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

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Abstract

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. We have invented a vast array of fishing methods that extract fishes from almost every region on the planet in an equally vast range of violent and painful ways. Fisheries managers regularly fail to prevent overfishing to ensure healthy populations of target species, have not adequately addressed the impacts on other marine species and the broader environment, nor prevented human rights abuses on board fishing vessels. Fish welfare has not been a consideration. 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 fisheries this means a reduction in the number of fishes killed, by addressing overfishing and wasteful capture methods, and reducing the length of time fishes suffer during capture. 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. Both sectors 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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Keywords: fish, welfare, fisheries, aquaculture, sustainability

Why should we care about fish welfare?

Humans interact with fishes in a variety of contexts and many of these have welfare implications (Huntingford et al.). 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. In response, aquaculture is increasingly filling the gap. It is estimated that between 0.79 and 2.3 trillion fishes were killed each year by commercial fishing operations between 2007 and 2017 (based on registered landings only, not including all bycatch and discards); another 48 to 160 billion farmed fishes were slaughtered in 2015 (fishcount.org.uk). By comparison, the number of terrestrial animals killed each year for human consumption is ca 75 billion (birds and mammals; Food and Agriculture Organization of the United Nations, *FAOSTAT*). Recreational fishing is also an extremely popular pastime for many people and this interest group represents a surprisingly strong political lobby in developed nations (in this special issue see Wadiwel). Fishes are the most numerous pet in the world and second only to cats and dogs in per capita pet ownership. In Australia, for example, 38% of households own a dog, 29.2% own a cat, but there are more pet fishes (ca 8.7 million) than cats and dogs combined (ca 6.3 million; Animal Medicines Australia). It is not commonly known that fishes follow rats and mice in terms of the total number used in scientific experiments, and they are becoming increasingly popular research models in evolutionary biology and medicine. 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 (Arthington et al.). Each of these contexts brings unique fish welfare and ethical considerations, but to date fishes have largely remained off the animal welfare radar (Brown).

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 suffering' (*Tasmanian Animal Welfare Act 1993*, Sect. 4(2)).[1]

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 (Brown et al.). In many domains they are as intelligent as most land animals (Bshary et al.; Vila Pouca and Brown, 'Contemporary Topics'). 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 phenomenon in non-human animals (for comprehensive reviews of fish cognition see Brown; Brown et al.; Vila Pouca and Brown 'Contemporary Topics'; Vila Pouca and Brown 'Fish – How to Ask').

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 (Brown). People are far more likely to show empathy towards animals whom they believe are intelligent (Myers). Moreover, animals who are intelligent have greater capacity to suffer (Bekoff). This is largely due to their ability to learn from previous events and project their experience into the future. 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 (Chandroo et al.; Yue et al.).

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 (Sneddon et al., 'Fish Sentience Denial'), the overwhelming evidence suggests that fishes do feel pain much like humans (Sneddon). 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 (Walters, 'Nociceptive Biology'). 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 (Sneddon et al., 'Do Fishes Have Nociceptors?'), the debate over whether fishes feel pain has been repeatedly repositioned (Rose et al.). 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 (Woodruff), 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 (Broom). 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 stay away. There is little value in detecting painful stimuli without remembering to avoid them again in future (Broom). 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 Walters, 'Defining Pain' and Sneddon et al. 'Defining and Assessing'), 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 the table 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 (Sneddon et al., 'Defining and Assessing'; Walters, 'Defining Pain').

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 (Sneddon et al., 'Do Fishes Have Nociceptors?'). 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. Mettam et al. 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 (Millsopp and Lamming), or if a companion fish was in an adjacent compartment (Dunlop et al.), 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 Dunlop et al. experiment 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 (Brown and Warburton). Companionship can also buffer emotional stress (Culbert et al.).

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 makes close connections between human emotions and their evolutionary precursors in animals. Darwin proposed that emotions are adaptive (350-2). 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 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 (Balcombe). 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 (Dawkins).

