Catching Up

Fish Welfare in Wild Capture Fisheries

January 2021

Authors: Douglas Waley, Moira Harris, Ian Goulding and Margarida Correira - MegaPesca Lda, Griffin Carpenter
Editors: Siobhán McGonigle, Maren Schmid
Design: Angela Lyons, Blush (p. 33)

Contents

EXECUTIVE SUMMARY

Introduction

Every year, somewhere around one trillion (1,000,000,000,000) wild fish are captured, with a significant majority being killed for food. Even with this conservative estimate, this far outnumbers any animal farmed for food, and yet despite scientific evidence that fish are sentient – i.e. have the capacity to suffer fear, pain or distress as well as a sense of well-being – public concern and consumer awareness about fish and their welfare is far behind that of other farmed animals.

It is true that unlike farmed fish, wild fish enjoy a near-natural life. However, for wild-caught fish, the end of each life is commonly exceptionally stressful due to practices that would not be allowed in any kind of terrestrial animal production. During the capture process, fish are often chased to exhaustion, crushed, asphyxiated, injured due to interaction with fishing gear, eaten by predators while trapped, or subject to decompression injuries as they are brought to the surface. If they survive the capture process, they often die of asphyxia due to air exposure, or are killed without pre-slaughter stunning. By-catch (e.g. non-target species that are inadvertently caught) that are thrown back into the sea often have little chance of survival.

With more attention on welfare aspects of commercial fishing, better practices can be introduced and enforced, attempting to close the gap between the scientific consensus about the importance of fish welfare, consumer expectations about making welfare-based choices – made possible with more comprehensive labelling – and the reality for fish.

This report looks at the various hazards faced by wild fish throughout the process of capture, through to handling and death, and proposes measures and strategies to reduce unnecessary suffering.

Main hazards to fish welfare during capture

Fish are subject to a multitude of hazards during the capture process, most of which can cause acute stress and even lead to death.

- **Crowding:** Overcrowding of fish in a given space, such as when hauling them onboard in a net, increases stress levels and can result in physical injuries and/or asphyxiation.
- **Physical injuries:** Whether due to crowding, interaction with fishing gear or the vessel, the capture process can lead to unintentional injuries such as fin damage, scale damage and puncture wounds. Fish that are injured before being discarded are more likely to die.
- **Depredation:** When fish are constrained by the fishing gear used, they unable to escape or defend themselves, and are therefore more likely to be preyed upon by a predator.
- **Thermal shock:** Exposing fish to abrupt temperature increases by raising nets quickly from deeper water, or by using a chilling or freezing process on live fish causes acute physiological responses.
- **Barotrauma:** When fish are hauled rapidly to the surface from a great depth, they can experience decompression injuries that cause internal bleeding, organ distension and organ rupture.
- **Exhaustion:** With long capture periods, fish's stress levels rise as they struggle to escape. This can lead to exhaustion and fatigue death.
- **Asphyxiation:** The main cause of asphyxiation in capture fisheries is air exposure, but this can also occur when the breathing movements are restricted due to crowding or being crushed against equipment or the vessel.

Fishing methods and their impact on fish welfare

There are three main methods of catching fish: by towing trawls or dredges; by encircling fish by nets; or by static means where fish swim into the gear and become caught or trapped. Depending on the method, different types of fishing gear are used. The below looks at welfare issues related to the capture process.

Trawling and dredging

Trawling involves the capture of fish using a net that is towed behind the vessel. Fish suffer from exhaustion as they are chased by the net, especially at faster towing speeds and with longer soak times. They face injury, asphyxiation and crushing as they are forced into the narrow cod end of the net during the capture process.

Dredging involves the towing of a rigid structure along the seabed to target shellfish. Shellfish come to the surface alive as this is often a requirement for sale. However, non-target species may be injured or suffocated, especially with long soak times.

Ways to improve welfare

- Select well-designed gear that minimises injury
- Reduce towing speed and duration to prevent exhaustion
- Reduce catch sizes to prevent crowding
- Minimise ascent rates to limit decompression injuries

Seine nets

With purse seine fishing, a large net is used to surround a shoal of fish. The bottom of the net is then drawn together to enclose them. Fish face injury, asphyxiation and crushing if they are hauled on board in nets.

Ways to improve welfare

- Reduce catch sizes and prevent crowding
- Crowd fish in steps and to the minimum density possible
- Pump fish on board instead of lifting with nets

Hanging nets

A gill net is a wall of netting that hangs in the sea, invisible to fish. When fish are too large to swim through the mesh of the net, they become trapped by their gills as they try to reverse out. Tangle/trammel comprise looser-hung gill nets that entangle fish rather than trap them. Fish can suffer from damage to their gills, fins and scales due to contact with nets.

Ways to improve welfare

- Use thicker twines in place of monofilament
- Reduce duration of capture to limit depredation
- Reduce target depth and minimise ascent rates to limit decompression injuries

Hook and line

Longlining involves a line of light rope or heavy nylon, sometimes many kilometres long, with numerous baited hooks used to target particular species. With pole and line fishing, fishers use single or multiple hooked rod and reel set-ups to catch demersal species, often using live bait to create a feeding frenzy.

In all cases, hooks can become deeply embedded (deep-hooking) if fish try to swallow the bait, with certain types of hook causing more damage.

Ways to improve welfare

- Choose hooks that cause least injury, e.g. barbless and circle hooks
- Prohibit the use of live bait
- Reduce duration of capture to prevent exhaustion and limit depredation
- Hooks are removed gently and not torn from fish

Traps

Pots, creels and other fish traps are structures where fish or shellfish are guided through funnels that encourage entry but limit escape. Traps are usually baited and are often left for several days. Non-target species have difficulties escaping traps and are vulnerable to starvation or being preyed upon by a predator.

Ways to improve welfare

- Select well-designed gear that minimises injury
- Reduce duration of capture to limit depredation

Main hazards to fish welfare after capture

Between capture and possible or eventual death, fish face a range of hazards.

Onboard handling

When landing fish using nets, the pressure can cause crushing, resulting in physical injuries or asphyxiation. Further injuries can result when fishers pull entangled fish from the net rather than pushing them through. Larger fish that are brought on board using a gaff hook can bleed to death due to the severity of injuries.

Onboard sorting leaves fish vulnerable to additional hazards that may have a cumulative impact on welfare. Prolonged exposure to air, increased temperatures, impact with or entrapment in equipment such as conveyor belts, being thrown or moved with gaffs are just some of the risks fish face. For fish caught using hooks, de-hooking can inflict extra injuries. Some fish may even have body parts removed, e.g. the bill, for economic reasons or easier handling.

Where fish need to be stored alive after capture, whether for live sale or use in aquaculture, this can lead to sublethal stress or even death.

Ways to improve welfare

- Fish should be brought on board using fish pumps rather than nets
- The use of gaff hooks should be minimised and should always be followed immediately by humane slaughter
- Time spent out of water before slaughter should be minimised
- Fishers should be educated on the correct use of gears and equipment, with a focus on reducing stress and harm

Slaughter

In most cases in wild capture fisheries, no specific killing method is used. Death results incidentally during the capture and processing of the fish, and often results in inhumane slaughter through one of the following methods:

- **Death in air:** A slow process whereby gill collapse results in asphyxiation, causing a maximal stress response.
- **Live chilling and death in ice slurry:** Placing fish in chilled water or ice slurry induces cold shock, which simultaneously chills, sedates and eventually asphyxiates the fish.
- **Exsanguination:** Blood is drained by cutting the major blood vessels, and depending on the species, can involve throat cut, gill cut or pectoral cut. This often takes place without stunning, resulting in a slow death.
- **Decapitation:** Even with the complete separation of the head from the rest of the body, loss of consciousness is not necessarily immediate, depending on the species.

Several methods of humane fish slaughter of fish exist, where killing is preceded by stunning that renders fish unconscious and insensible to pain:

- **Electrical stunning/electrocution:** Depending on the parameters used, electricity can be used to render fish insensible by stunning or kill them by electrocution. At yet uncommon in wild-capture fisheries, this method has the advantage that handling is minimised, large numbers of fish can be stunned at the same time, and a stressful death due to air exposure can be largely avoided.
- **Percussive stunning/killing:** In percussive stunning, the fish is removed from the water and restrained before a blow is delivered to its head. When the blow is delivered correctly, cranial pressure massively increases, leading to immediate loss of consciousness and sensibility. In the wild capture context, this method would only be practical for the stunning of high-value fish, in low volumes.
- **Spiking:** This involves inserting a spike through the fish's skull to destroy the brain. Performed correctly – with individual handling and expert execution – it results in immediate brain death.

Ways to improve welfare

The most urgent need to improve welfare in wild capture fisheries is to further develop and implement humane slaughter practices. An effective stunning method followed by a suitable killing method, or a killing method that results in immediate loss of sensibility, should be applied as soon as possible after capture.

Fish welfare in fisheries management

Overfishing, the removal of a species of fish from a body of water at a faster rate than the population can replenish itself, remains a serious problem worldwide, with the United Nations' Food and Agriculture Organization (FAO) estimated that in 2015, one-third of the world's fish stocks were overfished. Overfishing leads to resource depletion, reduced growth rates, low biomass levels, and in some cases, upsets entire marine ecosystems.

Discarded catch, or by-catch, are fish that are returned to the sea, either dead or alive, for reasons such as being too small, due to economic or market demands, or due to fishing quotas being exceeded. By-catch is often injured or highly stressed during the capture process, and as a result, survival rates when thrown back into the sea can be low.

Mutilation of live creatures – such as the declawing of crabs and shark finning – also raises serious welfare concerns.

Ghost gear – fishing gear (such as nets, traps or hook and line) that has been lost or discarded by fishers and that can continue to passively catch fish and other marine creatures – can have an ongoing negative impact on animal welfare. It can inflict physical injury or cause asphyxiation or depredation, and is an unrecorded source of mortality and pollution.

Ways to improve welfare

- Fishing levels and environmental management regimes should aim to reach and maintain the largest fish populations that 'optimal' environmental conditions can maintain.
- By-catch should be reduced or where possible, eliminated.
- Discards that have a poor chance of survival should be humanely killed.
- No body part should be removed from a live animal.
- Efforts should be made to limit ghost gear, including clearly marking gear, logging lost gear, and recovering gear.

Fish welfare in EU capture fisheries

Article 13 of the Treaty on the Functioning of the European Union requires that EU policies, including fisheries policies, 'pay full regard to the welfare requirements of animals'. However, in spite of this, there is no explicit protection of the welfare of wild-caught fish in EU regulations, including in the 2013 Common Fisheries Policy (CFP) which encompasses the conservation of all marine biological resources – i.e. fish and marine ecosystems – and the management of fisheries activities.

The CFP does include provisions directly relevant to fish welfare and protection – such as regulations on the technical aspects of fishing gear and how they are used – but these face issues in terms of implementation and compliance, as well as transparency and respect of scientific advice.

This means that the welfare of the 40–65 billion wild fish captured in EU fisheries every year needs better protection.

Conclusion

The welfare of wild fish has traditionally been overlooked and their plight has had little visibility in civil society, policy circles and in the animal welfare movement in general. With the body of evidence now clearly showing that finfish have well-established capacities for sentience, pain and fear, it is essential to reduce the level of suffering of wild-caught fish as much as possible.

The wide range of technologies and practices used include many opportunities to improve fish welfare. Foremost among opportunities and priorities is the implementation of effective stunning before slaughter.

Equipment and processes used in wild capture should all be reviewed with fish welfare in mind. Ultimately, to meet consumer demand for higher welfare fish products – and continue to raise awareness of the importance and relevance of fish welfare – product labelling should include clear welfare information so that consumers can make welfare-based purchase decisions.

A concerted effort is required from the fishery sector and from regulators to implement meaningful improvements not only improve the welfare of wild-caught fish, but that will also ensure that issues related to fisheries management – such as overfishing, by-catch and ghost fishing – are tackled in a comprehensive way.

1. INTRODUCTION

Every year, around one to two trillion wild fish are captured, with a significant majority being killed for food. Even with this conservative estimate – there are no official figures, and current estimates of between 0.79 and 2.3 trillion are obtained using tonnage statistics published by the Food and Agriculture Organisation of the United Nations (FAO) together with estimated mean weights for fish species – this far outnumbers any other animal farmed for food.

And yet, despite the fact that since the mid-2000s scientific evidence has increasingly supported the consensus that fish are sentient – i.e. have the capacity suffer fear, pain or distress as well as a sense of well-being – it is clear that public concern and consumer awareness surrounding fish and their welfare is far behind that of other farmed animals.

While the welfare of farmed fish in aquaculture systems has started to receive attention – for example, at the end of 2017, the European Commission published a study into the welfare of fish during transport and at slaughter in European Aquaculture – the welfare of wild-caught fish, alongside the scale of fishing operations, deserves to be brought squarely into focus as many of the welfare issues – and environmental issues – are different from those involved in aquaculture.

*finfish caught or farmed for meat annually from 2007 - 2016, fishcount.org.uk
**killed for meat 2018, FAO
Source: http://fishcount.org.uk/studydatascreens/2016/fishcount_estimates_list.php

An unnatural end to a natural life

Wild fish may live a near-natural life, but the end of each life is commonly exceptionally stressful. Their welfare is compromised at every stage of their interaction with humans, due to practices that would not be allowed in any kind of terrestrial animal production. During the capture process, fish are often chased to exhaustion, crushed, asphyxiated, injured due to interaction with fishing gear, eaten by predators while trapped, or subject to decompression injuries as they are raised to the surface. If they survive the capture process, they often die of asphyxia due to air exposure, or are killed without pre-slaughter stunning. By-catch (e.g. non-target species that are inadvertently caught) that are discarded and thrown back into the sea often have little chance of survival.

An inescapable conclusion is that vast numbers of wild fish are being caught and subjected to unnecessary suffering as they are captured and killed for food. This situation is not due to unexpected problems or breakdowns of equipment, but rather due to built-in processes and mechanisms of wild capture fisheries. As such, they can be documented and their negative effects on fish welfare can be mitigated so as to reduce suffering as much as possible.

With more attention on welfare aspects of commercial fishing, better practices can be introduced and enforced, attempting to close the gap between the scientific consensus about the importance of fish welfare, consumer expectations about making welfare-based choices – made possible with more comprehensive labelling – and the reality for fish.

Scope of this report

This report provides an overview of the extent to which fish welfare can be impacted in wild capture fisheries, and considers the key welfare issues from the start of the capture process, through landing and handling until death. Section 2 details the main welfare hazards faced by wild fish during the capture process. Section 3 describes the main fishing methods and gears and looks at the hazards associated with them as well as mitigation measures. Section 4 discusses welfare issues that arise after capture, notably during onboard handling and slaughter. It also looks at the fisheries management-related issues of overfishing, discards/by-catch, mutilation such as declawing and shark defining, and ghost fishing. Section 5 looks at the prevalence of different fished species and fishing methods in EU fisheries and explores fish welfare in European fishery policy. Section 6 is a set of recommendations for improving fishing policy and practice. Case studies throughout the report illustrate examples of better welfare practices in commercial use.

The welfare of wild-caught fish has previously been investigated in the 2010 report, 'Worse Things Happen At Sea', which explores the major fish capture methods and the welfare aspects of each, and also looks at fish welfare after capture and discusses various research projects and papers. This report builds on that work with up-to-date information and additional analysis.

Environmental factors impacting welfare in the wild

Unlike farmed fish that have been grown and produced in an unnatural environment, wild fish enjoy the freedom of a near-natural life. However, while it might seem logical that these 'natural' seas and oceans would provide a better home for wild fish, this environment has unfortunately been depleted to such an extent that it is actually much poorer than it should be, especially in two important ways: oxygen depletion and acidification.

The concentration of dissolved oxygen in the ocean is one of the most important environmental factors for marine ecosystems. It is also the measure that has changed most quickly over a short period of time as a result of human activities. Hypoxia, a condition that deprives an organism of adequate oxygen supply at the tissue level, is one of the most acute symptoms of the reduction in dissolved oxygen. Among other things, loss of oxygen in the ocean is starting to progressively alter the balance of life, favouring hypoxia-tolerant species at the expense of hypoxia-sensitive ones.

Ocean deoxygenation and acidification, along with ocean warming, are major 'stressors' on marine systems and typically occur together because they share a common cause – carbon dioxide emissions into the atmosphere that simultaneously warm, deoxygenate and acidify marine systems . Around a quarter of the carbon dioxide released by burning coal, oil and gas does not stay in the atmosphere but instead dissolves in the ocean, which is why ocean acidification has been called 'climate change's evil twin'.

When carbon dioxide dissolves in water, the water becomes more acidic – oceans are already 30% more acidic than they were 200 years ago. For marine life including fish, which have evolved over millions of years, adapting to such rapid change is extremely difficult. The acceleration of ocean acidification is so fast that it is impossible to predict the consequences. Some organisms will do well, whereas others will struggle and may even go extinct. And these changes in biodiversity are affecting fisheries and aquaculture.

believe humane slaughter is important or essential for good fish welfare.

