But there is more to empathy than just pain. Recent research suggests that fishes have an impressive range of cognitive abilities, including the ability to feel positive emotions in the form of play and other behaviours that are likely to involve a positively valued experience. Having made the argument for pain, research can now focus on other aspects of fish sentience. This will not only provide a more complete picture of fishes' mental life and abilities, but also promote their well-being and protection. *(Ed.)*

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Farming fish: from stress to quality of life and to the dish

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1. Introduction

Animal welfare has been defined in different ways according to the emphasis the authors give to different aspects of the concept. Many definitions have been proposed, but a classical one, by *Broom [1]* captures the essence of what animal welfare encompasses, remaining updated and operational. Broom defined animal welfare as the individual state as regards its attempt to cope with its environment. The individual state includes a physical and a mental dimension, which are inextricably related.

Measures of organic functioning in fish have been developed for many years now. But studies of their mental state have been more difficult not only due to its subjectivity but also because there is no direct way to access this information. Still, many indirect approaches have been explored for some species. Broom's concept of welfare ranges from very poor, when animals fail or find permanent difficulties to cope; to very good, when they enjoy good health and are able to express much of their potential as individuals *[2]*. Appropriate husbandry requirements are relevant for welfare but, as the World Organisation for Animal Health (OIE) highlights in its definition *[3]*, welfare is about the internal state of animals and, to understand it, validated physiological and behavioural measures must be used.

All views of welfare are impregnated of moral values. The FishEthoBase mentions the potential of the species and individuality *[4]*; the Swiss Animal Welfare Act includes philosophical concepts, such as dignity or intrinsic value *[5]*. Whatever the approach is, animal welfare needs to be understood in the scope of the animals' natural adaptations and their physical and mental coping mechanisms to go about its life *[6]*.

Any time a fish faces a stimulus, which can potentially disrupt its internal balance *(stressor)*, a stress response is triggered in an attempt to keep or re-establish the balance. Stimuli are received by a multitude of possible receptors linked to different sensory organs *(e.g. eyes, skin)*. This information is than passed to the brain via the peripheral nervous system. Once there, the stimuli activate many relevant brain areas, which will organise, prioritise and label the received information in what is called the animals' cognitive assessment *(also named 'appraisal')*. The appraisal process includes cognitive and emotional components. It categorises information according to previous experiences and acquired memories, including those related to emotions such as learned fear, pain or comfort, and also selects the most appropriate coping response *[7]*. This is the reason why the more the perceived stimulus is under the own's expectations, understanding and control, the less stressful it is appraised.

The physiological and behavioural responses to stress are meant to be adaptive, even if they transiently decrease welfare. Whether the stimulus is negatively or positively appraised, it induces a physiological response with the release of both adrenaline and cortisol *(in fish)* aiming to prepare the body for action. Negative stimuli may trigger a vast array of self-protective responses in fish, from the classical fight-or-flight response to very complex and highly contextual behaviour *[8] [9]*. Positive stimuli may produce approach to stimulus, consumption, or more complex and specialized patterns of behaviour. Above certain levels of the stimuli intensity, duration, etc., these responses may become maladaptive and cause prolonged poor mental and physical states. In fish, states of chronic stress dramatically threaten the immune system, creating pathological conditions, which are very difficult to revert *[10]*.

Quality of life has been defined to a stable and prolonged state of well-being. Originally, meant to humans, quality of life is related to the subjective and dynamic self-evaluation of the individual's circumstances and the extent to which these meet its expectations, which results in feeling-related *(affective)* responses. The measurement of quality of life led to the development of multi-dimensional evaluation indexes with application in multiple onsets. These are quantifiable measurements related to different dimensions of welfare in humans *(e.g. pain, disease, stress)* and use behavioural, physiological and biochemical markers. Nowadays, the quality of life's concept has been increasingly adapted to animals *[11]*. Owners, farmers, caretakers or veterinaries complete questionnaires on objective *(quantitative)* and subjective *(qualitative)* measures. Qualitative measures rely on the perceived mental state, personality and reactions of animals and have been validated against well-known physiological and behavioural measures. Quality of life evaluations differ from more classical on-farm evaluation schemes, which neither use qualitative parameters nor address animal-based parameters in depth.

2. Assessing fish welfare

Indicators of welfare are the responses of animals while dealing with their baseline or changing environment. Operational indicators of welfare should be science-based, able to assess long-term welfare, measurable in aquaculture settings and relevant to husbandry practices *[12]*.

The physiological stress response ranges from immediate and reversible neuroendocrine changes to prolonged chemical alterations. Components of this response have been used as measures of welfare. Among these, cortisol has been widely used as a stress hormone, in the sense of negative contexts and diminished welfare *[13]*. Cortisol can be sampled from blood, urine, body's homogenates or from the holding water, according to the species and the specific research context and objective. Cortisol is a very important metabolic hormone since it powerfully affects physiology, behaviour and brain functions. However, various studies in vertebrate species, including fishes, have reported increased cortisol levels in contexts of environmental enrichment and/or positive excitement, showing that cortisol is better interpreted as a measure of arousal *[14] [15]*. Understanding its dynamics imply taking into consideration related variables such as species-specific baseline levels, patterns of diurnal variation.

Other physiological indicators of stress used, some of which post-mortem, include ***blood metabolites*** *(e.g. glucose, lactate, hepatic glycogen, heatshock proteins and metabolically active enzymes)*, immune system function *(e.g. number of circulating lymphocytes)*, other hormones and neurotransmitters, corticosteroid-receptors abundance and specific gene regulatory pathways *[2]*.

In aquaculture contexts, measures of health and productivity are often used as welfare indicators. **Physical condition** *(e.g. spinal deformities, fin erosion, injuries)*, growth and reproductive rates, incidence of disease and mortality levels are usual examples *[16] [17]*. However, all of them are late indicators of the internal state and provide little or no information on early mental disturbances. Whether the objective is to reduce stress or to promote good levels of welfare, these measures portray a state that can already be very difficult and expensive to revert. As such, they are of little practical use for a well-refined husbandry practice. Earlier and sensitive indicators of stress have been increasingly preferred because interventions in minimising stress can be put into practice at earlier stages. Behaviour is the earliest and subtlest indicator of welfare. Its evaluation is practical, cheap and non-invasive, though it is often difficult to understand and interpret.

Behaviour is shaped by a number of individual *(e.g. anatomy, early experiences, motivation)* and environmental characteristics, not only related to the present moment but also shaped throughout the individual life and the species evolution. Understanding them is important to infer aspects of welfare. For example, in relation to individuals' coping styles, the lack of activity in a shy animal *(passive coping, high cortisol responder)* cannot be interpreted as in a bold animal (active coping, low cortisol responder). For example, a study *[18]* found that two selected lines of rainbow trout for stress responsiveness have different growth rates. Bold fish have higher growth rates, which may be related to their likelihood to win in competition *(greater aggressiveness)* or to direct interference of cortisol on growth.

A behavioural pattern often reflects both organic and mental dimensions of welfare. For example, regardless the original causes, excessive inactivity may be simultaneously a sign of **organic dysfunction** *(e.g. disease, injury)* and a sign of disturbed mental states *(e.g. discomfort, pain, social fear, etc.)*. But it is the context and the combination of different indicators, which will provide the best behavioural interpretation. Measures of behaviour have consistently been used to assess organic functioning in fish for a long time *[12]*. Examples include: foraging and feeding behaviour, ventilatory activity, swimming patterns, use of available area, aggression and its consequences *(e.g. injuries)*. In turn, mental states started to be scrutinized later and have been inferred from studies of preferences and operant behaviour, anticipatory activity (reward anticipation), stereotypes and other abnormal behavioural patterns, exploratory and play behaviour, and cognitive bias *(inference of optimism/pessimism)*. Whether these behavioural categories reflect negative or positive mental states is not linear. Still, approach behaviour, behavioural diversity and exploration/play are usually related to positive appraisals; whereas escape behaviour, stereotypes and other abnormal behavioural patterns are used as measures of negative appraisals.

One of the relevant effects of chronic stress is cognitive impairment *[19]*. Therefore indicators related to cognitive abilities have been studied and could be developed in aquaculture settings *(e.g. performance of specific behaviour, tool use according to natural behaviour, changes in memory/learning function)*.

Methods of monitoring behaviour in aquaculture tanks have been developed, which include subaquatic cameras, remotely operated vehicles, telemetry *(e.g. SmartTags)*, etc. Modern monitoring systems allow identifying behavioural indicators at individual and group-level in big tanks, with great advantages for high standard husbandry routines.

3. From stress to quality of life

In aquaculture, it is impossible to avoid procedures such as grade, harvest transport, slaughter, among many others, which cause disturbance, fear and, sometimes, major stress. A high profile husbandry should aim not only minimising stress but also promoting opportunities for the animals to experience a good quality of life.

Best stress management can be achieved by reducing unnecessary stressful procedures *(e.g. some handling and transport)*, by following the already available species-specific best practices and by taking into consideration the mental dimension of animals in the stress management. It is possible to reduce the impact of inevitable stressful procedures by taking into consideration fish perceptions *(appraisal)* and adjusting management procedures accordingly. For example, a study *[20]* observed that food conditioned Chinook salmon *(Oncorhynchus tshawytscha)* would reduce the stress impact of transport. Another study *[21]* found a reduced cortisol response to confinement due to previous training to make this event predictable through visual signalling *(Figure 1)*.

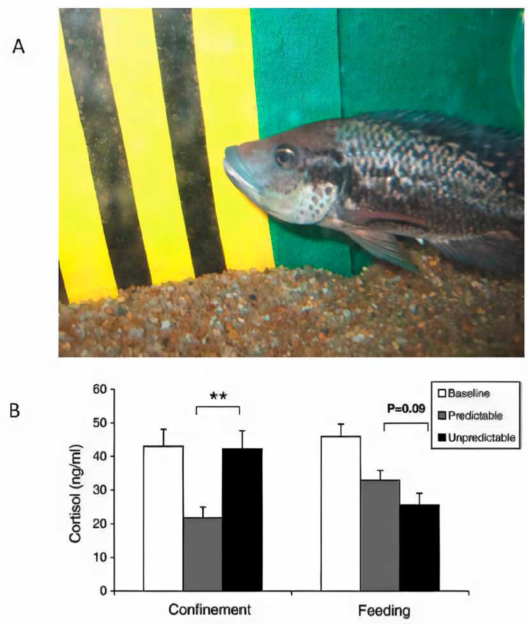

Figure 1:

A. Visual sign used to condition Mozambique tilapia to negative and positive predictable events (confinement and feeding, respectively). (Photo: © L. Galhardo)

B. Cortisol response in the baseline (social isolation for 8 days), predictable and unpredictable events after (a) confinement and (b) feeding events.

*** level of statistic significance, P<0.01. (Originally published in [21]).*

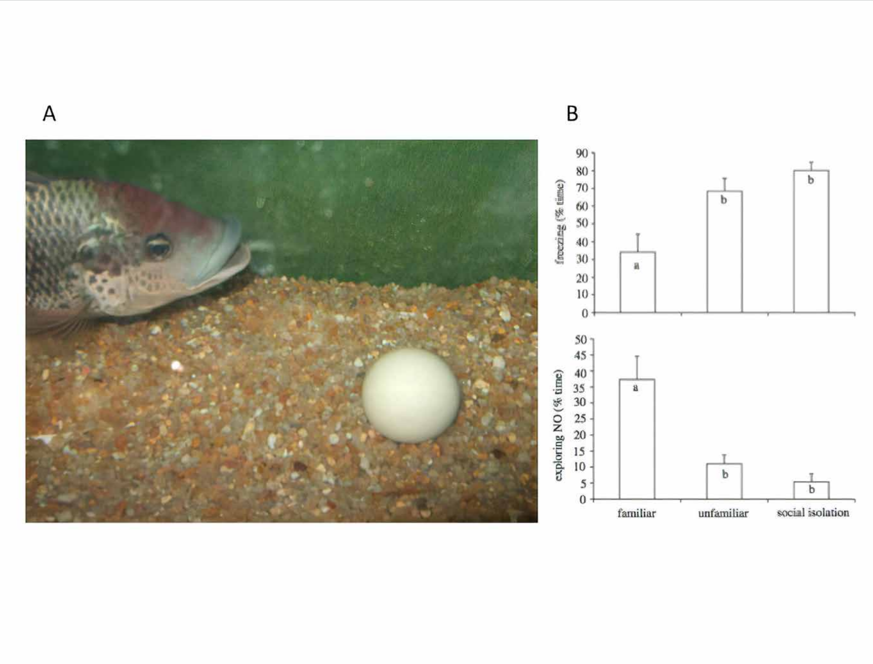

Figure 2:

A. Novel Object (NO) Test in Mozambique tilapia: a table tennis ball filled with sand placed in the focal male tank, after which trials started. Behaviour of focal males was compared among three different social contexts: isolated males, in visual contact with a familiar companion and in visual contact with an unfamiliar companion. (Photo: © L. Galhardo)

B. Time spent freezing and exploring the NO in the three social contexts; different letters represent significant statistical differences between treatments. (Originally published in [22]).

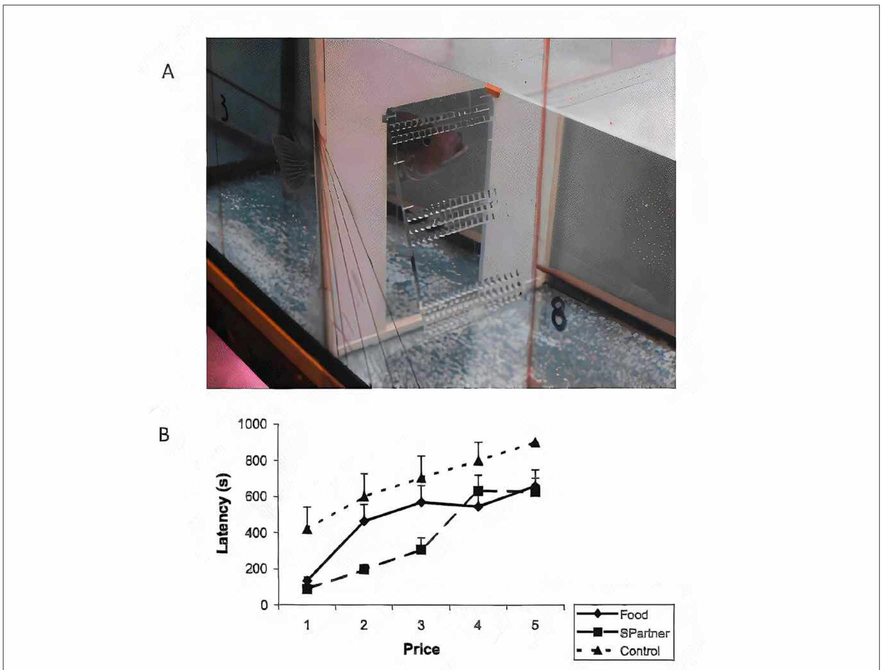

Figure 3:

A. Tank with a start compartment where a male of Mozambique tilapia was required to push a door of different weights (price) in order to access the resource compartment. Motivation to push the door was analysed for three conditions in the resource compartment: substrate-only (control), substrate + food and substrate + social partner. (Photo: © L. Galhardo)

B. Latency (s) for opening the push-door as price increases to obtain access to different resources: food, social partner and control (substrate only (Originally published in [14]).

A third study *[22]* also found that neophobia *(aversion to novel objects)* decreases in animals housed with familiar conspecifics *(Figure 2)*.

Giving animals a degree of control over their environment, where animals access resources or behave by their own initiative rather than in response to external stimuli, has been related to a significant welfare increase in many species. For example, in aquaculture the potential benefits of self-feeders, operated by individual fish, were related to the selection of diets according to individual specific requirements *[23]*. Control over the environment has also to do with providing significant environmental choices to animals (e.g. different ranges of temperature or water depth, possibility to be or not in social contact with others, to seek shelters, etc.). For example, as study *[24]* found that the mere provision of a shelter, where juvenile salmons stay in the vicinity rather than actually using it, is enough to reduce their maintenance metabolism. Another study *[14]* reports that Mozambique tilapia *(Oreochromis mossambicus)* males are willing to work through a push-door to have access to a new tank compartment for food or a social partner contact *(Figure 3)*.

Therefore, promoting quality of life can be achieved by providing opportunities for optimal social contexts, encouraging mental stimulation, behavioural diversity and the expression of natural behaviour. Positive affective states can be further strengthened through a dynamic environment, appropriate complexity and a certain degree of control. Some relevant topics that must be addressed in order to promote quality of life include:

- Improving the tanks' design respecting the anatomy and behavioural features of specific species;
- Providing behavioural opportunities that are as similar as possible to the evolving environment of the species (e.g. bottom-feeder fishes should be given sinking pellets);
- Promoting a better quality of the environment (including water quality but also all stimuli that may impact on fish perception—auditory, visual, chemical, vibrational, etc.);
- Providing appropriate environmental enrichment schedules, for physical and

cognitive stimulation (e.g. training), in order to promote physical and mental fitness and well-being;

- Forming appropriate social contexts in terms of composition, density and stability over time, according to the species-specific social features;
- Providing subordinate animals with means to escape, hide and have access to relevant resources (e.g. food);
- Promoting excellent practices during handling, transport and slaughter.

4. For and ethical farming and a better dish

The moral status of animals as to do with the reason humans should be concerned with their protection. In the sphere of moral ethics a range of diverse arguments has been the basis for different approaches to the moral protection of animals. Nowadays, one of the most widely accepted of these arguments relies on sentience, or the ability to feel suffering or pleasure.

The discussion of moral status of fishes has been delayed in comparison to

that of other vertebrates *[25] [26]*. One likely reason for this is the obvious difficulty in empathizing with fishes. The aquatic environment where they move, the perceived anatomical and functioning differences between humans and fishes, and the lack of emotional expressions prevent easy human-fish bonds.

Another important reason for the delay in fish acquiring moral status is the divergent opinions in relation to their sentience. A small group of researchers have been fostering a controversy denying the fish ability to feel pain *[27] [28]*. However, electrophysiological, behavioural and pharmaceutical studies have clearly established how fish, as other vertebrates, receive and process noxious stimuli at the brain level, and respond with non-reflexive behaviour aiming to avoid getting hurt *[29]*. Indeed, more than twenty years of research have found astonishing advanced and highly specialized characteristics in this very diverse group of species. They have homologous brain structures to other vertebrates, they form long-term memories, social species learn with each other and adjust behaviour accordingly, they can use tools, etc.. The bulk of present information relative to fish neuro-anatomic structures and cognitive abilities allow inferring that they must make use of high cognitive resources and, at least, a certain degree of consciousness.

So, if fishes are sentient, it is on their interest not to suffer and feeling well *[30]* When farming them, humans have the moral responsibility to avoid unnecessary suffering and to improve their quality of lives. Therefore, measures should be consistently adopted to integrate this duty in the scope of the aquaculture's mission and activities. Even when information is lacking on which ways and contexts fishes may suffer, adoption of the precautionary principle remains the most ethical solution for a best practice approach.

The ethical aquaculture is a broader concept, also encompassing that of sustainability. In this enlarged scope, animal welfare values have to be balanced against the production of good and safe foods, while preserving wild populations and habitats; avoiding waste discharge, diseases to wild populations and invasion of exotic organisms. At the same time, aquaculture should not misuse natural resources, should promote wealth and fair trade, respecting local communities. In this complex but synergetic system, animal welfare calls for less intensive systems focused on promoting fish quality of life, use of local products and avoidance of live fish transport, use of less chemicals in husbandry and adoption of a more behavioural-based type of management.

Promoting animal welfare in aquaculture is not only an issue for farmers, rather being a task involving many stakeholders with a common goal: a more sustainable fish production. Farms should use the best equipment and management practices and adopt good practice guidelines and certification systems. The academia should promote the identification of species-specific needs and validated ways to assess welfare on farming fishes. Governmental and non-governmental agencies should promote consumer's education and appropriate guidelines, rules and their implementation. But the last word in this complex system definitely belongs to the consumers *[31]*. They should learn to value local products, they should learn what balanced and healthy diets are. And they should also learn how they can, with their choices, promote a fairer relationship with the fishs they seek as a protein source in their dish.

Take Home Message

Data on fish health and growth are still often used in aquaculture as indicators of fish welfare. However, such data provide little or no information on early mental disorders, and as late indicators of internal condition, they represent a condition that is difficult and costly to reverse. A far-sighted aquaculture management therefore prefers earlier and sensitive stress indicators to implement early-stage stress reduction interventions. The behaviour of fishes is the earliest and most subtle indicator of their well-being. Its assessment is practical, cost-effective and non-invasive; however, behaviour is often difficult to understand and interpret.

Behaviour is shaped by a number of individual (e.g. anatomy, early experiences, motivation) and environmental characteristics, which are not only related to the present moment but are also shaped throughout individual life and the evolution of the species. Understanding them is important in order to be able to draw conclusions about aspects of fish welfare. Behavioural measurements have long been used to assess the organic functioning of fishes. Psychological conditions, on the other hand, were not studied until later.

In aquaculture, procedures such as sorting, transport, slaughter and many others cannot be avoided, but they cause disturbance, anxiety and sometimes great stress to the fishes. Optimal stress management can be achieved not only by reducing unnecessary stressful procedures (e.g. some handling and transport), but also by modulating the way fishes perceive (appraise) some of their stressors. However, a model farm should not only aim to minimise stress, but should also promote ways in which the animals experience a good quality of life.

Promoting animal welfare in aquaculture is not only an issue for fish farmers, but rather a task involving many stakeholders from fish farmers to consumers, with the common goal of more sustainable fish production.

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Coping styles, a tool to better understand fish welfare

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Today, ***fish welfare*** is a buzz word for the aquaculture industry, not just for public perception, marketing and product acceptance, but also often in terms of production efficiency, quality, and quantity. Many of the aquaculture practices such as transport, handling, feeding techniques, human presence, and stocking densities, potentially elicit acute and chronic stress responses. Thus, the responsible aquaculture comes in front to ensure better rearing conditions and quality of life for the animals being farmed. However, fundamental insights are lacking on whether and how fish are coping with acute and chronic stressors in aquaculture rearing conditions.

What are *coping* styles?

Coping styles can be defined as the consistent individual variation in behaviour, physiology, and cognitive/emotional patterns. In animals, including fishes, consistent individual differences in several aspects of stress responsiveness have been associated with differences in behaviour and physiology *[1] [2] [3] [4]*. These individual differences may reflect distinct ***coping*** styles *(often also referred as personalities, temperament,* ***behaviour syndromes****, bold/shy continuum).* In fishes, two main coping styles category types are recognised: proactive and reactive. Proactive individuals are behaviourally characterised by territorial control, active avoidance, and aggression, and physiologically by low hypothalamus-pituitary-adrenal *(HPA axis)* reactivity to stress, and low parasympathetic reactivity, while sympathetic reactivity is high. In contrast, reactive individuals are behaviourally characterised by immobility, passive avoidance, and low levels of aggression, and physiologically by an increase in HPA reactivity, high parasympathetic reactivity, and low sympathetic reactivity *[5]*. *Coping* styles are shaped by evolution and are adaptive response patterns to challenges in the natural environment, so different patterns according to different environments are expected. In a stable environment, proactive individuals are characterised by easily developing routines and a rigid type of behaviour, which might be an advantage in an aquaculture stable rearing systems *(e.g. recirculation*

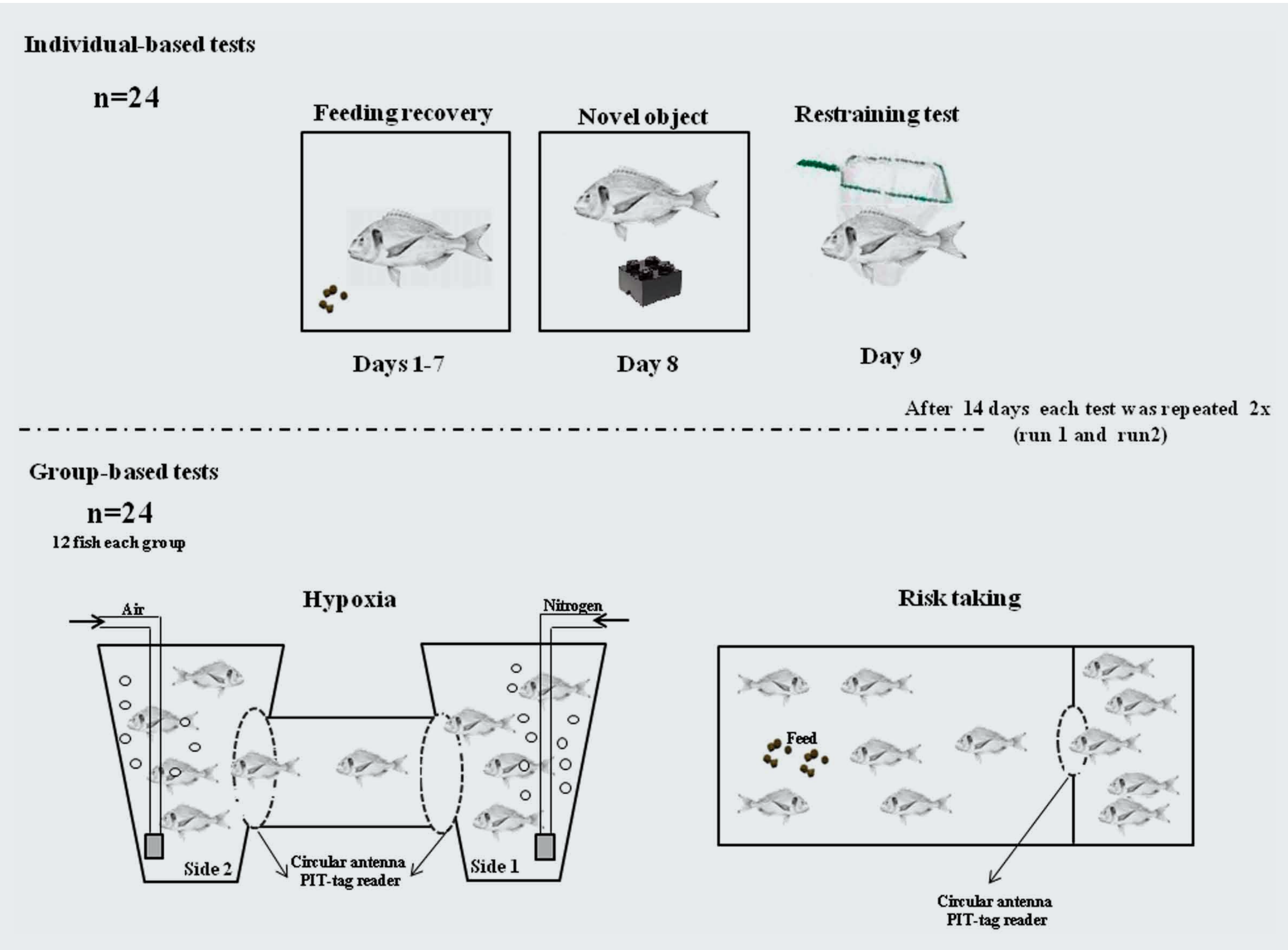


Figure 1: Schematic representation of the experimental set-up used to determine personality in Gilthead seabream (Sparus aurata). Daily feed intake recovery on isolated fish (n=24) was recorded during 7 days. On day 8 and 9 the same fish were submitted to novel object test and net restraining test, respectively. Each test was repeated twice (run 1 and run 2) with an interval between runs of 14 days. Individual-based tests were run first (both run 1 and 2) followed by the grouped-based tests.

aquaculture systems, RAS). In contrary, reactive individuals might be better equipped to cope with a changing or unpredictable environment (e.g. sea cages), as they are more flexible and react more adequately to environmental stimuli.

Understanding how animals respond to stress in aquaculture is extremely important, as proactive and reactive fish will differ in their coping strategies and perception of external events. Consequently, while one individual may interpret a situation as being highly stressful, another may interpret it as mildly stressful or even as not at all stressful.

How to measure *coping* styles in farmed fish?

