Routledge Handbook of Animal Welfare

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Commercial fisheries

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Introduction

Worldwide, approximately one trillion wild fish are captured every year, outnumbering any farmed animal. Table 17.1 illustrates that numbers of wild-caught fish far exceed those of the most popularly produced species slaughtered for meat – poultry and farmed fish (fishcount.org.uk, 2016; Food and Agriculture Organization of the United Nations, 2021). In the past, the capacity of fish to experience pain and suffering has been overlooked but there is now extensive scientific evidence that finfish are sentient (capable of experiencing pain and distress as well as positive emotions; e.g. see EFSA, 2009a). Public concern and consumer awareness about fish have traditionally been less than for terrestrial farmed species. However, recent research across Europe (Eurogroup for Animals/Compassion in World Farming, 2018) showed that a majority of consumers understand fish are sentient, think their welfare should be better protected, and want to use welfare as a guide in their purchasing choices. In this survey, 89% of people said they believe that humane slaughter is important or essential for good fish welfare.

Compared to farmed fish, those in the wild may enjoy the majority of their lives in relatively natural conditions but, by contrast, the end of life is commonly extremely unpleasant and often prolonged. A variety of methods are used to extract fish from water, each of which has associated threats to their welfare (described in Table 17.2). Outlined in this chapter are the many potential problems that can befall fish during the period between initial contact with fishing gear, through catching, handling, and finally death. These welfare issues can be quite different from those associated with fish farming. In particular, the vast majority of wild-caught fish are killed without any effective means of pre-slaughter stunning and are thus fully conscious immediately before their death.

The situation is not without hope, however. The chapter incorporates recommendations for improving the welfare of wild-caught fish, covering fishing methods, handling, stunning and slaughter, and concludes that following these recommendations would result in significant mitigation of many current issues.

Hazards to fish welfare during capture

Capture of fish and landing, during which they are brought onboard the fishing vessel or onto land, can involve multiple different threats to fish welfare, which are summarised below.
Duration of capture

The time between first contact with fishing gear and hauling onboard a vessel or onto land can last from minutes to several hours. Capture involves physiological changes, forcing 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 a combination of events such as crowding, injury, hypoxia, or exhaustion (Chopin et al., 1996). The longer the capture process, the more risk of undesirable effects, and the higher the levels of physiological distress.

Crowding density

The presence of a high density of fish in a given space during capture (crowding) forces fish into direct physical contact with each other and/or with fishing gear, potentially resulting in injury, asphyxiation, and elevated stress levels (Raby et al., 2015). It can lead to hypoxia if respiration is restricted either because the operculum (the bony structure protecting the gills) cannot move and/or due to depletion of oxygen in the water (Raby et al., 2015). Sea bass and sea bream that had been overcrowded displayed vigorous movements for several minutes before death, suggesting high levels of stress, and further increasing oxygen needs due to their vigorous movements (Robb and Kestin, 2002). Negative consequences of overcrowding have been reported in lingcod, sablefish, walleye pollock, Pacific halibut, sardines, and salmon.

Physical injuries

Some physical injuries to fish are intentional, such as hook and line injuries, and capture can also cause unintentional injuries (Raby et al., 2015) including scale loss, fin damage, dermal lesions, haemorrhages, damage to gills and eyes, and puncture wounds. These injuries are caused by excessive crowding or by interaction with fishing gear, the vessel, or its crew. Fish skin has pain receptors (Sneddon et al., 2003) and nerve fibres which means that injuries hurt fish. Epidermal injuries can further compromise welfare by disrupting osmotic balance or increasing vulnerability to infection (Noble et al., 2018).