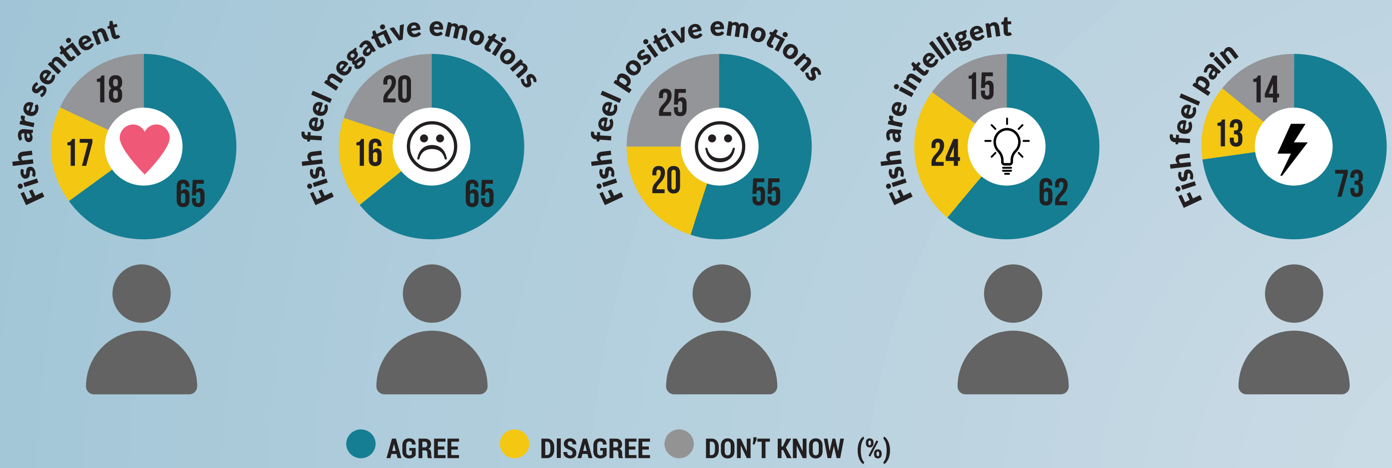
People are looking for welfare guarantees on fish products, as it is an indication of their most important product attributes: quality and sustainability.

Consumer concern about fish welfare

Recent research across Europe shows clearly that consumers recognise the relevance and importance of fish welfare, and want to use welfare as a guide in their purchasing choices[2].

A significant majority of people agree that fish are sentient, that their welfare should be

People know that fish are sentient and that they feel pain, and think that the welfare of fish should be better protected than it is now.

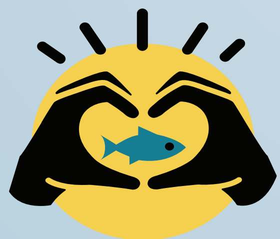


People recognise the importance of improving welfare during capture and killing.

79%

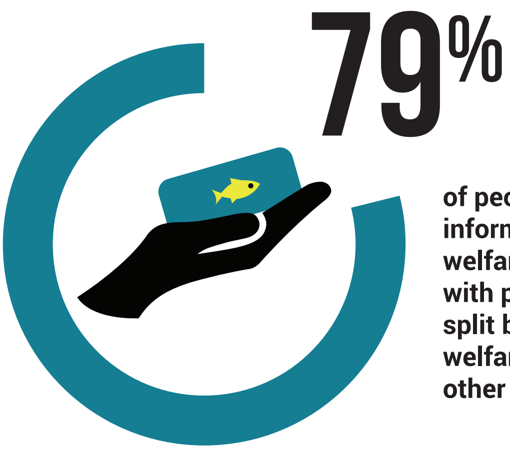
of people believe that the welfare of fish should be better protected than it is now.

of people think that the welfare of fish should be protected to the same extent as the welfare of other animals we eat.



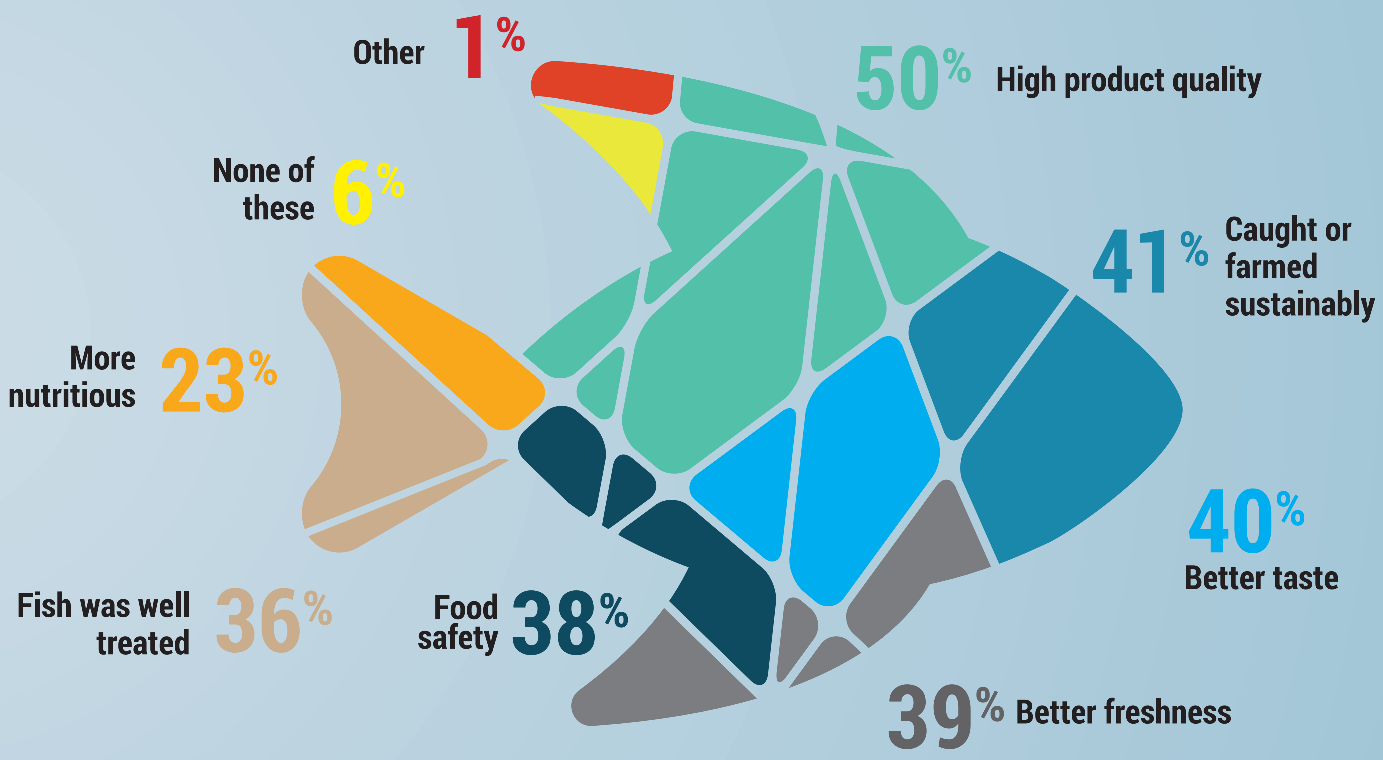
better protected, and that humane killing is essential for good welfare.

There is also growing consumer demand for welfare information to be included on product labelling, with consumers believing that there are many benefits from choosing higher-welfare fish products.



of people would like to see information about the fish's welfare on the product label, with preferences evenly split between a stand-alone welfare label and as part of other labels.

Consumer opinions on the benefits of higher welfare fish products:



2. MAIN HAZARDS TO FISH WELFARE DURING CAPTURE

Wild-caught fish experience suffering throughout the capture process until death, notably: during the capture process itself, which may last hours or days; during the landing process when they are brought on board the fishing vessel; and during the slaughter process when they may be intentionally killed or simply die during processing.

Some welfare hazards that are likely to result in negative impacts on fish welfare are common across different types of fishing methods and gear, while others are more specific to particular practices, environments or species.

This section starts by categorising and discussing welfare hazards that arise during the capture process in capture fisheries – physical injuries, depredation, thermal shock, barotrauma, exhaustion and asphyxiation.

Section 3 goes on to detail the major methods that are used for the capture of fish, giving descriptions of each capture method and gear used, its impacts on the welfare of fish, the prevalence of the method, the species associated with it, and indications of how welfare can be improved when using the method.

Section 4 looks at welfare issues related to practices beyond, or unrelated to, the capture process itself.

Physical injuries

While some physical injuries to fish are intentional, such as hook and line injuries, the capture process can also lead to unintentional physical injuries that can vary in severity from minor bruising, wounds and abrasions to deep wounds and crushing[3]. These injuries are caused by excessive crowding or by interaction with fishing gear, with a fishing vessel, or with its crew. Injury types can include scale loss, fin damage, dermal lesions, haemorrhages, gill damage, eye damage, organ puncture and puncture wounds.

Fish skin has nociceptors[4] (i.e. pain receptors) and nerve fibres which means that injuries hurt fish. Epidermal injuries can further compromise fish welfare by disrupting osmotic balance or increasing their vulnerability to infection[5]. Most commonly, lesions occur on a fish's dorsal surface and flanks, but deeper lesions can penetrate through the muscle layer revealing structures such as rib bones or internal organs[6]. Fish may even be crushed to death.

Trauma to fish's gills can profoundly affect both health and welfare[7]. Injuries can occur due to punctures from hooks, and from crushing and tearing when fish struggle to escape from the mesh of fishing nets[8]. In fish that are captured then released, traumatic gill haemorrhage increased post-release mortality in Atlantic salmon[9] while gill trauma directly impacted post-release mortality in Southern flounder[10].

A review of 85 published articles on fish welfare[11] collated what is known about the effects of the capture process in capture fisheries on fish welfare. Teleost (ray-finned) fish – a group that includes most commonly recognised fish species – caught in commercial fisheries were specifically considered and the results covered both discarded and landed fish. Scale, skin and fin injuries occurred more frequently in trawls, purse seines, gill nets, traps and seines than in capture involving hooks. Pressure injuries occurred with all gear types, and varied depending on gear depth. Mortality was generally higher in trawls, purse seines and seines than in gill nets, or with hooks and traps. The choice of gear type based on concerns for fish welfare involves a trade-off between injury types, injury levels, mortality levels, and ecological and economic consequences such as by-catch rates and fuel costs.

Improvements were available within gear types, such as using circle hooks rather than J-style hooks to reduce deep-hooking and the resulting mortality. Being selective about size (i.e. catching bigger fish) and species will contribute to improved welfare. A longer fishing

Wild-caught fish experience suffering throughout the capture process until death

duration and a greater capture depth were associated with more external injuries and higher mortality – and these could be reduced by reducing fishing duration or by bringing gear to the surface more slowly to ensure a more gradual change in depth and pressure. Reducing capture depth could also reduce injuries and mortality, although most fish species are only found at specific depths. Large changes in water temperature, a longer duration of air exposure and a high density of fish in the net were associated with higher mortality. Catching fish at lower surface water temperatures could be one way to reduce mortality[12].

Some fishing gears specifically aim to cause injury to fish by piercing parts of the body with a hook, spear or gaff-hook. Hooking occurs mostly in the jaw[13,14], tongue, gills or eye. Escaped fish have been found with hooks in their oesophagus and stomach, indicating that other sites may also be pierced. Hooking injuries and hooking mortality levels are variable and affected by many factors.

Fish that are injured before being discarded are more likely to die, due to the death of skin, gill and muscle tissues, or due to secondary infections caused by opportunistic bacteria and fungi[15]. Fin damage such as erosion and splitting may have a negative effect on movement and postural control, potentially affecting future welfare and survival.

Depredation

Many fishing methods involve long periods of capture with fish being constrained by the fishing gear used. As a result, fish can be incapable of any escape or defensive reaction, and so are vulnerable to predation, i.e. being preyed on by a predator.

While healthy fish in their natural environment are also subject to predation, the natural avoidance response of fish in the process of being captured, as well as escapees and discards, may be compromised by fishing gear, especially longlines and hanging nets.

Other fish, marine mammals, seabirds and other aquatic predators specifically target fishing activities where it is likely that captured fish will be easy targets.

Thermal shock

Fish can be exposed to abrupt temperature increases during capture as water temperatures change rapidly at different depths. Exposure to warmer water was found to increase heart rate and mortality in lingcod[15,16], while elevated sea water temperatures in sablefish led to increased mortality within 48 hours[18]. On the other hand, removing fish from water in freezing temperatures can cause immediate damage to wet soft tissues such as their gills and eyes.

Acute physiological responses occur as a result of bringing fish into ambient air temperatures and then exposing them to low temperatures as part of a chilling process (like ice, ice/water slurry, refrigeration or chilled seawater) or a freezing medium (such as air blast or freezing brine) while they are still alive.

Barotrauma

When fishing methods are performed at depth, fish can suffer from decompression injuries as they are hauled to the surface. Gas can accumulate inside the organs, resulting in pressure-related injuries known as barotrauma, which can present as internal organ haemorrhage, organ distension (particularly the swim bladder) and organ rupture[19,20]. When the swim bladder ruptures, gases escape into the abdominal cavity, distending it. In more severe cases, distension can cause eversion (turning inside-out) of the stomach and gut.

Externally visible pressure injuries can include protrusion of the gut or swim bladder from the mouth or anus, bulging of the eye, air trapped behind the cornea, and air trapped under the skin[21].

Exhaustion

How fish respond to exhaustive exercise varies among species, but in all cases, the stress response from excess physical activity causes an increase in metabolites and measurable ion imbalances. In spring chinook salmon, researchers observed an initial flight response followed by struggles of decreasing magnitude due to exhaustion[22].

Attempts to evade and escape capture lead fish to exhaustive exercise stress. When the extent of the stress is so great that consequent physiological stress response overcomes the fish's ability to cope, metabolic acidosis (a serious imbalance in the body's acid-base balance) occurs and, with it, death. For example, The Seafish Industry Authority reported experiments with gill netting for cod in the North Sea where all the fish died after a soak time of nine hours[23].

Swimming exhaustion and fatigue deaths have, additionally, been observed in a variety of different capture methods and for different species.

Asphyxiation

Fish extract oxygen from water through the fine membranes (lamellae) of their gills and distribute it via the blood to the cells in their body. Some fish can obtain oxygen from air, either to supplement gill respiration (e.g. some species of catfish), or, in the case of obligate air breathers, because they will suffocate if they do not have access to air (e.g. African lungfish). The gill lamellae can only function fully and efficiently if water keeps moving across them from front to back. When the gill filaments are in contact with air, they stick to one another and collapse. As well as transporting oxygen, blood picks up carbon dioxide (CO_2) from cells and transports it back to the gills to be released. If this gas exchange is compromised, the fish asphyxiates. When this happens, several physiological systems are affected, and the fish suffers severely. The longer a fish is exposed to the air, the greater the physiological stress response. While the main cause of asphyxiation in capture fisheries is air exposure[24], asphyxiation also takes place when respiration is restricted, either when the operculum (the bony structure protecting the gills) cannot move or due to water oxygen depletion.

All of these causes ultimately result in acute anoxia[25], i.e. a complete loss of oxygen supply. Acute asphyxia results in an irreversible loss of consciousness and is considered to be one of the most stressful killing methods[26,27].

3. FISHING METHODS AND THEIR IMPACT ON FISH WELFARE

The main fishing methods can be described in three groups: the towing of trawl or dredge nets; encircling fish by nets; or by static means where fish swim into the gear and become caught or trapped. Depending on the method, different types of fishing gear are used:

- towed or dragged gear, used for bottom trawling, pelagic or mid-water trawling, and dredging,;
- encircling gear such as purse seine nets or surrounding nets; and
- static gear such as fixed and set nets, drift nets, longlines, pole and line, pots, and fish traps.

Each type of gear has its own way of working, including the depths at which it is deployed and the species it targets. The most common methods and gear are described below in relation to the impact they have on fish welfare. For each type of gear, additional variables will affect how it impacts fish welfare, and the major variables are shown together with mitigation options below.

Common issues across fishing methods

While some welfare impacts are related to the specific fishing method and gear used, there are two factors that can leave fish more susceptible to, and amplify, the hazards discussed in section 2; these are duration of capture and crowding density.

Duration of capture

The capture process (i.e. the time between the fishers' first intervention and the hauling of the fish onboard a vessel or onto land) can last from minutes to several hours. Capture involves a series of physiological changes. It forces fish to combine aerobic and anaerobic activity and results in the depletion of energy stores, osmoregulatory changes, pH disruption, and accumulation of metabolites such as lactate. Fish may die due to a direct cause such as asphyxiation, or due to a combination of events such as crowding, injury, hypoxia or exhaustion[28]. The longer the capture process, the more risk of undesirable effects, and the higher the levels of physiological distress.

In fish, intense handling can cause a stress response indicated by a rapid increase in plasma cortisol levels, and even mild handling can cause a brief rise. There is a clear link between the severity of the stressor and the magnitude of the stress response, with extreme stressors causing extreme responses.