During my PhD works I investigated whether individual differences in behavioural responses to a variety of challenges can be used to assess personality in fish. Several tests were developed *(Figure 1)*: ***feed intake recovery*** in a novel environment, ***novel object, restraining, risk-taking*** and ***hypoxia*** *[6]*. These tests focus on one personality dimension: the exploration-avoidance *[7]*.

Gilthead seabream *(Sparus aurata)* was used as a model species, as it is widely used in research due to its robustness and well-known biology and behaviour. It is also ranked second as the most important European farmed fish.

Individual-based tests *(Figure 1)*

Feeding recovery test

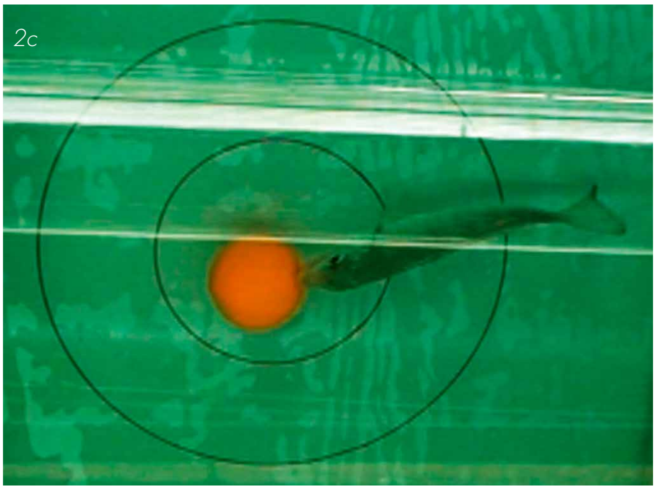
The feeding recovery test consisted of the daily feed intake by fishes housed in isolation for 7 days. Fish were fed ad libitum, by hand, twice per day *(09:30 and 15:30)*. The order of feeding was randomized every meal. Five pellets were added at the start of feeding and replaced by new ones as soon as they were consumed; the number of pellets eaten by each fish were noted. Feeding continued for a maximum of 1 h, after which the remaining pellets were collected and counted. ***Feeding recovery*** was determined as following: feeding latency (time in seconds taken by each fish to consume the first pellet); total feeding time (total time in seconds taken by each fish to consume all pellets until apparent satiation); number of feeding acts (number of times an individual approached the pellets resulting in feed consumption), number of feeding days (number of feed intake days) and feed intake (in per cent of body weight).

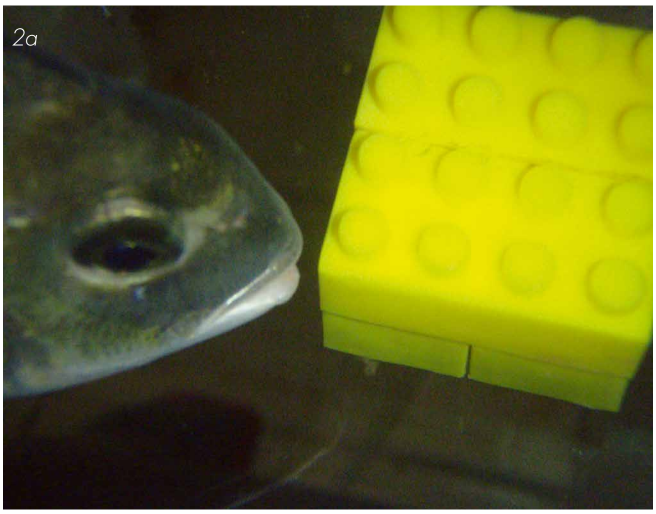
Novel object test

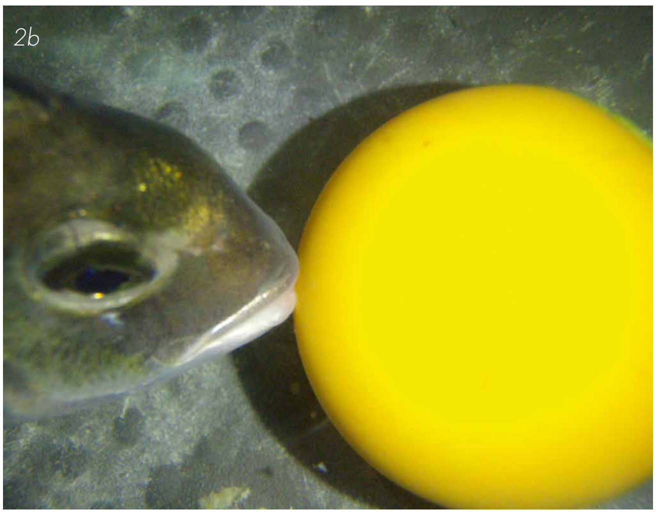
The novel object test (day 8, after onset of isolation) consisted of a Lego® brick *(3 cm length x 3 cm width x 2.3 cm height – used during the first run, Figure 2a)* or a table tennis ball filled with sand *(2 cm radius – used during the second run, Figure 2b)* that were dropped suddenly in the middle of the tank. The bottom of the test tanks was divided into three distinct zones: 5 and 10 cm radius around the novel object and the remaining area, which were marked with a text marker on the bottom of the tank *(Figure 2c)*. Fish behaviour was video recorded *(SONY, DCR-SR190E, Japan)* for posterior analyses. Cameras were placed above the tanks. The observation period lasted 15 minutes and started immediately after the novel object was dropped in the tank. During the 15 min observation period the following parameters were measured: latency to enter the 5 cm and 10 cm radius areas (time in seconds taken by each fish to enter in each area) and the number of times a fish entered in each area. The entrance in the area was defined when the snout of the fish was inside the area.

Restraining test

The net restraining test (day 9, after onset of isolation, last day of individual-based tests) consisted of holding each fish individually in an ***emerged net*** for three minutes







Figures 2a, 2b and 2c: Novel-Object Test (Photos: MF. Castanheira).

(Figure 3), while the following behaviours were measured: latency to escape (time in seconds taken by each fish to show an escape attempt; escape attempt was defined as an elevation of the body from the net); number of escape attempts, and total time spent on escape attempts (total time in seconds taken by each fish escaping since the first to the last escape attempts).

Group-based tests *(Figure1)*

Hypoxia test

The hypoxia test consisted of reducing the oxygen levels in one side of a two-chamber tank and measuring the escape behaviour from the hypoxia to the normoxia side. The tank was composed of two similar circular tanks (40 L) that were connected with a transparent plastic pipe (40 cm length x 6 cm radius, *Figure 1*). In the extremes of the connection pipe two circular antennas were placed (diameter 100/125 x 20 mm Trovan®, Netherlands) to allow individual tracking of the fish passing through the pipe *(Figure 4)*. Each side of the tank was equipped with water inflow, outflow and air stone supply. The connection pipe was closed with a removable door (13cm length x 13cm width) before the start of the test. Each group of fish (n=12) was allowed to settle overnight in one side (side 1) before the start of the experiment. At the beginning of the experiment the water supply was stopped on both sides. Aeration on side 1 was turned off and replaced by nitrogen which leads to a gradual decrease in oxygen concentration *(Figure 1)*. Afterwards, the door blocking the connection tube was removed and the circular antennas started to register the fish movement between sides. The dissolved oxygen in the water (DO) was measured by an Oxyguard handy probe (Handy Delta, USA). During the ***hypoxia*** test, fish behaviour was recorded on video (MicroVideo™ camera MCV2120-WP-LED, Canada) for posterior analyses. The following behaviours were measured: latency to escape ***hypoxia*** (time in seconds taken by each fish to escape hypoxia conditions); order of escape and number of returns (number of times an individual returned to the hypoxia side after being in the normoxia side). The ***hypoxia*** test was finalised when half of the fish escaped from the hypoxia side or when a concentration of 3 mg/L DO was reached.

Risk-taking test

The ***risk-taking*** test was done in a 300 L fibreglass tank (100cm length x 60cm width x 50cm depth) separated in two distinct areas: safe and risk areas. The areas were divided using a solid plastic partition (2 mm thickness) with a hole (6 cm radius), connected to a circular antenna, diameter 100/125 x 20 mm (Trovan®, Netherlands) that allowed the identification of which fish passed through the hole and the time of each passage. The connection hole was closed with a removable door (13 cm length x 13 cm width). Each group of fish (n=12) was allowed to settle overnight in the safe area before the start of the experiment. At the beginning of the experiment the door was removed and 10 pellets (6% of body weight) were released into the risk area every 5 minutes to stimulate fish going to the risk area. Fish behaviour was recorded on video (MicroVideo™ camera MCV2120-WP-LED, Canada) for subsequent measurement of: latency for risk-taking (time in seconds taken by each fish to enter the risk area); order of risk-taking and number of returns (number of times an individual returns to the safe area after dwlling in the risk area). The risk-taking test was finalised when half of the fish entered in the risk area or 4.5 hour after the beginning of the experiment.

What are the consequences of different stress coping styles in farmed fishes for aquaculture?

The presence of ***coping*** styles may have several implications for aquaculture. Individual fishes within a population often differ in how strongly they respond, behaviourally and physiologically, under stress conditions. A failure to accommodate the ***coping*** styles of fishes under farming conditions can lead to problems linked with production (e.g. aggression, growth, and disease resistance).

Growth performance and energetics

One of the best examples of the implications of ***coping*** styles in performance traits comes from studies with African catfish *[8]* that showed that the most efficient individuals were those reacting quicker to the presence of pellets and consuming their meals faster after transfer into a novel environment. These individuals were also those that exhibited a lower cortisol response after acute stress. All these characteristics (better feed efficiency and lower stress

Figure 3: Fish in the restraining test (Photo: MF. Castanheira).

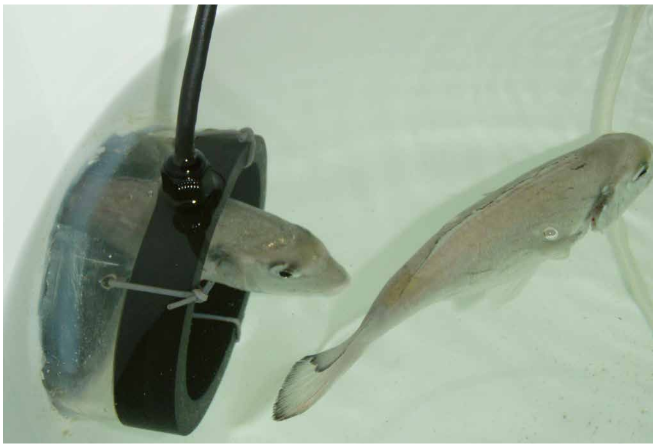


Figure 4: Fish in the hypoxia test. Individual tracking of the tagged fish was possible with the help of a PIT antenna (Photo: MF. Castanheira).

responsiveness) are clearly beneficial under aquaculture conditions. Also, Killen et al. *[9]* reported that in Sea bass, the amount of risk-taking among individuals was positively correlated with their routine metabolic rate. However, *Martins et al. [10]* have reported opposite results in metabolic rate (oxygen consumption) measured when Senegalese sole were housed in respirometry chambers. These authors suggested that different individuals reacted differently when housed in the metabolic chambers that functioned as confinement chambers. Individuals that consumed less oxygen in a respirometry chamber were also the individuals that reacted sooner to a confinement stress (typical behaviour of proactive individuals). This apparent contradiction may have to do with the passive benthic life-style of sole, compared to other more active fish species, highlighting the fact that individuals may interpret the same situation in different ways.

Selection programmes

Selection programmes in farmed fish are extremely important and focus essentially on growth performance *[11]*. As seen before, proactive individuals exhibit fast growth but have also shown to be more aggressive *[12] [13] [14]*. Therefore, we also need to be aware that selection for fast growing individuals may results in co-selection of undesirable traits such as aggression. Actually, aggressiveness has been linked with a diversity of aquaculture problems including decreased feed intake, growth dispersion, chronic stress and disease vulnerability *[15]*, reinforcing the possible co-selection of undesirable traits during broodstock selection. Furthermore, fighting brings a significant cost in terms of increased energy expenditure that may promote inefficient growth. In addition, aggression among fishes in production systems can be a cause of skin and fin damage. This damage can directly reduce the value of the farmed product and increase the vulnerability to diseases. Moreover, proactive individuals have also been shown to develop routines more easily *[16] [17] [18] [19] [20]*. Such characteristics may be more advantageous under stable conditions provided by intensive husbandry systems but prejudicial in extensive or semi-intensive husbandry systems with lower standardised conditions.

In farmed rainbow trout, where coping styles were characterised by the time period until first feeding, both the proactive and the reactive individuals showed lower growth than the intermediate *[21]*. This promotes the idea that selection criteria should perhaps favour individuals with intermediate coping styles characteristics, avoiding the extremes proactive and reactive. The same was verified in a small on-growing Sea bass farm in Slovenia, where the selection of the larvae for the on-growing site was based on intermediate growing characteristics *[22]*. Consequently, selection programmes in the aquaculture industry have recently included 'decreased within-population deviation in growth' as a desirable trait.

Disease resistance and parasites

Another important implication of ***coping*** styles in farmed fishes is the different disease susceptibility exhibited by proactive and reactive individuals. Diseases are one of the main challenges in aquaculture and can represent a considerable financial burden to the farmer. Early studies on inflammatory challenges with bacterial pathogens reported distinct disease resistance between ***coping*** styles *[23] [24] [25]*. *Fevolden et al. [23]* suggested selection by targeting distinct coping styles rather than for specific immune traits, selecting for a broad spectrum of defence mechanisms and hence affecting resistance to several diseases. Moreover, *MacKenzie et al. [25]* showed distinct regulation of proinflammatory gene expression suggesting that fundamental differences in cytokine regulation exist in fishes with distinct ***coping*** styles.

Among the diseases, Salmon lice is considered the major threat to marine farming of Salmonids *[43]*. *Øverli et al. [44]* showed that salmons with higher black skin spots harboured fewer mature female lice carrying egg sacs, suggesting that individual host traits may decrease parasite infestation. Moreover, the same authors also demonstrated that the presence of sea lice affects behaviour and brain serotonergic activity in Atlantic salmon. Also, *Kittilsen et al. [51]* provided evidence for individual variation in parasites resistance to sea lice, particularly salmon louse *(Lapeophtheiras salmonis)* carrying egg sacs.

The few studies above have not investigated the correlation between immune reactivity, individual variation, and associated mechanisms. This calls for the needsof fundamental studies to understand individual disease vulnerability.

Fish welfare and stress

In most fish species, chronic or acute stress is considered as the main factor reducing animal welfare in intensive husbandry productions *[15][26]*. It is accepted that some individuals passively withdraw from potentially harmful stimuli (i.e., reactive), whereas others actively avoid or try to fight harmful and challenging situations (i.e., active). However, despite the link between acute response to challenges and coping styles, very little information is available about chronic stressors and coping styles. For example, *Korte et al. [27]* observed that adaptive processes, i.e., actively maintenance of stability through change (allostasis), are dependent on the personality type and associated stress responses. The benefits of allostasis and the costs of adaptation (allostatic load) may lead to different trade-offs in health and stress related diseases, reinforcing that both ***coping*** styles (proactive/reactive) can be successful, under different environmental conditions. Undoubtedly, ***coping*** styles play an important role in understanding how different individuals appraise the housing environment and thereby their welfare status.

Knowing that farmed fishes have ***coping*** styles and that coping styles differ in how they appraise their environment may help designing farming environments that are more diverse and could improve the welfare of individuals with different coping styles. In turn, this may increase production output and decrease diseases vulnerability. In general, the range of the ***coping*** style spectrum that leads to maximum growth performance, highest welfare condition, and disease resistance may change depending on the husbandry system, because different types of intensive, semi-intensive or extensive systems present very different social and environmental conditions to fishes. Therefore, individual variation in the threshold for when a challenge becomes inhibiting rather than stimulatory is likely correlated with how a specific individual is coping with a welfare issue within a particular situation.

Are *coping* styles for life?

Social context

A pertinent topic is also to understand if coping styles are maintained lifelong. For instance, are coping styles influenced by social context of by a fish's development stage? This was also something that I took a look into during my PhD works *[28]*, trying firstly to understand if the consistency of escape behaviour, one of the main dimensions of personality in animals, remained consistent under different social contexts, i.e. if other group members influence the consistency of individual avoidance behaviour. Here, the escape/avoidance response during the restraining test indicated a consistent personality trait in intermediate and control groups: individuals showing lower latency to escape, higher number of escape attempts and spending more time escaping during the initial screening, showed a similar behaviour after one month when the test was repeated. In proactive and reactive groups, no correlation was found. Several studies suggests that social context strongly influences the individual personality *[29]*. Social context is involved in the regulation of numerous characteristic behaviours such as social facilitation *[30]*, social familiarity *[52]*, social dominance *[31]*, social plasticity *[32] [33]*, and social learning *[34]*. For example, the presence of conspecifics may cause individuals to enhance or suppress threat-sensitive behaviour such as activity, exploration/risk, foraging, feeding rate, and courting opportunities *[35] [36] [37] [38]*. Furthermore, individuals with extreme personality types may be affected in a different way. Our results therefore suggested the potential influence of the social context in fishes. A finding that can be explained by the fact that individuals tend to adjust their social behaviour according to the available social information in the group, to adjust and optimise their own personality type. These adjustments could have an ecological and evolutionary significance related with adaptation to new environmental conditions. The understanding of those differences may have several practical implications. One example is the possibility to takes advantage of this social behaviour and develop rearing conditions accordingly. For example, the aquaculture industry may takes advantage of this group heterogeneity in semi-intensive and extensive conditions where the individuals are more susceptible to environmental changes (i.e. in a changing environment, the social support may result in a potential boost of the production, and the performance of some individuals may be reflected in a faster growth. On one hand, our results comply with previous studies indicating the presence of personality types that seemed based on innate traits *[5] [12] [13] [39] [40] [41] [42]*. On the other hand, personality types can be modified by the influence of other group members *[45] [46] [47]*.

Life stage influence

Another question that might pop up when studying the coping styles in fishes is if they are consistent during the whole life cycle, especially in those species that suffer deep biological changes (e.g., sexual reversion). Therefore, one of the objectives of my PhD was also to characterise fish coping styles considering the consistency of behavioural responses over time and during life history using the behavioural responses during a net restraining test and cortisol responsiveness at distinct life history stages *[48]*. We found consistency in behavioural responses (over time) during the restraining test until 8 months after the first screening. However, during sexual maturation this escape behaviour consistency under restraining was lost. This lack of consistency found in coping styles across life stages is a new important finding and suggests that differences in coping styles expressed at early developmental stages may change according age and life history experiences. This highlights that coping styles are not fixed and this can be reflected in distinct behavioural strategies to cope with the same stressful condition. Thus, different life stages could mean a paradigm shift in coping styles field and following hypotheses may be considered to contribute to this lack of consistency in escape behaviour responses:

1) the sexual maturation and the sex inversion process compromise the consistency of coping styles abilities or/and

2) the contextual importance of the net restraining response may differ according to age and fish development.

Take Home Message

The presence of coping styles is now well recognised in farmed fishes and its implication for aquaculture can be as wide as here reviewed. Taken together, the extensive literature on coping styles in fish shows that screening for coping styles is species-specific. The recent development of group-based tests and the use of proxies may provide an opportunity for mass screening in the future. Mass screening into different coping styles may help optimising the production systems as optimal conditions for proactive individuals are likely to be different from those for reactive individuals.

In addition, the recognition that farmed fishes exhibit coping styles means that several behavioural and physiological responses will vary as part of a common "package" that should be taken into consideration when designing selection programs.

Measuring fish welfare in the context of individual variation in coping ability was assisted by some studies of differences in central nervous system functions between proactive and reactive individuals *[49] [50]*. In aquaculture rearing conditions, these differences in the nervous system must be included somehow when gene and environmental interactions are explored to evaluate the stability of welfare relevant trait correlations.

However, coping styles screening is far from being used in a daily aquaculture practice due to lack of knowledge and/or the time required. More awareness and practical approached on the topic should be addressed in the near further.

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Fish welfare: Interconnections among stress, health, environment and diversity

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In this paper the connections between welfare, stress and health in fishes are discussed briefly in relation with the relevant factors affecting this connection, such as the variability and diversity among fish species and the ability to adapt to different environments, the individuality in coping strategies and behaviour, and the variety and capacity of sensoring the environment. The paper focus in the proximity of the content of the concepts health and welfare, especially when applied to indicators or how to measure and manage welfare and health.

Stress, welfare, and health

Welfare is a concept with many connections with the health concept. Although we normally associate health in animals with the lack of disease or the lack of pathogen input, it is normally true that healthy animals correspond well with animals in good welfare, i.e. without significant functional alterations and developing a rather normal life. It is true that some aspects of welfare associated to the development of natural behaviour may not appear into this health/welfare concept, but it is also true that episodes of discomfort, heavy stress or disease can appear in natural conditions. Therefore, in most cases such correlation health/welfare can work. Moreover, in humans other concepts exist such as *public health* or the *'one-health'* concept. Under these concepts, not only the lack of pathologies and the inexistence of disease is considered, but also aspects such food safety, equilibrated diets, exercise, or avoiding stress are included among other healthy habits.

These concepts can also be applied to farm animals including fishes, thus approaching even more closely the health and the welfare features. As an example, some episodes of sudden death in Sea bass during the nineties decade in South Mediterranean sea cages could have been clearly associated to non-pathogenic sources like fatty diets and reduced exercise as a result of pressure for fast growth and higher culture densities *[1]*. This situation involved reduced welfare as a result of the lack of ***healthy habits*** infringed to fish.

Welfare in animals including fishes has been most often associated to the lack of suffering and to the association with the **Five Freedoms**[1] *[2]*, and particularly to episodes of euthanasia and anaesthesia in aquaculture harvesting or fish transport with trading fish in aquariology. Nonetheless, when it comes to measure welfare and determine suitable indicators, the welfare criteria use to match with the lack of stress, as stress includes most of the situations in which fishes experiences significant altered status *(Figure 1)*, from mild alarm to eventual suffering. When fishes are stressed, as it happens with most vertebrates, there is an increase of susceptibility to pathogens, there is an increase of disease incidence and consequently, loss of welfare *[3] [4] [5]*. In this way, stress indicators may reasonably help to characterise a welfare status, provided that the stress physiology of fishes has been studied from decades [6] and indicators of different nature (concerning physiology, metabolism, genome, behaviour, performance, etc.) are available.

Perceiving stress

How fishes perceive stressors is very relevant in terms of developing a response, for reacting in a particular direction and for the recovery of a welfare status, physiological balance and maintain overall health. Fishes are animals intensively connected with the environment with many receptors associated with the changes in biotic and abiotic features of the water and the characteristics of the organisms living in it. Therefore, temperature, ionic and osmotic components, currents, but also all types of pathogenic and non-pathogenic microorganisms are in constant interaction with the fish, and in particular to external fish sensors and mucosal surfaces. In recent years it has been shown that mucosae (skin, gut, gills and nasal) are key sites for fish-environment interaction and therefore relevant actors in the modulation of the transitions between welfare and health status and stressed and pathological *[7]*. The assessment of select-

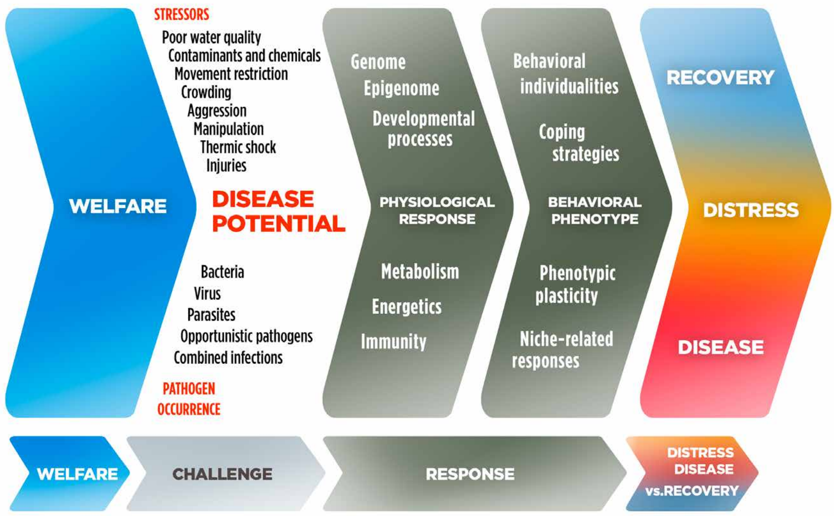

Figure 1: Interconnections between stressors and endogenous responses in fish welfare.

[1] The concept of the ***'Five Freedoms'*** comes from the report of the British Committee of Inquiry into the Welfare of Animals in Intensive Systems (Brambell Report, 1965). Farm animals should have the freedom to *'stand up, lie down, turn around, groom themselves and stretch their limbs'*. *(Ed.)* *https://www.canr.msu.edu/news/an_animal_welfare_history_lesson_on_the_five_freedoms*

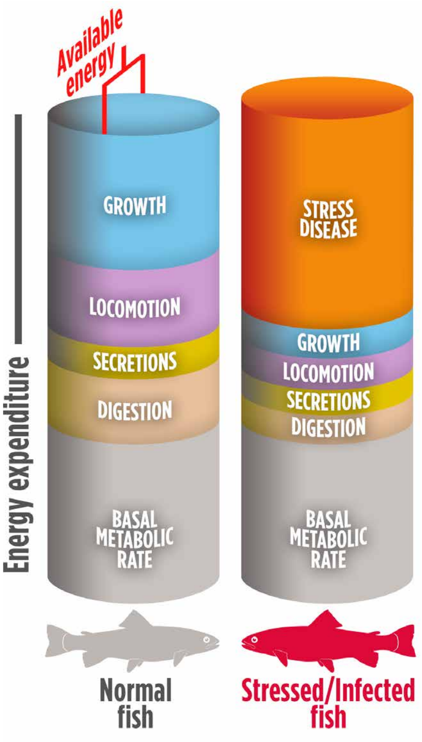

Figure 2: The energetic drive in fishes under stress or infection.

ed indicators obtained from specific sensors of these mucosal surfaces can be also indicators of welfare and even predictors of welfare alteration *[8]*.

However, a main drawback for describing a unified and integrated physiological stress response in fishes concerns to their extreme diversity of lifestyles and ecotypes *[9]*. Fishes can live under extreme conditions including freezing waters, dry ponds or huge pressures in deep waters; fishes are able to adapt to changing conditions such as freshwater-seawater transitions, low oxygen waters or temperature changes; fishes have adapted also to all types of feed resources; fishes can show sophisticated predatory activity or efficient mimetic strategies. Some fishes, such as African killifish, live only a few months during the wet season in dry climates [10], whereas other species may live centuries in Greenland cold waters *[11]*. This adaptive ability has resulted in the fact that almost half of the existing vertebrate species are fishes. This fact also shows that the ability of fishes to overcome stressors has been quite successful. As recently pointed out *[12]*, when defining stress responses in fishes we should analyse the stressotope, an adaptive niche-related scenario subjected to environmental selective pressures that elicit multilevel responses and produce a measurable allostatic load in every organism. When this coping is successful, fishes are able to retain welfare.

Responding to stress

One of the main descriptors of a stress situation is the energetic component (as it is for other basic functions or organismic performance such as growth, disease resistance or reproduction). Thus, any situation of stress, discomfort or lack of welfare can be translated in terms of the energetic component. Since all animals and plants follow the ***homeostatic rule,*** *(i. e., to react to any challenge in order to recover the balance of internal variables and adapt to the environmental inputs)*, such reaction always involve minute or longer term reorganisation of resources and therefore changes in the allocation of available energy *(see Figure 2)*. Therefore, significant alterations of the energetic balance as a result from stressors such as heavy space restrictions, flying from predators, aggression, injuries, pathogens, or those resulting from discomfort or mild stressors, can indicate changes in welfare. In this way, performance functions like growth, disease resistance or reproductive capacity will receive less resources, with the consequent impairment or alteration of the degree of such performance.