Most commonly, lesions occur on a fish’s dorsal surface and flanks, but deeper lesions can penetrate to the ribs or internal organs (Bottari et al., 2003). Trauma to gills can profoundly affect both health and welfare (Noble et al., 2011). In fish that were captured and

Table 17.1  Number of animals slaughtered every year globally for meat

<table>
<thead>
<tr>
<th>Species or animal group</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish</td>
<td>Wild: at least 787 billion (up to 2.3 trillion)</td>
</tr>
<tr>
<td></td>
<td>Farmed: at least 51 billion (up to 167 billion)</td>
</tr>
<tr>
<td>Chickens and other poultry</td>
<td>86.5 billion</td>
</tr>
<tr>
<td>Pigs</td>
<td>2.2 billion</td>
</tr>
<tr>
<td>Rabbits</td>
<td>1.5 billion</td>
</tr>
<tr>
<td>Sheep and goats</td>
<td>1.3 billion</td>
</tr>
<tr>
<td>Cattle</td>
<td>340 million</td>
</tr>
</tbody>
</table>

Source: adapted from fishcount.org.uk (2016); Food and Agriculture Organization of the United Nations (2021); Waley et al. (2021).
### Table 17.2 Fishing methods used in EEA fisheries, their target species, and impacts on fish welfare

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Target species</th>
<th>Impact on fish welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Trawling</td>
<td></td>
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</tr>
<tr>
<td>Pelagic or mid-water trawl</td>
<td>- Trawl net towed from vessel's bow or stern in mid-water</td>
<td>- Generally a single pelagic species (e.g. mackerel, herring) with small bycatch (e.g. whiting, bass)</td>
<td>- Exhaustion, injury, asphyxiation, and crushing during towing and hauling</td>
</tr>
<tr>
<td></td>
<td>- Tow times vary from a few minutes to a few hours depending on density of target species and size and power of vessel</td>
<td></td>
<td>- Barotrauma and thermal shock associated with greater depths</td>
</tr>
<tr>
<td>Beam trawl</td>
<td>- Trawl net towed on seabed, held open by a wooden or steel beam</td>
<td>- Mainly flatfish and demersal species (e.g. plaice, sole, cod)</td>
<td>- Exhaustion, injury, asphyxiation and crushing during towing and hauling</td>
</tr>
<tr>
<td></td>
<td>- Beam towed behind vessel and tow times vary from a few minutes to a few hours depending on density of target species and size and power of vessel</td>
<td></td>
<td>- Barotrauma and thermal shock associated with greater depths</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Large catches of non-target species are common</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Can have a significant impact on seabed fauna</td>
</tr>
<tr>
<td>Bottom trawl</td>
<td>- Large trawl net towed from vessel’s bow or stern, on or near seabed, held open by pair of trawl doors</td>
<td>- Demersal species (e.g. cod, sole, plaice, rays, anglerfish, bass, whiting)</td>
<td>- As for beam trawl</td>
</tr>
<tr>
<td>Dredge</td>
<td>- Rigid structure, consisting of a frame and toothed bar, with a collecting bag, towed along seabed to target shellfish</td>
<td>- Shellfish, particularly scallops</td>
<td>- Shellfish come to the surface alive as this is often a requirement for sale</td>
</tr>
<tr>
<td></td>
<td>- One or more dredges (up to 22 per side) towed on either side of vessel</td>
<td></td>
<td>- Non-target species may be injured or suffocated</td>
</tr>
<tr>
<td>2. Seine nets</td>
<td>- Large net used to surround a shoal of fish. Bottom of the net is then drawn together to enclose them</td>
<td>- Pelagic species for Danish seine and demersal species for Scottish seine</td>
<td>- Crowding and then crushing when fish are lifted onto the deck</td>
</tr>
<tr>
<td></td>
<td>- Headrope carrying floats is used to keep the net on the surface</td>
<td></td>
<td>- Large species may gaffed</td>
</tr>
<tr>
<td></td>
<td>- Net has rings along its lower edge through which a cable is passed, forming a bowl-like shape and preventing fish from escaping downwards</td>
<td></td>
<td>- Barotrauma and thermal shock associated with greater depths</td>
</tr>
</tbody>
</table>

(Continued)
### Table 17.2 (Continued)