There is no doubt that fish welfare is more heavily compromised during a longer capture process, when compared to a quick death. And when fish survive the harvesting process, the duration of the capture and the level of exhaustion experienced is likely to make fish more vulnerable to depredation.

Crowding density

The presence of a high density of fish in a given space during capture is known as crowding. This jeopardises the welfare and health of the fish and can result in different stress responses and types of injuries.

Crowding forces fish into direct physical contact with each other and/or with fishing gear, potentially resulting in injury, asphyxiation and elevated stress levels[29,30,31]. It can lead to hypoxia if respiration is restricted either because the operculum (the bony structure protecting the gills) cannot move or due to depletion of oxygen in the water[32].

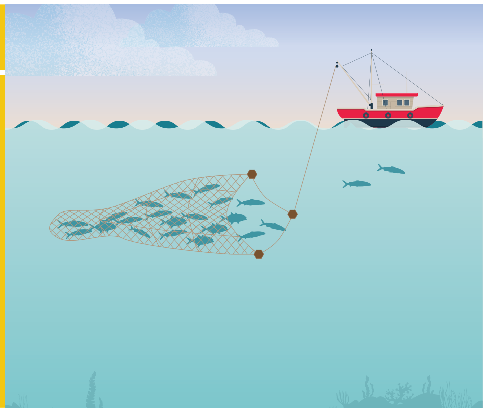
Sea bass and sea bream that had been subjected to overcrowding displayed vigorous movements for several minutes before death, suggesting high levels of stress[33].

Negative consequences of overcrowding have also been reported in wild capture fish species including lingcod, sablefish, walleye Pollock, pacific halibut, sardines and salmon.

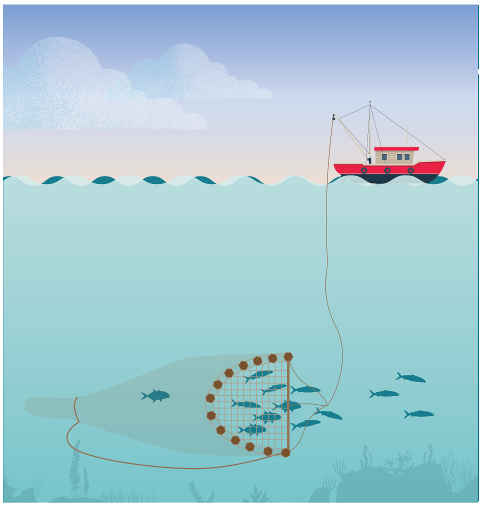
Trawling

Pelagic or mid-water trawl

Description of method	Target species	Impact on fish welfare
A trawl net towed in the mid-water to catch pelagic fish. The net is towed from the vessel's bow or stern, and tow times vary from a few minutes to a few hours depending on the density of the target species and the size and power of the vessel.	Generally a single pelagic species (e.g. mackerel, herring) with small by-catch (e.g. whiting, bass).	Target species face exhaustion, injury, asphyxiation and crushing during towing and hauling, with the possibility of death during capture. Barotrauma and thermal shock are associated with greater depths.



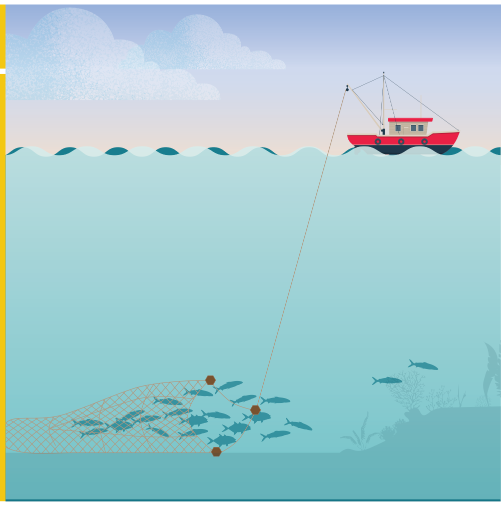
Beam trawl



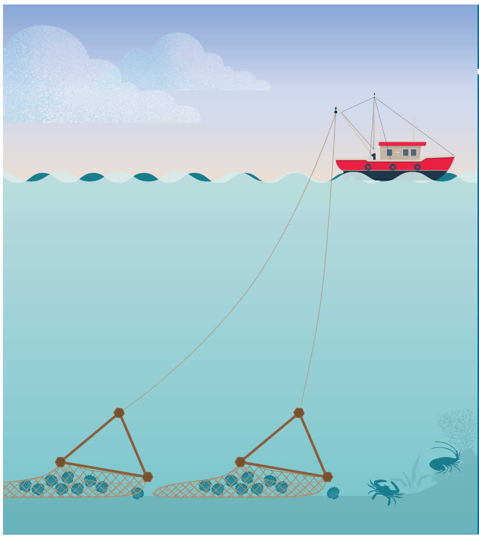
Description of method	Target species	Impact on fish welfare
A trawl net towed on the seabed, held open by a wooden or steel beam. The beam is towed behind the vessel, and tow times can vary from a few minutes to a few hours depending on the density of the target species and the size and power of the vessel.	Mainly flatfish and demersal species (e.g. plaice, sole, cod).	Target species face exhaustion, injury, asphyxiation and crushing during towing and hauling, and can come to the surface alive or dead. Barotrauma and thermal shock associated with greater depths. Large catches of non-target species are common. Can have a significant impact on seabed fauna.

Bottom trawl

Description of method	Target species	Impact on fish welfare
A trawl net towed on or near the seabed, held open by pair of trawl doors. Usually a much larger net than a beam trawl. The net is towed from the vessel's bow or stern, and tow times vary from a few minutes to a few hours depending on the density of the target species and the size and power of the vessel.	Demersal species (e.g. cod, sole, plaice, rays, anglerfish, bass, whiting).	Target species face exhaustion, injury, asphyxiation and crushing during towing and hauling, and can come to the surface alive or dead. Barotrauma and thermal shock associated with greater depths. Large catches of non-target species are common. Can have significant impact on seabed fauna.



Dredge



Description of method	Target species	Impact on fish welfare
A rigid structure towed along the seabed to target shellfish. Consists of a frame and a toothed bar to dig scallops out of the sand, with a collecting bag made of chain mesh and netting. One or more dredges are towed on either side of the vessel, with some vessels towing up to 22 per side. Large areas are often harvested mechanically.	Shellfish, particularly scallops	Target shellfish come to the surface alive as this is often a requirement for sale. Non-target species may be injured or suffocated.

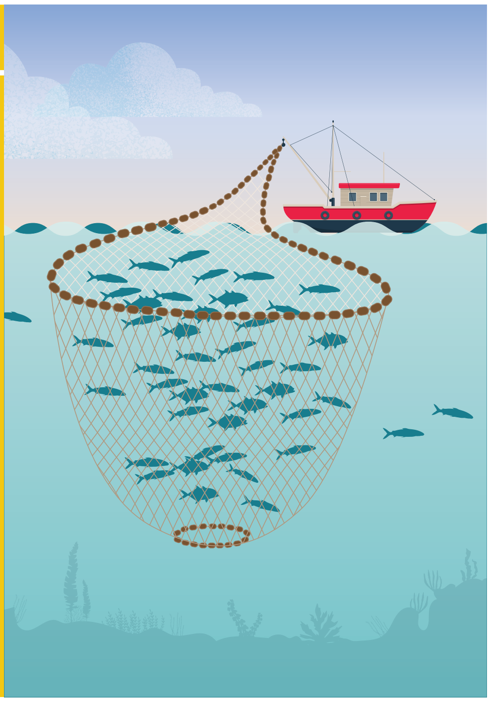
Variables and mitigation measures

Variable	Adverse effect on target species	Potential mitigation measures
Rigid parts	Crushing and physical injuries due to impact.	Select well-designed equipment that uses appropriate materials to avoid fish injuries.
Cod end	Crushing, physical injuries, exhaustion and hypoxia due to crowding and interaction with the net.	Re-design the wings and cod end to reduce injuries. Reduce the catch size in each haul.
Towing speed	Increased speed likely to generate greater injuries. Exhaustion in escapees.	Reduce the towing speed.
Towing duration	Increased exhaustion, injuries and mortality rates. Exhaustion in escapees.	Reduce the towing duration.
Catch size	Gradual blocking of cod end meshes results in crushing, increased exhaustion, higher rate of injury and asphyxiation, increased mortality during hauling, increased handling while sorting, and increased air exposure.	Reduce the catch size in each haul.
Depth	Increased injury due to barotrauma and thermal shock. Increased mortality when hauling.	Minimise ascent rates. Reduce the numbers caught in deep water fishing.
Handling	Crushing and physical injuries during hauling. Mechanical damage from sorting. Asphyxiation stress during sorting of large catches.	Use fish pumps rather than nets to bring fish onboard. Swift handling once onboard. Gentle handling to reduce physical trauma. Introduce stunning/humane killing methods. Eliminate methods that result in thermal shock.

Seine nets

Seine and surrounding nets

Description of method	Target species	Impact on fish welfare
A large net is used to surround a shoal of fish. The bottom of the net is then drawn together to enclose them. A headrope carrying numerous floats is used to keep the net on the surface. The net has rings along its lower edge through which a cable is passed, forming a bowl-like shape and preventing fish from escaping downwards. The operation is carried out directly from main vessel (the seiner) or from an additional smaller boat.	Pelagic species for Danish seine and demersal species for Scottish seine	Target species are crowded and then crushed when they are lifted onto the deck alive (where they subsequently suffocate or are flash frozen). Large species like tuna may also be gaffed (hooked in the flesh). Barotrauma and thermal shock are associated with greater depths.

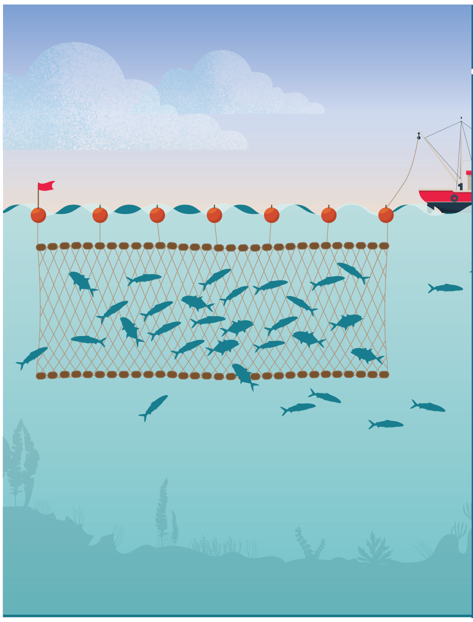


Variables and mitigation measures

Variable	Adverse effect on target species	Potential mitigation measures
Catch size	Physical injuries due to entanglement in the mesh increased by overcrowding.	Minimise catch size with shorter soak times and smaller net areas.
Duration of capture	Exhaustion and hypoxia increased by long confinement. Depredation from other species within the net and outside.	Minimise duration of capture.
Net hauling	Compression trauma and asphyxiation (compressed opercula) during hauling increases exhaustion, injury and asphyxiation. Holding nets tight may elevate stress and crowding conditions, with oxygen depletion.	Avoid crowding densities that results in a maximal stress response. Use fish pumps rather than nets to bring fish on board. Reduce drying up time.
Handling	Lengthy period on deck or during sorting leads to asphyxiation.	Smaller net size to reduce catch volume. Minimise sorting time.

Hanging nets

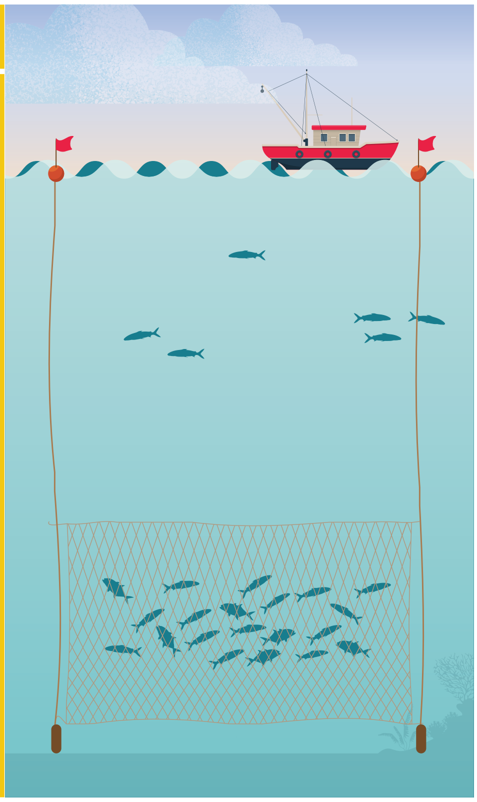
Drift nets



Description of method	Target species	Impact on fish welfare
The net is suspended from buoys in the water and drifts on the prevailing currents. The net usually hangs just below the surface but can be anywhere between seabed and surface to target pelagic species. Nets are either attached at one end to the vessel or left to drift and be recovered later. Fish become entangled when the mesh is caught behind their gills. Soak time is generally a few hours.	Mainly pelagic species (e.g. mackerel, herring) but can be set to drift along the seabed in sandy areas to catch prawns	Suffocation, injury, exhaustion, depredation. Barotrauma and thermal shock are associated with greater depths.

Fixed and set nets

Description of method	Target species	Impact on fish welfare
The net is suspended in the water, either hanging from buoys to drift on prevailing currents or fixed to anchored poles. The net usually hangs just below the surface but can be anywhere between the seabed and surface. Nets are attached at one end to the vessel or left to drift and be recovered later. A gill net is a single wall of netting whereas a trammel/tangle net is a wall of small, fine mesh between two outer layers of rope. Fish become entangled when the mesh is caught behind their gills. Soak times vary from one tidal cycle to several days.	Demersal species (e.g. cod, hake, flatfish, monkfish, rays)	Suffocation, injury, exhaustion, depredation. Barotrauma and thermal shock are associated with greater depths.



Variables and mitigation measures

Variable	Adverse effect on target species	Potential mitigation measures
Netting materials	Gill injury, exhaustion, hypoxia and exsanguination due to gill net. Open wounds, scale and skin loss, fin damage, and other injuries due to entanglement. Hypoxia due to covered or compressed opercula in trammel nets.	Modify net materials and applied tension.
Duration of capture	Increased fatigue and asphyxiation due to escape attempts. Depredation during entanglement and hauling.	Reduce soak times.
Depth	Barotrauma when hauling nets (for deep-water species).	Reduce target depth. Reduce speed of hauling to minimise rate of pressure change.
Handling	Removal of entangled fish generates secondary injuries, particularly for smaller fish that are usually pushed through the net.	Minimise time spent out of water before killing.

Hook and line

Longline

Description of method	Target species	Impact on fish welfare
Can be left anchored or drifting, with numerous baited hooks. The main line is made of light rope or heavy nylon monofilament and may be many kilometres long. Longlines target particular species and can minimise by-catch based on the time of year, the depth the line is set to, the soak time, the type and size of bait, and the hook type.	Can be rigged for demersal or pelagic species.	Injuries resulting from hooks: fish may swallow the bait (deep hooking); being unhooked can result in damage to the gut and throat. Injuries from use of gaff hooks to bring fish on board. May swallow bait and remain hooked underwater for several hours or days.

Pole and line

Description of method	Target species	Impact on fish welfare
Single or multiple hooked rod and reel set-ups using live or dead bait, or artificial lures and feathers. Can also include trolling (towing baited lines behind a moving vessel). In handlining, trolling and jigging, the fisher is in physical contact with the line and reacts when a fish bites the bait. Fishing trips are usually during daytime hours only.	Demersal species (e.g. mackerel, bass, cod, pollock).	Injuries resulting from hooks: fish may swallow the bait (deep hooking); being unhooked can result in damage to the gut and throat. Live bait is held in small containers until suddenly introduced to a new water environment and a feeding frenzy.

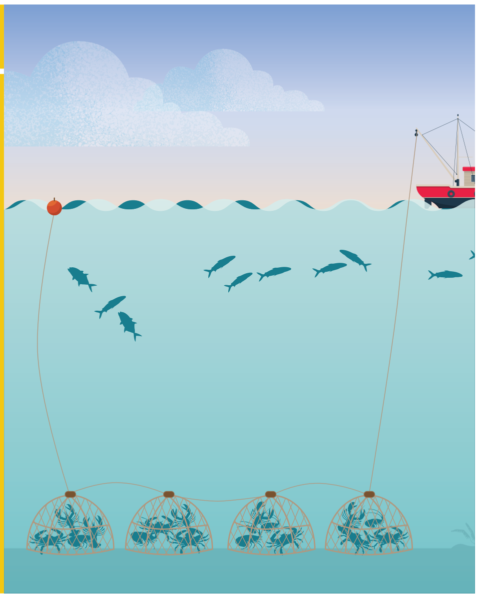
Variables and mitigation measures

Variable	Adverse effect on target species	Potential mitigation measures
Hook size and type	Physical perforation and tearing injuries at mouth. Internal injuries from deep-hooking.	Restrict use of certain types of hooks, e.g. barbed hooks.
Bait type	Live bait holding conditions. Welfare of hooked/unhooked live bait (intentional perforation). Exhaustion. Intentional depredation.	Reduce/prohibit use of live bait.
Duration of capture	Intentional exhaustion whilst hooked. Depredation whilst hooked (fixed gears).	Reduce capture times.
Depth	Injuries caused by barotrauma. Depredation during hauling.	Minimise ascent rates.
Longlining	Continuous hyperactivity leading to hypoxia and consequent exhaustion, and death before hauling.	Reduce longlining soak times.
Handling	Asphyxia due to air exposure during the time needed to remove hook. Inflicted secondary injuries due to hook removal or use of gaff hook. Secondary injuries in manual/automatic hooking. Morbidity/mortality on discard/release.	Reduce use of gaff hooks for handling. Increase skills and knowledge of fishers. Rapid handling on board. Minimise time spent out of water before killing.