Another aspect of fish diversity that is relevant to the response to stressors and challenges and therefore to the maintenance of welfare is the individual variability. This feature, that is common to most vertebrates, is also observed in fishes *[13]*. Some authors name it personality, although a better word could be individuality, as personality refers too directly to human features *[14]*. Whether a fish behaves proactively/aggressively or reactive in front of a challenge depends on the individual coping strategy, life-story experiences, evolutionary constrictions, behavioural plasticity, and social context, provided that there is competition for space, resources or reproductive partnership *[15]*. Such diverted behaviour is much associated to the ability of fishes to maintain or recover welfare. Reactive fishes, more plastic to confront novel environments, may become inactive or shy thus avoiding injuries and heavy stress when facing a possible episode of aggression, whereas proactive fishes may take much more risk but having the opportunity to increase welfare through abundant feeding or effective reproductive success *[16]*. Fishes also indulge in a panoply of reproductive modes, ranging from ***gonochorism*** *(separate sexes)* to sequential or simultaneous hermaphroditism, with few species being true parthenogenetic *[17]*. This diversity also influences the onset of physiological responses to environmental stressors *[18]*. Individual behavioural preferences, intraspecific sex differences, and combined stressors, such as mixtures of toxic chemicals, and changes of ***environmental variables*** *(temperature, salinity)* during pathological states, may transform adaptive responses to stress into maladaptive ones *[19]*.

Fish health and welfare management

Since many fishes are subjected to ***anthropogenic sources of potential stress*** *(fisheries, aquaculture, fish trading, aquariology, and research)*, the issue of fish health management and welfare management is increasingly becoming a priority for those involved in these activities. In this way, indicators of both welfare and health management have been developed *[20]* and are still being developed for fishes for the objectives of maintenance of good health and disease prevention and to obtain a welfare standard or even a welfare certification. When it comes to assessing operational welfare or health, the indicators used become more and more very similar.

Take Home Message

As a rule, healthy animals probably also enjoy good welfare. In most cases, there is therefore a correlation between health and welfare. In a *'One Health'* concept, healthy habits include aspects such as food safety, balanced diet, exercise or stress avoidance. When it comes to measuring animal welfare and determining appropriate indicators for this, the criteria are tailored to the absence of stress, since stress covers most situations in which fishes experience a significantly altered status. When fishes are stressed, their susceptibility to pathogens increases, leading to an increase in disease incidence and consequently to a loss of welfare.

Fishes are animals that are intensively connected to the environment and have many receptors for its perception. Therefore, temperature, ionic and osmotic components, currents, but also all kinds of pathogenic and non-pathogenic micro-organisms are in constant interaction with the fish. Mucous membranes are key sites for fish-environment interaction and thus relevant actors in the modulation of transitions from the state of well-being and health to the state of stress and pathology *[7]*.

Some fishes can live under extreme conditions. Thanks to this adaptability, almost half of the vertebrate species are fishes, whose ability to overcome stressors seems to have been quite successful. In defining stress responses in fishes, we should analyse the stress phototope, an adaptive niche scenario exposed to selective environmental pressure that induces responses at multiple levels and produces a measurable allostatic load in any organism. If this coping is successful, the fishes are able to maintain their well-being.

As many fishes are exposed to potential stress from anthropogenic sources, the issue of managing fish health and welfare is increasingly becoming a priority for fish stakeholders. Indicators for the management of fish welfare and fish health have been and are being developed and are becoming increasingly similar in their operational application. *(Ed.)*

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Hatchery in a northern Italian trout farm (Photo: © Studer / fair-fish)

Structural Enrichment at Fish Farms: the Science and the Fiction

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Environmental enrichment: concepts and relevance

Environmental enrichment (EE) can be generally defined as *'the stimulation of the brain by its physical and social surroundings'*. Looking for a more applied definition into animal world, some authors understand EE as altering the living environment of captive animals in order to provide opportunities to express more of their natural behavioural repertoire *[1]* or improving the biological functioning of captive animals from modifications in their environment *[2]* based on understanding the animal natural history *[3]*. Other authors defined EE as a systematic scientific approach to understanding and providing for the psychological and behavioural needs of captive animals *[4]*. Therefore, taking all these aspects into consideration, EE can be defined as *'providing the environmental stimuli necessary for optimal behavioural, physiological, morphological and psycological welfare'*. Its objective is to improve the psychological and physiological wellbeing of animals in captivity, providing new sensorial and motor stimulation in order to help meet their behavioural and psychological needs, and increase the animal's behavioural and animal skills options, while reducing the frequency of abnormal behaviours.

For those reasons, the addition of ***structures to enrich the rearing environment*** *(structural EE)* is considered as a highly recommended tool to guarantee or improve the welfare of laboratory or captive fishes *[5]*, and may therefore be an effective way to promote positive welfare in captivity *[6]*. However, very few fish farming companies apply this type of tool in their facilities today, and some enrichment strategies might not work in the intended way. This might probably be due to the poor communication between researchers and producers, or to the particular characteristics of the application of these structures at commercial scale, given that EE strategies must be designed according to species' needs, life-stage, farming/husbandry system and fish densities, and farming conditions and needs. From fish-farmers' point of view, if structural EE can increase fish growth and improve final product quality, as well as welfare conditions, they might get economic and ethical benefits. Fish welfare is an important issue for the industry, not only because of public perception, commercialization and acceptance of products, but also because of benefit in terms of efficiency, quality, and quantity of production *[7]*.

Environmental enrichment and farmed fishes

The farming facilities are generally designed and constructed to optimize growth and health, and therefore, on the basis of economic and human ergonomic requirements, with little consideration for animal welfare. The production of fin-fish aquaculture, and in particular intensive farming systems, can cause welfare problems such as stress, health problems, psychological stress, and even mortality at any stage of the production process *[8] [9]*. Rearing environments in fish farms generally lack structures, mainly for practical reasons for the farmer, and stressors in aquaculture, such as handling, transportation, stocking densities and feeding are unavoidable. Reducing both stress and its harmful effects is a fundamental goal for successful growth, production, and welfare *[7]*. In this way, the addition of EE in captive fishes might help fishes to cope better with such stressful events.

In recent years there has been an increase of interest on the effects of EE in captive fishes of farming interest, and therefore in the number of related studies. Depending on the objective, the enrichment can be (1) physical if it is an added structure or any modification; (2) sensorial by which the sensory organs are stimulated; (3) occupational when the possibilities for exercise or psychological challenge are given; (4) dietary which includes changes in the type or the delivery of food; and (5) social if any type of contact with conspecifics and/or other species is allowed. The following lines are focused on the first type, structural EE, given that it is probably the best known among EE measurements, and therefore the most used from labs to farms nowadays.

Physical or structural enrichment at farms

Structural EE can be defined as a strategy to add physical complexity with structures, objects or any structural modification to increase heterogeneity of the rearing environment *[10]*. This kind of EE is based on the fact that some fish species use the floor substrate or shelters in their natural environment, and therefore, they might make also frequently make use of structural enrichment when held in captivity. Enrichment structures can be built with a wide variety of products, shapes and sizes. However, it is of special concern for fish farmers that the application of structural EE in the farming system can be also associated with some problems *(e.g. food particles and faeces accumulation, inadequate designs and materials, neophobia, territoriality, etc.)*, compromising the health and well-being of fish. It is necessary, therefore, to experimentally test the possible effects of the designed structures on the target species, taking into account all aspects mentioned above, before implementing it on a commercial scale. Among structural EE, 4 different types can be found: shelters, floor substrate, incubation substrate, and habitat complexity.

Regarding those EE providing shelter to captive fishes, there is a wide range of studies on different species. For instance, some works on catfish species demonstrated that simple structures, such as plastic strips or tubes, can provide hiding places, but also increase growth and survival of fish, as well as inhibit cannibalism and aggressive behaviour in the rearing environment *[11] [12] [13]*. Other studies showed that EE structures, such as plastic tubes and shredding, can in addition reduce fin damage and erosion, and decrease related fin infections, on 3 species of salmonids *[14] [15] [16] [17] [18]*, but also reduce the swimming activity and net-interactions on **Atlantic cod** *(Gadus morhua) [19] [20] [21] [22]*. The implementation of EE structures can also affect fish territoriality, and some studies with Cichlids and plastic seaweed mimics demonstrated that such effects are highly density-dependent *[23][24]*.

There are different materials that can be added to the rearing environment providing floor substrate (e.g. sand, pebbles, cobbles, stones, etc.). Some studies on **salmonids** *(Oncorhynchus clarkii, O. mykiss)* demonstrated that adding such kind of

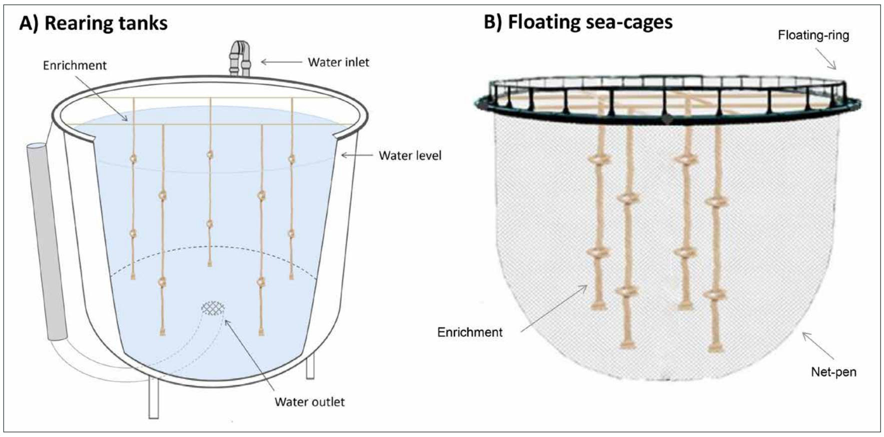

Figure 1. Schematic representations of simple structural enrichment with hanging ropes made of plant fibres, which can be used in rearing tanks (A) and on-growing sea-cages (B) to improve the welfare conditions of Sea bream (modified from [49] and [50]).

substrates helped to reduce fin and skin erosion and decrease infections *[14] [16] [25]*. In **flatfish species** *(Hippoglossus hippoglossus, Solea solea, Paralichthys olivaceus)*, it also increased resting behaviour, reduced metabolic rate, and decreased cannibalism *[26] [27] [28] [29] [30]* and also reduced or eliminated **ambicolouration** *[31] [32]*. In the case of **Mozambique tilapia** *(Oreochromis mossambicus)*, sandy bottoms can reduce aggressiveness during courtship and nest-building, and therefore, reducing stress and increasing welfare of breeding *[56]*. Similarly, some studies on **Gilthead seabream** *(Sparus aurata)* reported similar positive effects by adding gravel in the bottom of the rearing environment, but authors shed light on the fact that different colours can lead to different effects *[33] [34] [35]*.

Other EE structures can provide incubation substrate. **Salmonid alevins** *(yolk-sac fry)* hatch from eggs buried in gravel and spend the first time of their life within this substrate. Adding hatching mats at the bottom of the tanks provide a wide range of positive effects, which are already widely demonstrated on different salmonids species (for a review see [10]). These hatching mats improve growth and survival of alevines, reduce yolk-sac constrictions and improve yolk conversion efficiency, reduce alevines swimming activity and malformations, and permit rest in normal position on the bottom. It has been shown that they also promote positive physiological changes, increase brain growth, decrease stress, activity and oxygen consumption. Indeed, several commercial salmon hatching mats are already available on the market and implemented in most of the salmon hatcheries worldwide. Similar positive effects on hatchlings have been shown for **Atlantic sturgeon** *(Acipenser oxyrinchus)* and **White sturgeon** *(A. transmontanus)* adding sand and/or gravel of the bottom of the tanks *[36] [37] [38] [57]*.

Structural enrichment can simply add environmental complexity and heterogeneity. Recent studies on diverse species of salmonids have demonstrated that farmers might increase fish growth and condition, modify the water flow and swimming activity by adding aluminium bars and strings of spheres from the top of the tank *[39] [40] [41] [42] [43] [44] [45] [46]*. In addition, these EE structures seemed to improve predatory avoidance, a relevant aspect for successful restocking programs *[47]*. Other studies on Gilthead seabream added hanging plant-fibre ropes in rearing environments (tanks and cages), showing that such simple structures can reduce fin erosions, modify distribution of fishes, increase spatial use and exploration, as well as fish cognitive and learning abilities *[48] [49] [50]* *(see figure 1)*. Nevertheless, there are many other studies in scientific literature that show contradictory, undesired or unexpected results [10], which might indicate the use of **inadequate structures** *(wrong design or materials)* for each specific species, life-stage and rearing conditions.

Other considerations and remarks

Overall, it has been shown that EE influences several aspects of the biology and ***behaviour of fishes in captivity*** *(e.g. aggressiveness, susceptibility to diseases, swimming activity, cognitive capacity, exploration, appetite, growth rate, physical condition, deformities, survival rates)*. These effects often vary in direction and magnitude, and each species and stage of life needs special consideration with respect to its natural history and preferences.

However, it is of special concern for fish farmers that the application of structural EE in the farming system can be also associated with some problems, compromising the health and well-being of fishes. The natural environment cannot be exactly recreated in the hatcheries, so the objective when designing enrichment is to modify elements of the artificial environments in order to provide welfare benefits without compromising the biosecurity of the farms. For example, some structures or objects can accumulate food particles and faeces, making cleaning and disinfection tasks difficult, and thus compromise the health and welfare of fishes. In these cases, increasing the periodicity of tank cleaning should be considered (e.g. increasing the effort of manual labour or application of internal filters).

It can also happen that the structures used filter out ***potentially hazardous chemicals to the environment*** *(e.g. PVC phthalates)*, or that their design is inadequate and causes ***physical or psychological disturbances or damage to the fish*** *(e.g. small holes, cracks, protrusions, noise)*, increasing the risk of infections, stress or the mortality rate. Another aspect to consider is that the introduction of new objects in the environment can cause ***negative mental states*** *('neophobia')* in some fishes, or an increase of territoriality and aggressive/defensive attacks *[51] [52] [53]*.

In addition, **structural EE** can be implemented together with other kind of EE, such as ***sensorial*** *(e.g. wall and bottom colours, lights, covers. noise)*, ***occupational*** *(e.g. water flow currents and disturbances)*, ***social*** *(e.g. densities or space available, presence of other species)* and ***dietary*** *(e.g. food type or feeding strategy)*. Therefore, the effect of the EE on fish welfare is not always clear because the reaction can be different depending on the species, the life-stage, the number of fishes affected, the husbandry system, and the type of the enrichment *[54] [55]*. It is necessary therefore to take into account all these aspects before designing and using any EE at farms, as well as to expand the knowledge of the effects of EE and its applicability in the aquaculture industry in a wider extent, adapting EE solutions to the biology of the species and the farming systems.

Take Home Message

Structural environmental enrichment is considered as a highly recommended strategy to guarantee or improve the welfare of laboratory or captive fishes. Its objective is to improve the psychological and physiological wellbeing of animals in captivity, providing new sensorial and motor stimulation in order to help meet their behavioural and psychological needs, and increase the behavioural and animal skills options of the animals, while reducing the frequency of abnormal behaviours. In fish farms, the environments where the fishes are kept generally lack structures, mainly for practical reasons for the farmer. However, during a cycle of aquaculture production there are several situations that can be very stressful for fishes, and structural enrichment might help improve the welfare of fishes, especially after stressful activities. In recent years there has been an increase of interest on the effects of structural enrichment in captive fishes, and therefore in the number of related studies, though there are still some gaps to bridge.

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Knowledge as prerequisite for fish welfare – FishEthoBase as a basis

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Change of focus from profitability to welfare

Since 1950, the production in aquaculture has increased from 0.6 million to 82.1 million tonnes per year, with tendency to rise *[1]*. This comprises inland as well as marine aquaculture, with inland aquaculture being the larger part at 47 million tonnes. The range of systems is large. In Asia, which by far leads the aquaculture sector worldwide *(almost 96% of aquaculture employees worldwide are from Asia; China produces more farmed fish than the rest of the world combined ([2], p. 5 and 28)*, earthen ponds dominate. Furthermore, there are raceways, tanks, cages, and Recirculating Aquaculture Systems which are systems in which the water is treated and gets re-used *([2], p. 20)*.

Important for the construction are often practical considerations behind which the welfare of the fishes takes a back seat: In the Asian region, one uses rice fields or pits that result from digging soil *[3] [4]*—missing protection from rain, heat, and predators may afflict the fishes, though *[5]*. Concrete tanks are a possibility to keep fishes in regions that do not offer enough soil—yet, having no substrate at all may lead to fin erosion *[6]*, and the water quality may be worse than in earthen ponds *[7] [8]*. Cages make use of the naturally occurring conditions of open waters—nevertheless, being exposed to storms, algal bloom, temperature, and predators may result in stress *[9]*. Recirculating Aquaculture Systems score with the possibility to optimally control water parameters *[10]*—but the accumulation of substances may hinder growth *[11]*. If fish welfare is of second concern after practicability, the efforts to implement it will reach a limit. For a species-appropriate housing, the system should be adjusted to the animal, not the other way around.

Of course growth and mortality are checked—but against the background of maximising profits. Aquaculture is a business that millions of people worldwide live on *([2], p. 31)*. When it comes to optimising conditions, the idea is to find a balance between costs and benefits. This may lead to not recommending the condition with highest potential for growth but the one with highest promise for overall profit *[12] [13] [14]*.

Furthermore, whether an individual is well, is only partly evident from the growth rate. Without a doubt, health is an important prerequisite for high welfare. Fishes, however, are also sentient *[15]* and intelligent beings *[16] [17]*—ethics demand to respect these needs. Instead of pursuing just a health-based functional approach, one could combine with a nature-based and feelings-based approach *[18]*.

To achieve that, it takes building a habitat and conditions which resemble those of the original surrounding as best as possible and allow **natural behaviour** *(nature-based approach)*, are free from hunger, thirst, discomfort, pain, fear, and stress, provide positive experiences as well as cognitive challenges, and consider social structures and differences in personality *(feelings-based approach [18] [19] [20])*. To be able to do so, habitat, conditions, and prerequisites for positive experiences and welfare have to be known. The amount of considerations and experimental studies on that increases constantly.

Figure 1: Examples of different aquaculture systems, clockwise: earthen pond without protection from heat and rain, from [23]; concrete tank without substrate, from [23]; recirculation system with circulation pump, from [27]; floating net cage, from [27].

Knowledge as prerequisite for welfare

Our team from the **Fish Ethology and Welfare Group** and **fair-fish international** respectively has declared it our task to gather and provide open access to all ethological knowledge of the most commonly farmed fish species in the **FishEthoBase** — as a stimulation to extend existing aquaculture systems and as enrichment for the planning of new systems but also to point to knowledge gaps *[21]*. Our goal is that fishes in captivity experience high welfare and may reach their full potential *[22]*.

In 19 categories and several sub-categories *(Table 1)*, we present the essences of studies individually for each species and summarise several studies in a general statement. If, for example, there are findings for the *African catfish (Clarias gariepinus)* on inundated vegetation as well as mud, the general statement on substrate preference is: opportunistic *[9]*. In a separate part of the **FishEthoBase**, we convert the findings from the 19 categories into specific recommendations for farmers. For substrate, this could be: ***'For the most natural solution, provide mud and vegetation'*** *[10]*. The recommendations are not meant to be an all-including rearing manual but rather hints on which conditions are disadvantageous to welfare. The three parts — introductory overview, findings, recommendations — form the ethological full profile of a species. At the moment, **FishEthoBase** offers 11 full profiles *(as of August 2020)*.

Ethological short profiles and FishEthoScore

For a faster overview, the **FishEthoBase** presents a short profile with 10 selected criteria for each species. For each age class separately, we compare the findings from the wild with the situation in aquaculture and estimate the probability for ***welfare under minimal conditions*** *('Likelihood')* and ***under high-standard conditions*** *('Potential')* as well as how certain we are of these judgements given quantity and quality of the references *('Certainty')*. Whenever we score 'high' in a criterion, the counter of the three component **FishEthoScore** increases *(Likelihood, Potential, Certainty)*, at most resulting in 10|10|10 with 10 criteria. At currently 46 short profiles *(as of August 2020)*, the ***Nile Tilapia*** *(Oreochromis niloticus)* with a **FishEthoScore** of 3|8|6 has the

Table 1: Findings categories and sub-categories of a full profile in the FishEthoBase.

Categorie	Sub-categorie
1. Remarks	1.1 General remarks
	1.2 Other remarks
2. Ethograms	
3. Distribution	
4. Natural co-existence	
5. Substrate and/or shelter*	5.1 Substrate
	5.2 Shelter or cover
6. Food, foraging, hunting, feeding	6.1 Trophic level and general considerations on food needs
	6.2 Food items
	6.3 Feeding behaviour
7. Photoperiod	7.1 Daily rhythm
	7.2 Light intensity
	7.3 Light colour
8. Water parameters	8.1 Water temperature
	8.2 Oxygen
	8.3 Salinity
	8.4 pH
	8.5 Turbidity
	8.6 Water hardness
	8.7 NO4
	8.8 Other
9. Swimming	9.1 Swimming type, swimming mode
	9.2 Swimming speed
	9.3 Home range
	9.4 Depth
	9.5 Migration

* Highlighted categories are also dealt with in the short profile.

Categorie	Sub-categorie
10. Growth	10.1 Ontogenetic development
	10.2 Sexual conversion
	10.3 Sex ratio
	10.4 Effects on growth
	10.5 Deformities and malformations
11. Reproduction	11.1 Nest building
	11.2 Attraction, courtship, mating
	11.3 Spawning
	11.4 Fecundity
	11.5 Brood care, breeding
12. Senses	12.1 Vision
	12.2 Olfaction (and taste, if present)
	12.3 Hearing
	12.4 Touch, mechanical sensing
	12.5 Lateral line
	12.6 Electrical sensing
	12.7 Nociception, pain sensing
	12.8 Other
13. Communication	13.1 Visual
	13.2 Chemical
	13.3 Acoustic
	13.4 Mechanical
	13.5 Electrical
	13.6 Other
14. Social behaviour	14.1 Spatial organisation
	14.2 Social organisation
	14.3 Exploitation
	14.4 Facilitation
	14.5 Aggression
	14.6 Territoriality
15. Cognitive abilities	15.1 Learning
	15.2 Memory
	15.3 Problem solving, creativity, planning, intelligence
	15.4 Other
16. Personality, coping styles	
17. Emotion-like states	17.1 Joy
	17.2 Relaxation
	17.3 Sadness
	17.4 Fear
18. Self-concept, self-recognition	
19. Reactions to husbandry	19.1 Stereotypical and vacuum activities
	19.2 Acute stress
	19.3 Chronic stress
	19.4 Stunning reactions

* Highlighted categories are also dealt with in the short profile.

best prospect to experience high welfare in aquaculture. The second best **FishEthoScore** of 0|6|5 holds the *African catfish* (*C. gariepinus*). The majority (39 species) reaches a potential of 2 max.

Even though the **FishEthoBase** momentarily covers just a fraction of the more than 530 aquatic species currently farmed worldwide (among them 362 fin fishes and a further 68 aquatic vertebrates [2]), the mostly low **FishEthoScore** is disillusioning. Among the reasons for the low score is missing knowledge. For the creation of short and full profiles we consult the following types of knowledge:

1. Knowledge of natural behaviour in the wild to

a) build aquaculture systems accordingly and thereby promoting natural behaviour, e.g., natural reproductive behaviour determines substrate, stocking density, and sex ratio in captivity,

b) compare natural behaviour to that in aquaculture, recognise abnormal behaviour, and change conditions, e.g., higher fertility in the wild could be an indication for sub-optimal conditions in captivity [25].

2. Knowledge of natural conditions in the wild to

a) build aquaculture systems accordingly and thereby promoting natural behaviour, e.g., photoperiod, temperature, and other water parameters,

b) determine connections between natural conditions and behaviour, e.g., triggers for reproduction or migration.

3. Knowledge of behaviour in captivity (aquaculture or lab) to

a) determine plasticity, e.g., higher temperature or higher density than in the wild,

b) adjust conditions for which there is no model in the wild, e.g., stress reactions to stunning and slaughter.

Especially the knowledge of natural behaviour in the wild is scarce. This is, however, the most important indicator for welfare [26]. How is a fish farmer supposed to know whether a fish displays stress, if one is not able to distinguish relaxed from stressed behaviour? Besides avoidance of stress, natural behaviour provides insights into how the ideal state should look like. As long as this state is not reached, a fish might experience absence of stress at most but not high welfare. For that to be the case, there need to be positive incentives. More on that further down below.

Observation of behaviour as the sole method to determine welfare could fall short, though, because behaviour is variable across time and differences in personality [27]. Relying exclusively on physiological parameters is unreliable, too, because an increased cortisol level might as well hint on positive excitement instead of stress [28] [29]. In the **FishEthoBase**, we cite studies with a broad spectrum of indicators for welfare [20] [27] [30] (Table 2). This allows us to give extensive advice in the recommendations part for farmers.

General recommendations—albeit extensive and species specific—reach a limit in the face of differences in farming conditions, personalities, and changes over time. Ideal would be the implementation depending on the respective farming population and—even better—depending on the individuals. Technical innovations like underwater video observations [31] and individual measuring tags [32] make a valuable contribution.

All efforts to avoid stress and stress-releasing factors do not necessarily lead to the goal of creating high welfare—a life without sorrows but also without positive experiences is a boring life [30]. Which stimuli are perceived as positive one can determine with the help of preference tests [30]. ***Nile Tilapia males*** (*O. niloticus*), for example, preferred gravel or shelter over bare bottom when they had the choice [33]. Giving the individuals control can also have a positive effect: ***Carp juveniles*** (*C. carpio*), for example, displayed lower glucose or cortisol levels if they triggered self-feeders as opposed to being fed by hand [34]. A third possibility are opportunities to explore and discover the habitat—again, substrate and other means of environmental enrichment play an important role [35]. The announcement of a reward and unexpected increase

Table 2: Fish welfare examples from the FishEthoBase.