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Target species</th>
<th>Impact on fish welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Hanging nets</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Drift nets</td>
<td>Net suspended from buoys in the water and drifts anywhere between seabed and surface</td>
<td>Mainly pelagic species (e.g. mackerel, herring) but can be set to drift along the seabed in sandy areas to catch prawns</td>
<td>Suffocation, injury, exhaustion, depredation, Barotrauma and thermal shock associated with greater depths</td>
</tr>
<tr>
<td></td>
<td>Nets are either attached at one end to the vessel or left to drift and be recovered later</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Fish become entangled when the mesh is caught behind their gills</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soak time is generally a few hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed and set nets</td>
<td>Net suspended in the water, either hanging from buoys to drift or fixed to anchored poles, anywhere between seabed and surface</td>
<td>Demersal species (e.g. cod, hake, flatfish, monkfish, turbot, rays)</td>
<td>As for drift nets</td>
</tr>
<tr>
<td></td>
<td>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</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fish become entangled when the mesh is caught behind their gills</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soak times vary from one tidal cycle to several days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Hook and line</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longline</td>
<td>Left anchored or drifting with numerous baited hooks</td>
<td>Can be rigged for demersal or pelagic species</td>
<td>Fish may swallow the bait (deep hooking); being unhooked can result in gut and throat damage</td>
</tr>
<tr>
<td></td>
<td>The main line is made of light rope or heavy nylon monofilament and may be many kilometres long</td>
<td></td>
<td>Injuries from use of gaff hooks to bring fish onboard</td>
</tr>
<tr>
<td>Pole and line</td>
<td>Single or multiple hooked rod and reel set-ups using live or dead bait, or artificial lures and feathers</td>
<td>Demersal species (e.g. mackerel, bass, cod, pollock)</td>
<td>Fish may swallow bait and remain hooked underwater for several hours or days</td>
</tr>
<tr>
<td></td>
<td>Can also include trolling (towing baited lines behind a moving vessel)</td>
<td></td>
<td>Live bait is held in small containers until suddenly introduced to a new water environment and to a feeding frenzy</td>
</tr>
<tr>
<td></td>
<td>In handlining, trolling and jigging the fisher is in physical contact with the line and reacts when a fish bites the bait</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
then released, gill trauma increased post-release mortality in Atlantic salmon (Mäkinen et al., 2000) and southern flounder (Smith and Scharf, 2011). A review of 85 published articles (Veldhuizen et al., 2018) found that scale, skin and fin injuries occurred more frequently in trawls, seines, gill nets, and traps than in capture involving hooks. Pressure injuries occurred with all gear types and mortality was higher in trawls and seines than with gill nets, hooks, or traps.

Some fishing gear aims to cause injury to fish by piercing parts of the body with a hook. Hooking occurs mostly in the jaw (Davis, 2002), tongue, gills, or eye but escaped fish have also been found with hooks in their oesophagus and stomach. Fish that are injured before being discarded are more likely to die, due to damage to skin, gill and muscle tissues, or secondary infections (Kojima et al., 2004). Fin damage may have a negative effect on movement and postural control, potentially affecting future welfare and survival.

**Depredation**

Many fishing methods involve long periods of constraint within fishing gear. As a result, fish can be incapable of any escape or defensive reaction, and so are vulnerable to predation. Other fish, marine mammals and seabirds specifically target fishing activities where it is likely that captured fish will be easy prey.

**Thermal shock**

Fish can be exposed to abrupt temperature increases during capture as water temperatures change rapidly at different depths. Exposure to warmer water increased heart rate and mortality in lingcod (Olla et al., 1997), and elevated water temperatures in sablefish led to increased mortality within 48 hours (Davis et al., 2001). Removing fish from water in freezing temperatures can cause immediate damage to wet soft tissues such as gills and eyes. Acute physiological responses occur when fish are brought into ambient air temperatures and then exposed to low temperatures as part of a chilling process or freezing medium.