Traps

Pots and traps

Description of method	Target species	Impact on fish welfare
Pots, creels and other fish traps are structures where fish are guided through funnels that encourage entry but limit escape. Traps differ in shape, size and material according to local practices and target species. Can be set singly on the seabed or in strings with a marker buoy at each end. Usually baited and can be left overnight or for several days.	Shellfish (e.g. nephrops, lobster, crab, whelk). Trap fisheries for wrasse for use in salmon farms.	Depredation. Shellfish and some non-target species are trapped for several days and are usually captured alive. Main welfare impacts are on non-target species that are trapped, and on capture of the bait species.



Variables and mitigation measures

Variable	Adverse effect on target species	Potential mitigation measures
Trap material	Interaction between fish and trap induces injuries such as scale loss.	Select trap design and material to avoid fish injuries
Depth	Barotrauma if traps are used at depth.	Slowing ascent rates may reduce welfare concerns
Duration of capture	Trapped fish is exposed to depredation and possible starvation.	Check traps more frequently. Minimise soak times.
Handling	Air exposure and on-deck injuries occur during handling.	Minimise time spent out of water before killing.

4. MAIN HAZARDS TO FISH WELFARE AFTER CAPTURE AND IN FISHERIES MANAGEMENT

This section describes fish welfare issues associated with current and common practices other than the capture method. It includes onboard handling and slaughter, and gives an overview of all the welfare hazards in wild capture fisheries. The slaughter of fish is of particular concern as it is directly linked with preventable suffering in very large numbers of fish.

The section goes on to discuss practices related to fisheries management, including overfishing, discards/by-catch, mutilation of live fish/animals (such as declawing of crabs and defining of sharks), and ghost fishing. For each, there are descriptions of the practice, their impacts on the welfare of fish, information on the species they are associated with, and indications of how welfare can be improved.

For some topics in this section, case studies are included to illustrate examples of better welfare practices in commercial use.

Onboard handling

Many fish die before coming on board fishing vessels or during subsequent handling, although it is very difficult to obtain numbers of these pre-slaughter casualties. Overcrowding with crushing and oxygen depletion, decompression, exhaustion and long exposure to air are the main causes of death before the designated slaughter process. The time required for fish to die depends on various factors such as species, size and water temperature[34].

If fish are not already dead when removed from their natural environment, they are subject to handling in air. This is inherently stressful, and additionally so if the fish has been overcrowded, crushed, decompressed or exhausted. Handling may take place on the deck, through moving, sorting and other onboard operations. The handling time is defined as the time from when a fish is under full control of the fisher to when it is killed or dies. Handling times can vary considerably with different fishing methods and vessel design and, as is the case with capture time, the longer the fish is exposed to hazards, the greater the threat to its welfare[35]. Handling time may be zero in cases where fish die in the fishing gear before being under the control of the fisher (e.g. before a gill net or longline is hauled).

Handling out of water stresses fish in combined ways. Fish suffer simultaneously from the effects of direct handling and from deprivation of oxygen, with these events occurring during critical periods of physiological stress and heavy physical exertion. Long handling in air has the potential to increase physiological stress (for example in rainbow trout[36]). A recent study of Pacific Salmon showed the lowest mortality range (0 - 5%) was caused by a maximum handling time of 10 seconds in air and 3 minutes in water[37].

The response to handling extends the suite of acute stress response reactions initiated during capture, and this complex feedback has been found to be species-specific and dependent on the duration and nature of the stressor. During this stage, the additional physiological disturbances as a result of exhaustive exercise may lead to enough physiological impairment to cause death. The effects of handling are magnified by the fact that it occurs in conjunction with air exposure and temperature increase. Air exposure induces the collapse of the gill membranes, impeding the flow of gases and consequently interfering with all metabolic processes.

CASE STUDY

Holding fish pre-slaughter

As is apparent from this report, for optimum quality and best welfare, fish should be stunned and bled as soon as possible and preferably immediately after capture. However, in reality, when fish are caught on a large scale, they may be kept in storage bins for several hours and the last fish is often dead long before it has been bled and gutted; limited numbers of crew members on board fishing vessels, combined with high capture efficiency, limits the ability to stun fish properly.

A series of projects carried out by the Norwegian research institution Nofima has evaluated catching white fish (Atlantic cod, saithe and haddock) and keeping them alive in water storage tanks for a period of time – ranging from hours to months – until they can be stunned and killed in a controlled manner. Results indicate that more than 90% of catches can be kept alive on board vessels. Currently, around 60 seiner vessels and trawler vessels have installed technology to keep white fish alive after capture until controlled slaughter is possible.

Researchers from Nofima note that to maximise fish welfare, it is also important to shorten towing times, reduce the size of catches, and handle catches gently until they are slaughtered[38].

Hauling aboard

Lifting the fish out of the water is a critical handling step. When lifting nets full of fish from the water, the pressure can cause physical injuries, crushing, and consequent hypoxia due to compression from adjacent fish. Removing fish from fishing gear roughly can disrupt the mucous coat of the fish and cause scale loss and abrasions. Using gloves to handle fish can make injuries worse, and fish may be dropped during their handling, an obvious threat to their welfare.

When fish (especially smaller fish) are entangled in nets, fishers tend to pull them from the net rather than pushing them through, which causes further injuries and/or induces observable stress reactions[39]. Fine twines and monofilament nets cause greater injury on de-netting. For seine fishing, coho salmon removed using traditional ramping (hauling the entire net on board) had higher mortality and displayed higher stress than those removed by brailing (removing fish from the net still in the water[40]).

Some vessels that operate with trawl or seine nets use hydraulic fish-lifting devices. Typically, a vacuum pump lifts the water, bringing the fish with it. Physiological responses have been observed in response to pumping, as well as external injuries including skin abrasions, punctures, lacerations, split fins and broken spines. Properly designed and operated fish pumps result in significantly lower stress responses than alternative methods for hauling fish on board.

Bringing larger fish on board usually requires extra equipment and further physical intervention. Common tools used to control large fish are nets, or a gaff consisting of a handle with a sharply pointed U-shaped hook. The fisher places the point of the gaff deep inside the fish at a point where the weight of the fish will be supported when it is brought out of water. It is usual practice to gaff the fish in the gill operculum which allows the fisher to haul and control the fish without damaging its flesh. This practice causes additional severe injuries to fish. Gaff-related injuries often result in significant bleeding and may lead to exsanguination if human killing does not intervene[41].

Onboard sorting

De-hooking inflicts extra injury on the fish. The extended handling time and air exposure needed to remove hooks endangers fish welfare, whether the fish are kept or discarded. Hook removal methods vary, from careful manual removal, to de-hooking devices or automated hook removal equipment such as a crucifer. Studies evaluating different hook removal methods used to release halibut by-catch caught by longline fisheries found that the most common reason to consider fish in poor condition, leading to higher mortality, was injuries sustained while being removed from the hook[42].

Sorting fish on deck can have a cumulative negative impact on the welfare of wild-caught fish. Sorting operations can cause further physical damage due to throwing fish or movement using gaffs and fish picks, fish falling on the deck and by other careless actions. Equipment such as sorting tables and conveyor belts may have sharp protrusions and design features that allow fish to become stuck. Large catches, and longer and high-density tows and nets can increase sorting times, exposing fish to the air and to increased temperatures during sorting.

Finally, intentional mutilation may also sometimes be practiced. Examples of this are removing the bill from billfish like marlin and swordfish, either for economic reasons or for easier handling.

Live storage

Fish are sometimes caught in the wild for live sale or more often for use in aquaculture, with the collection of either juveniles, broodstock, mature fish for fattening, or cleaner fish from the wild. In these cases, the fish are held and transported live in confined spaces. There can be significant levels of mortality during the initial capture, during the grading and sorting process after capture, during transport from the capture area to the aquaculture facility, and as part of the recovery or acclimatisation process upon arrival in aquaculture or holding facilities. Even with higher survival rates, optimal welfare may be compromised through sublethal stress, injury, competitive interactions and other factors[43]. In addition to the obvious impacts on fish welfare, significant mortality has negative impacts on the economic activity of holding fish alive, and this has driven the development of less damaging capture methods in several specific fisheries.

Slaughter

In most cases in wild capture fisheries, no specific killing method is used, and death results incidentally during the capture and processing of the fish. This section starts by looking at some of killing methods that, when used without prior stunning, can be considered as inhumane slaughter methods.

Several methods of humane fish slaughter exist, whereby killing is preceded by stunning that renders fish unconscious and insensible to pain. For some of the methods described in this section, the stunning technique can cause fish to die, whereas others must be followed by a different killing method.

Effectiveness of the various methods of stunning and killing can be evaluated through indicators of the state of insensibility achieved until death occurs – however, identifying this state and differentiating it from the moment of death is difficult. For example, immobilisation may be misinterpreted as the absence of consciousness and, conversely, some fish species exhibit post-mortem reflexes that may be interpreted as them still being alive.

The World Organisation for Animal Health (OIE) Aquatic Animal Health Code[44] and the European Food Safety Authority (EFSA) give some indicators for effective stunning of farmed fish, such as the immediate loss of body and respiratory movements (loss in opercular activity), loss of visual evoked response (VER) resulting from brain dysfunction, incapacity to respond to light flashes directed at the eye and loss of vestibule-ocular reflex as determined by the absence of eye rolling. This is confirmed by the work of Kestin et al. 2002[45] who examined a wide range of fish species and concluded that behaviours (e.g. swimming), response to stimuli such as handling, and clinical reflexes – like eye rolling or breathing – indicate a state of awareness, and therefore the capacity to experience suffering, in several species of fish.

Inhumane slaughter

Asphyxiation in air

Wild fish commonly undergo asphyxiation on board until they die. Most species of fish eventually die when held in air due to gill collapse and physiological incapacity for gas exchange. The time required to die from asphyxiation depends on the species and on both the exposure time and temperature. In general, when exposed to higher temperatures, most fish die more quickly due to increased metabolic rates and higher oxygen demand[46]. This is not a quick process; sea bream left to die in air lost self-initiated responses after 4 minutes, took around 7 minutes to lose response to stimuli, and 14 minutes to cease reflexes[47].

Concentrations of the stress indicator variables, such as plasma cortisol and glucose, measured in Senegal sole after asphyxiation, showed they were significantly higher than the resting value[48]. Observations of carp behaviour[49] recorded that fish violently flapped when removed from water, taking five hours to cease movements of the gill covers. Asphyxiation in air is considered to be a killing method that causes a maximal stress response, violent attempts to escape, and aversive reactions with associated extreme physical activity[50,51,52].

Live chilling and death in ice slurry

Hypothermia is used to kill some commercial fish species. Fish are placed in chilled water or water-ice slurry causing a temperature differential of up to 30°C. This induces cold shock, which simultaneously chills, sedates and eventually kills the fish by asphyxia[53,54]. The fish may then be left in the chilling medium, or removed, drained and iced (with or without bleeding).

Initially, carp exposed to chilled water appeared comfortable and exhibited normal swimming activity; however, abnormal behaviours suggesting aversion followed[55]. When exposed to chilled water, African catfish and turbot displayed violent reactions and muscle tremors until they became immobilised[56,57]. The hypothermia effect on sea bream resulted in immobilisation before unconsciousness[58].

Cold shock causes progressive muscle paralysis, which makes changes in behaviour difficult to assess. Sublethal physiological and behavioural consequences of cold shock stress on fish include severe disruption of the fish's metabolic rate, its movements and behaviour, and as oxygen consumption is also impaired, the fish succumbs to hypoxia and becomes immobilised[59]. Live chilling before slaughter resulted in significantly increased blood levels of cortisol and lactate, indicating increased pre-slaughter stress. In Atlantic salmon, the muscle pH also fell, indicating that metabolic changes and consequent acidosis were occurring[60].

The hypothermic effect is induced more quickly when fish live in warmer waters, since the effectiveness of the process depends on the temperature difference between the ice slurry bath and the fish's usual habitat. When fish live in cold waters, their physiology is cold-adapted, and they will be more likely to die from anoxia in the chilled water than from cold shock. Live chilling has been used as a killing method for farmed species like Atlantic salmon and rainbow trout because chilling cools the muscles, improving carcass quality, as well as immobilising the fish so it can be handled[61].

Sedation and loss of consciousness due to chilling is reversible if the fish is transferred back into its normal water conditions. Studies on welfare aspects of live chilling[62,63,64] have recorded diverse degrees of physical activity, but all demonstrate chilled fish showing signs of consciousness including eye-rolling and respiratory activity when removed from the chilling tank. Immediate stress responses such as squirming and thrashing when fish were gilled and gutted, after being chilled, were also observed. Therefore, live chilling is an unsuitable method of stunning fish before slaughter as it does not induce insensibility. Where validated alternatives exist, these should be used instead of live chilling.

Exsanguination

During death by exsanguination, blood is drained by cutting the major blood vessels. Methods of bleeding vary between species and can involve throat cut, gill cut or pectoral cut. All procedures consist of inserting a sharp knife under the area in question and severing major blood vessels. Exsanguination often takes place without stunning, and in some cases, non-stunned fish may also be subject to direct evisceration (i.e. removal of their internal organs). Following cutting of the blood vessels, fish struggle vigorously, initially due to being restrained, handed and exposed to air. Tail flapping and head shaking were observed to last for about 30 seconds after gill cutting in salmon. Behavioural responses stop around 2 minutes after gill cutting and visual evoked responses (indicating brain activity) are present for up to 7 minutes[65,66]. Exsanguination without stunning appears to cause a maximal aversive stress response, but with more rapid loss of consciousness than asphyxiation.

Fish killed by methods that do not result in immediate insensibility, such as exsanguination without prior stunning, lose their response to stimuli and reflexes progressively over a prolonged period. Responses to stimuli took over 15 minutes to be lost in turbot,[67] and turbot[68] struggled and experienced the highest stress levels at slaughter, taking longer than an hour to cease ventilation movements or muscle activity.

Movements slowly decrease, the fish loses consciousness as a direct result of exsanguination and finally succumbs to anoxia due to ischaemia (a restriction in blood supply to tissues that results in a shortage of oxygen). Differences in the number of vessels severed and effectiveness of cutting are likely to cause a great variation in the bleeding and onset of unconsciousness, as determined in Atlantic salmon and turbot[69]. Higher temperatures also affect the time to lose brain function. When subjected to lower temperatures, fish have a lower requirement for oxygen because of reduced metabolic rate. Exsanguinated trout therefore take longer to lose VERs at lower temperatures[70].

Decapitation

Decapitation consists of the complete separation of the head from the rest of the body. Even with decapitation, loss of consciousness is not immediate or even quick: eel heads have shown signs of life for up to 8 hours[71]. On average, EEG tests[72] showed that decapitated eels took more than 10 minutes to demonstrate loss of VERs. Individual handling and proper restraint methods need to be applied prior to decapitation, although handling and restraint increase the amount of stress experienced overall. Where validated alternatives exist, these should be used instead of decapitation.

Carbon dioxide saturation

Fish can be rendered insensible by replacing oxygen with carbon dioxide (CO_2). This is a relatively common method used in aquaculture[73] where it has been mechanised and applied to fish on a batch basis, reducing the need for labour. By contrast, it does not appear to be currently used in wild capture fisheries.

Saturating water with carbon dioxide creates an acidic and oxygen-deficient environment that places fish in a narcotic state[74]. Carbon dioxide immobilises the fish; however, there can be a delayed loss of consciousness which may result in fish being slaughtered before becoming insensible. If used for prolonged periods, this technique can potentially cause death by acute hypoxia.

In response to CO_2 narcosis, fish express strong escape behaviours with aversive initial flight reactions. Vigorous head and tail shaking for up to nine minutes has been described in salmon. Similarly, in carp subjected to CO_2 saturated water, strenuous activity was observed with fish keeping their mouths and gill covers closed, followed by collisions due to vigorous swimming[75]. Some fish, such as eels and sturgeon, appear to be more resistant to carbon dioxide saturation and were reported to show escape and aversive behaviour for more than an hour. Activity during stunning by CO_2 can lead to scale diffusion, increased mucus secretion and haemorrhaging of the gills[76,77,78].