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 (Mellor, 'Animal Emotions'). 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 (Boissy et al.). Cognitive bias is one such example (Harding et al.) that has been used as a tool to assess animal emotions and welfare (Mendl et al., 'Cognitive Bias'). 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 (Destrez et al.; Mendl et al., 'Dogs'). 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 Cerqueira et al.; Kittilsen; and Millot et al.). 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 (Burn; Mellor, 'Moving Beyond') and there is a growing movement towards encouraging positive welfare states (Wolfensohn et al.).

Implications for commercial fisheries and 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 2018,* FAO estimated that in 2016 the global production of 'fish' (fishes, crustaceans, molluscs and other aquatic animals, but excluding aquatic mammals, reptiles, and plants) peaked at about 171 million tonnes (FAO, *State of World Fisheries*). Of this, 88% of wild-caught fish were for direct human consumption. The remaining 12% of fish caught, 20 million tonnes, were for non-food uses – 15 million tonnes was 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.

A recent study from the University of British Columbia (Pauly and Zellar) 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 (Pauly and Zellar 1).

As populations of fishes have declined globally due to overfishing, and catches began to decline after the peak in 1996 (Pauly and Zeller), 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 represented 47% of total fish production and 53% if non-food uses are excluded (FAO, *State of World Fisheries* 2).

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%) (FAO, *State of World Fisheries* 2).

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.

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 (FAO, *State of World Fisheries* 2). 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 (FAO, *State of World Fisheries* 5).

How we catch 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 (fishcount.org.uk).

The primary concern with regard to wild fishes is how we catch and kill them. The majority of fish are caught by industrialized commercial fisheries (Pauly and Zeller). There are a wide variety of methods used to pull fishes from their watery homes, depending on the size and type of fishes being targeted and where they live. These range from simple small-scale gear operated by hand from boats or the water's edge, such as spear guns, traps, handlines, and small nets, through a variety of mechanically operated hook and line designs, to the top end of industrial scale bottom and mid-water trawls with nets that could contain large aircraft, and giant purse seine nets that could enclose several Olympic pools (for an overview see Cashion et al.). In addition, we have developed technologies that can seek out fishes efficiently and allow vessels to operate everywhere, from the Antarctic to the Arctic, and with longlines and trawls that can target deep-sea species, a few kilometres below the surface. There is simply nowhere for fishes to hide.

The suffering inflicted on individual fishes differs vastly for each type of fishing gear and depends on a variety of factors: the duration of fishing (how long the gear is left in place or towed), how quickly fishes are pulled from the water once caught, the depths and water temperatures they come from, and how quickly they are killed once they are landed (Chopin and Arimoto; Veldhuizen et al.).

Fishes can be hooked on a longline or snagged in a gillnet for many hours before hauling, leaving them injured, stressed, at risk of asphyxiation, and unable to escape predators (Morgan and Burgess; Uhlmann and Broadhurst). Many fishes suffer varying degrees of barotrauma from the change in pressure – those pulled from significant depths appear at the surface with bulging eyes, burst swim bladders, and with stomachs or swim bladders forced out of their mouths

(Roach at al; Veldhuizen et al.). Fishes caught on lines are hauled to the boat via a hook that pierces their mouth, throat, or gut, and larger fishes are often stabbed with a gaff when they reach the side of the vessel – a long pole with a sharp hook on the end – to haul them on board.

One of the most traumatic fishing methods is trawling, particularly bottom trawling. These large cone-shaped trawl nets are towed through the water by one or two vessels. The net size and trawl times depends on the target species, but the mouths of nets can be 100 to 200 metres wide, with tow times of between 1 to 8 hours. During towing, fishes swim in the net until they are exhausted, fall back into the rear of the net, and are crushed along with thousands of others. Then they are hauled to the vessel and dumped on the deck or onto conveyer belts for sorting. Bottom trawls (including shrimp trawls) also damage seabed habitats and have the highest bycatch and discard rate of all fishing methods – they catch around 23% of all fish landed but account for nearly 60% of discards (Cashion et al.).