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**Table 17.2 (Continued)**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Target species</th>
<th>Impact on fish welfare</th>
</tr>
</thead>
</table>
| 5. Pots and traps | - 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  
- Can be set singly on the seabed or in strings  
- 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 |

Source: adapted from Waley et al. (2021).
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Barotrauma

Fishing at depth can lead to decompression injuries as fish are hauled to the surface. Expanding gas can accumulate inside the organs, resulting in pressure-related injuries known as barotrauma, which can present as internal organ haemorrhage, organ distension, and organ rupture (Pribyl et al., 2011). Rupture of the swim bladder causes gases to 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 and air trapped behind the cornea or under the skin (Mason and Lowe, 2008).

Exhaustion

Response to exhaustive exercise varies among fish 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 (Lindsay et al., 2004). When the extent of exercise stress is so great that consequent physiological stress response overwhelms the fish’s ability to cope, metabolic acidosis occurs which may lead to death. Swimming exhaustion and fatigue deaths have 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 bodily organs. Some fish can obtain oxygen from air, either to supplement gill respiration or because they are obligate air breathers that need to access the surface to breathe. However, the gill lamellae can only function 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 (CO₂) 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 main cause of asphyxiation in capture fisheries is air exposure (Ferguson and Tufts, 1992), but it also takes place when respiration is restricted, either because the operculum cannot move or due to water oxygen depletion. All of these causes have the same end result of acute anoxia, the severe loss of oxygen supply (Raby et al., 2015). Acute asphyxia results in an irreversible loss of consciousness and is considered to be one of the most stressful killing methods (Bagni et al., 2007).

Hazards to fish welfare after capture

After fish have been captured, they are usually subjected to handling followed by slaughter using one of a variety of methods. Many fish die before being brought onboard 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. Welfare hazards associated with handling and slaughter are described below.
Handling

Handling fish in air is inherently stressful, and additionally so if the fish have been overcrowded, crushed, decompressed, or exhausted. Handling times can vary considerably with different fishing methods and vessel design and the longer the fish are handled, the greater the threat to their welfare (Davis, 2002). 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. A study of Pacific salmon showed that lowest mortality was caused by a maximum handling time of ten seconds in air and three minutes in water (Patterson et al., 2016).

The response to handling extends the suite of acute stress response reactions initiated during capture, and this complex feedback is species-specific and dependent on the duration and nature of the stressor. During this stage, additional physiological disturbances as a result of exhaustive exercise may cause death. The effects of handling are magnified by the fact that it occurs in conjunction with air exposure and temperature increase.

Hauling onboard

Lifting 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 hypoxia. 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.

When fish (especially smaller ones) are entangled in nets, fishers tend to pull them from the net rather than pushing them through, which causes further injuries and observable stress reactions (Veneranta et al., 2017). Fine twines and monofilament nets cause greater injury on de-netting. For seine fishing, coho salmon removed using traditional ramping (hauling the net onboard) had higher mortality and displayed higher stress than those removed by brailing (removing fish from the net still in the water; Farrell et al., 2000).

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 to pumping and external injuries have been observed, but properly designed and operated fish pumps have the potential to be less stressful than alternative methods for hauling fish.

Hauling larger fish usually requires extra equipment and physical intervention. Common tools used to control large fish are nets, or a gaff consisting of a handle with a sharply pointed hook. The fisher places the point of the gaff deep inside the fish to support its weight when it is brought out of water. It is usual to gaff the fish in the gill operculum which allows it to be hauled and controlled without damaging the flesh, but this practice causes additional severe injuries including significant bleeding and may lead to exsanguination if death does not intervene (Davie and Kopf, 2006).

Onboard sorting

De-hooking inflicts extra injury on the fish. Hook removal methods vary from careful, manual removal to de-hooking devices or automated hook removal. Studies evaluating different hook removal methods found that the most common reason to consider halibut bycatch in poor condition, leading to greater mortality, was injuries sustained while being removed from the hook (Kaimmer and Trumble, 1998).
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Sorting fish on deck can have a cumulative negative impact on their welfare and can cause physical damage due to throwing or movement using gaffs and picks, fish falling on the deck, and from 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 air and increased temperatures.