The combined effects of live chilling and moderate carbon dioxide narcosis have been tested in Atlantic salmon and this combined stunning method was reported to be superior to narcosis by itself[79]. This combination is used in commercial practice to reduce extreme aversive behaviour and handling stress, and provide a longer pre-rigor period, which is reported to increase fillet quality. In this case, live-chilled, gas-exposed fish may present limited reactions simply as a result of cold immobilisation, which is not enough to induce loss of brain function. Industry codes and guidance notes recommend sustaining fish in CO_2 saturated water for up to ten minutes before slaughter, which in effect means that fish are exsanguinated or gutted while still conscious[80]. Therefore, it is not considered an acceptable method of stunning fish before slaughter.

Humane slaughter

The best death for a wild capture fish consists of being stunned quickly and effectively so that it rapidly loses consciousness and becomes insensible to pain, followed by a suitable killing method before the fish has regained consciousness.

Electrical stunning

Depending on the electrical parameters, electricity can be used to render fish insensible by electrical stunning or kill them by electrocution. The general principle of electrical stunning is to pass sufficient current through the brain, stimulating higher nerve centres to cause their dysfunction. The electrical stunning system may be conducted dry, where fish are passed over an electrified surface out of water, or semi-dry, where an electrical current is applied directly into the fish. Alternatively, electrical stunning may be carried out in water. In wild capture fisheries, few fish are stunned using electrical methods, compared to their extensive use in aquaculture. According to the OIE, electrical stunning/killing methods have been declared as

CASE STUDY

Ekofish Group

The Dutch flatfish trawling company Ekofish has two vessels with electrical stunners. Ekofish catches fish such as plaice, lemon sole, turbot and brill from the North Sea. After capture, fish are moved via a conveyer belt through an electric dry stunning machine being adapted from the aquaculture sector. They are then hand-gutted and placed on ice.

The Ekofish Group combines concern for the environment with concern for the welfare of the fish it catches and sells. On their vessels, Ekofish use an integrated sustainable method of operation: the cod end of the net has a large mesh size which allows juvenile fish and discards to escape.

This is combined with floating fishing gear that touches the seabed more lightly than traditional beam trawling. The boats use a twin rig method, with two trawls side by side, thus lowering the vessels' fuel consumption.

Ekofish's innovations in fish welfare and environmental advancement include[82]:

- **2009: Increasing the mesh size of the nets and cod end.** This allows juvenile fish to escape from the net without being caught, rather than catching them and throwing them back into the sea or landing them.
- **2010: Introduction of escape panels in the nets.** Larger, square mesh panels are positioned on top of the nets where non-target round fish naturally swim up to escape.
- **2012: Introduction of the first stunning equipment on board.** A device to make fish insensible after catch, with an electric pulse.
- **2013: New twin rig net developed,** with pelagic trawl doors, synthetic lines and sweeps with balls.
- **2019–2020: Two new boats** allow caught fish to be passed from a net into a tank of water, reducing the time spent out of water before stunning.

CASE STUDY

Humane Harvest by Blue North

The Humane Harvest Initiative™ seeks to promote the ethical treatment and handling of wild fish at harvest, as well as encouraging harvesters (fishers) to take all steps possible to reduce stress, pain and fear from capture to processing. Guided by evidence-based studies that show significant quality benefits gained by the ethical treatment of fish at capture[83], this initiative works internationally to increase the recognition of fish as sentient beings deserving of ethical treatment.

Humane Harvest was launched by the Alaska-based Blue North fishing company, which recognises the close links between the humaneness of capture methods for its Pacific cod and the quality of the end product. Blue North uses traditional hook-and-line fishery to catch fish one at a time via a "moon pool" inside the centre of the boat. Their unique moon pool method helps to safeguard the well-being of the crew as they are less exposed to weather and to the risk of falling into the water, compared to most fishing boats where the crew stand on deck. By allowing the crew access to the fish immediately as it breaks the surface of the water, the time of the landing and handling process is minimised.

Each fish is individually brought aboard directly from the water, through an entrance port, to a semi-dry automatic stunning table. It is then immediately taken to a manual bleeding table. The processed cod are frozen on board and sold internationally as a premium product, still frozen.

a humane killing procedure for some species of farmed fish, but no advice has been given regarding capture fisheries.

The current that is passed through the fish's brain causes it to go through an epileptic-like fit, with tonic (causing a stiffening of muscles) and clonic (characterised by jerking or twitching) seizures. Several authors have reported on the behaviour of fish during these phases, and have noted that this varies between species. Increased intensity and duration of the electrical system can cause physical injuries. Welfare is maximised by ensuring good practice during the stunning procedures, which may mean adapting the procedures used in aquaculture. The effectiveness and duration of unconsciousness depends on the intensity of the current and the length of time it is applied, with death occurring if the application is prolonged. If fish are not killed by the electrical process, they can recover consciousness gradually – for example, most trout were fully recovered after three minutes.

Various studies have led to the formulation of some minimum requirements for effective electrical stunning[81]. In some farmed species, electrical stunning has potential advantages, such as the fact that handling is minimised, large numbers of fish can be stunned at the same time, and a stressful death due to air exposure can be largely avoided. However, insufficient electrical current, voltage or duration of current can lead to immobilisation only and unsuccessful stunning.

Percussive stunning/killing

In percussive stunning, the fish is removed from the water and restrained before a blow is delivered to its head. A plastic, metal or wooden club or hammer, or a semi-automatic percussive stunning device can be used[85]. When a heavy blow is delivered correctly over the brain, cranial pressure massively increases causing disruption of normal brain electrical activity. Effective percussive stunning was studied in Atlantic salmon and found to cause cerebral concussion leading to epileptic-like tonic/clonic seizures and instant reduction or loss of consciousness. Induced brain haemorrhage may then impair the blood flow, ultimately leading to death[86,87].

Correct percussive stunning leads to immediate loss of consciousness and sensibility and impeded recovery[88]. After semi-automatic stunning, heart fibrillation and haemorrhage in the brain cavity of Atlantic salmon has also been observed[89]. With instrumental percussion, there was instant loss of self-initiated behaviour and loss of consciousness after approximately 30 seconds[90].

However, if the blow is inaccurate or not forceful enough, fish do not lose consciousness but may not display normal behaviours, can

CASE STUDY

Long-line stunning

The fishing equipment manufacturer Efectos Navales del Atlántico has developed an electrical stunning device for use in surface longline fisheries[84]. The fish come into contact an electrode in the water as they approach the boat, and are stunned before being brought onboard. The system was designed to make it easier to bring the fish aboard and to manipulate them on the fishing vessel.

be rendered immobile without losing consciousness or may incur physical injuries. For example, percussive stunning was found to render salmon insensible with one blow to the head but for some other species, increasing percussive force in order to bring about instant insensibility also caused broken jaws and burst eyes[91,92]. Some species such as sea bream, African catfish or eels are unsuited to percussive killing due to their anatomy[93,94].

Percussive stunning also requires air exposure and individual handling of fish. When manually inducing percussive stunning, the type of instrument, correct restraint, force and location of the blow all affect the degree of insensibility the process will achieve. Mis-hits can occur and variations in the size of fish and orientation in the machine must be taken into account if using automatic percussion machines.

As with other methods of stunning/killing, percussive stunning requires that personnel are individually and correctly trained. Welfare will be maximised by ensuring good practice during the stunning procedure and adapting it to meet species-specific requirements. In the wild capture fishery context, this method could only be used for manual percussive stunning of high-value fish, in low volumes.

Spiking

Spiking involves the insertion of a spike through the fish's skull to destroy the brain. It requires individual handling and restraint of fish, and can be done manually or by using a pneumatically operated pistol[95]. It is most commonly used for stunning larger fish such as tuna and salmon and, when spiked correctly, immediate brain death occurs[96,97]. Perforation of the hindbrain, which is usually located slightly behind and above the eye, produces an instant tonic reaction which is limited to a few flaps of the tail and minor muscle tremors with the fish's fins flaring before all motion stops. There is also immediate loss of VERs and electroencephalographic signs.

Modifications to spiking can include captive needle stunning and ikijime, a humane method of killing fish that originated in Japan, but is now in widespread use.

Captive needle stunning involves pneumatically firing a captive needle into the brain, followed by injection of compressed air[98]. In African catfish, inserting compressed air in the brain provoked slow muscle contractions for a few seconds and they subsequently demonstrated no reaction to painful stimuli, either through behavioural observation or EEG[99].

Fish killed by spiking therefore have slower but more extensive post-mortem muscle acidification due to reduced physical activity and reduced stress responses before death[100]. However, when spiking is not performed accurately, fish may not be effectively stunned and will suffer until death occurs[101]. This can happen if fish brains are small or if the spike misses the target area. As with other stunning/killing methods, spiking requires individual and correct handling of fish, otherwise it may lead to injury without loss of consciousness. Ensuring good practice during the procedure is the best way to maximise welfare.

CASE STUDY

Ikijime

Spiking and ikijime are methods used to kill fish by inserting a spike into their brain (either manually or using a machine). Ikijime is a Japanese technique that consists of spiking followed by the insertion of a flexible pithing rod or wire along the spinal cord. This reduces the amount of muscle contraction and carcass twisting that damage the flesh, and extends post-mortem glycolysis[102] (the breakdown of glycogen into lactic acid).

The method was originally developed for large, high-value fish such as tuna but may be used for other fish. When correctly and accurately applied, spiking leads to immediate loss of sensibility.

In a review of the impact of fish slaughter on welfare, spiking and ikijime were considered to have low impact compared to other methods of slaughter[103].

However, fish brains tend to be small, and successful spiking requires accuracy. The ability to identify anatomical markers that allow the brain to be targeted accurately, such as the pineal window in tuna, is therefore important. As fish make vigorous attempts to escape during spiking, the method can be prone to misapplication, which can lead to fish becoming injured and disabled but not unconscious.

Ikijime.com gives four tips for optimal use of ikijime as a humane killing method that produces the best fish quality:

1) **Time.** Killing should be done quickly, preferably within a minute of the fish being caught, using either ikijime or a firm knock on the head.

2) **Tools.** The ikijime procedure can be done using either a sharp knife, a sharpened screwdriver or specially designed ikijime tools.

3) **Technique.** Ikijime requires more precision than knocking a fish on the head, but results in lower stress levels for the fish and improves the quality of the flesh. Firmly inserting the spiking tool into the correct area (which depends on the species and size of the fish) and wiggling it around kills the fish immediately, causing its body to go limp. It is important to pinpoint the exact location of the fish brain before performing ikijime (the website ikijime.com provides an Ikijime Fish Finder Search Bar allowing website users to do this).

4) **Temperature.** Once the fish has been killed, placing it on ice or into ice slurry will maximise the quality of the flesh. Bleeding the fish after ikijime will also improve flesh quality and storage life, particularly if it is bled then immediately placed in an ice slurry.

Overview of welfare issues in wild capture fisheries

The diagram below gives an overview of the various welfare hazards that wild-caught fish may experience from the initial contact with the fishing gear, through the main capture and landing process, ending with onboard handling and finally, death.

Fish welfare in fisheries management

Overfishing

Overfishing is the removal of a species of fish from a body of water at a faster rate than the population can replenish itself. As a result, species can become depleted or very underpopulated in a given area. Overfishing can occur in water bodies of any size, up to and including oceans, and can lead to resource depletion, reduced biological growth rates and low biomass levels. Some forms of overfishing, such as the overfishing of sharks, has led to the upset of entire marine ecosystems. The ability of a population to recover from overfishing depends on whether the ecosystem's conditions are suitable for the recovery. Dramatic changes in species composition can contribute to potentially irreversible ecosystem shifts, making recovery difficult or impossible. For example, once trout have been overfished, carp might take over in a way that makes it impossible for the trout to re-establish a breeding population.

Objective 2 of the European Union's Common Fisheries Policy (CFP) contains a commitment to reaching the objective of 'progressively restoring and maintaining populations of fish stocks above biomass levels' by 2020. However, it appears that this key objective will not be achieved with current efforts. In some ecoregions, good progress is being made, but in others, overfishing remains rampant. In a 2018 report[104], the United Nations' Food and Agriculture Organization (FAO) estimated that in 2015, one-third of the world's fish stocks were overfished.

Discards/by-catch

Discards, or discarded catch, are the part of the catch that is returned to the sea, either dead or alive. Discarding may occur because fish are too small, due to economic or market demands, due to fishing quotas being exceeded, or because catch composition rules impose discarding. Discards may include one or many species, and they can be thrown away on purpose or fall through fishing gear by accident[105].

Discarding dead fish raises the clear concern that fish suffered and died unnecessarily. Discard of live fish, which may have sustained injuries due to fishing practices, carries its own range of consequences for the survival and well-being of released fish. Releasing live unwanted catches can expose fish to additional stress associated with on-board handling, air exposure and physical injuries. When released, fish can be in poor physical condition and some will die due to their experience of having been fished (known as fishing-induced mortality). The welfare of discarded fish is highly compromised throughout the process of harvest, capture, handling and release methods[106].

Welfare of discarded fish may therefore result in 'hidden mortality'. Post-release mortality rates have been recorded for some species and some fishing methods – for example, in skate caught with bottom trawlers, the overall short-term survival was 55%[107] and only 21% of those with poor health status survived being caught. Longline-caught Atlantic cod's short-term mortality rate varied from 0 to 69%[108] and their survival rate was affected by depth, temperature and de-hooking.

Short-term mortality upon release will be affected by trauma and physical injuries, hypoxia and intracellular acidosis following exhaustive exercise. Discarded fish experience sublethal stress, and this can lead to reduced feeding ability, altered behaviour, reduced growth and disrupted reproduction[109]. Although these factors do not directly induce post-release mortality, they can have significant consequences for the welfare of caught and discarded individuals[110].

Mutilation of live fish/marine animals

Declawing

Declawing is a procedure where one or both of a crab's claws are removed, by hand, before it is returned to the water. Crabs can regenerate lost limbs after a period of time, leading to the practice being viewed as potentially sustainable[111]. However, big crabs probably will not live long enough to regenerate their claws, which, together with newer knowledge about pain in crustaceans and the ethics of declawing, suggests the practice probably should not be carried out.

To ensure a clean break along the natural fracture plane, one finger is placed along the basal cheliped joint. A quick and firm downward pressure is then applied as the claw is fully extended, breaking the claw at the basi-ischium, between the coxa at the base of the leg and the merus. Claw removal can facilitate the storage and transport of crab meat, eliminate cannibalism within storage tanks, and make them easier to handle by crew.

Declawing is not necessarily fatal but can markedly reduce the crab's chance of surviving in the wild. In an experiment using commercial techniques, 47% of Florida stone crabs that had both claws removed died after declawing, as did 28% of single claw amputees. Around three-quarters of these deaths occurred within 24 hours of declawing[112]. Declawing affects the ability of a crab to feed, as crabs generally use their claws to capture and consume prey. Declawed crabs scavenge for food rather than actively hunting and foraging and may die from starvation. Declawed crabs also demonstrate significantly lower levels of activity and may have difficulty attracting mates[113,114].

Shark finning

Consumer demand for shark fins has led to the practice of removing the fins of live sharks, with finless sharks typically being returned to the ocean while still alive. Discarding the finless sharks saves storage space on the vessels. The fins, which are of much higher economic value than the rest of the body, are sold as ingredients for shark fin soup and traditional cures, particularly in China. After their fins have been removed, sharks are unable to swim effectively. They sink to the bottom of the ocean and die, either by suffocation (as they are unable to filter water through their gills) or by being eaten by predators.

Several species of shark are subject to this practice including some (like hammerheads) that are now threatened with extinction. It has been argued that shark finning, perhaps combined with by-catch, is the reason why numbers are currently low.

In an attempt to prevent this barbaric practice, many countries, areas and regions have introduced legislation stating that, where sharks are fished, their fins must arrive back on land attached to their bodies. The EU closed a final loophole in June 2013 on its 2003 shark finning ban. By introducing a stricter 'fins naturally attached' (FNA) policy, with no exceptions, shark finning by EU vessels has been banned[115].

Ghost fishing

Ghost fishing is a term applied to fishing gear (such as nets, traps or hook and line) that has been lost or discarded by fishers. Ghost gear is often made of plastic and other materials that last for a very long time. Even though they are no longer in use by fishers, they can continue to passively catch fish and other marine life, so have an ongoing negative impact on animal welfare. They may inflict physical injury or cause asphyxiation or depredation, and predators attracted by the captured prey as well as other non-target species may also become trapped in the ghost gear.

Ghost fishing is an unrecorded source of fish mortality and there are concerns regarding its impact on sustainability. Initiatives exist for the recovery of ghost fishing gear but until now, even though the animal welfare impacts are significant, these aspects have not featured significantly in the rationale for managing ghost gear. Non-biodegradable or plastic gear is predicted to persist in the marine environment for up to 600 years[116]. The Global Ghost Gear Initiative (GGGI)[117] is one initiative that collaborates on an international level to address the problem of ghost gear worldwide, comprising stakeholder representatives from the fishing industry, governments and animal protection groups.