Fish welfare indicator	Example from the FishEthoBase
Behaviour	
Feeding	**African catfish juveniles** *(C. gariepinus)*, being transferred to an experimental aquarium, did not or barely feed in the first 24 h [40] **Crit. 16 Personality, coping styles ⟶ Exploration-avoidance continuum** **Crit. 19.3 Chronic stress ⟶ Husbandry disturbance**
	European perch juveniles *(Perca fluviatilis)* displayed lower feed intake with husbandry disturbance than in undisturbed tanks [41] **Crit. 19.3 Chronic stress ⟶ Husbandry disturbance**
	Atlantic salmon juveniles *(Salmo salar)* displayed higher feed intake in isolation than in group rearing, probably due to absent food competition [42] **Crit. 6.3 Feeding behaviour⟶ Food competition and growth**
	European seabass juveniles *(Dicentrarchus labrax)* maintained the subdivision in zero-trigger-, low-trigger and high-trigger individuals with the self-feeder even after size grading and disruption of social structure [43] **Crit. 14.2 Social organisation ⟶ Social organisation type**

Fish welfare indicator	Example from the FishEthoBase
Behaviour	
Ventilatory frequency	Nile tilapia adults *(O. niloticus)* displayed increased ventilatory frequency when paired with a larger resident *[44]* Crit. 14.2 Social organisation ⟶ Features of subordination or after 30 min confinement *[45]* Crit. 19.2 Acute stress ⟶ Confinement
	Rainbow trout juveniles *(Oncorhynchus mykiss)* displayed higher opercular beat rate after injection of acetic acid in upper and lower lips *[46]* Crit. 12.7 Nociception, pain sensing ⟶ Nociception spectrum
Aggression	African catfish fry *(C. gariepinus)* displayed more aggression with six than three feeding times per day *[47]* Crit. 6.3 Feeding behaviour ⟶ Feeding frequency and stress African catfish juveniles displayed more chasing, bites, barbel fights under 24 h than 12 h photoperiod *[48]* Crit. 7.1 Daily rhythm ⟶ Photoperiod and stress
	Atlantic salmon parr *(S. salar)* displayed more aggression under 1 lux than in darkness *[49]* Crit. 7.1 Daily rhythm ⟶ Daily rhythm
	Nile tilapia juveniles *(O. niloticus)* displayed more bites and lateral fights in aquaria with substrate than without *[50]* Crit. 5.1 Substrate ⟶ Substrate and stress
	Gilthead seabream juveniles *(Sparus aurata)* displayed more aggression than control individuals when they had experienced restraining before *[51]* Crit. 15.1 Learning ⟶ Learning and aggression
Swimming	African catfish fry *(C. gariepinus)* displayed lower browsing and higher resting activity in aquaria with black plastic shade *[52]* Crit. 5.2 Shelter or cover ⟶ Shelter or cover and stress African catfish juveniles displayed more swimming and less resting activity under 24 h than 12 h photoperiod and under 150 than 15 lux *[48]* Crit. 7.1 Daily rhythm ⟶ Photoperiod and stress
	Rainbow trout juveniles *(O. mykiss)* increased taking cover, decreased swimming in open area, increased *'freezing'* when presented with skin extract from conspecifics *[53]* Crit. 13.2 Chemical ⟶ Signalling stress achieved higher relative critical swimming speed when fed 2 % or 1 % body weight than 0.5 % *[54]* Crit. 9.2 Swimming speed ⟶ Swimming speed displayed random and disorganised swimming under high than low stocking density [55] Crit. 14.1 Spatial organisation ⟶ Stocking density and stress
	Atlantic salmon adults *(S. salar)* displayed erratic swimming and three times higher swimming speed with infrasound *[56]* Crit. 12.3 Hearing ⟶ Noise and stress
	Common carp juveniles *(Cyprinus carpio)* displayed erratic swimming when sound was switched on *[57]* Crit. 12.3 Hearing ⟶ Noise and stress
	Pangasius juveniles *(Pangasianodon hypophthalmus)* swam faster in green aquaria than in white ones *[58]* Crit. 9.2 Swimming speed ⟶ Swimming speed
Stereotypical and abnormal behaviour	African catfish juveniles *(C. gariepinus)* increased air breathing with increasing stocking density *[59]* Crit. 14.1 Spatial organisation ⟶ Stocking density and stress
	Atlantic salmon adults *(S. salar)* jumped 18 times more under high than under low light intensity *[56]* Crit. 12.1 Vision ⟶ Visible spectrum

Fish welfare indicator	Example from the FishEthoBase
Exploratory behaviour	**Rainbow trout juveniles** *(O. mykiss)* took longer to go near a novel than a known object, spent less time in its vicinity, more out of reach *[15]* **Crit. 16. Personality, coping styles ⟶ Exploration-avoidance continuum**
	Common carp juveniles *(C. carpio)* differed in the time they needed to leave cover to explore a novel surrounding; the differences were consistent over weeks *[60] [61]* **Crit. 16. Personality, coping styles ⟶ Exploration-avoidance continuum**
Food-anticipatory behaviour	**Atlantic salmon parr** *(S. salar)* displayed more aggression and more attacks under predicted than unpredicted feeding schedule *[62]* **Crit. 6.3 Feeding behaviour ⟶ Feed delivery and stress**
Pain	**Pacific whiteleg shrimp adult females** *(Litopenaeus vannamei)* rebound when having their eyestalk ablated without anaesthesia, displayed erratic spiral swimming *[63]* **Crit. 12.7 Nociception, pain sensing ⟶ Nociception spectrum**
	Rainbow trout juveniles *(O. mykiss)* increased taking cover, rocked from side to side, and rubbed their lips on the substrate or the aquarium wall after being injected with acid in the lips *[46]* **Crit. 12.7 Nociception, pain sensing ⟶ Nociception spectrum**
Fear	**Rainbow trout juveniles** *(O. mykiss)* learned to swim to another compartment when an object plunged into the aquarium, some *'freezed'* and sank to the bottom *[64]* **Crit. 17.4 Fear**
	Common carp juveniles *(C. carpio)* could not be tested in isolation from the group because they displayed such strong indications of stress, e.g., restlessness *[65]* **Crit. 17.4 Fear**
	Nile tilapia juveniles *(O. niloticus)*, having escaped faster from a confinement situation, returned slower to the area and spent less time there than other juveniles *[66]* **Crit. 17.4 Fear**
Playing	**Rainbow trout kelts** *(O. mykiss)* dashed at coins that were thrown into the water – play? *[67]* **Crit. 15.4 Other ⟶ Playing**
	Pacific whiteleg shrimp adult males *(L. vannamei)* approached other males or immature females, crawled underneath their tail, chased them – playing? *[68]* **Crit. 15.4 Other ⟶ Playing**
Preferences	**Nile tilapia adult males** *(O. niloticus)* preferred sand over sand-bivalve-mixture for nest building, avoided stones and barren aquaria *[69]* **Crit. 11.1 Nest building**
Communication	**African catfish juveniles** *(C. gariepinus)* elicited an electrical discharge during aggressive encounters with conspecifics *[70]* **Crit. 13.5 Electrical ⟶ Signalling stress**
	Nile tilapia adult males *(O. niloticus)* elicited a number of sounds when a rival entered their territory *[71]* **Crit. 13.3 Acoustic ⟶ Sounds during nest defence**
	Gilthead seabream juveniles and adults *(S. aurata)* turned to darker body colouration and erected their dorsal fin during aggressive encounters *[72][73]* **Crit. 13.1 Visual ⟶ Signalling aggression**
	Pangasius juveniles *(P. hypophthalmus)* turned to darker body colouration in green and black than white tanks *[58]* **Crit. 13.1 Visual ⟶ Colouration and habitat**

Fish welfare indicator	Example from the FishEthoBase
Health	
Injuries	Rainbow trout fry *(O. mykiss)* had less fin erosion in tanks with substrate than those without *[20]* Crit. 5.1 Substrate ⟶ Substrate and stress
	Nile tilapia juveniles *(O. niloticus)* displayed injuries under 24 h scotoperiod *[74]* Crit. 7.1 Daily rhythm ⟶ Photoperiod and growth
Immune reactions	Pacific whiteleg shrimp juveniles *(L. vannamei)* displayed increased haemocyte levels after confinement and air exposure *[75]* Crit. 19.2 Acute stress ⟶ Confinement
	Pangasius juveniles *(P. hypophthalmus)* displayed higher levels of immunoglobulin when given levamisole than lipopolysaccharide or saline *[76]* Crit. 6.2 Food items ⟶ Feed enrichment and stress tolerance
	Common carp fry *(C. carpio)* had higher levels of leucocytes, gut bacteria, and lactic acid bacteria given food enriched with 2-3% fructo-oligosaccharides *[77]* Crit. 6.2 Food items ⟶ Feed enrichment and stress tolerance

Note: Indicators from *[20] [27] [30]*.

of the reward may lead to positive experiences *[39]*. An example of positive emotions while expecting a reward are ***cods** (Gadus morhua)* that gather at the feeding site in anticipation of food *[36]*.

Criticism on nature as yardstick for welfare

The last example already showed that nature does not have to be the model in all cases. Feeding migration is not necessary in captivity with regular and sufficient feeding. Also, migration due to changing water parameters or mating migration do not play a role in aquaculture—this is at least what is assumed. Whether the need to migrate is non-existent due to missing necessity is just as unclear as whether not being able to pursue the need is experienced as loss of welfare *[26] [37]*. It is difficult to distinguish external triggers *(e.g., changing water level or temperature)* from internal causes. Here again, more knowledge of the ethology of a species is a prerequisite to provide high welfare. Indications to solve the conflict or realise that there is no conflict after all, because the plasticity of the individuals is large enough, can only come from further research—for example by studies investigating how much individuals are willing to do to satisfy a need *[26]*.

Nature is not necessarily ideal in yet another way: A species is adapted to the conditions of its ecological niche, but water temperatures for example display a certain range given season or other external factors. Temperatures at the upper limit of the range usually result in higher growth *(see criteria 8.1.1 Standard temperature range and 8.1.3 Temperature and growth in the full profiles of the* **FishEthoBase**). Aquaculture allows controlling water parameters and therefore potentially better growth than in the wild. Thus, species may profit from conditions in aquaculture even if they are not a realistic image of the natural water conditions including oscillations throughout the year. The transition to stress is fluid, though, and further research is needed—especially preference tests—to find the ideal temperature range.

The third aspect that could be argued about why nature is not the gold standard results from domestication and the associated adjustment to aquaculture conditions. There is no survival stress in the face of predators or lack of feed; individuals do not have to compete for mating partners; it is not so much the risk-avoiding but the stress-resistant personality type that is in demand. Fish farming, however, does not have the long tradition that farming terrestrial animals has *[38]*, and the degree of domestication does not correlate with the potential of a species to experience high welfare under high-standard aquaculture conditions according to the **FishEthoScore** *[21]*. Even if we assume that domestication removes from the species-specific natural behaviour, it takes further research to find hints that nature becomes redundant as a yardstick as domestication progresses.

Until then, we from the **Fish Ethology and Welfare Group** advocate focusing on farming a small number of species whose needs are well researched and easily satisfiable in captivity as well as with high plasticity and low tendency for stress. The short profiles of the **FishEthoBase** allow an evaluation of the suitability for aquaculture by means of the **FishEthoScore** *[39]*. Only with sufficient knowledge and further research will it be possible to provide fish species in captivity with conditions that closely resemble those in nature or that individuals prefer respectively. This knowledge is gathered better, faster, and with more detail for a manageable number of farmed fish species.

Take Home Message

- Often, when building aquaculture systems, the focus lies on practicability, when deciding about conditions, the focus lies on profitability.
- Fishes are sentient and intelligent and deserve satisfaction of their needs.
- To do so, it takes knowledge of natural conditions and natural behaviour, of prerequisites for positive experiences and welfare.
- The FishEthoBase aims to gather and provide open access to all ethological knowledge of the most commonly farmed fish species.
- To what extent aquaculture should adhere to the natural habitat and natural conditions as a gold standard or whether it may deviate from it without loss of fish welfare, further research needs to show.
- Due to the high number of farmed fish species and the too big challenge to research them all in detail, we advocate focusing research and farming on a small number of species.

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Welfare of Fish – No Longer the Elephant in the Room [1]

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The concept of fish welfare is fairly recent and was overlooked for many years, based on a popular misconception that fish were ***'stupid'*** creatures devoid of any kind of sentience or mental capability. However, a growing body of research on fish research made clear that this is evidently not the case—fish are sentient, socially complex animals that have highly developed mental abilities as well as the neural substrate to support them. As this evidence grew larger, the uncomfortable questions regarding the welfare state of fish and the ethical implications of fish farming became an ***elephant in the room*** that was difficult to ignore. However, there are recent indications that things are changing, and the collection of papers in the recent book 'Welfare of cultured and experimental fishes' *[1]* suggests that all the interested parties (scientists, farmers, retailers, NGOs and consumers) are now directly approaching the subject. Ladies and gentlemen, the elephant has left the building.

In fact, the papers in *[1]* are a fantastic example of the many perspectives that may be used when tackling fish welfare. In a pilot study regarding fisheries of **catshark** *(Scyliorhinus canicular), Barragán-Méndez et al. [2]* demonstrate that the standard practices of exposing the wild-caught animals to air are not only extremely harmful for the fish but also modify muscle texture properties and reduce the quality of the meat. This study demonstrates the urgency of improving the welfare of wild-caught fish and indicates the road ahead regarding the assessment of humane practices in fisheries. The paper by *Strauch et al. [3]* also highlights how a common practice of adding phosphate to integrated aquaponic systems as a fertilizer can have negative effects in **African catfish** *(Clarias gariepinus)*, not only on their welfare but also on the meat quality. These two studies emphasize a correlation that should be clear for the fish industry: when the welfare of animals is improved, both the quality of the product and its value increase – a rare case when the interest of the industry and the ethical standards underlying its activity walk hand in hand.

This study highlights the need to take into account the age of the individuals when designing prevention and treatment plans as well as rearing routines. The study by *Moreira et al. [4]* takes an ontogenic approach into amyloodiniosis, a well-known health problem in **white seabream** *(Diplodus sargus)* farmed in Southern Europe. Focusing on fish health is not new in welfare research. After all, health is one of the key components for conceptual framework of welfare, together with the mental and natural components. The novelty of this paper is to search for a non-veterinary approach to deal with a health issue, using one of Tinbergen's Four Questions *(see box)* that is so often overlooked: development. The results show that young fish are far more susceptible to infection by Amyloodinium ocellatum because they lack immune and physiological responses that only appear later in ontogeny. This study highlights the need to take into account the age of the individuals when designing prevention and treatment plans as well as rearing routines.

Zebrafish welfare was another surprisingly ignored issue until recent times. The number of cultured individuals arguably surpasses any other commercially farmed species, yet even when the subject of welfare in aquaculture started to be addressed, zebrafish were apparently left behind. Now, two studies by *Woodward et al. [5]* and *Deakin et al. [6]* focus on two important topics that impact zebrafish welfare: the first shows that environmental enrichment in zebrafish housing promotes aggression and risk-taking behaviours in zebrafish *[5]*, and the authors explain this with the social and territorial behaviour of the species, in which the enrichment structures provide resources to monopolise; the second suggests a novel method to analyse pain responses to standard experimental procedures in this species. Using fractal analysis of behaviour, the authors create (and validate) a pain intensity scale for zebrafish, and propose that variations in complexity of movement should be a good indicator of welfare in this species *[6]*. This paper also adds compelling evidence that fish are sentient and able to feel pain. Both studies dive into the biology of welfare in zebrafish, using basic behavioural variables and knowledge on the ethology of the species to highlight the importance of the natural [5] and mental *[6]* dimensions of welfare.

The importance of understanding the ethology of reared species is further explored in the review by *Gonçalves-de-Freitas et al. [7]*, where the social behaviour of **Nile tilapia** *(Oreochromis niloticus)* is proposed as a key component in the welfare of this fish. In this study, the authors thoroughly review the social ethology of tilapia, elegantly addressing both proximate and ultimate mechanisms to provide operational insights that may improve its welfare. The social environment is demonstrated to have impacts on stress levels, growth and aggression, and the authors offer solutions to mitigate the effects of rearing conditions: lighting, environment colour and enrichment structures are pinpointed as simple ways to reduce the detrimental effects of human-induced social disturbance.

The review by *Fife-Cook and Franks [8]* proposes a framework for positive welfare in fish (i. e., mental and physical states that exceed what is necessary for immediate survival), which would replace the traditional paradigms that focus on mitigating the negative impacts of rearing. The positive welfare approach requires a deep understanding of the species' behaviour and biology and would demand taxa-specific standards. However, the knowledge already available from fish and other taxa allows both the identification of positive welfare states in fish and the suggestion of active measures: ***species-specific housing*** *(including ambient colour and appropriate social environment, as already suggested in [7])* and the ***promotion of cognitive engagement*** *(visual stimulation, novel objects, play, etc.)*. The authors conclude that

[1] The article originally appeared as an introduction to the special issue '*Welfare of Cultured and Experimental Fishes*' of the *journal Fishes [1]*. Courtesy of the publisher and authors.

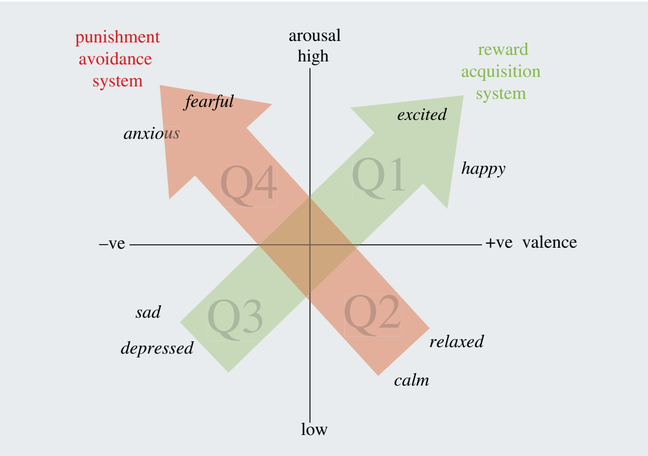

Figure 1: Core effect depicted in two-dimensional space. Italic terms indicate possible locations of specific reported affective states (including discrete/basic emotions). Positive affective states are located in quadrants Q1 and Q2, and negative states in quadrants Q3 and Q4. Arrows indicate putative bioethological behavioural systems associated with the acquisition of rewards (Q3–Q1 axis of the core affect, green) or with the avoidance of punishment (Q2–Q4 axis of the core affect, red). From Mendl et al. [11].

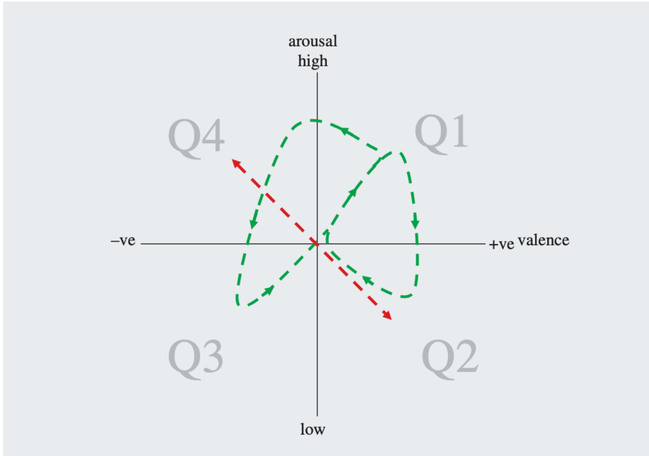

Figure 2: Hypothetical examples of how an organism's core affective state can change over time. The right green loop represents changes during successful cycles of reward acquisition. The left green loop represents changes during unsuccessful cycles. The red line represents changes that occur in response to the presence (quadrant Q4) or successful avoidance (Q2) of threats or punishment. From Mendl et al. [11].

the positive class of experiences are currently being neglected in fish and urge for more research in this area.

Finally, *Saraiva et al. [9]* propose a framework to assess the welfare of farmed fishes at a species level: the **FishEthoBase**. This **open-access database on fish ethology** and welfare aims to provide a tool to evaluate the welfare state of (ultimately) all farmed species worldwide. In that sense, the authors have built the portal www.fishethobase.net where an impressive amount of data concerning the biology of farmed species and the impacts of aquaculture on their welfare is scrutinised, organised and summarised. Using the data on 41 species already available, the authors analyse their welfare state and conclude that (i) the general welfare state of farmed fishes is poor, (ii) there is some potential for improvement, and (iii) this potential is related to research on species' needs, but (iv) there are many remaining knowledge gaps, and (v) current fish farming technologies do not seem to fully address welfare issues.

Fish welfare seems to have gained a considerable momentum and, although there is yet much work ahead, we can optimistically say that the wind is blowing in a favourable direction.

Can fishes experience happiness?[2]

It is true that happiness is a subjective evaluation of an internal state, so the word may be misleading when referring to animals. It is also true that positive emotional states have been receiving far less attention than negative, perhaps for obvious reasons *[10]*. That is why there is an objective definition of emotional states in animals *[11]* which can be measured according to objective indicators, as shown in figure 1.

From this figure and definition, we can predict that an animal is ***'happy'*** if he is experiencing high arousal and a positive internal state *(the Q1 in the figure 2)*. Since we cannot ask directly to the animal (in this case the fish), this can be assessed through indicators: brain activity in the reward system, behaviours, hormones, etc.

From this groundwork, all the papers that I suggested present compelling evidence that fish can experience postitive emotional states:

1 – *Cerqueira et al [12]* state in page 6: *'In this study we have shown that Sea bream exposed to stimuli that vary according to valence (appetitive, aversive) and salience (predictable, unpredictable) exhibit different behavioural, physiological and neuromolecular states that are specific to each combination of valence and salience (i.e. appetitive predictable, appetitive unpredictable, aversive predictable, aversive unpredictable).'* In other words, Sea bream displays all the major emotional states, – including happiness.

2 – *Kittilsen [13]* suggests positive emotions in fish in page 157, referring to studies in cod: *'The memory of this (positive) association between light and the delivery of food was retained for at least 3 months. It has also recently been shown in cod that environmental enrichment promotes a higher propensity for exploration of novel areas and socially facilitated learning'.*

3 – *Braithwaite et al [14]* dive deeply into the evidence for cognition and emotional states in fish, describing why there are differences among species but highlighting in page 16: *'The example of pain and suffering above indicate emotions in a negative domain, but little is known about the potential for positive, or pleasurable, effects in fish. However, given that fish possess similar general neural systems that modulate the feeling of well-being and seeking positive reinforcement that are found in mammalian brains (e.g., the serotonergic and dopaminergic systems), the capacity for positive feelings in fish would seem likely.'*

4 – *Franks et al [15]* actually present behavioural evidence for positive emotions in zebrafish. In the summary on page 1,

[2] Explanation by *João L. Saraiva (2019)* to a sceptical fish farmer

the authors suggest: *'Collectively, these results are similar to the patterns that typify positive emotional behavior in other animals, for example, social grooming and social play'* and in page 10, they conclude: *'Our results suggest that heightened-shoaling episodes may be another promising area of inquiry for future investigations into positive emotions in zebrafish.'*

5 – *Brown [16]* reviews and discusses cognitive abilities in fish. While not directly referring to positive emotional states, there are many references to emotions in fish in a comparative and functional approach.

6 – Finally, *Fife-Cook and Franks [8]* extensively describe positive emotions in fish and from page 6 onwards there is a whole section dedicated to the topic. Page 7: *'Physiological evidence suggests that fish possess the necessary anatomical and chemical structures to experience emotion'*; page 8: *'A number of behaviors, many of which have been documented in fish, can signal positive emotional experience in animals, including successful coping, accessing reward, and successful goal-directed behavior.'*; *'grooming represents another group activity that has been linked to positive emotion, such as inducing a relaxed state in fish and other vertebrates. In fish, it has been shown that tactile stimulation can lower stress levels and facilitate future pro-social interactions. Taken as a whole, these lines of research indicate that, under certain circumstances, the presence of a conspecific and pro-social behavior is likely to involve positive emotional responses in some species of fish.'*

Box

Tinbergen's Four Questions of Ethology, applied to fish welfare [17]

In 1963, Nikolaas Tinbergen published a groundbreaking model for the study of animal behaviour: the Four Questions of Ethology *[18]*. This central idea sets out the four levels of analysis that provide an integrative approach to any behavioural question. In aquaculture, these questions can be applied to seek and offer solutions for fish welfare based on sound science.

1. Mechanism *(causation)*: What stimuli elicit the behavioural responses to the farming conditions? What are the molecular, neural, endocrine and overall physiological mechanisms behind these behavioural responses?

2. Development *(ontogeny)*: How does the behaviour of farmed fishes change with age, and what early experiences are necessary for these behaviours to develop? What are the relative roles of genes versus the environment? Do these behaviours occur as in nature?

3. Function *(adaptation)*: How does the behaviour influence the animal's fitness in the wild? How does it influence the animal's welfare under farming conditions? Is the behaviour performed in the same context as in the wild?

4. Evolution *(phylogeny)*: How can the behaviour be compared with that of related species? What are the selection processes leading to this behaviour? How can farming conditions match these processes?

Take Home Message

For a long time fish were seen as 'stupid' creatures without any kind of sensibility. As the evidence for the mental abilities of fish grew, the uncomfortable questions about fish welfare and its ethical implications for fish farming became an 'elephant in the room' that no one wanted to address. Recently, however, there have been increasing signs that all interested parties—scientists, fish farmers, retailers, NGOs and consumers—now want to address the issue directly.

As the latest research shows, the issue of fish welfare has gained considerable momentum. Studies show that the quality and value of the product increase when fish welfare is improved—a rare case where industry interest and ethical standards go hand in hand. Other work is concerned with ways of structurally enriching the usually monotonous aquaculture habitat, creating opportunities for retreat but also challenges. Other studies shift the emphasis from avoiding negative experiences for the fish to promoting positive fish welfare, i.e. mental and physical conditions that go beyond what is necessary for immediate survival—an approach that calls for more research, since positive emotional states have so far received far less attention than negative ones. Finally, to avoid the danger of misleading interpretations from the subjective evaluation of 'happiness', one study proposes an objective definition of emotional states in animals.

Even though there is still a lot of work ahead, we can optimistically say that the wind is blowing in a favourable direction.

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Development of fish welfare guidelines for the 'Friend of the Sea' (FOS) certification *

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In May 2017, fair-fish international, owner of the FishEthoBase *[1]*, together with Friend of the Sea *(FOS)*, one of the leading labels for sustainable fishing and aquaculture, agreed on a cooperation with the following goal:

- *to develop a set of core fish welfare criteria for all fish species kept on FOS-certified farms, with the aim of integrating corresponding guidelines into the FOS certification standard,*
- *developed on the basis of two visits to FOS-certified companies. The first visit served a gap analysis between the scientific knowledge gained and the observations before species and ended in a report to the farmer with recommendations on how he could improve the welfare of his fish. Half a year later, a second visit was carried out to determine which improvements had already been successfully implemented or were in the planning stage and which had not, and for what reasons not.*

The decisive factor in our approach was not to develop guidelines at the table, but in direct interaction with practice. In this way we wanted to ensure that *future fish welfare guidelines*

- *feasible,*
- *controllable, and*
- *relevant for which fish.*

This plan convinced the Silicon Valley-based foundation Open Philanthropy Project *(OP) [2]*, which aims to promote animal welfare in aquaculture. In this context, OP awarded project contribu-tions to various ***certification programs*** *(including ASC or GAA/BAP)* and ***NGOs*** *(including the Albert Schweitzer Foundation)* before the end of 2017, thus launching a unique competitive boost for fish welfare standards. Twenty years after the first efforts of fair-fish in Switzerland and Vissenbescherming in Holland, the long neglected and smiled at topic finally received broad support.

Work started in early 2018 with the first site visits and continued until late summer 2020 with the handover of the criteria and indicators for the last of 24 species. In early 2019, the work was officially taken over by our newly founded spin-off Fish Ethology and Welfare Group *(FishEthoGroup) [3]*, based at the CCMAR Marine Research Institute of the University of the Algarve in Faro, under an agreement between CCMAR and fair-fish international.

1.1 Results of the first visits to FOS aquaculture farms

Between January 2018 and March 2019 we visited 51 fish farms belonging to 33 companies in 12 countries (28 companies in 8 EU member states, 3 companies in Turkey, 1 company in Panama, 1 company in Chile). The reports contained an average 4.5 recommendations per farm.

In criteria with high severity, the most frequent recommendation was for ***stunning before slaughter*** *(in 73% of all companies)*, followed by ***stress reduction during handling and harvesting*** *(48%)*, ***environmental enrichment*** *(36%)*, ***reduction of density*** *(15%)* or of ***crowding*** *(12%)*, ***improving light conditions*** *(12%)*, and ***water quality control*** *(12%)*. A further 18 recommendations, each with less than 10% of the companies, require in particular the dimensions of the housing system to the needs of the species, and daily removal and killing of moribund fish.

For criteria of medium severity, the ***lack of training of personnel in fish welfare issues*** *(in 82% of all companies)* came first by far, followed by a ***lack of observation and noting of fish welfare indicators*** (15%) and a ***lack of traceability of stressful measures like handling of fish, etc.*** (12%). The remaining 3 recommendations in this category concerned only 3% of all companies and also mainly concerned fish monitoring issues.

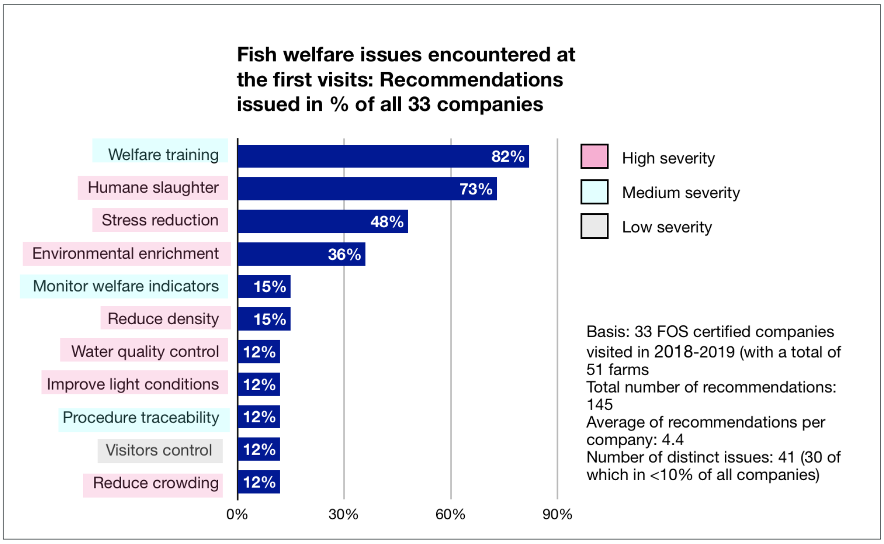


Figure 1: Recommendations to FOS fish farmers, by frequency

* Updated and translated version of a presentation on 28 Nov 2019 at the *Annual Conference on Applied Ethology* in Freiburg, Germany. A former version of the present report had been published on 28 Jan 2020.