Once on deck, those fishes that are still alive die either from being left to suffocate in air, or by a combination of suffocation and evisceration. Being removed from the water is extremely stressful, and fishes will thrash about violently in an attempt to escape, causing further injuries. Fishes are often put onto ice or into iced water to suffocate and, contrary to the belief that this is better for the fishes, the process of chilling may increase their distress and cause them to suffer longer (Poli et al.; Robb and Krestin). Some fishes have their gills cut and are left to bleed out. Others are gutted or disembowelled alive. Fishes can survive for up to an hour following gutting (Mood), and even longer if left to asphyxiate, depending on the species and the temperature (Ashley; Robb and Krestin; van de Vis et al.). Eels and flatfish, for example, are adapted to low oxygen environments and can survive for hours out of water before asphyxiating (Poli et al.).

Consideration must also be given to the vast range of bycatch species – unwanted fish, and other marine animals, considered regrettable but acceptable casualties of fishing (Kelleher). Unwanted fishes are often the last to be dealt with, and are often trampled on by fishers, and left to asphyxiate before being shovelled overboard. Sharks and rays often have their fins sliced off

while alive. Other common casualties of fishing include seabirds, sea turtles, and marine mammals (for example, Clarke et al.).

We must also remember that wild fishes are not without suffering caused by humans during the rest of their lives: we have dammed rivers; over-developed estuaries and coastlines; mined, dredged and trawled the seabed; spread diseases and invasive species; polluted waterways and oceans; and now the twin evils of climate change and ocean acidification are warming our seas and changing their chemistry.

How we farm and kill fishes

When it comes to farming, 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 (Allsopp et al.) and cause the most suffering to fishes, particularly through overcrowding, handling, transport, starvation, and slaughter (Ashley 2007; Santurtun et al.).

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 (Ashley 2007; Santurtun et al.). 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 (Iversen et al.; Santurtun et al.; Stien). 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 (Vindas et al.). 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 (Ashley; Robb and Krestin; van de Vis et al.) 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 (Ashley; Humane Slaughter Association; Santurtun et al.).

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 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.

When it comes to fisheries, managers struggle to ensure the recovery or sustainable harvesting of target fish populations, and regularly fail to meet national and international agreements to achieve this. Regulations to mitigate bycatch are often poorly applied and monitored (for example, Clarke et al.), and illegal fishing and human rights abuses are rife (for example, McKinnel et al.). Fish welfare is not an industry priority. Moreover, it is difficult to imagine how fish welfare could ever be adequately addressed within industrial scale wild fish capture fisheries, and in fact is unlikely to be within their current form. There would have to be a fundamental reinvention of commercial fishing methods, such as pumping fishes on board rather than lifting them in nets, and humane killing methods such as percussion and or electrical stunning. While such methodologies are already being trialled, wide-spread utilisation is unlikely because of the prohibitive costs.

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:

Magnitude of welfare problem = Severity x Duration x 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; FAO, *State of World Fisheries*) 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.

In parallel, we must reduce the number of fishes caught in fisheries by managing fisheries sustainably – by reducing catches of target species to sustainable levels and shifting to more selective practices that kill fewer non-target species and produce less waste. To address the duration and severity of suffering, fisheries must switch to gear types that cause less suffering and reduce both the length of time gear is left in the water and haul times (Veldhuizen et al.). We will need to totally reconsider some types of fishing, like deep-sea fishing. 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 (Santurtun et al.). 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.

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, sophieskitchen.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 (Knowles). 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 (Borderias and Sanchez-Alonso; Digre et al.). Similarly, redesigning vessels can address safety issues for fishers as well as some fish welfare issues. For example, on the Blue Harvest, a new longline vessel targeting Pacific cod, lines are set and hauled through a hole in the centre of the boat, called a moon pool, that enables the crew to operate quickly and safely from inside the boat, avoiding dangerous conditions of the Alaskan seas. It also incorporates an electrical stunning table to render fishes unconscious quickly before processing (Blue North).

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.

Note

[1] Links to each State's legislation are listed here: https://kb.rspca.org.au/knowledge-base/what-is-the-australian-legislation-governing-animal-welfare/

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Table 1:

Pain Criteria for Animals

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

Source: adapted from Walters, 'Defining Pain and Painful Sentience in Animals'; and Sneddon et al. 'Defining and Assessing Animal Pain'.