5. FISH WELFARE IN EU CAPTURE FISHERIES

Fish captured by EU fleets

Around 40 - 65 billion wild fish are captured in EU fisheries every year, a take of around 5 million tonnes. This page uses total catch volumes by fishing methods and species specific data for the top 20 species by volume across all fishing methods from the STECF 2018 Annual Economic Report on the EU Fishing Fleet. Fish numbers are calculated using fish size estimates collected by www.fishcount.org.uk.

The EU's coastal waters include the Mediterranean, Baltic, North and Black Seas, and the Atlantic Ocean. A wide variety of species are fished, and there is considerable diversity within each of the fishing gear categories used here.

The European Union Common Fisheries Policy

Article 13 of the Treaty on the Functioning of the European Union, which came into force in December 2009, requires that the formulation and implementation of EU policies, including fisheries policies, 'pay full regard to the welfare requirements of animals'.

In spite of this, there is no explicit protection of the welfare of wild-caught fish in EU regulations, as can be seen in other jurisdictions, such as requirements on the killing of wild eel in the Netherlands[118], and requirements on the killing of fish caught and held alive in New Zealand[119]. The basic act of the Common Fisheries Policy (CFP)[120] from December 2013 only mentions in its recitals that it should pay full regard, when relevant, to animal welfare, but does not include any further provision on how their welfare should be assessed or ensured.

Scope and objectives of the CFP

The scope of the CFP encompasses the conservation of all marine biological resources – i.e. fish and marine ecosystems – and the management of fisheries activities. As regards the freshwater environment, fish processing, marketing and aquaculture, its scope is limited to markets and financial measures.

PELAGIC TRAWL

TOTAL: 1,812,961 TONNES

SPECIES	TONNES	NUMBER OF FISH
SPRAT	337,409	19,847,561,111
ANCHOVY	21,955	2,744,419,984
HERRING	748,443	7,484,434,990
MACKERELS	599,114	6,526,992,083

BEAM TRAWL

TOTAL: 135,519 TONNES

SPECIES	TONNES	NUMBER OF FISH
COD	1,991	2,488,231
PLAICE	50,746	46,132,791

BOTTOM TRAWL

TOTAL: 1,142,045 TONNES

SPECIES	TONNES	NUMBER OF FISH
SPRAT	107,624	6,330,819,717
MACKERELS	79,192	1,431,596,271
BLUE WHITING	27,985	207,299,515
COD	115,273	144,090,841
ARGENTINE HAKE	52,263	130,656,545

DREDGE

TOTAL: 167,826 TONNES

SPECIES	TONNES	NUMBER OF FISH
G. ATLANTIC SCALLOP	40,264	NO DATA
ALL OTHER	125,598	NO DATA

SEINE

TOTAL: 738,559 TONNES

SPECIES	TONNES	NUMBER OF FISH
SPRAT	2,744	161,439,382
ANCHOVY	84,817	10,602,169,924
MACKERELS	102,259	2,754,680,975
PILCHARD	134,628	1,951,134,661

HANGING NETS

TOTAL: 108,726 TONNES

SPECIES	TONNES	NUMBER OF FISH
SPRAT	420	24,725,638
HERRING	1,829	18,285,524
MACKERELS	5,546	115,926,720
EUROPEAN HAKE	26,923	14,957,321

HOOK & LINE

TOTAL: 127,947 TONNES

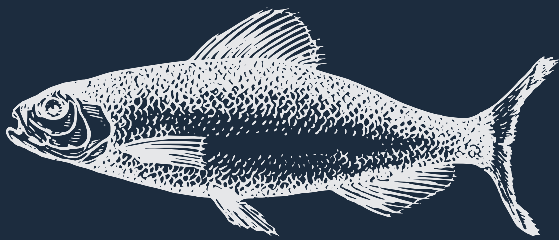
SPECIES	TONNES	NUMBER OF FISH
ANCHOVY	5,930	741,275,425
MACKERELS	11,806	102,029,804
PILCHARD	1,916	27,773,731

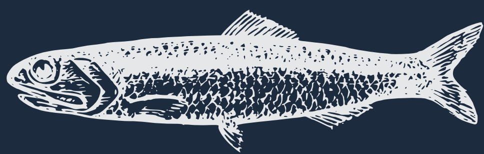
POTS & TRAPS

TOTAL: 115,876 TONNES

SPECIES	TONNES	NUMBER OF FISH
NORWAY LOBSTER	2,158	NO DATA
EDIBLE CRAB	43,537	NO DATA


MACKEREL

HERRING



ANCHOVY

SPRAT



COD

The basic act of the CFP[121] establishes a framework for the annual scientific review of fish population sizes, the annual setting of total allowable catches from each population, and provisions including the discard ban[122].

The CFP aims to ensure that fishing (and aquaculture) activities are environmentally sustainable in the long term, and managed in a way that is consistent with the objectives of achieving economic, social and employment benefits, as well as contributing to the availability of food supplies. The interests of both consumers and producers are taken into account. The legislation covers activities in the Member States, activities by all fishing vessels in EU waters, activities by EU fishing vessels outside EU waters, and fishing activities anywhere by individual EU citizens.

Provisions significant for fish welfare

Despite the lack of specific fish welfare provisions in the CFP, there are areas in which EU fishery regulations under the CFP already overlap with, and impact, the welfare of fish and other fished animals.

One of these regulations is the EU Technical Measures Regulation[123], which governs technical aspects of fishing gears and how they are used. Some of its provisions that benefit fish welfare directly are:

- An objective to optimise exploitation patterns to provide protection for juveniles and spawning groups of marine animals, to minimise catches of non-target species, and to minimise environmental impacts.
- Restrictions on the use of fishing gears, include prohibiting nets on the seabed in some locations, banning the use of drift nets for certain target species, limiting the length of drift nets, restricting the number of hooks on longlines, limiting the length and soak time of gill nets, controlling mesh sizes, controlling hook length and thickness, and banning the use of explosives and chemicals.
- Certain mutilations are prohibited. The declawing of crabs at sea is controlled. A separate regulation[124] prohibits the cutting off of sharks' fins on board vessels.

Implementation of fish welfare aspects of the policy

The CFP provisions that are directly relevant to fish welfare and protection face issues in terms of implementation and compliance, as well as transparency and respect of scientific advice.

The stated objective of fishery management measures in EU waters, which is one set of provisions, is to restore and maintain fish stocks above levels capable of producing maximum sustainable yields. On an annual basis, data is turned into scientific advice, and quotas are set politically, organised with multi-annual plans covering either a single species or fishery in a geographical area. In fact, around half of European fish stocks have quotas set above sustainable fishing levels[125], and in the Mediterranean, 90% of fish populations are fished above sustainable levels[126]. Several of the most important multiannual plans are still to be established, and several of the plans that are in place lack the required clarity on time-frames or management approaches[127].

Another provision, the landing obligation, requires that all catches of managed species be brought and retained on board the fishing vessels, and then recorded and counted against quotas. To facilitate implementation of the landing obligation, by-catch will be avoided and minimised including via technical measures[128]. The landing obligation has been phased in for most species, but many exemptions are in place, and non-compliance is widespread[129].

Other important environmental measures have also under-performed:

- Most Member States have so-called 'no-take' zones, but the joint fish stock recovery areas foreseen in the CFP have been established.
- Most Member States show poor compliance with the requirement to align with other EU environmental legislation such as the Habitats Directive[130], the Birds Directive and the Marine Strategy Framework Directive (MSFD)[131].
- Emergency measures to protect fish populations have rarely been used.
- Transparency requirements over the allocation of fishing opportunities in Member States are frequently not met[132].
- While Member States are required to identify overcapacity and adjust the size and nature of their fishing fleets to their fishing opportunities, the European Commission has not made Member States' reports publicly available, as required. According to assessments by WWF[133] and FishSec[134], overcapacity continues to be a key problem.
- Compliance with control and enforcement measures is low[135].

> The CFP provisions that are directly relevant to fish welfare and protection face issues in terms of implementation and compliance, as well as transparency and respect of scientific advice.

6. RECOMMENDATIONS

Slaughter recommendations

The most urgent need to improve welfare in wild capture fisheries is to further develop and implement humane slaughter practices. An effective stunning method followed by a suitable killing method, or a killing method that results in immediate loss of sensibility, should be applied as soon as possible after capture.

Different humane slaughter practices are appropriate for different fishing metier and different species. Training and experience are essential for operating stunning equipment effectively, and especially for carrying out manual stunning and killing procedures.

- Out-of-water electrical stunners should be further implemented, and the technology adapted to other fish species.
- In-water electrical stunning technology should be further developed for wild capture fishing vessels.
- Manual percussive stunning should be used more, especially in small-scale fisheries.
- After stunning, a killing method must be applied. With large fish, this will typically be exsanguination (gill cutting) or decapitation. With smaller fish, putting stunned fish quickly on ice will likely result in death before sensibility is recovered.
- Spiking is an immediate killing method that consists of inserting a spike through the skull. It should be used with large fish, and with smaller fish that are handled individually.

Recommendations for fish handling between capture and slaughter

- Time spent out of water between capture and slaughter should be minimised.
- Handling should be gentle.
- Live fish should be held in water.
- Fish should be brought on board using fish pumps instead of by hauling trawl nets or using brail nets. Where pumping is not possible, the number of fish in the brail net should be limited to avoid crushing and injury, nets should preferably be fully lined to lift water with the fish or at least the sides of the net should be lined to reduce injury by abrasion.
- Handling equipment and procedures should be organised to avoid throwing fish, moving fish with gaffs or picks, fish falling on the deck, fish getting caught on equipment, or fish being injured by equipment.
- Equipment coming into contact with fish should be kept moist.
- The use of gaff hooks should be minimised and avoided when possible, and must always be followed immediately by a killing procedure.
- No body part should be removed from a live animal e.g. shark fin, swordfish bill, crab claw, with the exception of the decapitation of stunned fish.
- Practices causing thermal shock to live, non-stunned fish should be eliminated.

- The monitoring and recording of capture injuries should be required at the time of processing.
- Fish species that are not used to captivity should not be held alive unless it can be demonstrated that their welfare needs are met by the holding systems.
- Fish held and/or transported alive after capture should be held, transported, and killed in line with regulations and best practices applicable in aquaculture.

High-level policy recommendations

- Fisheries policy should pay full regard to animal welfare. The ethic of mitigating fish suffering should be instilled in fishing practices and culture.
- Fish welfare should be an explicit objective of fisheries policy.
- More focus should be placed on product quality and fish health, particularly in relation to pre-slaughter stress and to physical injuries.
- More focus should be placed on making fishers the stewards of the sea, promoting localised responsibility for implementation but with strong enforcement by the EU.
- Research programmes should prioritise fish welfare in wild capture fisheries.
- Fishery subsidy regimes should prioritise improvements in fish welfare in wild capture fisheries, and in particular, support innovators in implementing and developing better practices.
- Subsidies should only be available to fishing vessels that adopt best welfare practices.
- Fish welfare should be integrated into consumer preferences research and consumer education, including the categorisation of production methods in labelling rules.
- Fish labelling should give the consumer information that allows them to make welfare-based choices, through the fishing method categories used, and preferably through explicit welfare guarantees.

Fishery management recommendations

- Fishing levels and environmental management regimes should have the objective of reaching and maintaining the largest fish populations that ‘optimal’ environmental conditions can maintain.
- By-catch should be further reduced and, where possible, eliminated.
- Discarding of fish with a poor chance of long-term survival should be eliminated. These fish should be killed using best slaughter practices.
- The catch of larger-sized and sexually mature fish should be preferred.

Suffering and injury to fish should be minimised. Metier, handling practices, and equipment should especially be designed and manufactured with this goal in mind.

Fishing practices recommendations

Recommendations common across fishing methods

- The capture period should be minimised. This means minimising the tow duration during trawling and trolling, minimising the soak time for gill and trammel nets, minimising the deployment and drying up time of seine nets, and minimising the time between checking of pots.
- Training should increase the skills and knowledge of fishers on using fishing gears, and on handling and slaughtering fish with full regard to fish welfare.
- Suffering and injury to fish should be minimised. Metier, handling practices, and equipment should especially be designed and manufactured with this goal in mind.
- Softer materials and knotless net construction should be preferred in all nets including trawl nets, gill and trammel nets, and braille nets.
- The capture depth should be minimised.
- The ascent rate during hauling should be minimised.
- The towing speed should be minimised.
- Maximum target catch volumes per haul should be established, in relation to gear capacity, alongside a plan to reduce volumes if these are regularly over target.

Recommendations for specific fishing methods

Trawl

- The cod end and wings of trawl nets should be designed so as to reduce injuries.
- Fish should be brough on board using fish pumps instead of by hauling trawl nets.
- Catches so large that the net funnels are overwhelmed and selectivity fails, and where compression in the cod end is excessive, should be avoided.
- The towing speed should be minimised.
- Bottom trawling, and especially beam trawling, should not be allowed.

Seine nets

- Fish should be crowded in steps and to the minimum density necessary. Maximal stress response should be avoided. Drying up time should be as short as possible.
- Fish should be brought on board using fish pumps instead of brail nets.

Hanging nets

- Thicker twines should be used in place of fine twines and monofilaments.

Hook and line

- Barbless hooks should be used when possible.
- Circle hooks rather than J-style hooks should be used when possible.
- Live bait should not be used, including for chumming and for baiting hooks.
- Hook removal should be carried out by hand and with the appropriate training.
- Hooks should not be torn from fish.

Recommendations for ghost gear management

- Tackling abandoned, lost or otherwise discarded fishing gear (ALDFG) and ensuring fishing gear is disposed of properly on land, and not dumped at sea, should be an explicit objective of fishery regulations.
- Fishing vessels should carry and use the equipment necessary to recover lost fishing gear.
- Fish aggregating devices (objects such as buoys or floats used to attract pelagic fish such as tuna and marlin – FADs) and lost gear should be recovered when possible.
- Biodegradable materials should be used for some gear types and for escape panels in pots and traps.
- Lost gear should be recorded in logbooks.
- The 'balance' of gear on board should be controlled.
- Gear should be marked in several places to identify its owner and operator.

CONCLUSIONS

With wild fish living largely unseen in our seas and oceans, their welfare has traditionally been overlooked, and capture fisheries have operated and developed without addressing the welfare of the fish they catch. Added to this physical distance and unfamiliarity is the fact that, until the mid-2000s, there was little consensus about whether or not fish were sentient beings, meaning that their plight had little visibility in civil society, policy circles and in the animal welfare movement in general.

The body of evidence now clearly shows that the level of cognitive complexity displayed by finfish (as vertebrates) is on a par with other vertebrates, and that they have functional similarities including shared brain structures, and well-established capacities for sentience, pain and fear. The diversity of species fished and of processes used to catch and kill wild fish means that specific measures as well as a generalised approach is necessary in order to reduce the level of suffering as much as possible.

The wide range of technologies and practices used in wild capture fisheries include many opportunities to improve fish welfare. Foremost among opportunities and priorities is the implementation of effective stunning before slaughter. The technology is well advanced and the benefits for fish welfare and for product quality are well established. This would mean that the long, stressful asphyxiation experienced by so many fish today could be avoided.

Equipment and processes used in wild capture should all be reviewed with fish welfare in mind. Duration of capture should be reduced to minimise exhaustion and physical injuries should be avoided through smaller catch sizes and more welfare-oriented training for fishers on the use of gears and handling. Nets and gear should be designed to minimise physical injuries, smaller catch sizes should be sought to avoid crowding, and pumps rather than nets should be used to bring fish onboard, and fish should not be left to asphyxiate at any time. By-catch should be reduced or eliminated, and where unavoidable, injured by-catch should be killed humanely rather than being thrown back to sea.

Ultimately, to meet consumer demand for higher welfare fish products – and continue to raise awareness of the importance and relevance of fish welfare – product labelling should include clear welfare information so that consumers can make welfare-based purchase decisions.

A concerted effort is required from the fishery sector and from regulators to implement meaningful improvements that will not only improve the welfare of wild-caught fish, but that will also ensure issues related to fisheries management – such as overfishing, by-catch and ghost fishing – are tackled in a comprehensive way.