For criteria of low severity, we gave 9 recommendations to the companies, mainly concerning hygiene and control: *registration of visits* (12%), *footbath and wheelbath at the entrance* (9%), as well as measures to improve data collection.

1.2 First consequences: Humane slaughter and fish welfare training

We were astonished by the high percentage of three quarters of the companies visited, which harvest the fish without anaesthetising them afterwards. On the one hand, these are mainly breeding *Sea bream (Sparus aurata)* and *Sea bass (Dicentrarchus labrax)* in the Mediterranean, for which we propose solutions with electric anaesthesia, which have now been implemented or are under serious examination *(see section 2.3)*. On the other hand, many smaller trout farms in Northern Italy are sceptical about electric stunning because they fear a loss of quality (haemorrhaging) and higher operating costs. However, these companies are aware that slaughtering trout without anaesthesia could lead to market losses in the future. Colleagues from a Northern Italian research institute have therefore developed an alternative to stunning by thermal shock, which is being tested experimentally by our FishEthoGroup in comparison to stunning with electricity, with MS222 and without stunning.

The lack of training of personnel in fish welfare issues observed in more than four-fifths of the companies has also led us to develop a Fish Welfare Course. The three-day course for practitioners, auditors and other interested parties from the industry has been held for the first time in November 2019 by experts at the headquarters of FishEthoGroup at the Marine Research Institute CCMAR of the Universidade do Algarve in Portugal, with about 50 participants *[4]*. A second course will be held online in spring 2021.

1.3 Improvements noted during the second visits

We were able to visit 25 of the 33 companies a second time or to interview them by questionnaire or telephone (mainly companies that had not yet addressed any of the recommendations). For 8 companies, a second visit or interview was not possible for the following reasons:

- *No recommendations issued after first visit, therefore no second visit needed (2);*
- *Second visit impossible, because the company had been severely damaged by storms (1);*
- *the management changed after the first visit was not interested (1);*
- *No reply or refusal of the demand for a second visit for unknown reasons (4).*

The results of the second visits represent the vast majority of cases.

During the visit or interview, we checked which of the recommended improvements had been implemented or were at least under serious consideration, and which were not, and for what reasons. To get an overview of the situation, we scored the reactions of the companies as follows:

- *Improvement implemented: Score = 1.0*
- *Improvement under serious consideration: Score = 0.5*
- *Measure neither implemented nor considered: Score = 0.0*

At the second visit after about six months, the 25 companies had already implemented 17% of all the recommendations we had made to them, and 37% companies were in the planning stage. While these companies had received an average of 4.6 recommendations per company, they reached an average improvement score of 2.5 per company. This means that these companies have implement-ed more than half of the improvements in six months or are currently seriously considering solutions. If we relate this to the usual transition periods for newly introduced label criteria of one, two or even more years, the adjustment performance of these companies so far signals that an integration of fish welfare criteria criteria into the FOS certification standard is not unrealistic. This presupposes, of course, that the measures only under planning so far will be implemented later as well, let alone measures not yet taken into account for the time being.

However, the fact that the FOS-certified companies still face a challenging task becomes clear when we consider all 33 companies that were once visited: Of the total 145 recommendations made *(an average of 4.4 per company)*, only 20 (14%) were fully implemented during the second visits.

As expected, the easiest measures to implement are those to reduce stress. At the second visit, 67% of the companies to whom we recommended to tackle this issue were found to reduce or plan to reduce stress by handling procedures, to limit the time the fish spend out of water to a maximum of 15 seconds, to reduce the number of sorting processes during the fish's life cycle or to harvest the fish using pumps instead of nets. 50% percent of these companies have already a solution at work.

47% of the companies to whom we recommended pre-slaughter stunning were found at the second visit seriously planning to implement a stunning procedure; 11% of these companies meanwhile already implemented electric stunning.

43% of the companies to whom we recommended to get fish welfare training reported at the second visit currently examining participation, in many cases by participation in our Fish Welfare Course; 14% of these companies have already found a solution (one company has solved the problem by having three of its employees complete a specialist training course, whereas the quality manager has also completed a fish veterinary course).

As expected, more difficult to tackle are those recommendations that intervene more strongly in the operational process, such as the installation of structures (substrate, hiding places), the avoidance of crowding or the introduction of monitoring measures regarding behaviour, water quality and handling processes; *see Fig. 4* for details.

2. Development of fish welfare criteria for the FOS-Standard

From the outset, Friend of the Sea had decided to integrate the future fish welfare criteria as a binding component of its own standard and – in contrast to what the Aquaculture Stewardship Council *(ASC) [5]* appears to be doing – not to pursue an add-on strategy that would allow individual farms to choose whether to subject themselves to animal welfare requirements in addition to environmental ones. Friend of the Sea found it difficult to communicate on the market one FOS label with and one without fish welfare add-ons. Thus, the definition of fish welfare criteria applicable to all FOS farms faces the fact that for some of the problems observed there are no practical examples yet that a comparable farm could simply adopt.

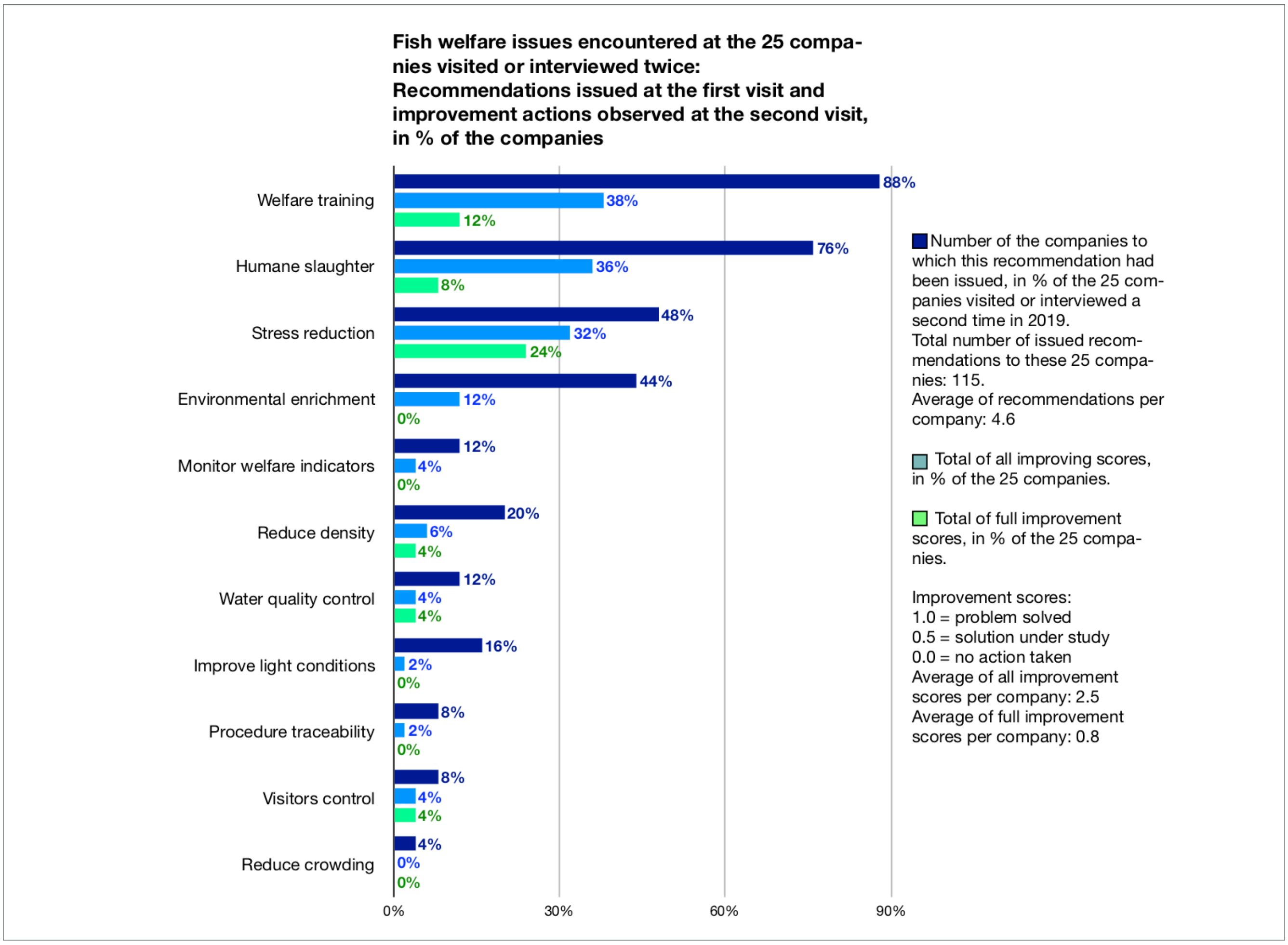


Figure 2: Implementation of our recommendations after half a year

We therefore recommended that **Friend of the Sea** *(FOS)* should not make such criteria mandatory until a farm with the same species and similar system has implemented a recognised solution. This would be in line with the current situation of the long neglected fish welfare in aquaculture, which has grown and still grows extremely rapidly in terms of volume since the 1950s and by farming a number of species eighteen times greater than in terrestrial farming.

The aim is to improve the welfare of fish on as many FOS certified farms as possible or to lose as few farms as possible when integrating welfare into the FOS standard. However, the FOS certification scheme does not allow for the flexibility we proposed. Similar to ASC, for example, any change or addition to the standard requires a predetermined decision-making process in which the representatives of the various interest groups must agree, which is only possible on the basis of conclusively formulated proposals. Nevertheless, in order to improve fish welfare step by step according to wise developments in practice, FOS will classify the criteria into one of the following three categories ac-cording to their current feasibility:

- ESSENTIAL: *In the event of non-conformity identified by the auditor, the farm will be given three months to rectify the problem. If the nonconformity persists during a follow-up inspection, the company loses the certificate.*
- IMPORTANT: *In the case of a non-conformity identified by the auditor, the company will be given three weeks to present a corrective plan which must be carried out at the next inspection about one year later, otherwise the company loses its certificate.*
- RECOMMENDED: *In the case of a non-conformity identified by the auditor, the farm is free to follow a recommendation for improvement. The auditor's reports on the behaviour of the farms are an indicator of whether a criterion in this category should be declared mandatory in the future.*

This is the path on which currently recommended criteria can be given a more binding character in a next revision of the standard.

For each of the 24 fish species *(see table 5)* integrated into the project, the **FishEthoGroup** developed a set of over 80 criteria and indicators, each subdivided into up to 5 production or life stages: eggs, larvae, juveniles, adults, parent animals. *(See table 1 for an example).*

At deadline of this report *(end of August 2020)* the experts of Friend of the Sea are in the process of integrating the recommendations of the **FishEthoGroup** into a proposal for the extension of the standard and preparing stakeholder consultation.

Table 1: Example (extraxt) of a fish welfare criteria and criteria sheet for Friend of the Sea

European seabass – Ongrowing			
13. Welfare requirements			
13.01. Captive environment			
No	Requirement	Level	Indicators *
13.01.1	Production units should providing horizontal and vertical withdrawel space, optimising fish welfare conditions regarding spatial constraints.	Essential	There must always be #horizontal and vertical empty space.
13.01.2	Production units must not have sharp protrusions which may be injurious to the fish.	Essential	Absence of dangerous protrusions.
13.01.3	Production units and equipment must be checked for holes, faults and fouling. All equipment must be maintained regularly and recors must be ready for inspection.	Essential	Good overall condition of nets and infrastructures. Records of periodicity and methods.
13.01.4	Farm design should be such that inspection of all stock is possible.	Essential	Water visibilty, ROVs, divers, cameras …
13.01.5	Oprimal photoperiod for fish welfare must be determined on a site-by-site basis matching natural limits and using practical experience, research and welfare specialist advice. NorthAtlantic latutudes photoperiod max. range: 16L:8D-8L:16D	Essential	Facility allocated within the natural photoperiod and geografical range of the species.
13.01.6		Important	Depth net-pen.
13.01.7	Additional lighting either fixed or portable must be available, but only should be switched to allow examination of the animals and equipment.	Important	Stock inspection all times.
13.01.8	Structural enrichment should be provided. If deemed impossible or harful, other type of enrichment should be implemented (occupational, dietary, social, sensorial).	Recommended	Presence of enrichment – but observing 13.1.3
13.01.8	The cags should be located in a site protected from human induced noise. The maximum sound pressure level should be unter 150 dB re 1μPa rms in the 0,2-1kHz frequency range in any point of the tank at all times.	Important	Absence of noise, recorded with a hydrophone and analysed with appropiate software.

** Management-based indicators, see: Operational Welfare Indicators (OWI table)*

3. Future research and consulting activities

At a meeting of the fish welfare projects supported by Open Philanthropy in April 2019 in Brussels, it became clear that **fair-fish international** resp. its **FishEthoGroup** had made the most progress in the development of guidelines. At the beginning of 2020, Open Philanthropy complied with our application for continued funding. This allows the **FishEthoGroup** to support the implementation of the fish welfare criteria on the currently about one hundred FOS-certified aquaculture farms with research, consulting and training. At the same time, the **FishEthoGroup** has started to make its services available to other players in the aquaculture sector, like the ASC and the Spanish fish farming company Culmarex, in order to promote fish welfare.

Take Home Message

To date, there are no certifiable guidelines for improving fish welfare in aquaculture worldwide *(exception: the RSPCA guidelines for Atlantic salmon and rainbow trout)*. The fair-fish international associa-tion and its Fish Ethology and Welfare Group *(FishEthoGroup)* were commissioned by the Friend of the Sea *(FOS)* certification scheme to develop fish welfare criteria for the FOS standard. The Open Philanthropy Foundation secured funding for the project.

The basis for the development of the guidelines was, on the one hand, the scientific findings in the freely accessible online database FishEthoBase.net set up by fair-fish for a growing number of species *(currently 51)* and, on the other hand, visits to FOS-certified fish farms. The first visit was for a gap analysis, with a report and suggestions for improvement to the farm, the second six months later to observe which of the suggestions could be implemented and how, and which could not, and why. A total of 51 fish farms from 33 companies in 12 countries with a total of 26 fish species were visited.

Conclusion after the first visit: The most common problems concern lack of fish welfare training of the staff, lack of stunning before slaughter, stress of the fish and lack of enrichment of the facilities with substrate and structures. Conclusion after the second visit: About half of the recommended improvements were under serious consideration or already implemented after half a year. This adapta-tion performance of the farms shows that an integration of fish welfare criteria into the FOS certifica-tion standard is not unrealistic.

The criteria and indicators developed by fair-fish are currently *(August 2020)* being prepared by Friend of the Sea for its own standard and will then be submitted to the stakeholder process. Implementa-tion is planned for 2021, with the support of the FishEthoGroup, which is now making its services in research, consultancy and training available to other stakeholders in aquaculture.

Links

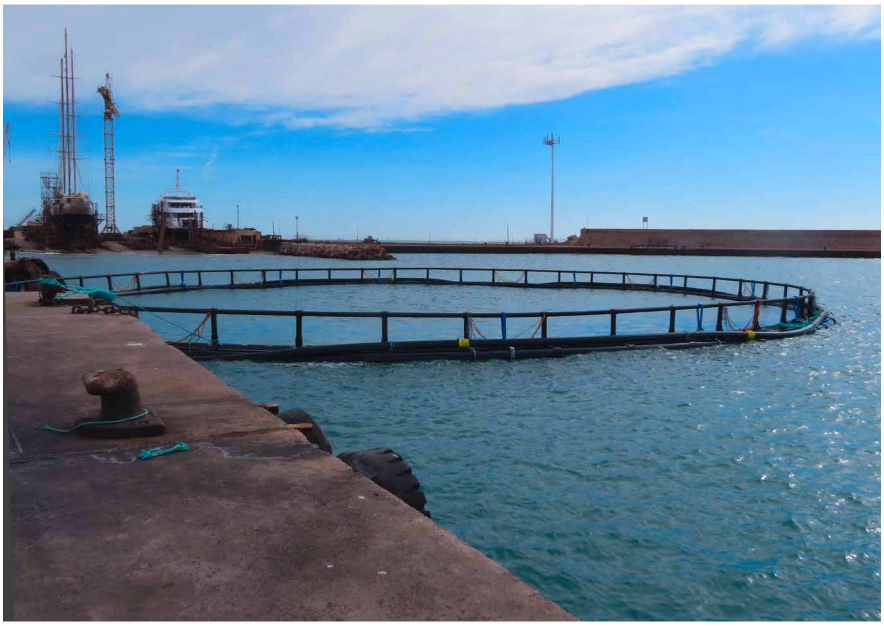
[1] *http://www.fishethobase.net/db*

[2] *https://www.openphilanthropy.org*

[3] *http://www.fishethogroup.net*

[4] *https://www.ccmar.ualg.pt/avanced-tech-training/fish-welfare-course*

[5] *https://www.asc-aqua.org/news/latest-news/asc-responds-to-fish-welfare-report/* – see also Janneke Aelen's contribution of on *'Fish welfare indicators for the ASC standard'* in this issue



Net cage brought ashore for repair from a Sea bass farm in Spain (Photo: © Studer/fair-fish)

Fish welfare indicators for the 'Aquaculture Stewardship Council' (ASC) standard

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Background ASC

The Aquaculture Stewardship Council *(ASC)* is an independent non-profit organisation that manages a stringent certification and labelling programme for responsible aquaculture based on species-specific standards. The ASC standards and certification guarantees to consumers that the seafood they are purchasing is sustainable for the environment, and socially responsible. The ASC was founded in 2010 by the World Wide Fund for Nature *(WWF)* and the Dutch Sustainable Trade Initiative *(IDH)*.

The ASC is an example of multi-stakeholder governance, and a full member of the ISEAL Alliance, the global organisation for credible sustainability standards whose members must meet internationally accepted best practice. Within its current ASC species-specific standards, fish welfare is only very partially addressed, and ASC has in 2019 embarked on a Fish Welfare project aimed at assessing how to expand comprehensively the list of fish welfare-related indicators and requirements in its standards.

Animal welfare within ASC certification

The ASC standards originally have been structured around two major sustainability issues: environmental impact and conditions of those working in in aquaculture and communities that are directly affected by aquaculture practices. The aquaculture dialogues, initiated by WWF prioritized these two aspects when developing the original ASC standards as they formed the major impacts from this industry.

Since its founding over 10 years ago, ASC has been growing in size and capacity, which allows the organisation to evaluate and expand its scope. This will inevitably lead to a more holistic approach on achieving responsible and sustainable production by addressing an increasing amount of issues that are impacted by aquaculture practices. Animal welfare can be seen as one of these.

Once animals are kept in captivity to produce food, farmers have an ethical responsibility to provide them with acceptable, if not the best possible welfare conditions throughout their life cycle *[1]*. As other production animals, fishes in captivity don't have the option to avoid or escape from stressful events like aggressive conspecifics, parasites or harmful environmental changes. Systems with a higher degree of intensification usually pose a higher risk for animal welfare issues. The advantage of intensified systems is however that these farmed species are under greater (environmental) control which provides opportunities to address and control potential welfare issues *[2]*.

Although animal welfare touches upon the three well-known pillars of sustainability (economic, environmental and social), locating the concept within one of these domains has been complex *[3]*. Animal welfare is sometimes placed under the social pillar as a social issue that needs to be met and animal health can sometimes be found under the environmental pillar. Both animal welfare and health can be seen as factors contributing to economical sustainability. For animal health the interlinkage with environmental health and human health is widely proven and recognized within the One Health concept *[4]*. Lesser known is the One Welfare *[5]* concept, highlighting the interconnections between animal welfare, human wellbeing, and the environment and emphasizing a holistic approach when addressing welfare related topics.

This interlinkage between animal welfare and other (sustainability) issues is increasingly being investigated and recognised. For example, The EU and EFSA define it as an issue linked to food safety *[6]*, and also the FAO links animal welfare to food safety, as well as to human and animal health, sustainability, and rural development. The targets of the UN Sustainable Development Goals *(SDG)* have been reviewed in compatibility with improving welfare, and especially SDG 12, responsible consumption and production, and SDG 14, life under water, were found to have a mutually beneficial relationship with animal welfare *[7]*. In a survey on options for a seventeenth SDG, animal protection achieved the second highest score *[8]* and the *2019 Global Sustainable Development Report* identified animal welfare as a missing key issue *[9]*. With this growing recognition of animal welfare as a critical issue in food production, the inclusion of fish seems not only relevant but necessary, given the relevance of aquaculture in current food production. Of course a strong scientific basis is required to actually address fish welfare in a robust manner.

About 20 years ago fish welfare was a topic which was barely studied, but this has changed over the last two decades. With thousands of papers being published on fish welfare, fundamental questions on fish intelligence, stress and pain experience are being answered and a foundation is being created for implementation within legislation and welfare certification schemes *[1] [2]*. Examples of the progress of fish welfare science are the handbooks on welfare of Atlantic Salmon and Rainbow Trout, published as part of the *FISHWELL project by Nofima [10]*. These elaborate reports describe operational welfare indicators for these two common aquaculture species. The scientific knowledge is not as advanced for all aquaculture species, but this is developing rapidly as gaps are being identified by different stakeholders and research is focussing on practical implementation in farming environments.

Consumers seem willing to be a premium for fish produced with an improved level of welfare, but the availability of background information and the timing of this information are key factors in the final consumer choice *[11]*.

This is exactly where (independent) labels play a vital role. Labels are a driver for consumers when making ethical purchase decisions and information coming directly from the industry is often distrusted. Moreover, information on higher animal welfare can be a purchase motivation in itself, independent from the consumer level of empathy towards animals, meaning that consumers are sensitive to relevant information, rather that creating awareness is required *[12]*. So as long as animal welfare is not guaranteed through other frameworks, food labelling adds value to the products and can be a motivation for consumers to shift towards higher welfare animal products.

The need for welfare labelling is especially evident when legislation is lacking or is not unequivocal between countries. Fish have the status of sentience beings on EU level, and are protected by EU Council Directive 98/58/EC concerning the protection of animals kept for farming purposes *[13]* which states 'to ensure the welfare of animals under their care and to ensure that those animals are not caused any unnecessary pain, suffering or injury'. On national level, the inclusion of fish welfare in legislation varies from none to very specific requirements for example in Norwegian legislation. Globally, fish protection in national law is still the exception.

Given the fact that aquaculture products come from various regions in the world, independent labelling seems like an ideal option to provide consumers with aquaculture products where fish welfare is assessed in a credible way.

Definition of animal welfare

Animal welfare is a multidimensional concept based on principles from veterinary sciences, ethology, ethics, endocrinology, and other fields *[3] [14]*. It contains aspects on a physical as well as a mental level *[21]*, which makes it a very broad field and impossible to measure directly *[15]*. Another defining factor is that welfare science in principle addresses animals in captivity and how they cope with these constrained conditions which is driven by a societal ethical concern *[16]*.

Frequently used interpretations of animal welfare are the feeling-based, function-based and nature-based definitions, where the feelings-based definition focuses on the subjective state of the animal; the function-based definition on the ability of the animal to cope with its environment, and the nature-based definition on the ability to express natural behaviour *[17]*.

Another well-known framework to describe animal welfare are the Five Freedoms, drawn up by the FAWC. This framework uses five freedoms to describe desirable states to address welfare. These five freedoms are freedom from hunger and thirst; discomfort; pain, injury or disease; fear and distress; and freedom to express normal behaviour *[18]*. The Five Freedoms have been a reference for many assessment methodologies and are still often referred to. However, they are also criticized and described as outdated. The freedoms are interconnected as some can be seen as a cause and effect of another, and it is also not defined on what level they should be met for good welfare to be experienced. The Five Freedoms also neglect the concept of positive welfare, whereas a moderate state of hunger and thirst is not necessarily negative welfare. Finally, the Five Freedoms framework lacks to reflect systematically on cause and consequences of the freedoms not being met, therefore the underlying cause of welfare issues may not be addressed when using these freedoms as a guideline *[19] [20]*.

Then there is the question if animal welfare just can be defined as the absence of suffering? Most animal welfare scientists believe there is more required for welfare to be obtained *[16] [19]*. The possibility to experience positive welfare, or pleasure doesn't have the same moral significance as avoiding suffering, but it is a crucial condition to be able to speak about welfare.

Another determining factor of welfare is that all these negative and positive states are experienced on an individual basis *[20]*. Every sentient animal can have a different experience of the same (environmental) situation and like all the other factors and conditions, this has consequences for animal welfare assessment.

Probably the most controversial aspect of animal welfare science is that it aims to measure a subjective state of the animal, although it is widely accepted that animal have a qualitative experience of life and are capable of emotional suffering *[21]*. For animals to experience a certain quality of life, species should at least have neural structures which allows consciousness *[1] [19]*.

Capabilities linked to this *'emotional brain'* to experience welfare are experience, memories, re-evaluation of needs in anticipation of physiological, psychological and behavioural requirements *[22]*. All of these mechanism have a biological function to make animals able to learn from previous experience and avoid certain negative experiences in the future by learning. So these qualities have to be identified in fish to determine if the principles of terrestrial animal welfare apply to fish. The massive diversity in fish may make it difficult to prove this for all fish species, but general agreement among scientists is that fish are conscious and experience emotions. Numerous studies do confirm that fish have strong cognitive abilities as well. These are very strong reasons to accept that fish experience welfare and that their welfare should be carefully assessed when being kept in captivity for aquaculture practices.

Animal welfare assessment

The multidimensional aspect of animal *(and thus fish)* welfare requires an approach of complementary measures. There is no single measure that can confirm good welfare or the absence of it. So welfare assessment relies on a range of indirect, reliable physiological, biochemical and behavioural indicators, reflecting all different dimensions of welfare *[15] [23] [24]*.

As for any other standards, some common ground rules ensure a framework of robust indicators. For this to be obtained, principles used should be science-based, ethically valid, practical, and meet approval of producers and public expectations *[21]*. Chosen measures also should be specific, valid, repeatable, and feasible *[15] [22]*. In case of assessment as part of certification, assessment principles would be translated into standards and be supported by elements of advice, inspection, certification, and accreditation. The certification scheme should meet certain conditions like having an appropriate scope, practical focus, quality, transparency, effective communication, broad participation, and reflection and improvement on its standards [25]. The inspection takes place as audits, which should follow a structured plan, be an independent and objective evaluation, should assess the reliability and sufficiency of provided information, assess the correspondence between claims and physical evidence, and communicates its findings in a clear written report [21].

Certification programmes can be based on three different principles:

1. Resource-based;

2. Outcome-based;

3. Continuous improvement.

A resource-based approach describes requirements for welfare determining resources for the animal. Indicators taken from this approach are easy to assess, but are insufficient on their own to draw conclusions on good welfare. Outcomes-based approaches use minimal limits of (un)desired results. They measure welfare in a more direct manner than resource-based indicators, but there are potential practical challenges for carrying out the measures. Continuous improvement requires regular monitoring of certain criteria to ensure improvement and can be a direct driver for change. Comparing different farms is likely to be challenging using this approach, as the baseline level will vary between different farms. Ideally, in certification the three approaches are used complementary *[25]*.

Implementation within ASC certification

ASC has established a multi-stakeholder Technical Working Group *(TWG)* for the Fish Welfare project with representatives from academia, the aquaculture industry, and NGO's. As expertise is required on various technical aspects and a range of species, the majority of the group exist of technical experts from universities and veterinarians. This TWG will consider the scientific research available on the various aspects of welfare issues in aquaculture systems. The fish welfare indicators will be on a species-specific level where needed. The developed content by the TWG will go through two rounds of public consultation, where any stakeholder has a chance to provide feedback on this work.