GLOSSARY

TERM	EXPLANATION
Acidification	An ongoing decrease in the pH of the oceans caused by the uptake of carbon dioxide from the atmosphere.
Asphyxiation	The state or process of being deprived of oxygen.
Barotrauma	Injury caused by a change in air pressure as fish are hauled to the surface during fishing techniques performed at depth.
Brailing	A method of landing fish that involves scooping up part of the catch in a smaller net (a brail net), opening and closing the bottom of the smaller net, and dropping fish onto the vessel.
By-catch	Animals caught unintentionally by fishers while trying to catch the target species. By-catch also includes undersized individuals of the target species.
Chumming	The practice of scattering bait fish (usually live) to encourage target species to snap at the fishers' hooks. Especially used in pole and line fishing of tuna.
Cod end	The narrow, closed end of a trawl net where the captured fish collect.
Cognition	The neural processes related to acquiring, retaining and using information.
Demersal	Referring to the part of the sea near the seabed. Demersal species are species that inhabit this zone. Demersal trawling, including bottom trawling, targets these species.
Depredation	Removal or killing of a fish by a predator while it is trapped within fishing gear and incapable of defensive reactions.
Deoxygenation	The reduction in oxygen content of the ocean due to human activities that impact the environment.
Discards	By-catch that is thrown back into the sea (often dead) is called 'discarded by-catch' or 'discards'. A fish may be discarded because it has low market value or cannot legally be landed.
Drift net	A gill net that is suspended in the water and allowed to drift with the prevailing currents.
Electrical stunning	A method used to stun/kill fish by passing an electric current through the water. If performed properly, this method can stun and kill fish with immediate loss of consciousness.
Escapees	Fish that come into contact with fishing gear and subsequently escape without being caught and landed. Escapees may die as a result of stress and injury.
Exsanguination	Draining the blood from an animal by, for example, cutting the gills.
Fishing gears	The tools used to capture marine and aquatic resources. Gill nets and trawl nets are examples of fishing gears.
Fish pump	A means of landing or moving fish without removing them from the water. Fish pumps can cause injury to fish, but can also minimise stress and injury.
Gaffing	Stabbing fish with a hand-held hook to bring them on board.

TERM	EXPLANATION
Ghost fishing	The capture of fish by lost or discarded fishing nets or traps.
Gibbing	A gutting technique used on herring in which the gills, long gut and stomach are removed from fish by inserting a knife at the gills.
Gill net	A wall of netting, hanging in the sea, that is invisible to fish as they swim into it. Fish become trapped, often by the gills as they try to reverse out of the net.
Gills	Delicate organs in fish that are responsible for gas exchange, excretion of nitrogenous compounds and osmoregulation.
Gutting	Cutting a fish open to remove its guts.
Handling time	The time from when a fish is under full control of the fisher to when it is killed or dies.
Invertebrate	An animal that does not have a vertebral column, or backbone.
Longline fishing or long lining	A fishing method in which long lines of up to 100km are set horizontally or vertically in the water. Short lengths of line carrying baited hooks are attached at intervals. Lines are retrieved hours or days after being placed.
Metier	A group of fishing operations that target a similar (assemblage of) species, using similar fishing gear, during the same period of the year and/or within the same area and which are carried out in a similar way.
Osmoregulation	The physiological processes by which an organism maintains an internal balance between water and mineral ions in their body fluids.
Overfishing	A level of fishing that is unsustainable due to its effect on the target species or on other species in the ecosystem.
Pelagic	Referring to any part of the sea that is not on or near the seabed. Pelagic species are species that inhabit this zone. Pelagic trawling, also called midwater trawling, targets these species.
Pole and line fishing	A hook and line fishing method in which schooling fish, such as tuna, are enticed to snap at hooks by chumming. Once hooked, the fish are quickly landed.
Purse seine fishing	A fishing method in which a wall of netting encircles a school of fish and is then pulled tight like a drawstring purse.
Selectivity	For a fishing method, the extent to which the unintentional capture of animals is avoided.
Sentient	Sentient animals are aware of feelings and emotions, e.g. they have the capacity to suffer or to experience a sense of well-being.
Soak time	The time interval between setting fishing gear, such as nets or traps, and retrieving it.
Vertebrate	An animal that has a vertebral column, or backbone.

REFERENCES

1. IUCN. Laffoley, D. and Baxter, J.M. (editors). 2019. *Ocean deoxygenation: Everyone's problem*. https://www.unitgraphics.com/deox/IUCNDeoxreportBOOK15-11-2019.

2. Eurogroup for Animals/Compassion in World Farming. 2018. *Fish Welfare Survey*. https://comresglobal.com/polls/eurogroup-for-animals-ciwf-fish-welfare-survey/

3. Raby, G.D., Wilson, S.M., Patterson, D.A., Hinch, S.G., Clark, T.D., Farrell, A.P. and Cooke, S.J. 2015. A physiological comparison of three techniques for reviving sockeye salmon exposed to a severe capture stressor during upriver migration. *Conservation Physiology*, 3.

4. Sneddon, L.U., Braithwaite, V.A., and Gentle, M.J. 2003. Do fishes have nociceptors? Evidence for the evolution of a vertebrate sensory system. *Proceedings of the Royal Society of London B: Biology*, 270 pp 1115-1121.

5. Noble, C., Gismervik, K., Iversen, M.H, Kolarevic, J., Nilsson, J., Stien, L.H. and Turnbull, J. 2018. Welfare indicators for farmed Atlantic salmon: Tools for assessing fish welfare. Nofima report.

6. Bottari, T., Greco, S. and Pamebianco, A. 2003. Trolling lesions: Incidence in some fish species and preliminary statistical evaluations. *Veterinary Research Communications*, 27 Suppl. 1 pp 285-288.

7. Noble, C., Cañon Jones, H., Damsgård, B., Flood, M. Midling, K., Roque, A., Sæther, B. and Cottee, S. 2011. Injuries and deformities in fish: their potential impacts upon aquacultural production and welfare. *Fish Physiology and Biochemistry*, 38 pp 61-83.

8. Cook, K.B., Hinch, S.G., Watson, M.S., Paterson, D.A. Reid, A.J. and Cooke, S.J. 2018. Experimental capture and handling of chum salmon revealed thresholds in injury, impairment, and physiology: Best practices to improve bycatch survival in a purse seine fishery. *Fisheries Research*, 206 pp 96-108.

9. Mäkinen, S.T., Niemelä, E., Moen, K. and Lindström, R. 2000. Effects of gill net and rod-and-reel capture on upstream migration of atlantic salmon (*Salmo salar L.*) following radio tagging. *Fisheries Research*, 45 pp 117-127.

10. Smith, W.E. and Scharf, F.S. 2011. Post release survival of sublegal Southern Flounder captured in a commercial gill-net fishery. *North American Journal of Fisheries Management*, 31 pp 445-454.

11. Veldhuizen, L.J.L., Berentsen, P.B.M., de Boer, I.J.M., van de Vis, J.W. and Bokkers, E.A.M. 2018. Fish welfare in capture fisheries: A review of injuries and mortality. *Fisheries Research*, 204 pp 41-48.

12. Veldhuizen, L.J.L., Berentsen, P.B.M., de Boer, I.J.M., van de Vis, J.W. and Bokkers, E.A.M. 2018. Fish welfare in capture fisheries: A review of injuries and mortality. *Fisheries Research*, 204 pp 41-48.

13. Muoneke, M.I. and Childress, W.M. 1994. Hooking mortality: A review for recreational fisheries. *Reviews in Fisheries Science*, 2 pp 123-156.

14. Davis, M.W. 2002. Key principles for understanding fish bycatch discard mortality. *Canadian Journal of Fisheries and Aquatic Sciences*, 59 pp 1834-1843.

15. Kojima, T., Ishii, M., Kobayashi, M. and Shimizu, M. 2004. Blood parameters and electrocardiogram in squeezed fish simulating the effect of net damage and recovery. *Fisheries Science*, 70 pp 860-868.

16. Olla, B.L., Davis, M.W. and Schreck, C.B. 1997. Effects of simulated trawling on sablefish and walleye Pollock: The role of light intensity, net velocity and towing duration. *Journal of Fish Biology*, 50 pp 1181-1194.

17. Prystay, T., Eliason, E., Lawrence, M., Dick, M., Brownscombe, J., Paterson, D., Crossin, G., Hinch, S. and Cooke, S. 2017. The influence of water temperature on sockeye salmon heartrate recovery following simulating fisheries interactions. *Conservation Physiology*, 5 pp 10.

18. Davis, M.W., Olla, B.L. and Schreck, C.B. 2001. Stress induced by hooking, net towing, elevated sea water temperature and air on sablefish: Lack of concordance between mortality and physiological measures of stress. *Journal of Fish Biology*, 58 pp 1-15.

19. Gravel, M-A. and Cooke, S. 2008. Severity of barotrauma influences the physiological status, post release behaviour, and fate of tournament-caught smallmouth bass. *North American Journal of Fisheries Management*, 28 pp 607-617.

20. Pribyl, A., Kent, M., Parker, S.J. and Schreck, C. 2011. The response to forced decompression in six species of Pacific rock fish. *Transactions of the American Fisheries Societies Society*, 140 pp 374-383.

21. Mason, J.E. and Lowe, C. 2008. The effects of barotrauma on the catch-and-release survival of Southern Californian near shore and shelf rockfish (Scarpaenidae Sebastes spp.). *Canadian Journal of Fisheries and Aquatic Sciences*, 65 pp 1286-1296.

22. Lindsay, R.B., Schroeder, R.K., Kenaston, K.R., Toman, R.M. and Buckman, M.A. 2004. Hooking mortality by anatomical location and its use in estimating mortality of spring Chinook salmon caught and released in a river sport fishery. *North American Journal of Fish Management*, 24 pp 367-378.

23. Seafish Industry Authority, Data Sheet No.1994/24/FT/ed2, Humber Laboratory, 1994, www.seafish.org/media/Publications/datasheet_94_24_FG.pdf

24. Ferguson, R.A. and Tufts, B.L. 1992. Physiological effects of brief air exposure in exhaustively exercised rainbow trout (Oncorhynchus mykiss): Implications for "catch and release" fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*, 49 pp 1157-1162.

25. Raby, G.D., Wilson, S.M., Patterson, D.A., Hinch, S.G., Clark, T.D., Farrell, A.P. and Cooke, S.J. 2015. A physiological comparison of three techniques for reviving sockeye salmon exposed to a severe capture stressor during upriver migration. *Conservation Physiology*, 3.

26. Ottera, H., Roth, B. and Torrissen, O.J. 2001. Do killing methods affect the quality of Atlantic salmon? In: Kestin, S.C. and Warriss, P.E. (eds), Farmed Fish Quality. Oxford: Blackwell Science Ltd. pp 398-399.

27. Bagni, M., Civitareale, C., Priori, A., Ballerini, A., Finoia, M., Brambilla, G. and Marino, G. 2007. Pre-slaughter crowding stress and killing procedures affecting quality and welfare in Sea Bass (*Dicentrarchus labrax*) and Sea Bream (*Sparus aurata*). *Aquaculture*, 263 pp 52-60.

28. Chopin, F.S., Arimoto, T. and Inoue, Y. 1996. A comparison of the stress response and mortality of sea bream Pagrus major captured by hook and line and trammel net. *Fisheries Research*, 28 pp 277-289.

29. Davis, M.W. 2002. Key principles for understanding fish bycatch discard mortality. *Canadian Journal of Fisheries and Aquatic Sciences*, 59 pp 1834-1843.

30. Marçalo, A., Guerreiro, P., Bentes, L., Rangel, M., Monteiro, P., Oliveira, F, Afronso, M.L.C., Pousao-Ferreira, P., Benoit, Gugues, Breen, M., Erzini, K. and Goncalves, J. 2010. Effects of different slipping methods on the mortality of sardine, Sardina pilchardus, after purse-seine capture off the Portuguese Southern coast (Algarve). *PLOS ONE*, 13 pp 334-344.

31. Raby, G.D., Wilson, S.M., Patterson, D.A., Hinch, S.G., Clark, T.D., Farrell, A.P. and Cooke, S.J. 2015. A physiological comparison of three techniques for reviving sockeye salmon exposed to a severe capture stressor during upriver migration. *Conservation Physiology*, 3.

32. Raby, G.D., Wilson, S.M., Patterson, D.A., Hinch, S.G., Clark, T.D., Farrell, A.P. and Cooke, S.J. 2015. A physiological comparison of three techniques for reviving sockeye salmon exposed to a severe capture stressor during upriver migration. *Conservation Physiology,* 3.

33. Bagni, M., Civitareale, C., Priori, A., Ballerini, A., Finoia, M., Brambilla, G. and Marino, G. 2007. Pre-slaughter crowding stress and killing procedures affecting quality and welfare in Sea Bass (*Dicentrarchus labrax*) and Sea Bream (*Sparus aurata*). *Aquaculture*, 263 pp 52-60.

34. Robb, D.H.F. and Kestin, S.C. 2002. Methods used to kill fish: Field observations and literature reviewed. *Animal Welfare*, 11 pp 269-282.

35. Davis, M.W. 2002. Key principles for understanding fish bycatch discard mortality. *Canadian Journal of Fisheries and Aquatic Sciences*, 49 pp 1834-1843.

36. Ferguson, R.A. and Tufts, B.L. 1992. Physiological effects of brief air exposure in exhaustively exercised rainbow trout (Oncorhynchus mykiss): Implications for "catch and release" fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*, 49 pp 1157-1162.

37. Patterson, D.A., Robinson, K.A., Lennox, R.J., Nettles, T.L., Donaldson, L.A., Eliason, E.J., Raby, G.D., Chapman, J.M., Cook, K.V., Donaldson, M.R., Bass, A.L., Drenner, S.M., Reid, A.J., Cooke, S.J., and Hinch, S.G. 2017. Review and evaluation of fishing-related incidental mortality for pacific salmon. Canadian Search Advisory Secretariat Research Document 2017/010 (Pacific Region).

38. https://nofima.no/en/

39. Veneranta, L., Pakarinen, T., Jokikokko, E., Kallio-Nyberg, I. and Harjunpää, H. 2017. Mortality of Baltic sea trout (Salmo trutta) after release from gillnets. *Journal of Applied Ichthyology*, 34.

40. Farrell, A.P., Gallaugher, P.E., Clarke, W.C., Delury, N.C., Kreiberg, H., Parkhouse, W. and Routledge, R. 2000. Physiological status of coho salmon (Oncorhynchus kisutch) captured in commercial nonretention fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*, 57 pp 1668-1678.

41. Davie, P.S. and Kopf, R.K. 2006. Physiology, behavior, and welfare of fish during recreational fishing and after release. *New Zealand Veterinary Journal*, 54 pp 161–172.

42. Kaimmer, S.M. and Trumble, R.J. 1998. Injury, condition, and mortality of Pacific halibut following careful release of Pacific cod and sablefish longline fisheries. *Fisheries Research*, 38 pp 131-144.

43. FAO. 2011. Use of wild fishery resources for capture-based aquaculture. *FAO Technical Guidelines for Responsible Fisheries No.5 Supplement 6.*

44. World Organisation for Animal Health (OIE). 2019 Introduction to recommendations for the welfare of farmed fish. https://www.oie.int/index.php?id=171&L=0&htmfile=chapitre_welfare_introduction.htm.
45. Kestin, S., van de Vis, J. and Robb, D. 2002. Protocol for assessing brain function in fish and the effectiveness of methods used to stun and kill them. *The Veterinary Record*, 150 pp 302-307.
46. Robb D.H.F. and Kestin S.C. 2002. Methods used to kill fish: field observations and literature reviewed. *Animal Welfare*, 11 pp 269–282.
47. Kestin, S., van de Vis, J. and Robb, D. 2002. Protocol for assessing brain function in fish and the effectiveness of methods used to stun and kill them. *The Veterinary Record*, 150 pp 302-307.
48. Ribas, L., Flos, R, Reig, L., Mackenzie, S., Barton, B.A. and Tort, L. 2007. Comparison of methods for anaesthetizing Senegal sole (Solea senegalensis) before slaughter. *Aquaculture*, 269 pp 250-258.
49. Rahmanifarah, K., Shabanpour, B. and Sattari, A. 2011. Effects of clove oil on behavior and flesh quality of Common Carp (*Cyprinus carpio L.*) in comparison with pre-slaughter CO2 stunning, chilling and asphyxia. *Turkish Journal of Fisheries and Aquatic Sciences*, 11 pp 135-143.
50. Robb D.H.F. and Kestin S.C. 2002. Methods used to kill fish: field observations and literature reviewed. *Animal Welfare*, 11 pp 269–282.
51. Ribas, L., Flos, R, Reig, L., Mackenzie, S., Barton, B.A. and Tort, L. 2007. Comparison of methods for anaesthetizing Senegal sole (Solea senegalensis) before slaughter. *Aquaculture*, 269 pp 250-258.
52. European Food Safety Authority (EFSA). 2009. General approach to fish welfare and to the concept of sentience in fish: Scientific opinion of the Panel on Animal Health and Welfare. *The EFSA Journal*, 954 pp 1-27.
53. Tanck, M., Booms, G., Eding, E., Wendelaar Bonga, S. and Komen, J. 2000. Cold shocks: a stressor for common carp. *Journal of Fish Biology*, 57 pp 881-894.
54. European Food Safety Authority (EFSA). 2009. General approach to fish welfare and to the concept of sentience in fish: Scientific opinion of the Panel on Animal Health and Welfare. *The EFSA Journal*, 954 pp 1-27.
55. Rahmanifarah, K., Shabanpour, B. and Sattari, A. 2011. Effects of clove oil on behavior and flesh quality of Common Carp (Cyprinus carpio L.) in comparison with pre-slaughter CO2 stunning, chilling and asphyxia. *Turkish Journal of Fisheries and Aquatic Sciences*, 11 pp 135-143.
56. Lambooij, E., Kloosterboer, R.J., Gerritzen, M. and van de Vis, H. 2006. Assessment of electrical stunning in fresh water of African Catfish (Clarias gariepinus) and chilling in ice water for loss of consciousness and sensibility. *Aquaculture*, 254 pp 1-4.
57. Roth, B., Imsland, A., Gunnarsson, S., Foss, Atle and Schelvis-Smit, R. 2007. Slaughter quality and rigor contraction in farmed turbot (Scophthalmus maximus); a comparison between different stunning methods, *Aquatulture* 272 pp 754-761.
58. Van de Vis H., Kestin S., Robb, D., Oehlenschlager, J., Lambooij, B., Munkner, W., Kuhlmann, H., Kloosterboer, K., Tejada, M., Huidobro, A., Ottera, H., Roth, B., Sørensen, N.K., Akse, L., Byrne, H. and Nesvadba, P. 2003. Is humane slaughter of fish possible for industry? *Aquaculture Research*, 34 pp 211–220.
59. Hovda J. and Linley, T.J. 2000. The potential application of hypothermia for anaesthesia in adult Pacific salmon. *North American Journal of Aquaculture*, 62 pp 67-72.
60. Skjervold, P., Olav Fjæra, S., Braarød Østby, P. and Einen, O. 2001. Live-chilling and crowding stress before slaughter of Atlantic salmon (Salmo salar). *Aquaculture*, 192.
61. Erikson, U., Hultmann, L. and Steen, J.E. 2006. Live chilling of Atlantic salmon (Salmo salar) combined with mild carbon dioxide anaesthesia: I. Establishing a method for large-scale processing of farmed fish. *Aquaculture*, 252 pp 183-198.
62. Skjervold, P., Olav Fjæra, S., Braarød Østby, P. and Einen, O. 2001. Live-chilling and crowding stress before slaughter of Atlantic salmon (Salmo salar). *Aquaculture*, 192.
63. Roth, B., Imsland, A., Gunnarsson, S., Foss, Atle and Schelvis-Smit, R. 2007. Slaughter quality and rigor contraction in farmed turbot (Scophthalmus maximus); a comparison between different stunning methods, *Aquaculture* pp 754-761.
64. Lambooij, E., Kloosterboer, R.J., Gerritzen, M. and van de Vis, H. 2006. Assessment of electrical stunning in fresh water of African Catfish (Clarias gariepinus) and chilling in ice water for loss of consciousness and sensibility. *Aquaculture*, 254 pp 1-4.
65. Kestin, S., van de Vis, J. and Robb, D. 2002. Protocol for assessing brain function in fish and the effectiveness of methods used to stun and kill them. *The Veterinary Record*, 150 pp 302-307.