The first set of ASC welfare indicators will form a base from where the fish welfare work can be developed during each 5-year revision of the ASC standards. ASC aims to play an active role in knowledge generation and is part of partnerships addressing specific knowledge gaps to make sure that new background information is available for future revisions and implementation.

Obviously, developing practical and auditable welfare indicators comes with many challenges. One has to consider auditability, producer support, and consumer expectations in the process of indicator development to be sure the standards are carried out correctly and are meaningful. Consumer knowledge and interpretation of complex welfare issues may require accessible information. Auditors and farmers will need training to get familiar with the aspects of fish welfare in order to be able to carry out what is asked of them. Increased production costs as an effect of animal welfare criteria can form a barrier for producers to be able to meet them and therefore should be carefully considered. The aspects of different production have to be taken into account and there has to be a strategy in place for dealing with knowledge gaps on certain issues.

Take Home Message

Following the publication in September 2019 of an ASC Position Paper and of the Terms of Reference of its *Fish Welfare project [26]*, a *Technical Working Group (TWG)* has been establish in April 2020. It is composed of members from Academia, University, research institutions, NGOs, fish farmers and other industry-related stakeholders *(processors, etc)*. ASC has a very transparent process regarding the selection of a broad range *(sectoral, species-related and regional)* of key stakeholders related to the topic to be discussed.

The TWG has had a several constructive virtual meetings during which various aspects of fish welfare within aquaculture practices were discussed. The outcomes of these discussions will be processed into draft indicators and will go through two rounds of public consultation. All stakeholders with an interest in fish welfare are invited to provide feedback on the draft content developed by the TWG during these public consultation moments. The first round of public consultation is planned for September 2021.

The publication of the fish welfare indicators within the ASC standards will form a solid baseline for fish welfare which ASC will be able to continue to build on. Expected development of scientific knowledge and technologies that will keep advancing will progress fish welfare within aquaculture processes and ASC is keen to play an active role in this field to move this aspect of responsible production within its standards.

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View into a raceway with trouts (Photo: © Studer / fair-fish).

Tasks and working methods of the 'Aquaculture Welfare Standards Initiative'

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Introduction

The breeding of fish and other aquatic animals in aquaculture is attracting increasing global attention year on year. Trade in foodstuffs from this particular type of production has long been global and extended across borders. At the same time, there are rising demands by society for the protection of these animals from avoidable harm and suffering in many countries.

Due to inadequate international harmonisation of regulations on the protection of the welfare of aquatic animals in aquaculture up to this point, and a frequent lack of practical assistance, an initiative group of representatives from academia, animal breeding, business, public administration and trade and animal welfare set up the 'Aquaculture Welfare Standards Initiative' *(ITA)* . In addition to producer associations, animal welfare and science, this group already represents around 80 per cent of the German food retail volume, along with the leading aquaculture certification bodies.

Objective and procedure

The ITA is aiming to instigate and lead an industry-wide communication process for the development, drafting and implementation of international animal welfare standards, irrespective of legal requirements.

The ITA uses scientific knowledge, technical developments, as well as social and legal requirements for animal welfare-friendly aquaculture to develop recommendations for practicable international standards for the breeding of fish and other aquatic organisms. The first step is to collate and evaluate currently valid legal requirements for animal welfare-friendly aquaculture in Germany and other countries advanced in this field. The purpose of this being that they can then be appropriately applied to the production of fish and other aquatic animals in other producing countries.

New measures serving to improve animal welfare in aquaculture animals based on scientific knowledge, which have not yet codified by the legislator, as well as the communication of particularly practicable methods for improving animal welfare in the production process *('best practice')* will also be incorporated into ITA's activities.

When developing recommendations, ITA uses the ***stage-gate process*** in innovation management. Aspects that are eligible for animal welfare improvements are examined to determine whether they are acceptable and feasible at all stages of the value chain. Only aspects that meet this initial check can be considered as starting points for recommendations and are prioritised for processing.

All recommendations and criteria for an animal welfare-friendly aquaculture that result from the work of the ITA are subject to an ongoing improvement process. They will be continuously further developed even after their publication to enable long-term sustainable improvement of the quality of aquaculture. The ITA's recommendations are initially to be considered as non-binding guidelines. They serve as guidance for members of the ITA when reviewing and adapting their own guidelines (e.g. quality assurance measures in aquaculture production, procurement policy in food retail, adapting the guidelines of certification bodies, etc.). ITA does not have any influence or control over the way in which the recommendations are implemented in practice. Members of the ITA acknowledge that their recommendations must be implemented in compliance with antitrust regulations and in consideration of market requirements for investments and innovation management.

Requirements and strengths of the ITA

The animal welfare recommendations developed by the ITA are

- scientifically sound
- accepted across the industry
- socially relevant
- economically feasible
- socially and ecologically sustainable
- easy to understand, uniformly applicable, and simply formulated.

Limits on the activities of the ITA: It is expressly not the ITA's task to develop a new certification or a new umbrella brand; rather, it is responsible for drafting a new standard that is valid across the board as guidance and a benchmark for the further development of already-existing systems on the market. For the time being, the ITA will not deal with animal welfare issues concerning the catching of wild fish and marine animals but will concentrate its work on issues relating to the breeding of fish and invertebrates.

The ITA is essentially open to all stakeholders who make their own specialist contributions to the field of ***'animal welfare and sustainable aquaculture'*** or want to implement them in their field of work. The ITA particularly encourages and strives for the participation of experts with a focus on aquaculture, animal welfare or animal health in the following areas:

- Science and administration
- Food retail
- Fishing industry and aquaculture enterprises
- Representatives from recognised subject-oriented NGOs
- Certification providers and certifiers

The ITA operates internationally from Germany with the aim of including existing and new initiatives from other countries and achieving the broadest possible international impact.

ITA membership is awarded on the invitation of the project coordinator and the signing of a letter of intent, a non-disclosure agreement, and an antitrust law declaration.

Method of negotiation

Unless otherwise agreed in the invitation to the meeting, German is the language used for negotiations of the ITA.

ITA members, who act as representatives of a company or an organisation, ensure, to the best of their knowledge, that they have a mandate to negotiate the topics listed on the agenda issued before each meeting.

[1] *https://www.aquaculture-welfare-standards.net*

They undertake to treat each other with respect and to communicate in a spirit of mutual appreciation. It is in the common interest of all members to reach consensus on all issues to be decided, as far as this is possible, so that the greatest possible step is taken towards achieving ITA's objectives.

What obligations do the members have? For the time being, there are no costs or fees associated with taking part in the 'Aquaculture Welfare Standards Initiative'. For invited external experts and for representatives of non-profit organisations, travel expenses may be reimbursed by the project coordinator upon request. The plan is to organise a maximum of four joint face-to-face events per year for ITA members. Information is exchanged through e-mail correspondence, webinars, and online meetings.

Supervisory body, specialist working groups: currently there is no group hierarchy.

Why specific to individual fish species?

Each animal species has developed very special characteristics during its evolution in order to cope with the demands of the environment. In animal breeding, these species-specific characteristics must be adequately considered in order to avoid as far as possible any harm or suffering caused by husbandry.

In the case of terrestrial farm animals, experience has been gathered from several millennia of animal breeding and husbandry. In addition, agriculture focuses on a manageably small number of livestock species. In the case of aquatic animals, there is much less experience. Carp, for example, were not adopted into pond culture until the Middle Ages; trout breeding was only developed in the 19th century; and modern aquaculture systems for salmon only draw on experience spanning the past few decades.

The number of fish species bred in aquaculture around the world is far higher than that of terrestrial animals; it has already reached several hundreds of different species. Well-founded scientific knowledge on species-specific needs and peculiarities is available for very few of these species. The adoption of new species into aquaculture usually occurs through trial and error.

When formulating animal welfare recommendations, species-specific differences must be adequately considered. For example, not all stunning methods work equally well on different species. There is a need to specify more precisely the individual methods that can be regarded as appropriate for ensuring and maintaining animal welfare.

When selecting the animal species, the following should also be taken into account: their significance to food retail, the extent to which existing market certifications are available for them, and whether sufficient expertise can be obtained from the ITA for scientifically based recommendations. To start with, research will concentrate on species that are also produced in aquaculture in Germany It can be assumed here that, for the purpose of deriving initial recommendations, there is already a sufficient amount of data on good practice in accordance with applicable legal norms. In addition, species that are economically important and that are imported for German trade are to be selected. These are primarily:

- Trout
- Carp
- Salmon
- Gilthead seabream
- Sea bass
- African catfish
- Pikeperch
- Shrimp
- Tilapia
- Pangasius

Order: Trout and carp will be dealt with first, followed by salmon. Trout is ideal because there is already enough scientific background information on the relevant existing hotspots and it is an important product for the food retail sector. Furthermore, there is an imbalance between the number of trout products produced in accordance with German legal standards and the actual total number of trout products traded in Germany: according to estimates of the German food retail industry, a good 80 per cent of trout is imported and it is far from certain whether production already meets the animal welfare demands of German consumers. German aquaculture companies view this situation as a market distortion. A harmonisation of the production standards is desirable. *(See Table 'Which hotspots does the ITA focus on?' on p. 72)*

Intercultural communication as a challenge

The work of the ITA aims to make aquaculture more animal-friendly worldwide. In contrast to existing standards (RSPCA, fair-fish), the recommendations made by the ITA are not intended as a comprehensive draft on animal welfare in aquaculture. Rather, it proposes that basic minimum requirements should be defined which are globally acceptable and implementable, regardless of the country of origin and the type of culture.

The challenge will be to take into account cultural differences concerning the importance attached to animal welfare issues when communicating the objectives. For example, the question of effective pre-slaughter stunning in German-speaking countries is of great importance from the consumers' viewpoint. In contrast, in Mediterranean countries, where the perishability of fish as a foodstuff is a significant concern to the consumer due to the warmer climate, pre-slaughter stunning is less of a priority for fish farmers. And in Asian producing countries, for instance, far less importance is attached to animal welfare than in the EU.

In order to effectively level out such cultural differences, it is necessary to highlight the aspects of product quality, food safety, and improved economic stability that are associated with improvements in aquaculture animal welfare. *[See Table 'Comparison of stakeholder interests (stage-gate model)' on p. 73–74]*

Future of the ITA—an outlook

The work of the ITA will become increasingly international. Initially, the scope of activity will be expanded to include all German-speaking countries. After that, the ITA will have to agree on an expansion strategy into the rest of Europe that is compatible with the structure of the Initiative.

Currently, most of the communication takes place through direct face-to-face exchanges or in plenary sessions. This will no longer be sustainable once the Initiative reaches a critical size. At this point, the establishment of smaller working teams, along with a steering committee for quality assurance, will become an issue.

The ITA will be financed by project funds from the Albert Schweitzer Foundation until 2022. The foundation expects the desired project results to include an agreement on public recommendations for the stunning of the most important aquaculture animal species, along with recommendations on two issues included in the list of hotspots considered to be relevant.

With regard to the recruitment of suitable personnel *(competent, multilingual, strong communication skills)*, the Initiative will have to agree on alternative options for further financing over the course of 2021, provided that it appears to be desirable to continue the Initiative's activities beyond 2022.

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[1] *https://albertschweitzerfoundation.org/campaigns/welfare-standards-aquaculture-industry*

Take Home Message

At the end of 2018, representatives from academia, animal breeding, business, administration, trade, and animal welfare founded the German 'Aquaculture Welfare Standards Initiative' *(ITA)*. Around 80 per cent of the German food retail volume and the leading aquaculture certification bodies are also represented in this stakeholder group. The aim of the ITA is to instigate an industry-wide communication process in order to develop international animal welfare standards. The ITA develops recommendations for improving fish welfare on a scientific basis that is practice-oriented at the same time. These recommendations shall serve as guidance for ITA members for setting their own guidelines and measures. When developing recommendations, the relevant aspects are checked to determine whether they are acceptable and feasible at all stages of the value chain *(innovation management based on the stage-gate model)*. Only aspects that pass this initial check can be used as starting points for recommendations.

As the needs of the fish – and consequently the measures required to improve their welfare – differ between species, the recommendations are specifically developed for individual species. The plan is to develop recommendations for trout, carp, salmon, gilthead seabream, sea bass, African catfish, pikeperch, shrimp, tilapia, and pangasius. The ITA focuses on the hotspots of stunning and slaughter, transport, handling, feeding, and water quality. The plan is to overcome intercultural differences in dealing with animal welfare at product quality level.

Trout feeding (Photo: © Studer/fair-fish).

Which hotspots does the ITA focus on? The recommendations made by the ITA will mainly focus on animal welfare aspects of the following key issues:	
Stunning and slaughter	The practice of pre-slaughter **stunning** only plays a decisive role in the aquaculture rearing of aquatic animals within the last minutes of their life. However, from the consumers' viewpoint, the topic of *'killing'* plays an important role and needs to be dealt with accordingly with the necessary level of sensitivity. The process of slaughter is pushed into the background. However, deficiencies in stunning practice, or even the absence of any stunning before slaughter, create substantial potential for a scandal and therefore represent a level of reputational risk for all parties involved in the aquaculture value chain that should not be underestimated. The issue is also suitable as a communicative bridge in dealing with producers from cultures in which animal welfare aspects receive less social attention compared to within the EU. The avoidance of suffering and excessive stress during slaughter increases the product quality and shelf life to such an extent that these advantages can be used to formulate an interculturally, easily understandable justification for effective stunning methods without the need to emphasise ethical aspects.
Transportation	The **transportation** of stock and breeding animals is sometimes handled extremely differently in the producing countries, depending on their culture. The spectrum ranges from the use of a modern transport tank with ventilation control to simple placement in an open basket. In addition to animal welfare-related effects of excessive stress, injuries to the animal and possible contamination with pathogens should be avoided as far as possible. As with the issue of stunning, there are numerous aspects that help to improve both the ethical and economic quality of production. The gentler the transport process, the lower the harmful effects on the animals transported and on their continued breeding.
Handling	As regards the **handling** of animals in aquaculture for necessary examinations such as vaccinations, weighing, diagnosis, or when moving them to other areas of production, there is significant room for improvement in terms of animal welfare. Stress, injuries and hygiene risks can be significantly reduced by using suitable methods or by avoiding unnecessary measures. Production type and economic efficiency should factor into determining which animal-friendly handling methods can be implemented in practice. And in consumer communication, it is important to meet traditional expectations of *'proper handling'* of fish by explaining in a sensitive manner that less stressful technical methods for handling animals exist.
Feeding	When it comes to the issue of **feeding**, there is potential to improve animal welfare both in terms of feed composition and feeding methodology. Animal feed represents a decisive cost factor in aquaculture. Switching to supposedly cheaper feed could potentially not only cause loss of quality; it also involves animal welfare risks. Overfeeding and underfeeding should be viewed equally critically. When the feed is presented, excessive feed competition, and its consequences for animal welfare, can be reduced by applying simple measures.
Water quality	The **water quality** is, from the perspective of the animals cultivated in aquaculture, by far the most important welfare aspect. At the same time, this issue has the greatest need for scientific research and investigation. The impact of metabolites and feed residues on water quality, the introduction of oxygen, the presence of pathogens and predators, as well as the temperature are influencing factors that are, in part, strongly interrelated. Depending on the type of culture and production intensity, there are also various management strategies for maintaining sufficiently high water quality. It will be a challenge for the ITA to formulate recommendations on this issue that are simultaneously scientifically sound and practicable.
Stocking density	Food traders occasionally face demands by some animal welfare organisations to set upper limits on stocking density for the procurement of aquaculture products. The ITA will not make any recommendations on stocking density limits for the time being. The stocking density that leads to aquaculture conditions that risk animal welfare depends on a number of factors. Even in the case of extensive livestock farming with low stocking densities, there can be a total loss of the population due to predators or adverse climatic conditions. And within the same form of production, excellently managed farms with significantly higher stocking densities may comply better with animal welfare standards than those with serious deficiencies in culture management. In addition, only a binding commitment by food traders to pay higher prices for aquacultural products produced in compliance with animal welfare standards would mean that producers did not have to compensate for the costs of animal welfare improvements by moderately increasing production.

Comparison of stakeholder interests *(stage-gate model)*

When formulating minimum requirements for animal welfare in aquaculture, the demands and interests of the various stakeholders along the value chain must be adequately taken into account. If one aspect at a single stage of the chain encounters disproportionately large hurdles in terms of implementation, its discussion will be postponed, and another animal welfare aspect will become the focus of the ITA's work. Aspects that are deferred are not seen as less important for successful animal welfare. It is simply the case that their implementation depends on questions to which there are currently insufficient answers. The stakeholdergroups in the aquaculture value chain include all businesses and interest groups that can contribute to, or claim to improve, animal welfare at their level. This may have to be weighted differently depending on the issue being addressed.

Hatchery	The keeping of hatchlings (broodstock) gives rise to very specific issues from an animal welfare perspective. The extraction of germ cells through stripping and the use of genetically modified breeding lines are two examples that are currently attracting particular social attention. The **water quality** *(free from specific pathogens)*, **feeding** *(essential components, composition)*, **careful handling, and transportation** (*hygiene, survival rate)* are among the ITA's main topics of relevance to the production of fry/larvae.
Stocking fish production	The production of juvenile fish for stocking fish farms often takes place outside the actual farms. The **water quality** *(free of specific pathogens)*, **handling**, **feeding** *(essential components, composition)*, and **transportation** *(hygiene, survival rate)* are among the ITA's main topics of particular relevance to the production of juvenile fish.
Fish transportation	The issues of handling and transportation are particularly relevant to providers of commercial fish transportation between the various stages of production. The transportation of animals from aquaculture is also handled very differently from a cultural perspective and is strongly linked to traditional images from the consumers' viewpoint.
Technology providers	All of the ITA's main topics address specific aquaculture technology providers. For this sector, it should be noted that the available technology must be suitable for both smaller extensive aquacultures and larger units when it comes to scalability, technical requirements and required level of investment. A collaboration with the ITA can be advantageous for technology providers if new incentives for product improvement and product innovation can be derived from the recommendations made by the ITA.
Feed producers	In the production and composition of feed for animals in aquaculture, animal welfare-related matters arise that are only indirectly apparent to the producers. The issues of feeding and water quality are particularly affected. Clear communication between the feed producer and the breeder is required in order to adequately resolve these issues.
Fish farmers	All of the ITA's main topics are important for operators of aquaculture facilities, provided that slaughter is also the farm's responsibility. A particular challenge for the ITA is the fact that, depending on the type and intensity of production, farms can use different control methods to implement improvements relevant to animal welfare. Extensive carp farming in traditional ponds poses different challenges compared to intensive fish farming in closed circuit systems. The companies' sizes enable problems to be solved using investment-rich methods to varying extents. And last but not least, very different knowledge management and training requirements also apply across various forms of production.
Slaughterhouses	If the slaughter of aquaculture animals is outsourced to an external company, animal welfare-related issues arise for the company, especially as they relate to pre-slaughter stunning, transportation and handling. Depending on the size of the company and its location, different technologies can be used to solve these issues. For the ITA, it should be noted that existing technologies are not always adequately examined for their effectiveness with regard to animal welfare based on scientific data. Furthermore, slaughterhouse inspection was not necessarily part of the previous certification practice of certification bodies.
Cutting and processing	The processing of aquaculture animals is only linked to animal welfare issues in terms of the quality of the products. Extreme stress during transportation, stunning, and slaughtering reduces the quality of the meat. Obvious damage to the eyes, gills, skin, and fins make whole animal marketing difficult and also involves reputational risks. In this respect, processing companies certainly have their own vested interests in animal welfare improvements, but they can only be indirectly influenced through communication with their supplying producer/slaughterhouse.

Wholesalers	As an intermediate level, this stakeholder group has so far been minimally active or inactive on the issue of animal welfare in aquaculture. However, it could certainly be swayed by solutions from the ITA, provided that appropriate offers for discussions are made by producers and retailers. The good reputation of aquaculture is in the very best interests of fish wholesalers.
Food retail	Due to the interface function between producers, consumers, and market power, food retail is a main target for campaigns by NGOs. The reputational risk of all market participants is consistently high; a joint approach to reducing animal welfare problems is therefore in the interests of all companies in the food retail trade. There are options for action that individual actors can take, both through internal specifications for product procurement and the use of existing certificates. For the ITA, it should be noted that the question of product quantities available on the market is just as crucial as the need to make advertised animal welfare features verifiable on the product or in its production.
Certification bodies/Certifiers	The various certification bodies for sustainably produced animal products from aquaculture are already involved in incorporating animal welfare issues into their certificates. For the ITA, this results in the need to formulate recommendations for these stakeholders in such a way that they can be reflected in all existing certificates without endangering their independence as a brand. It is primarily about harmonisation and the avoidance of contradictions in dealing with animal welfare issues, as well as the avoidance of competition in this socially sensitive issue. It should also be noted that certificates cannot be continuously amended but are subject to clearly regulated revision cycles. Recommendations made by the ITA must also be geared towards the ability to certify animal welfare – it must be measurable, countable, verifiable, or otherwise documented for a certifier at company level in a legally secure manner. A third aspect is that sustainability-oriented certificates are usually issued at the level of aquaculture farms. Upstream areas such as feed production or downstream areas such as slaughtering must be recorded and mapped in a suitable manner at the same time.
Consumers	From the consumers' viewpoint, the question arises as to how improved animal welfare conditions can be identified when choosing aquaculture products. Studies show that end product labels do not achieve the desired broad impact; instead, they only appeal to a consistently narrow target group. In contrast, trust in the integrity of well-known brands and retail chains is a decisive factor for the successful marketing of animal welfare-improved products. For the ITA, it is essential to communicate the adopted recommendations to consumers in such a way that the work of the ITA is perceived as both trustworthy and technically well-founded and relevant.
NGOs	So far, the direct involvement of NGOs in the work of the ITA has been limited to the Albert Schweitzer Foundation's campaign for welfare standards in the aquaculture industry *[1]*. The publicly raised demands of other NGOs are continuously compared to the ITA's hotspots, and active participation in appropriate groups at EU level *(Eurogroup for Animals, etc)* is pursued as far as possible.
Official veterinarians/ supervisory authorities	Official representatives who deal with animal welfare issues in aquaculture demand that all recommendations adopted by the ITA must be based on applicable law. For example, a recommendation by the ITA on stunning aquaculture animals may go further than the legal requirements in the countries covered. However, as soon as a method is expressly not approved in a target country, no such recommendation may be given by ITA.
Research/ Science/ Training/ Consulting	There are numerous opportunities for the work of the ITA, starting from basic research on animal welfare issues in aquaculture to application-oriented research, the training of fish farmers, professional advice and advanced training for breeders, and the veterinary care of breeding stocks. An ITA recommendation should only be made based on sufficiently well-founded data. It does not matter whether this is the results of scientific research, empirical experience from good practice or the proprietary expertise of specialist advisors. It is crucial that the observations are reproducible and transferable, and that they can withstand third-party testing. The ITA's academic partners also play a decisive role in the transfer of knowledge for the successful implementation of the ITA's recommendations. For example, publicly accessible course content can be made available in other languages; or the curriculum of existing courses can be expanded.

Coordination in Swiss aquaculture

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The **Bern University of Applied Sciences** *(BFH-HAFL)* and the **Zurich University of Applied Sciences** *(ZHAW)* conducted a study with the aim of setting up a coordinating office for Swiss aquaculture, i.e. for a very small sector that has grown strongly in recent years and is undergoing diversification due to new types of production. This development phase brings uncertainties and challenges along the entire value chain, both for producers and for the authorities.

In order to support the development of Swiss aquaculture professionally in all areas, the **Federal Food Safety and Veterinary Office** *(FSVO)* intends to set up a coordinating office. Clarifications showed great interest in such a body, but the ideas regarding its tasks, financing and organisation differ. The aim of this study is to create a basis for decision-making on the content, organisation, and staffing of the coordinating office, and to define the necessary steps. To this end, the current situation of the aquaculture sector was examined. The information gathered was then used to assess the challenges of the development of the sector by various methods and to identify and prioritise the tasks of a coordinating unit. A scenario analysis of possible long-term developments and a proposal for the next steps, including the financing of a step-by-step implementation, conclude the study.

The research revealed that a majority of the stakeholders interviewed consider the state of the Swiss aquaculture sector to be unsatisfactory. There are many individual actors with their own goals, a high dependence on production factors, synergies are hardly used, information relevant to the sector is not accessible, production, processing, and sales are highly isolated, and there are knowledge gaps in the planning and operation of facilities. Together with the high price level in Switzerland, this results in high production costs. In addition, a lack of customs protection leads to comparatively low margins for domestic aquaculture products compared to imported goods. From the point of view of the trade, an improvement of the status quo of Swiss aquaculture must therefore take place through a higher level of professionalisation along the entire value chain, with a resulting reduction in production costs. Another solution would be to increase willingness to pay by promoting the image and better marketing of ***'Swissness'***. Fish welfare is seen as an important aspect for consumers and production in Switzerland.

It is proposed that the tasks of a coordinating office should initially serve as broad a circle of users as possible. The creation of an information portal and the coordination of synergies should offer added value to the sector. The visibility of Swiss aquaculture should be increased and the sector should be helped to grow in an orderly manner while complying with standards in animal welfare, environmental protection, and product quality. The exchange with thematically related sectors should be strengthened. There is disagreement about political representation.

The coordinating body can be set up over two years and in consultation with existing organisations. The role should be to coordinate and support, not to take over or replace existing activities. The coordinating body should only act where necessary. Initially, funding should come from the federal government and gradually be replaced by membership fees and advisory mandates. In the long term, federal contributions should be limited to the operation of the web portal and the preparation of an annual sector report on aquaculture and its development.

The report was finalised in September 2020 and is now available *[1]*. The BFH-HAFL and the ZHAW have received a new mandate from the FSVO for the next two years to create an information website, distribute the tasks between the various players and find a long-term funding model.

References

[1] **Report** 'Aufbau einer Koordinationsstelle für die Schweizer Aquakultur' **of 5 March 2021**, *https://www.blv.admin.ch/blv/de/home/tiere/tierschutz/nutztierhaltung.html*

Intensive aquaculture and animal welfare: a practical example

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At the beginning, there was *'only'* a market analysis for me: *fish consumption is trendy – fish is light, healthy, modern.* Moreover, the current marginal domestic share of about 2.5 per cent of Swiss consumption of *seafood* promises considerable growth potential for domestic fish production. From an economic point of view, this sounds very tempting – also to me.

After a series of clarifications and considerations, the noble fish pikeperch came into my focus. And so – together with committed partners – I founded the **SWIFISH company** almost five years ago, with the aim of becoming a major supplier of 100 per cent Swiss-bred pikeperch. Today, the company owns a stocking facility in Lyss *(BE)* and a RAS fattening facility for about 150 t of round fish per year, including its own processing installations in Susten *(VS)*.

However, it soon became clear that it is precisely because of our vivid imagination that special caution is required when putting such an idea into practice. In aquaculture, the promising starting point all too often tempts one to disregard the complex and demanding aspects of sustainable fish farming.

We at **SWIFISH** therefore set out on our journey quite consciously and only took one step at a time. Since the beginning, it has been part of the DNA of the **SWIFISH** team to approach things carefully and prudently. There are no isolated aspects to our approach – everything is somehow connected. Nevertheless, I would like to try to focus on the issue of animal welfare and explain our goals and experiences in this regard.

As to the baseline on the market: animal welfare is increasingly playing a special role in the development of the *'Swissness'* brand concept today. The classic Swissness quality concept originally referred primarily to the quality of products and services. However, the power of differentiation of these characteristics is constantly diminishing the better a comparable foreign quality becomes. For this reason, efforts are being made to upgrade the term *'Swissness'*, i.e. to supplement it with aspects that once again enable a credible positive distinction and thus differentiation from foreign competitors. We found what we were looking for in the areas of *'resource efficiency'* and *'animal welfare'*, as Switzerland is an international leader in both areas, both in terms of government regulation and in terms of reality.

This is important for us at **SWIFISH** because *'Swissness'* plays an important role not only in exports, but also in the Swiss market. A clear value positioning as a Swiss product is of central importance in the domestic market, as this facilitates the acceptance of higher prices which compensate for the higher Swiss production costs. In short, since there is no customs protection for fish, fish production without a Swissness premium would not be affordable or competitive under Switzerland's cost structure.

Note: Respect for animal welfare as a pillar of willingness to pay in the market is an economic necessity for the realisation of fish production in Switzerland that respects animal welfare. So much for the economic boundary conditions. (Figure 1).

For us at **SWIFISH**, however, respect for animal welfare is not primarily an economic necessity, but an ethical one. We recognise that we take on a special responsibility with the rearing of the still barely domesticated wild animal pikeperch. We are guided by

Figure 1: Fingerling tanks in Lyss (BE) (Photo: © G. O. Herriger).

the **five freedoms** as defined by the **Farm Animal Welfare Committee** *(FAWC)* in as early as 1993:

1. freedom from hunger, thirst and malnutrition
2. freedom from discomfort
3. freedom from pain, injury and disease
4. freedom from fear and distress
5. freedom to express normal behaviour

Crucial in this approach is to know or learn about the specific requirements of the chosen fish species and to take them into account. *(Figure 2).*

Figure 2: Male pikeperch on the nest (Photo: © G. O. Herriger).

In our opinion, the choice to breed pikeperch in closed recirculation systems is justifiable. It is true that – like all fish – it is a wild animal that has not or has hardly been domesticated and is kept in an artificial environment. However, the pikeperch is a predatory species that does not roam about but keeps still, lying in wait for its prey, and is therefore not unsuitable for a limited habitat in a recirculation system. After the first stages of development *(fry/fingerling)*, it is not very aggressive towards conspecifics, which allows for largely problem-free schooling with appropriate and controlled stocking densities.

However, the pikeperch is extremely demanding in the fry and fingerling stage. This includes the basic sensitivity of the larvae and fry with regard to water quality, light and temperature, the peculiarities in the ***initial feeding*** *(artemia)* and ***development*** *(swim bladder filling)*, all coupled with the tiny dimensions of the creatures. And then there is cannibalism! Apparently designed as a natural strategy for optimal feeding of the fittest, it is a constant operational challenge for us with the need for frequent size sorting.

The central challenges in terms of animal welfare are congruent with the economic goals: we have to design the husbandry conditions in such a way that as many individuals as possible survive undamaged and that no damage that impedes healthy further growth occurs.

In order to be really successful, the following criterion applies to me: I need to be able to employ highly qualified and highly motivated staff. Of course, the financial means for the appropriate equipment of the facilities must also be available … but in the end, it is not the money that is decisive, but the knowledge, the experience, and above all the unconditional commitment of the team. This is the only way to ensure that the living conditions for the animals are always optimal or at least acceptable – even in the case of technical breakdowns, which happen all the time. *(Figure 3).*

I am also firmly convinced that team spirit is the key success factor in highly sensitive aquaculture. The **SWIFISH team** is characterised by a constant willingness to work together in a thorough and disciplined manner, to be flexible and creative, to constantly observe and learn, to act as a community, and to solve tricky problems (if necessary, with several sleepless nights …). So far, there are only a few such experienced pikeperch specialists. **SWIFISH** is fortunate to have several such experts in its team, either as employees or as external consultants.

Every company has its own identity, which shapes the overall behaviour and commitment of all persons involved. In the case of **SWIFISH**, it is the value of animal welfare that constitutes the soul of the identity, so to speak – and has a corresponding effect externally and internally. *(Figure 4).*

But let's come back to the five freedoms in animal welfare: thanks to the efforts of our team and the installations they have designed or optimised, we are able to satisfy the first four freedoms in an animal-friendly

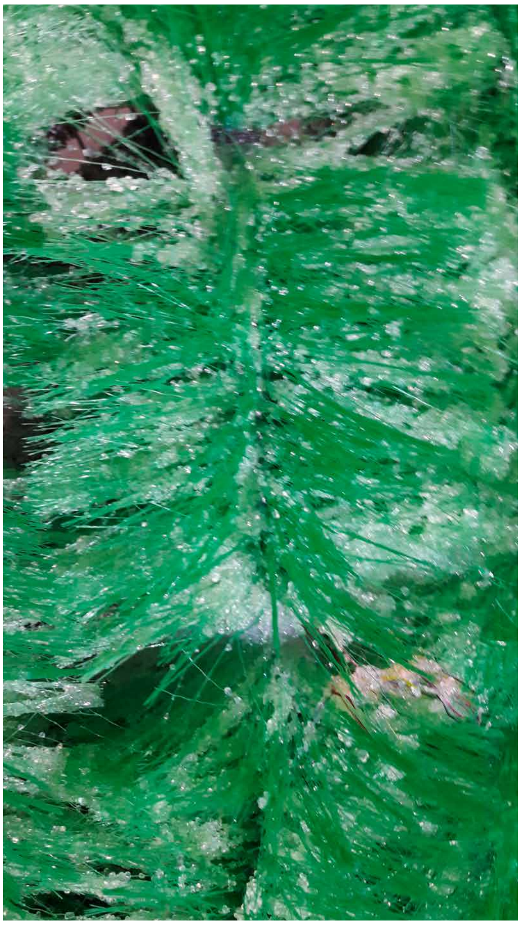

Figure 3: Pikeperch eggs (Photo: © G. O. Herriger).

Figure 4: Pikeperch larva (Photo: © G. O. Herriger).

way in terms of nutrition, husbandry, handling, and stress. With regard to the fifth freedom – the freedom to express normal behaviour – we have taken on a special, de facto unique challenge.

This is where a species-specific peculiarity of the pikeperch comes into play: that is, its extraordinarily complex reproductive behaviour, which we at SWIFISH classify not only as normal, but as essential behaviour and thus worthy of protection.

Pikeperch act in the mating season in a similar way to red deer: when the male pikeperch senses spring, he looks for a nest and roars like a deer bull; the pikeperch is the loudest freshwater fish! The intention is the same, namely to scare off competitors and attract females. These ***'test'*** the offers and, depending on the situation, are ready for a mating dance in which they lay about 100,000 eggs per kilogram of their own body weight. The milter, the male, then has about 10 minutes to fertilise the eggs that quickly stick to the nest. He then guards the nest and fans the eggs with oxygen-rich water. The female is no longer involved in caring for the brood…

SWIFISH gives preference to this natural way of reproducing on nests – in contrast to the common routine of using hormones, striping the pikeperch and hatching the eggs in jars. We find that this not only satisfies a special aspect of animal welfare, but also clears the way for ***'nature's intelligence'***, resulting in eggs of high quality. We attribute this to the fact that the timing of egg maturation and natural mate selection play an essential role in this.

In the last step – fattening – protection against diseases is the top priority with regard to animal welfare. Here, animal welfare and economic objectives coincide once again. Since fish breathe in the same medium in which they excrete, and since water is the same limited habitat for all animals, any mistakes not only affect animal welfare, but also endanger the existence of the entire stock. This is especially true for pikeperch with its high demand for oxygen, its sensitivity to light and its generally low resistance to stress. Again, only an experienced team is able to provide optimal care for the welfare and growth of the animals, combined with strict hygiene.

A comprehensive view of the aspects of animal welfare, however, leads us not only from the egg to the mature fish, but also to its optimal killing. In this respect, a little-communicated but all the more significant advantage of aquaculture in relation to wild-caught fish becomes apparent: the avoidance of agony at death. In aquaculture, the poikilothermic animals are kept in cool water for several days before slaughter, immobilised, then electrically anaesthetised, and subsequently killed individually by a gill cut. If carried out professionally, this is largely stress-free for the animals. *(Figure 5).*

This is in total contrast to the usual wild catching of fish where fish would die cruelly in nets, and which is analogous to the trapping of mammals. In terms of animal welfare, there is no greater contrast between aquaculture and wild catch than in the way humans let the animals die!

SWIFISH is still on its way to becoming one of the leading Swiss suppliers of pikeperch. To a certain extent, while ***'on the way'*** to this goal, a second objective has developed. This is namely, the manner in which SWIFISH conducts aquaculture; it wants to set certain sustainability standards in respect of fish welfare or, as it has been mandated since 1992 in Article 120 of the Swiss Federal Constitution: to take into account the dignity of the creature.

Figure 5: Fattening tanks in Susten (VS) (Photo: © G. O. Herriger).

The comprehensive new book of fish welfare

Kristiansen T S, Fernö A, Pavlidis M A, van de Vis H (Eds.), 2020.
The Welfare of Fish. Springer Nature Switzerland AG: Cham, Switzerland. 515 S.

This book, which is part of a series on animal welfare, seeks to highlight the need to respect and improve fish welfare. The editors brought a large group of renowned researchers who approach the welfare of these animals from different angles, bringing a very complete interdisciplinary view on the topic, both in theoretical and practical ways. In the first part of the book, the readers are presented to foundations of animal welfare, ethical questions, and general aspects of how fishes live, how their brain works and about their capabilities. These include behaviors, coping strategies, brain function, stimuli perceptions and responses, cognition abilities, and consciousness. In the second part, the book deeply explores the welfare issues, addressing each specific situation involving human actions that affects fish welfare, since fish farming or lab conditions to topics often neglected, such as the impact of anthropic actions on the welfare of wild fishes.

In this scenario, in chapter 1, the authors revisit the origins of the animal welfare movement, the various welfare definitions and how concern about domestic animals also gradually began to include fishes. In chapter 2, different theories of animal ethics are introduced and ethical and moral issues are discussed. The following chapters show how fishes live, from an ecological and behavioral approach, and how they are shaped by the environment. Thus, chapter 3 addresses the diverse world of fishes and how these animals have adapted to a variety of habitats. In chapter 4, the behavior of fishes in the wild is explored and in chapter 5, the authors examine the effects of early life experience on behavioral development in captive fish species. The book follows by presenting what the fish brain is like and how it works, besides discussing the senses, responses and conscience of these animals. Chapter 6 give an overview of the anatomy, functionality, and evolution of the nervous system. In Chapter 7, fish learning, cognition, and consciousness are explored. Chapter 8 discusses awareness in fishes and other animals. In chapter 9, a novel way to look at how the brain works is presented. In Chapter 10, pain perception in fishes is discussed. Moreover, chapter 11 brings a new look at stress in fishes, whereas chapter 12 review key components of stress coping styles.

After this background about animal welfare, how fishes live and their capabilities, chapter 13 go deep into the question of how to assess the welfare state of these animals and the challenges involved. The remaining chapters address specific issues about fish welfare related to the most diverse human actions and potential mitigation strategies. Thus, chapter 14 address challenges ***farmed fishes*** face; chapter 15 investigates problems with ***ornamental fish***; chapter 16 covers ***fishes used as laboratory animals***; chapter 17 deals with ***commercial fisheries scenarios***; chapter 18 addresses ***capture-based aquaculture*** combining ***capture fisheries with aquaculture practices***; chapter 19 discuss problems with ***recreational fishing***. Finally, chapter 20 review a question often ignored: the effects of anthropogenic pollution in aquatic environments for fishes.

Chapter 21 ends the book by bringing the editors' view on fish welfare based on the previous chapters, summarizing important aspects explored throughout the book, and highlighting that as fishes experience emotions, their life should be made as pleasant as possible. They also emphasize the need for more scientific research about subjective experiences, ranking different stressors, and the role of predictability and controllability aiming to focus on the gaps that most severely limit the welfare of fishes.

Caroline Marques Maia

Up-to-date overview of fish welfare in aquaculture and animal testing

Arechavala-Lopez P, Saraiva J L (Hsg.), 2019.
Welfare of Cultured and Experimental Fishes. MDPI: Basel, Switzerland. 121 S.

This book is a print edition of the nine articles published from 2018 and 2019 in the ***Special Issue Welfare of Cultured and Experimental Fishes*** of the ***open access Fishes journal***. The chapter 1 opens the book from the premise that the more evidence about the mental capacities of fishes in terms of behavior, cognition, learning and neuroscience grows, the more uncomfortable the questions about fish welfare and ethical implications become. This opening chapter highlights that although no one usually wants to solve such questions, recent indicators show that this scenario is changing and that is important to make clear to the industry that once fish welfare is improved, both the quality of the product and its value increase.

Thus, the following chapters of the book bring up diverse aspects related to fish welfare, including healthy, growing, slaughtering, behavioral expressions and negative and positive emotions, most of them clearly indicating the importance to take these aspects into account also to assure better and more profitable production systems. In this sense, although the chapters cover specific questions limited to the species investigated in each paper, the scope of fish welfare is large, showing important findings of physical, behavioral or emotional aspects. The book ends by discussing an online database that provides scientifically based information about the welfare of farmed species, bringing conclusions based on data already available in such base.

Chapters 2, 3 and 4 approach more physical aspects of fish welfare. In chapter 2, the air exposition affecting the quality of the meat of ***Catshark (Scyliorhinus canicular)*** is approached, indicating that they should be rapid slaughtered rather than die from asphyxiation. Chapter 3 brings the effect of phosphate fertilizers on growth, welfare and product quality of ***African Catfish*** *(Clarias gariepinus)*, showing that low-level phosphate fertilizers in the water can help plant growth in coupled aquaponics systems without negatively affecting this fish. Chapter 4 investigates the influence of ontogeny on the ***white seabream's*** *(Diplodus sargus)* response to a ***common disease*** *(Amyloodiniosis)*, showing that younger fishes respond worse.

Chapters 5, 6 and 7 approach specific issues more related to behavioral aspects of

[1] On the book, see also the article *'Welfare of fishes – no longer the elephant in the room'* in this issue.

fish welfare. Chapters 5 and 7 investigate problems related to aggressive behaviors, a case of enrichment increasing aggressiveness of ***zebrafish*** *(Danio rerio)* and a review covering common aquaculture practices negatively affecting aggressiveness of *Nile tilapia* *(Oreochromis niloticus)* and proposing practical ways to minimize it, respectively. In chapter 6, the authors address a behavioral expression related to pain, thus linking negative behavioral and emotional aspects of fish welfare by showing reduced movement complexity in zebrafishes when they feel pain. Finally, chapter 8 is a review that brings up the need to also consider positive experiences and emotions for fish welfare instead of just focus on preventing or reducing negative aspects, which is common.

Chapter 9 ends the book by presenting *FishEthoBase*, an ***online open access database*** that provides scientific information about behavior and welfare of the farmed fish species, a reliable tool to assess and improve welfare in aquaculture systems. Based on the already available information on this database, the authors conclude that the welfare status of farmed fishes is still poor and that current fish farming technologies do not fully address welfare issues, but there is potential for improvement, which depends on researching about species needs and also covering the many remaining gaps.

Caroline Marques Maia

About our relatives under water

Balcombe J, 2018.

What A Fish Knows. Macmillan, New York. 2016. ISBN 978-0-374-28821-1.

The North American ethologist Jonathan Balcombe has become well known to a wider audience since his book **'Pleasurable Kingdom'**[1] was published. His book **'What A Fish Knows'** is in no way inferior. In 304 pages, the author takes us across all kinds of fish species and shows an incredible variety of abilities of seeing, hearing, smelling, feeling, up to amazing cognitive performances of our ***'underwater relatives'***.

In **'Pleasurable Kingdom'** Balcombe, as a recognised scientist, showed the courage to assemble many anecdotal observations on animals that are commonly frowned upon as ***'not scientific'***. In **'What A Fish Knows'**, he also reproduces numerous anecdotes about observations of fishes that were brought to his attention. In the book, however, he clearly distinguishes between ***'scientific findings'***, i.e. results that can be reproduced by other scientists, for example from experiments, and ***'pre-scientific'*** observations, because they are not repeated. One of the strengths of the book is that this separation of two levels of perception is not drawn in a judgmental way, but merely in a clarifying way. And rightly so; for if science were shielded from random observations, it would hardly come up with the idea of testing this or that hypothesis. This would be all the more true for a science as young and widely ramified as that of fish behaviour, i.e. of well over 30,000 species.

Balcombe first takes us on his own little biography of dealing with fishes, from being taken to school and going fishing, to his studies in biology and ethology, to the germination of the inkling that fish are creatures like us. He spent five years immersing himself in the world of fishes to write the book. He presents the different senses in fishes, including the lateral line, which we can only understand theoretically because we do not experience anything similar, and he shows how the specific development of a particular sense in a species is related to the ecological niche that the species has managed to secure for itself in the course of evolution.

Thus, as one reads on, an incredible diversity of specific perceptual worlds becomes apparent. Sometimes, in a passage, you find yourself involuntarily asking the question: what is it actually like for me? How do I perceive this or that – and what remains hidden for me because I lack the sharpened sense for it? Balcombe's book is not only a great introduction to the life of fishes, it is also an invitation to wonder about life itself and its many forms. I wish for this book many readers who will not put it down until they have read the last page and who will then perceive the world with a little more reverence and love.

Billo Heinzpeter Studer

Stress and fish welfare: indicators in the mucus

Magnoni L J, Martos-Sitcha J A, Prunet P, Mancera J M, 2020. Welfare and Stressors in Fish: Challenges Facing Aquaculture. Lausanne: Frontiers Media SA.

This is a Research Topic with 15 papers published in the ***open access journal*** *Frontiers* in Physiology in 2019. The opening editorial brings up controlled and monitored environments as important to prevent fish stress in aquaculture production, which is in expansion. Stress may compromise fish health and survival, a problem affecting the economic success, public and scientists – as their awareness about fish welfare is now increased – and ethical aspects of the use of fishes for aquaculture, research and in fisheries. Then, the editorial unravels the next papers that address aspects about understanding, assessing and minimizing stress response of fish.

The studies assess new aspects about stress in ***rainbow trout*** *(Oncorhynchus mykiss)*, ***gilthead sea bream*** *(Sparus aurata)*, ***Senegalese sole*** *(Solea senegalensis)*, ***meagre*** *(Argyrosomus regius)* and ***European sea bass*** *(Dicentrarchus labrax)*, farmed fish species. There is a study about the role of cortisol in exercise-enhanced growth in ***zebrafish*** *(Danio rerio)* – a common lab animal, and another about acute stress in some species of octopuses after fish capturing. The studies cover common potentially stressful aspects of aquaculture as hypoxia, high density, temperature, diet problems, handling, transport and vaccination. Many of them describe procedures that can decrease negative effects, including a review about essential oils as stress-reducing agents. Some studies show indicators to assess stress response, as biomarkers and a device monitoring the frequency of physical and respiratory activity once attached to the operculum.

The paper of Ewa Kulczykowska brings up an interesting proposal to complement the evaluation of welfare of farmed fishes. The approach suggests the ***cutaneous stress response system*** *(CSRS)* as a new source of information about fish welfare. The author highlights that its research group has shown the basic conditions for the functioning of a CSRS in fishes similarly as in mammals,

[1] Palgrave MacMillan, 2007, ISBN 978-1-403986023

where melatonin, its biologically active metabolite and cortisol act together protecting the organism against unfavorable environmental conditions, a local stress response system in the skin. Ewa highlights that, although dissimilarities of the stress response systems of skin between fishes and terrestrial vertebrates are expected, analysis of fish ***skin mucus***, which is continuously secreted by cells and can be easily collected, contains many components, being a source of information on the welfare status of farmed fishes.

Ewa comments that metabolites such as glucose, lactate, protein, and cortisol in skin mucus have already been studied to judge their suitability for determination of physiological response to different stressors and that a positive relation between stress markers in plasma and skin mucus was recently demonstrated. Thus, the author concludes that the analysis of cortisol together with melatonin and its active metabolite AFMK from the secreted mucus seems to be a promising approach to on-farm assessment of fish welfare.

Caroline Marques Maia

Improvement of life regardless of the degree of sentience

De Mori, B & Normando S, 2019.
Is 'History' repeating itself? The case of fish and arthropods' sentience and welfare. Ethics & Politics, 2: 491–516.

This review starts pointing out that as there is no agreement on the definition of sentience, periodical debates about whether a certain species could be considered as sentient and thus deservers welfare considerations occur. The authors highlight that these tend to end with most of researchers recognizing sentience in the species or advising to consider it for precaution and that the debate then moves to a species less similar to humans, repeating the cycle. They go through fishes and, more recently, arthropods debates bringing them up as good examples of such repetitions.

Sentience of fishes and arthropods is then discussed. Although they lack the neocortex, which is involved in human conscious awareness, different structures evolving for a same function in different animals is expected. The authors highlight the presence of nociception mechanisms and related behavioral responses in these animals. The definition of sentience is then revisited. Although studies about animal cognition have helped, there is no ***'practical'*** definition of animal consciousness, but emotion-like states have been demonstrated in fishes, bees and other insects. Furthermore, examples of studies demonstrating capacities of mental representations and of thinking about one own action in these animals are shown.

In the final part, the authors propose a solution for the controversy from artificial intelligence, which shows complex learning and motivational responses without subjective experience, and state that as absolute scientific evidence of sentience is unlikely, ***'sufficient uncertainty'*** is enough to consider the species as worth of welfare protection. They emphasize that a ***'lower degree'*** of sentience does not mean less suffering and that classifying species based on how similar or emotionally important they are to us to discuss sentience has no scientific bases. The review ends highlighting we should focus less on debates of sentience and more on improving the life of the animals under our care.

Caroline Marques Maia

fair-fish: Idea with impact

Studer B H, 2020.
fair-fish — Because You Shouldn't Tickle Fishes, rueffer&rub,
ISBN 978-3-906304-83-0

In the beginning it was just a small idea, a leisure activity, so to speak, recalls Billo Heinzpeter Studer in his recently published book about the history of **fair-fish** from his personal perspective. In 1997, while still managing director of the ***Swiss farm animal protection organisation*** **KAGfreiland**, he had begun to develop guidelines for animal- and environmentally friendly fish farms and fisheries on the side. In 2000, together with several animal protection organisations, he founded the association fair-fish with the aim of creating publicity for the then still exotic concern of fish welfare, one of the first such organisations worldwide. The author describes the success in the course of the revision of the Swiss Animal Welfare Act, the reluctance of local professional fishermen and fish farmers to accept a label that promised them a higher price for special consideration for fish welfare and the environment, and the difficulties of creating a bridge for fairly caught and paid fish to European retail chains in a project lasting several years with artisanal fishermen in Senegal. The **fair-fish** association recognised that it was too small to have a direct impact on the market and has since pursued campaigns instead of label projects to use public pressure to target stressful, suffering-causing practices in fisheries and aquaculture.

In 2012, after several years of dispute with the veterinary authorities about deficiencies in the regulation and enforcement of fish welfare in aquaculture, the idea arose to compile the widely scattered studies in order to create an ethological profile for each farmed fish species, which would allow the formulation of scientifically based recommendations for improving fish welfare. The ***online database FishEthoBase***, which Studer in turn launched as a sideline after his retirement, developed in a few years into an innovative project with university connections that now employs seven people with research and consulting in various countries and sets new standards – just at the right time, as a growing number of fish farmers are now also willing to pay more attention to fish welfare.

Billo Heinzpeter Studer

Spawning pond of an organic carp farm in Austria (Photo: © Studer / fair-fish).

Fishes in animal welfare laws in Europe

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This article aims to provide a brief overview of the relevant sources and standards for the protection of fishes in the EU, Switzerland and Norway. In addition, a brief introduction to the relevant European structures will be given. Animal welfare law is understood to be the totality of all legislative legal norms which primarily pursue the goal of regulating the behaviour of humans towards animals and primarily prevent them from inflicting unjustified pain, suffering or harm or otherwise disregarding their dignity.

Overview of the legal structures of the European Union

European Union law is divided into primary and secondary law. Primary law is the highest-ranking law of the EU. It consists mainly of the founding treaties and the other amending treaties, accession treaties and supplementary treaties. In terms of content, primary law determines the distribution of powers and responsibilities between the EU and its Member States. For animal welfare laws in the area of European primary law, the Treaty of Lisbon is particularly worth mentioning. The legal provisions (regulations, directives, decisions, recommendations and opinions) based on the principles and objectives of the abovementioned treaties are referred to as secondary law.

Regulations are rules which are directly applicable in a Member State *(Art. 288 para. 2 of the Treaty on the Functioning of the European Union, TFEU)*. Directives, on the other hand, set out an objective to be achieved, but it is up to the individual Member States to enact their own legislation to achieve this objective *(Art. 288 para. 3 TFEU)*. This means that the directives must be transposed into national law by the EU Member States.

Animal welfare law in the European Union

According to the Treaty of Lisbon, animal welfare is part of the EU's remit. The European Union sees itself as an economic community and only regulates animal welfare issues if they have economic or trade policy implications. With the Treaty of Lisbon of 1 December 2009, the EU and its Member States committed themselves to pay full regard to the welfare requirements of animals as sentient beings in all policies relating to agriculture, fisheries, transport, the internal market, research, and technological development and space *(Article 13 TFEU)*. Through the explicit mention in the abovementioned provision, the Member States are accordingly obliged, not only in agriculture but also in fisheries, to take full account of the welfare of fishes as sentient beings.

In the field of secondary legislation, the Council of the European Union has adopted *Regulation (EC) No 1099/2009* of 24 September 2009 on the *protection of animals at the time of slaughter*. Article 1 of this regulation mentions that only the requirements laid down in *Article 3(1)* apply to fishes and that the regulation does not apply to recreational fisheries. *Article 3(1)* states that during killing and related activities, animals should be spared any avoidable pain, stress, and suffering. Each Member State is allowed to enact regulations that go beyond the minimum requirements. Germany, for example, has made use of this provision and issued the Animal Welfare Slaughter Ordinance. In addition to the requirements for the stunning and slaughter or killing of vertebrates, crustaceans or molluscs, this also contains regulations for the storage of fishes and crustaceans before slaughter. The stunning, slaughter and killing of fishes and crustaceans is regulated in § 12. Accordingly, in addition to the requirements under EU law, animals must be stunned in such a way that they are brought quickly and without pain or suffering to a state of sensory deprivation and insensibility that lasts until death. However, the provisions of the *Animal Welfare Slaughter Regulation* do not apply to mass capture if, according to the state of scientific knowledge, stunning would not be possible or would only be possible with disproportionate effort.

Since the EU framework law does not contain any concrete regulations regarding stunning, slaughter, and killing of fish, concrete requirements can only be enacted within the framework of the respective national laws of the Member States (see the example of Germany above). However, many Member States do not have any corresponding animal welfare regulations. EU-wide harmonisation would be desirable here.

The rules for the welfare of farm animals in the European Union are laid down in *Council Directive 98/58/EC concerning the protection of animals kept for farming* purposes. Fishes are explicitly mentioned in the Directive according to Art. 2, but only Art. 3 is applicable to them. This states that EU Member States are obliged to ensure that owners or keepers take all reasonable measures to safeguard the welfare of the animals in their care and to ensure that no unnecessary pain, suffering or injury is inflicted on these animals. Art. 4 sets out further requirements for the conditions under which animals are kept, but fishes are explicitly excluded.

Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations does not mention fishes, but as they belong to the group of vertebrate animals, the transport of fishes must be carried out in accordance with the regulation. The general rules for transport therefore apply to fishes. The general transport regulations are not appropriate for fishes, as they were generally developed for land animals.

Council of Europe Conventions on the Protection of Animals

The Council of Europe has also drawn up *five conventions* on the protection of animals. These conventions are international treaties that must be ratified in order to be binding. They only regulate minimum standards, as they are based on the consensus of the contracting nations.

[1] In principle, GAL follows the idea of 'One Health': it requires healthy humans and healthy animals to live together in order to ultimately bring about a recovery of the Earth system. Worldwide, about 2/3 of all infectious diseases originate from animals, including COVID-19.