66. Van de Vis H., Kestin S., Robb, D., Oehlenschlager, J., Lambooij, B., Munkner, W., Kuhlmann, H., Kloosterboer, K., Tejada, M., Huidobro, A., Ottera, H., Roth, B., Sørensen, N.K., Akse, L., Byrne, H. and Nesvadba, P. 2003. Is humane slaughter of fish possible for industry? *Aquaculture Research*, 34 pp 211–220.

67. Morzel, M., Sohier, S. and van de Vis, J.W. 2002. Evaluation of slaughtering methods of turbots with respect to animal protection and flesh quality. *Journal of the Science of Food and Agriculture*, 82 pp 19-28.

68. Ruff, N., FitzGerald, R.D. and Cross, T.F. 2002. Slaughtering method and dietary alpha-tocopheryl acetate supplementation affect rigor mortis and fillet shelf-life of turbot *Scophthalmus maximus L*. *Aquaculture Research*, 33 pp 703-714.

69. Morzel, M., Sohier, S. and van de Vis, J.W. 2002. Evaluation of slaughtering methods of turbots with respect to animal protection and flesh quality. *Journal of the Science of Food and Agriculture*, 82 pp 19-28.

70. Kestin, S., Wotton, S. Gregory, N. 1991 Effect of slaughter by removal from water on visual evoked activity in the brain and reflex movement of rainbow trout (*Oncorhynchus mykiss*). *Veterinary Record*, 128 pp 443-6.

71. Verheijen, F.J. and Flight W.F.G. 1997. Decapitation and brining: experimental tests show that after these commercial methods for slaughtering eel *Anguilla anguilla (L.)*, death is not instantaneous. *Aquaculture Research*, 28 pp 361-366.

72. Van de Vis H., Kestin S., Robb, D., Oehlenschlager, J., Lambooij, B., Munkner, W., Kuhlmann, H., Kloosterboer, K., Tejada, M., Huidobro, A., Ottera, H., Roth, B., Sørensen, N.K., Akse, L., Byrne, H. and Nesvadba, P. 2003. Is humane slaughter of fish possible for industry? *Aquaculture Research*, 34 pp 211–220.

73. Yue, S. 2008. "The Welfare of Farmed Fish at Slaughter" (2008). HSUS Reports 3. http://animalstudiesrepository.org/hsus_reps_impacts_on_animals/3.

74. European Commission. 2006. *Welfare of farmed fish: Common practices during transport and slaughter. Final Report*.

75. Rahmanifarah, K., Shabanpour, B. and Sattari, A. 2011. Effects of clove oil on behavior and flesh quality of Common Carp (*Cyprinus carpio L.*) in comparison with pre-slaughter CO2 stunning, chilling and asphyxia. *Turkish Journal of Fisheries and Aquatic Sciences*, 11 pp 135-143.

76. Marx, H., Brunner, B. and Weinzierl, W., 1997. Methods of stunning freshwater fish: impact on meat quality and aspects of animal welfare. *Zeitschrift für Lebensmittel und Untersuchung Forschning A*, 204 pp 282-286.

77. Roth, B., Moeller, D., Veland, J.O., Imsland, A. and Slinde, E., 2002. The effect of stunning methods on *rigor mortis* and texture properties of Atlantic salmon (*Salmo salar*). *Journal of Food Science*, 67 pp 1462-1466.

78. Robb, D.H.F. and Kestin, S.C. 2002. Methods used to kill fish: field observations and literature reviewed. *Animal Welfare*, 11 pp 269–282.

79. Erikson, U., Hultmann, L. and Steen, J.E. 2006. Live chilling of Atlantic salmon (*Salmo salar*) combined with mild carbon dioxide anaesthesia: I. Establishing a method for large-scale processing of farmed fish. *Aquaculture*, 252 pp 183-198.

80. Yue, S. 2008. "The Welfare of Farmed Fish at Slaughter" (2008). HSUS Reports 3. http://animalstudiesrepository.org/hsus_reps_impacts_on_animals/3.

81. Kestin, S., Wotton, S. and Adams, S. 1995. The effect of carbon dioxide, concussion or electrical stunning of rainbow trout (Oncorhynchus mykiss) on fish welfare. Abstract of poster. Aquaculture Europe '95, Trondheim, Norway, 9th - 12th August 1995. *European Aquaculture Society*, Special Publication 23, 380.

82. https://www.ekofishgroup.nl/nl/

83. http://humaneharvest.com/

84. http://www.pescadeatun.com/efectos_navales.asp

85. EFSA. 2009. Scientific Opinion of the Panel on Animal Health and Welfare on a request from the European Commission on species-specific welfare aspects of the main systems of stunning and killing of farmed rainbow trout. *EFSA Journal*, 1013 pp 1–55.

86. EFSA. 2004. Opinion of the Scientific Panel on Animal Health and Welfare on a request from the Commission related to welfare aspects of the main systems of stunning and killing the main commercial species of animals, The *EFSA Journal*, 45 pp 1-29.

87. Lambooij, E., Grimsbø, E., van de Vis, H.,Reimert, H., Nortvedt, R. and Roth, B. 2010. Percussion and electrical stunning of Atlantic salmon (Salmo salar) after dewatering and subsequent effect on brain and heart activities. *Aquaculture*, 300 pp 107-112.

88. Roth, B., Imsland, A., Gunnarson, S., Foss, A. and Schelvis-Smit, R. 2007. Slaughter quality and rigor contraction in farmed turbot (Scophthalmus maximus); a comparison between different stunning methods. *Aquaculture*, 272 pp 754-761.

89. Lambooij, E., Grimsbø, E., van de Vis, H.,Reimert, H., Nortvedt, R. and Roth, B. 2010. Percussion and electrical stunning of Atlantic salmon (Salmo salar) after dewatering and subsequent effect on brain and heart activities. *Aquaculture*, 300 pp 107-112.

90. Van de Vis, H., Kestin, S., Robb, D., Oehlenschlager, J., Lambooij, B., Munkner, W., Kuhlmann, H., Kloosterboer, K., Tejada, M., Huidobro, A., Ottera, H., Roth, B., Sørensen, N.K., Akse, L., Byrne, H., and Nesvadba P. 2003 Is humane slaughter of fish possible for industry? *Aquaculture Research*, 34 pp 211–220.

91. Roth, B., Imsland, A., Gunnarson, S., Foss, A. and Schelvis-Smit, R. 2007. Slaughter quality and rigor contraction in farmed turbot (Scophthalmus maximus); a comparison between different stunning methods. *Aquaculture*, 272 pp 754-761.

92. Lambooij, E., Grimsbø, E., van de Vis, H.,Reimert, H., Nortvedt, R. and Roth, B. 2010. Percussion and electrical stunning of Atlantic salmon (*Salmo salar*) after dewatering and subsequent effect on brain and heart activities. *Aquaculture,* 300 pp 107-112.

93. Van de Vis, H., Kestin, S., Robb, D., Oehlenschlager, J., Lambooij, B., Munkner, W., Kuhlmann, H., Kloosterboer, K., Tejada, M., Huidobro, A., Ottera, H., Roth, B., Sørensen, N.K., Akse, L., Byrne, H., and Nesvadba P. 2003 Is humane slaughter of fish possible for industry? *Aquaculture Research*, 34 pp 211–220.

94. EFSA. 2004. Opinion of the Scientific Panel on Animal Health and Welfare on a request from the Commission related to welfare aspects of the main systems of stunning and killing the main commercial species of animals, *The EFSA Journal*, 45 pp 1-29.

95. EFSA. 2004. Opinion of the Scientific Panel on Animal Health and Welfare on a request from the Commission related to welfare aspects of the main systems of stunning and killing the main commercial species of animals, *The EFSA Journal*, 45 pp 1-29.

96. EFSA. 2004. Opinion of the Scientific Panel on Animal Health and Welfare on a request from the Commission related to welfare aspects of the main systems of stunning and killing the main commercial species of animals, *The EFSA Journal*, 45 pp 1-29.

97. Poli, B., Parisi, G., Scappini, F. and Zampacavallo, G. 2005. Fish welfare quality as affected by pre-slaughter and slaughter management. *Aquaculture International*, 13 pp 29-49.

98. EFSA. 2004. Opinion of the Scientific Panel on Animal Health and Welfare on a request from the Commission related to welfare aspects of the main systems of stunning and killing the main commercial species of animals, *The EFSA Journal*, 45 pp 1-29.

99. Lambooij, E,. van de Vis, H., Kloosterboer, R.J. and Gerritzen, M. 2002. Neural, physiological and behavioural observations after head-only electrical and captive needle stunning of African catfish (*Clarias gariepinus*). In: International Congress of Meat Science and Technology: ICoMST, Rome, 2002.

100. Van de Vis, H., Kestin, S., Robb, D., Oehlenschlager, J., Lambooij, B., Munkner, W., Kuhlmann, H., Kloosterboer, K., Tejada, M., Huidobro, A., Ottera, H., Roth, B., Sørensen, N.K., Akse, L., Byrne, H.,and Nesvadba P. 2003 Is humane slaughter of fish possible for industry? *Aquaculture Research*, 34 pp 211–220.

101. Lambooij, E., van de Vis, H., Kloosterboer, R.J. and Gerritzen, M. 2002. Neural, physiological and behavioural observations after head-only electrical and captive needle stunning of African catfish (Clarias gariepinus). In: International Congress of Meat Science and Technology: ICoMST, Rome, 2002.

102. Robb, D.H.F. and Kestin, S.C. 2002. Methods used to kill fish: field observations and literature reviewed. *Animal Welfare* 11, 269-282.

103. Robb, D.H.F. and Kestin, S.C. 2002. Methods used to kill fish: field observations and literature reviewed. *Animal Welfare* 11, 269-282.

104. FAO. 2018. *The State of the World Fisheries and Agriculture 2018: Meeting the sustainable development goals.* p 40.

105. FAO. 2011. Legislative and Regulatory Options for Animal Welfare.

106. Campana, S.E., Joyce, W. and Manning, M.J. 2009. Bycatch and discard mortality in commercially caught blue sharks Prionace glauca assessed using archival satellite pop-up tags. *Marine Ecology Progress Series,* 387 pp 241–253.

107. Enever, R., Catchpole, T.L., Ellis, J.R. and Grant, A. 2009. The survival of skates (Rajidae) caught by demersal trawlers fishing in UK waters. *Fisheries Research*, 97 pp 72-76.

108. Milliken, H., Farrington, M., Rudolph, T. and Sanderson, M. 2009. Survival of discarded sublegal Atlantic cod in the Northwest Atlantic demersal longline fishery. *North American Journal of Fisheries Management*, 29 pp 985-995.

109. Cooke, S.J. and Wilde, G.R. 2007. *The fate of fish released by recreational anglers. In Kennelly, S. (Ed) By-catch Reduction in the World's Fisheries*. Springer. pp 181-234.

110. Wilson, S.M., Raby, G.D., Burnett, N.J., Hinch, S.G., and Cooke, S.J. 2014. Looking beyond the mortality of bycatch: sublethal effects of incidental capture on marine animals. *Biological Conservation*, 171 pp 61-72.

111. Patterson, L., Dick, J. T. A., Elwood, R. W. 2009. Claw removal and feeding ability in the edible crab, Cancer pagarus: implications for fishery practice. *Applied Animal Behaviour Science*, 116 pp 302-305.

112. Davis, G.E., Baughman, D.S., Chapman, J.D., MacArthur, D., Pierce, A.C. 1978. *Mortality associated with declawing stone crabs, Menippe mercenaria*. US National Park Service. Report T-522.

113. Davis, G.E., Baughman, D.S., Chapman, J.D., MacArthur, D., Pierce, A.C. 1978. *Mortality associated with declawing stone crabs, Menippe mercenaria*. US National Park Service. Report T-522.

114. McCambridge, C., Dick, J.T.A. and Elwood, R.W. 2016 Effects of autonomy compared to manual declawing on contests between males for females in the edible crab Cancer pagarus: Implications for fishery practice and animal welfare. *Journal of Shellfish Research*, 35 pp 1037-1044.

115. Humane Society International; Europe. 2013. *Shark finning and the European Union*.

116. Global Ghost Gear Initiative (GGGI) 2018. *Annual Report*. 48pp. https://static1.squarespace.com/static/5b987b8689c172e29293593f/t/5d0aada97196de000156ade8/1560980929408/LO-RES2.GGGI+annual+review.2018.spreads.pdf

117. Global Ghost Gear Initiative (GGGI) 2020, https://www.ghostgear.org/

118. Regulation No 17127055. 2018. Government of the Netherlands.

119. New Zealand Ministry for Primary Industries. 2018. Code of Welfare for Commercial Slaughter.

120. Regulation (EU) No 1380/2013 Common Fisheries Policy

121. Regulation (EU) No 1380/2013 Common Fisheries Policy

122. https://ec.europa.eu/fisheries/cfp/fishing_rules/discards_en

123. Regulation (EU) 2019/1241 Technical Measures

124. Council Regulation (EC) No 1185/2003 on the removal of fins of sharks on board vessels, as amended by Regulation (EU) No 605/2013.

125. https://neweconomics.org/2020/03/landing-the-blame-overfishing-in-the-northeast-atlantic-2020

126. https://oceana.org/blog/overfishing-and-pollution-have-trashed-mediterranean

127. https://ec.europa.eu/fisheries/cfp/fishing_rules/multi_annual_plans_en

128. Regulation (EU) 2019/1241 Technical Measures

129. https://www.efca.europa.eu/en/content/pressroom/evaluation-suggests-non-compliance-landing-obligations-certain-fisheries-north-sea

130. https://www.clientearth.org/press/groups-call-on-european-commission-to-take-legal-action-against-15-governments-over-huge-number-of-whale-and-dolphin-deaths/

131. http://mediterranean.panda.org/?uNewsID=338230

132. https://www.europarl.europa.eu/RegData/etudes/STUD/2015/540357/IPOL_STU(2015)540357_EN.pdf

133. WWF, (2018), Evaluating Europe's Course to Sustainable Fisheries by 2020

134. FishSec (2018), Too Many Vessels Chase Too Few Fish - Is EU fishing overcapacity really being reduced?

135. https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=41459

Eurogroup for Animals
Rue Ducale 29 – 1000 Brussels
Tel: +32 (0)2 740 08 20
info@eurogroupforanimals.org

eurogroupforanimals.org
Twitter @Act4AnimalsEU

Facebook @eurogroupforanimals
LinkedIn @eurogroup-for-animals