- European Convention on the Protection of Animals during International Transport of 6 November 2003. According to Art. 2, this convention applies to the international transport of all vertebrate animals, which means that fishes are also included. Accordingly, the objective of the convention is, as various articles agree, to protect animals from injury, pain or suffering and to ensure their safety during transport (cf. Art. 6 ff.).
- European Convention for the Protection of Animals kept for Farming Purposes of 10 March 1976. This convention is also applicable to fishes bred or kept for the production of food (cf. Art. 1). Art. 2 states that the principles of animal welfare set out in the following articles must be applied by each party. These include, for example, consideration of the stage of development, adaptation and domestication as well as the physiological and ethological needs of the animals or fishes. The convention thus aims to ensure that all animals kept for farming purposes are not subjected to unnecessary suffering or harm during husbandry, feeding and care.
- European Convention for the Protection of Pet Animals of 13 November 1987. Pets are animals which humans keep for their own pleasure and as companions, especially in their households, or animals which are intended for this purpose. Accordingly, fishes are also covered by this convention. According to Art. 3, no one may cause unnecessary pain or suffering to pet animals or put them in fear or abandon them.
- European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes of 18 March 1986 *(with Appendices)*. This convention applies to all animals used or intended for use in experiments or other scientific procedures where such procedures may cause pain, suffering, distress or lasting harm. An animal is any living vertebrate other than a human being. In particular, for fishes, Art. 3.8.5 mentions that tolerance to acid, chlorine and many other chemicals varies greatly from species to species.
- European Convention for the Protection of Animals for Slaughter of 10 May 1979. Art. 12 states that animals shall, if necessary, be restrained immediately before slaughter and anaesthetised by appropriate methods. Fishes are not explicitly mentioned in this convention, but fall under the term animals.

Switzerland

Animal welfare has had constitutional status in Switzerland since 1973 and is enshrined in Art. 80 of the Swiss Federal Constitution. The confederation is obliged to regulate the protection and welfare of animals in a binding and uniform manner for the whole of Switzerland. The *two most important enactments in Swiss animal welfare law* are the Animal Welfare Act *(AWA)* and the Animal Welfare Ordinance *(AWO)*. The AWA is a so-called framework law that regulates the legal treatment of animals in general. The corresponding detailed regulations are then found in the AWO. These federal provisions take precedence over any cantonal provisions in this area (Art. 49 para. 1 of the Federal Constitution). The principle of *'federal law breaks cantonal law'* applies. This means that the cantons are only entitled to enforce animal protection law and to issue corresponding implementing provisions.

Swiss animal welfare law is based on the guiding principle of regulating the behaviour of humans towards animals and accordingly establishing provisions for their protection and welfare. In the scope of the Animal Welfare Act Art. 2 para. 1 mentions that it applies to vertebrate animals. It is well known that fishes are vertebrates, which is why they also fall within the scope of the Animal Welfare Act. In addition, further animal protection principles can be found under the margin heading *'Principles'* in Art. 4 AWA. According to paragraph 2 of this provision, no one may unjustifiably inflict pain, suffering or harm on an animal, put it in fear or otherwise disregard its dignity. Likewise, the mistreatment, neglect or unnecessary overexertion of animals is prohibited by law.

The provisions of the Federal Act on Fisheries (FAF) in particular are reserved for the scope of the Animal Welfare Act. Notably, this law lays down the principles according to which the cantons must regulate and control fishing for fish and crayfish. Accordingly, the Federal Council issues the implementing provisions, while the respective cantons are responsible for enforcement (Art. 21 BFG).

Many cantons in Switzerland have so-called free fishing rights. This is understood as the right to fish in certain waters designated by the respective canton without further prerequisite, such as a fishing licence or similar (cf. for example § 3 of the Law on Fishing of the Canton of Zurich of 5 December 1976 LS 923.1). More detailed information, such as the permitted fishing methods, etc., can be found in the respective cantonal fisheries laws. In the light of general animal welfare legislation, cantonal free fishing rights should be viewed critically. In the past, criminal offences have repeatedly been found in which the accused free anglers did not kill the animals they caught in a proper and professional manner *(cf. criminal cases database of the Foundation for Animals in the Law)*. The sometimes inadequate expertise of free fishermen in dealing with fishes with regard to animal welfare legislation contains a correspondingly large potential for possible cruelty to animals within the meaning of Art. 26 et seq. AWA.

Box

Excursus: Animal welfare and the Common Fisheries Policy *(CFP)* in the EU.

A major problem for the health of the seas and their inhabitants is overfishing in the EU's marine areas. Overfishing means that more fish are caught than can naturally grow back. On the one hand, high catches of fish are desirable for the Member States, but on the other hand, the ability of fish stocks to reproduce must not be impaired. According to *Art. 38 TFEU*, the EU pursues a common agricultural and fisheries policy. The Common Fisheries Policy *(CFP)* is regulated by *Regulation (EU) No 1380/2013*. The aim is to ensure the long-term environmental, social, and economic sustainability of fisheries and aquaculture activities. The objectives of the CFP are to be achieved through multiannual plans, technical measures, and the setting and allocation of maximum allowable fishing effort. From an animal welfare point of view, *Regulation No 1380/2013* on the Common Fisheries Policy makes it clear in *paragraph 16 of the preamble* that full account must be taken of animal health and welfare requirements. This is done in implementation of the principles of *Article 13 TFEU* as primary law mentioned in the article.

Norway

Norway protects animals through its ***own Animal Welfare Act*** *(Lov om dyre-velferd of 19.6.2009)*. According to Section 1, the aim of this act is to promote animal welfare and respect for animals. The scope of this act also explicitly extends to fishes according to Section 2. Section 14 also mentions that it is prohibited to use violence against animals, to place animals in a helpless condition, to have sexual intercourse with animals or to perform sexual acts on them, or to use live animals as food or bait. Fishing shall be carried out in compliance with the Animal Welfare Act (§ 20). The penal provisions are contained in § 37; in the case of serious violations of this law, a prison sentence of up to 3 years is possible. The European Convention for the Protection of Animals during International Transport, the European Convention for the Protection of Animals kept for Farming Purposes, the European Convention for the Protection of Pet Animals, the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes, and the European Convention for the Protection of Animals for Slaughter have also been ratified by Norway. *Regulation (EC) No 1099/2009 of 24 September 2009* on the protection of animals at the time of killing does not apply to Norway, as Norway is not a Member State of the European Union.

Box

Excursus Fisheries Norway

The EU has concluded a ***'Northern Fisheries Agreement'*** with Norway. On the one hand, this fisheries agreement regulates the joint management of stocks with the aim of sustainable exploitation, and on the other, it is intended to regulate the exchange of fishing quotas and access to the exclusive economic zones of the partners. The fisheries agreement with Norway is the most comprehensive in Northern Europe. The main issues discussed in the annual consultations are the setting of ***maximum catch levels*** *(TACs for cod, plaice and haddock)* for the jointly managed stocks in the North Sea and the exchange of fishing opportunities.

Fishing vessels flying the flag of Norway may fish in Union waters within the TACs set out in *Annex I* to *Council Regulation (EU) 2020/123* of 27 January 2020 fixing for 2020 the fishing opportunities for certain fish stocks and groups of fish stocks, applicable in Union waters and, for Union vessels, in certain non-Union waters and are subject to the conditions laid down in this Regulation and in *Title III of Regulation (EU) 2017/2403*.

Currently, the Royal Ministry of Trade and Fisheries is considering new regulations for angling tourism. In the future, only anglers who have registered their holiday in registered tourist establishments will be allowed to export fish from the country:

- Holidaymakers will only be allowed to take 20 kg of whole, gutted and headed fish (instead of the previous 10kg of fish fillets).
- The export quota is to be increased from 7 days to one year.

The reasons for the changes are mainly sustainability and transparency.

Take Home Message

Most of the animal welfare legislation in Europe today applies to terrestrial vertebrates; fishes are only protected in very general terms. For fishes in aquaculture, their capacity to suffer is taken into account to some extent, whereas in fisheries the provisions focus on species protection, not animal welfare.

The EU animal welfare regulations also cover fishes, but are limited to general requirements, such as that fishes should also be spared any avoidable pain, stress and suffering during slaughter. However, prior stunning is left entirely to national legislation and is only required by a few Member States. Germany, for example, requires stunning before slaughter in aquaculture, but not in fisheries, as far as it is not possible or reasonable according to the state of science to carry out stunning in mass capture. With regard to the living conditions of farmed fishes, the EU also limits itself to the general provision that all reasonable measures must be taken to ensure the welfare of the animals and their protection from unnecessary pain, suffering or injury. Specific provisions are again left to the Member States.

The Council of Europe's five animal welfare conventions have also done little for fishes so far. The Convention for the Protection of Animals kept for Farming Purposes, which also requires that the development, adaptation and domestication stages as well as the physiological and ethological needs of fishes be taken into account, is based somewhat more deeply than the EU. Here too, however, the detailed regulations are left to the will of the individual contracting states.

Swiss animal protection law, which is the only one to date that also recognises the dignity of animals as worthy of protection, has also expressly applied to fishes since 2008, irrespective of the way in which they are used. The regulations for farmed fishes are similar to those in Germany. The requirement to immediately stun and kill wild fishes caught is, with exceptions, not applicable to commercial fisheries.

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The fish in Swiss law – current criminal cases

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Humans use fishes in a variety of ways. They are fished for food, kept as ornamental fish in aquaria, bred in aquaculture for food production and used in animal experiments to gain scientific knowledge. Fishes are living creatures capable of suffering and feeling. As vertebrates, they are covered by Swiss animal protection law in the same way as, for example, dogs, cats, birds or cattle. Accordingly, the principle that the welfare and dignity of animals must be protected *(Art. 1 of the Swiss Animal Welfare Act, AWA [1])* also applies to them. It is therefore forbidden, among other things, to unjustifiably inflict pain, suffering and damage on fish, to put them in fear, to humiliate them, to instrumentalise them excessively or to interfere profoundly with their appearance or capabilities *(Art. 3 lit. a AWA [1])*.

Nevertheless, the legal protection of fishes is insufficient in many respects. Similarly, the annual analysis of Swiss animal welfare law enforcement by the Foundation for Animals in the Law *(TIR)* shows that offences against fishes are still not prosecuted by the competent law enforcement authorities. Accordingly, an enormous number of unreported cases of animal welfare offences committed against fishes can be assumed. Both the current animal welfare regulations and the criminal practice in connection with animal welfare offences committed against fishes do not by far come up to the current state of knowledge regarding their sensitivity and cognitive abilities. The Federal Ethics Committee on Nonhuman Biotechnology *(ECNH)* states in its *'Ethical Treatment of Fishes'* report that the moral status of fishes has been discussed to a much lesser extent in jurisprudence than in the case of other vertebrates *[5, page 3]*.

The following is an overview of the current scientific discussion on the ability of fish to feel pain, the insufficient coverage of this issue by Swiss animal welfare legislation, and the inadequate prosecution and punishment of animal welfare offences committed against fish by the criminal authorities.

The moral status of fishes

Current research provides a differentiated picture of the fish that strongly deviates from the common notion that it is a mute, insentient creature. It is scientifically undisputed that fishes are sentient animals. Accordingly, they are also covered by animal legislation *(Art. 2 AWA [1])*. However, the fact that fishes are also capable of feeling pain is still a matter of dispute among scientists. Some experts doubt that fishes have the neurological prerequisites to feel pain at all *[6] (see for example the article by Lynne Sneddon [9] on this issue)*. The question of the ability of fish to feel pain is legally relevant and has implications for animal welfare regulations regarding their husbandry and killing. Based on the latest scientific findings, it can be assumed that fish do not simply react reflexively to pain stimuli, but that they have the physical and mental prerequisites to consciously perceive pain and to suffer as a result *[7, p. 52ff, 156ff] [8] [9] [13]*. For the majority of the ECNH members, scientific evidence does not provide proof of the sentience of fishes. However, the circumstantial evidence makes it difficult to deny at least certain fish species the ability to feel pain. Moreover, in view of the complexity of the phenomenon *'pain'*, the scientific findings to date are not sufficient to fundamentally deny fishes the ability to feel pain. A minority of the commission members were even of the opinion that, based on the scientific findings, fishes must be attested to have a form of pain perception *[5, p. 17]*.

Based on current scientific findings, it is therefore quite plausible to assume that fish can feel pain. Accordingly, fish are to be attributed a moral status (intrinsic value) independent of their benefit to humanity and the effects of the globally increasing fish consumption on the environment. This fact has already been reflected in animal protection legislation in recent years, but only insufficiently.

Inadequate legal coverage

The inadequacy of the ethical discussion on the moral status of fishes is reflected in the degree of differentiation of the legal regulations: It is true that fishes, like other vertebrates, fall within the scope of the Swiss Animal Welfare Act. However, if one compares the legal regulations concerning the husbandry and handling of fishes with those concerning other farm, pet or laboratory animals—given their wide biological range—the handling of fishes is regulated in a significantly less species-specific manner.

Any person handling fishes must take their needs into account in the best possible way and ensure their welfare *(Art. 4 lit. a and b AWA [1])*. In addition, no one may unjustifiably cause pain, suffering or harm to a fish, put it in fear or otherwise disregard its dignity *(Art. 4 para. 2 AWA)*. Furthermore, the general provisions of the Animal Welfare Ordinance *(AWO [2])* must be observed when handling fishes, in particular Art. 3 to 16. For example, fishes must be kept in such a way that their bodily functions and behaviour are not disturbed and their adaptability is not overtaxed *(Art. 3 para. 1 AWO [2])*. Table 7 of Annex 2 of the Animal Welfare Ordinance lists minimum requirements for stocking density and water quality for the keeping and transport of salmonids and cypriniforms only. With regard to the keeping of ornamental fish, Table 7 of Annex 2 *(AWO [2])* sets out certain minimum requirements for the size and equipment of aquaria. For example, they must not be directly visible from all sides, and parts of the aquarium must provide privacy and refuge for the fishes.

In view of the biological range of creatures that are called fish, the general keeping and handling regulations in the Animal Protection Ordinance are insufficient. According to current scientific knowledge, about half of the estimated 64,000 vertebrate species are fishes *[5, p. 7]*. The great diversity of species and the different needs of the animals are in no way taken into account by the existing regulations. For example, Art. 98 AWO *(keeping of fishes and crayfishes)* only deals with water quality and does not contain any further provisions on relevant keeping criteria such as stocking density, composition of the animals, available space, infrastructure, feeding, light, noise or social contacts. Likewise, the legislator has failed to react to the ongoing aquaculture trend. The fact that more and more fishes are being used as livestock for food production must be taken into account at the legal level by enacting appropriate husbandry and handling regulations—for example on stocking density or feeding. At present, the commercial breeding and farming of fishes for human consumption and restocking is only rudimentarily regulated. As already mentioned, specific husbandry and management regulations for individual fish species exist only for salmonids and cypriniformes, although in practice more and more new fish species are being farmed in Switzerland, such as perch, pikeperch, tilapia, and sturgeon *[14]*.

From an animal welfare point of view, the exceptions to the ban on the use of barbed hooks and live bait fish, as well as to the principle that caught fishes must be killed immediately (Art. 23 para. 2 OWA [2]), are particularly critical. These exceptions are regulated in the Ordinance to the Federal Law on Fisheries *(VBGF [3])*. Another major animal welfare problem is the exception in Art. *97 para. 3 OWA*, according to which the catching and killing of fishes is permitted without a certificate of competence for fishing in public waters if the canton concerned does not require a patent or a short patent of up to one month's duration. This regulation leads to the fact that in most cantons fishing is also allowed without training. It can be assumed that the lack of training of many hobby fishermen results in a high number of catches and killings that do not comply with animal protection regulations *[10, p. 43]*. The exceptions mentioned can lead to considerable suffering for the animals concerned and are an impressive example of the fact that the legislator does not take adequate account of the fact that fishes are sentient, painful and suffering creatures that have a legally recognised dignity.

The scientific confirmation of fishes' ability to feel pain must lead to a rethink in society and politics and ultimately to stricter animal welfare regulations with regard to all forms of husbandry and handling of fish – whether in aquaristics, aquaculture, commercial fishing, recreational fishing, breeding or in the context of animal experiments. The ECNH is also of the opinion that the latest scientific findings on fishes must have consequences for human interaction with them: stunning and killing methods as well as husbandry conditions in breeding, research, private husbandry and fishing must be reviewed *[5, p. 23ff]*.

Deficits in the enforcement of animal welfare offences committed against fishes

Animal welfare offences are punished on the basis of the criminal offences laid down in the Animal Welfare Act *(AWA)* and can largely be divided into the two main categories of ***'cruelty to animals'*** and ***'other offences'***. The offences of ***'mistreatment'***, ***'neglect'***, ***'unnecessary over-exertion'***, ***'disregard for dignity in other ways'***, ***'painful or wanton killing'***, ***'organisation of cruel animal fights'***, ***'carrying out unavoidable animal experiments'*** and the ***'release or abandonment of animals'***, as defined in *Art. 26 AWA [1]*, qualify as cruelty to animals. Violations under this article, if committed intentionally, are punishable by imprisonment of up to three years or a fine. If the offender acts negligently, a fine of up to 180 hours *(Art. 26 para. 2 AWA)* is to be imposed. The offences of cruelty to animals are thus misdemeanours according to *Art. 10 para. 3 of the Swiss Criminal Code, SCC [4]*.

All other violations of animal welfare law, on the other hand, are referred to as other offences within the meaning of Art. 28 AWA *[1]*. These are offences under *Art. 103 SCC [4]*, punishable by a fine of up to 20,000 Swiss francs. Negligence, instigation, aiding and abetting and attempt as defined in Art. 28 para. 2 AWA are punishable by a fine of up to 10,000 Swiss francs *(Art. 106 SCC)*. When applying the above-mentioned offences, it must always be checked whether an act to be judged already fulfils the requirements of an offence of cruelty to animals according to Art. 26 AWA. If this is the case, its application is mandatory. Art. 28 AWA thus represents a kind of catch-all offence for less serious interventions that nevertheless affect the dignity and welfare of animals in a way that is contrary to criminal law *[11, p. 18 et seq]*.

Although several million aquarium fishes of various species are kept in Switzerland *[12] [15]*, professional and angling fishermen together achieve a catch of around 2,000 tonnes of fish per year, and professional fish farms produce an additional 1,500 tonnes of fish *[16]*, the criminal authorities deal relatively rarely with animal welfare offences committed against fishes: in 2018, only 94 criminal proceedings were conducted in Switzerland for animal welfare offences committed against fishes. Of these, 27 cases concerned ornamental fishes and 67 cases the handling of fishes for human consumption *[17]*. In view of these low numbers of cases, it can be assumed that there is a high number of unreported cases of animal welfare offences that are not prosecuted and punished *[10, p. 44 et seq]*.

In the last 16 years, the most common offence in the criminal decisions dealing with violations against fishes has been fishing with barbed hooks. Other offences in focus were the failure to carry out an immediate kill, other cruel killing methods, mistreatment and violations of the keeping conditions. This ratio is also confirmed for the criminal decisions issued in 2018 *[17]*. If criminal proceedings are brought for offences committed against fish, then these are relatively often serious offences.

The use of barbed hooks in particular causes considerable pain to the fish and accordingly constitutes mistreatment within the meaning of Art. 26 para. 1 lit. a AWA. In 2018, 47 proceedings were conducted due to the use of barbs. However, the casuistry proves that the competent authorities still sometimes underestimate the capacity of fishes to suffer and classify the use of a barbs as a violation of the animal protection regulations *(Art. 28 para. 1 lit. a AWA)* – and thus merely as an offence and not as cruelty to animals, which ultimately leads to a considerably lower sanction *[10, p. 49] [17]*. Still in 2018, 22 cases were brought against fishermen who failed to kill a fish intended for consumption immediately and professionally. In the context of this offence variant, it is also evident that the competent prosecution authorities still do not draw the line between the individual offences defined by the Animal Welfare Act with sufficient precision. For example, the Zurich Municipal Office sentenced a defendant who merely stunned a fish with a blow to the head after catching it and then placed it in a plastic bag on the basis of Art. 28 Para. 1 lit. f AWA *(unlawful slaughter)*, although the more serious offence of Art. 26 Para. 1 AWA (cruelty to animals) was undoubtedly fulfilled. The incorrect stunning and killing of the fish led to considerable suffering *[17, cases ZH18/172 and VD17/0]*.

Similarly, it is still difficult for the competent prosecuting authorities to distinguish between poor husbandry *(Art. 28 para. 1 lit. a AWA) and neglect or maltreatment (Art. 26 para. 1 lit. a AWA)*: an animal is neglected within the meaning of Art. 26 para. 1 lit. a AWA if its owner or carer exposes it to the risk that its welfare could be impaired due to inadequate care (including inadequate medical care), nutrition, accommodation, employment or exercise opportunities *[11, p. 129ff]*. In contrast, any behaviour that causes an animal pain, suffering, harm or distress of a certain significance is considered mistreatment *[11, p. 120f]*. The offence of Art. 28 para. 1 lit. a AWA only applies if the offence in question is of an absolutely minor nature *[11, p. 129ff]*. The public prosecutor's office in St Gallen sentenced a defendant who had not cleaned his aquarium for seven months and had seriously neglected the water quality, only on the basis of Art. 28 para. 1 lit. a AWA. This is despite the fact that it can be assumed that the insufficient water quality severely impaired the welfare of the fish concerned, which is why the offence of neglect according to Art. 26 Para. 1 lit. a AWA should have been applied *[17, Case SG18/100]*. In this context, reference should also be made to the decision of the public prosecutor's office of the Bern-Mittelland region in 2015, in which a defendant who kept piranhas and ornamental fish in the same aquarium, so that they were attacked and injured and he failed to provide medical care, was wrongly convicted on the basis of Art. 28 para. 1 lit. a AWA and not on the grounds of cruelty to animals *[17, case BE15/176]*. The public prosecutor's office in Solothurn also convicted a defendant of a simple violation of the husbandry regulations, even though dead fishes were floating among the live animals in his heavily polluted aquarium *[17, case SO13/022]*.

In recent years, there have also been an increasing number of convictions for mistreatment or agonising killing of fishes caused by the pollution of watercourses.

In addition to the provisions of the Water Protection Act, animal welfare regulations must always be examined in such cases: if the water pollution causes pain, suffering, damage or distress to the affected fish, the offence of mistreatment pursuant to Art. 26 para. 1 lit. a AWA is fulfilled. If the animals die as a result of the pollution, the offence of agonising killing pursuant to Art. 26 para. 1 lit. b AWA must be examined.

Still trivialised

The above examples show that offences against fishes are still trivialised by the competent law enforcement authorities. This finding is also borne out by the fact that the penalties imposed for animal welfare violations committed against fishes are often very mild and the available range of penalties is far from exhausted *[10, p. 53ff]*. This is the case even when Art. 26 TSchG is correctly applied: the public prosecutor's office in Zurich, for example, sentenced a defendant to a conditional fine of 15 daily fines of 180 Swiss francs each for failing to clean his aquarium, change the water and replace the broken oxygen pump, so that the fishes suffered in the contaminated water and two animals died in agony due to the lack of oxygen *[17, Case ZH18/218]*. The Pfäffikon governor's office sentenced a defendant who first kept 27 caught fishes in a closed bucket in the sun and then killed the animals without prior stunning to a fine of 500 francs *[17, case ZH16/343]*. The public prosecutor's office of the Emmental-Oberaargau region sentenced a defendant who did not supply eight fishes with sufficient oxygen and did not ensure that they could not jump out of the basin to a conditional fine of 5 daily sentences of 100 francs each. Seven fish died and one fish swam *'not breathing'* on the surface of the water during the authorities' check *[17, case BE17/200]*.

Take Home Message

Fishes are still often regarded by society, lawmakers and law enforcement agencies as creatures without a sense of pain. However, this perception does not correspond to the current state of science, which recognises the ability of fishes to suffer and feel pain as plausible. The current animal welfare regulations as well as the casuistry of animal welfare offences committed against fishes show that both politics and the responsible authorities lack sufficient sensitivity for the needs of fishes. The Swiss Animal Welfare Act regulates the keeping and handling of fishes only rudimentarily and not in a way that reflects the considerable diversity of species. In addition, animal welfare offences committed against fishes are still trivialised by the prosecuting authorities. A more in-depth examination by science, society, politics, and law enforcement agencies of the pain perception of fishes and the related animal welfare problems is indispensable for the increased protection of fishes.

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Interview with an IGN member

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What are you most involved with at the moment?

My current professional focus is on the abandonment of tail docking in pigs. I am involved in the technical implementation of the National Action Plan for the Discontinuation of Culling in Bavaria at the LGL. It is also one of my tasks to support the various groups of people (including livestock owners, veterinarians and the authorities) in the practical implementation of this.

The routine docking of pigs' tails has been banned in the EU for a long time. Unfortunately, the reality is somewhat different. If you look around at conventional pig practice, you quickly realise that the majority of animals are docked or kept docked. There are many causes for tail biting, and so the successful keeping of undocked animals in our conventional pig houses is a great challenge. There is still a long way to go, but I am optimistic.

What brought you to your field?

To be honest, it was more of a coincidence than a destiny. In my opinion, the omnipresence of dogs, cats and horses in veterinary medicine studies is still very much in evidence today. Accordingly, pigs played a rather subordinate role for me (I actually always wanted to go into the field of exotics…). After my studies in 2013, however, I was offered the chance to work on a project at the Ludwig Maximilian University *(LMU)* in Munich that dealt with pig keeping. Through direct collaboration, I learned to appreciate pigs very quickly. You simply have to like pigs.

My private interest, however, is mainly in fishes. Even if it's not my main focus, I'm always pleased when I find professional interfaces in this thoroughly exotic field. To be honest, to this day I can't walk along a stream, river or lake without peering into the water at least once in the hope of spotting a scaled animal. This fascination is difficult to explain, but it has been strong in me from an early age.

Who was your most important mentor and why?

I would like to dedicate this answer to my former boss Prof. Dr. Dr. Michael Erhard. Through the exciting work during his professorship at LMU Munich, I was able to get involved in many different areas and thus develop professionally. Without Michael's open and tolerant manner and leadership, this would not have been possible. My time at university with him as professor and boss has had a great impact on me.

What advice would you give to a young colleague?

If I may give some advice (I am still relatively young myself), I would say that it is important to be open to everything, especially at the beginning of your professional life. There are many exciting, but also important, topics to work on that you might not have thought of during your studies.

It is of great value if you are given a certain amount of creative freedom, particularly if you are a young, enthusiastic research assistant. So if you get such an opportunity, you should take advantage of it. In my opinion, if things don't go as planned, it's not the end of the world (or the paper).

What is your motivation for your work?

Since I started my career, I have been dealing with animal welfare issues in the field of farm animals. Two topics that are particularly close to my heart are the gestation crate housing of sows and the use of occupational materials for pigs. Both areas are now gaining momentum with the planned amendment of the German Farm Animal Welfare Ordinance. Even though these are small steps with partly long transition periods, things are nevertheless moving forward.

Which current developments do you find good/bad?

Animal welfare, animal protection and animal-friendly husbandry are all terms that have found their way into everyday life and society more and more in recent years. Even if the meaning of these words is often not questioned further, one notices that the omnipresent interest in these topics has strongly increased. This is one of the reasons why one or another supposedly deadlocked discussion can still be brought up again, which for me is a positive development.

What comes to your mind when you think of IGN?

Even if only indirectly, I had contact with the IGN relatively early on. In my literature research, I have always come across one IGN booklet or another, which has always helped me in my respective tasks. For this reason, it is also a great honour for me to be able to contribute to the current issue.

I immediately associate the IGN with the unique international conference of applied ethology in Freiburg. The IGN award ceremonies in particular were a highlight for me every time. It is always exciting to learn about the different research results of other institutions. Of course, this event is also a great opportunity to meet and exchange ideas with many great colleagues (especially those from Austria and Switzerland).

What importance do you think fish welfare will have in ten years' time?

Fishes will always hold a certain special place in my heart. I often notice that my enthusiasm for them is not necessarily shared by others. Unlike a puppy dog or a chicken chick, a juvenile fish probably evokes few heightened emotions in most people. While they may not be the primary trigger of various animal welfare debates, fishes can certainly benefit from the general discussion around animal welfare in the coming years. For its part, the increasing research into pain perception in fish is also making an important contribution. Aquaculture (against the background of overfishing of the oceans) will also become increasingly important in the future. Consumers are already demanding more precise information on the labels of fish products. As you can see, the topic of fish welfare is present and will most likely become even more of a focus in the coming years.

We would like to thank Dr. Dorian Patzkéwitsch for the interview.

(Photo: © V. Patzkéwitsch).

NOTES

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