Slaughter

In many cases, no specific killing method is used and death results incidentally during capture and processing. Most specific slaughter methods are not preceded by stunning, and therefore can be described as inhumane. Several methods of more humane fish slaughter also exist, whereby killing is preceded by stunning that renders fish unconscious and insensible to pain, or the stunning method also causes fish to die.

Effectiveness of the various methods 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. 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 (2019) and European Food Safety Authority give some indicators for effective stunning of farmed fish, such as the immediate loss of body and respiratory movements, 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 Kestin et al. (2002) who concluded that, in a range of species, behaviours such as swimming, response to stimuli like handling, and clinical reflexes – like eye rolling or breathing – indicate a state of awareness and the capacity to experience suffering.

Asphyxiation in air

Wild fish commonly undergo asphyxiation onboard until they die. The time taken to die from asphyxiation depends on the species, the exposure time, and the temperature. In general, when exposed to higher temperatures, most fish die more quickly due to increased metabolic rates and higher oxygen demand (Robb and Kestin, 2002). This is not a quick process: sea bream left to die in air lost self-initiated responses after four minutes, took around seven minutes to lose response to stimuli, and 14 minutes to cease reflexes (Kestin et al., 2002).

Concentrations of stress indicator variables such as plasma cortisol and glucose in Senegal sole after asphyxiation were significantly higher than resting values (Ribas et al., 2007). 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 (Robb and Kestin, 2002; Ribas et al., 2007; EFSA, 2009a).

Live chilling and death in ice slurry

Hypothermia is used to kill some fish species. They 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 them by asphyxia (Tanck et al., 2000; EFSA, 2009a). Initially, carp exposed to chilled water appeared comfortable and exhibited normal swimming
activity; however, abnormal behaviours suggesting aversion followed (Rahmanifarah et al., 2011). The hypothermia effect on sea bream resulted in immobilisation before unconsciousness (van de Vis et al., 2003).

Cold shock causes progressive muscle paralysis which makes changes in behaviour difficult to assess. Sublethal physiological and behavioural consequences of cold shock stress include severe disruption of the fish's metabolic rate, movements, and behaviour, and as oxygen consumption is also impaired, it succumbs to hypoxia and becomes immobilised (Hovda and Linley, 2000). Live chilling before slaughter resulted in significantly increased blood levels of cortisol and lactate, indicating pre-slaughter stress. In Atlantic salmon, the muscle pH also fell, indicating that metabolic changes and consequent acidosis were occurring (Skjervold et al., 2001).

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.

Sedation and loss of consciousness due to chilling is reversible if the fish is transferred back into its normal water conditions. Studies (Skjervold et al., 2001; Lambooij et al., 2006, Roth et al., 2007) have demonstrated chilled fish showing signs of consciousness 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.

Exsanguination

During death by exsanguination, blood is drained by cutting the major blood vessels. Methods of bleeding vary between species and can involve a throat cut, gill cut, or pectoral cut. All procedures consist of inserting a sharp knife and severing major blood vessels and the gills are often cut because they are heavily vascularised and readily accessible due to their external bodily location. Exsanguination often takes place without stunning and in some cases, non-stunned fish may also be subject to direct evisceration (removal of their internal organs). Following cutting of the blood vessels, fish struggle vigorously, initially due to being restrained, handled, and exposed to air. Tail flapping and head shaking were observed to last for about 30 seconds after gill cutting in salmon. VERs are present for up to seven minutes (van de Vis et al., 2003). 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. Turbot took over 15 minutes to lose responses to stimuli (Morzel et al., 2002), and struggled and experienced the highest stress levels at slaughter, taking longer than an hour to cease ventilation movements or muscle activity (Ruff et al., 2002).

 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 cause variation in the bleeding and onset of unconsciousness, as determined in Atlantic salmon and turbot (Morzel et al., 2002). Differences in temperature also affect the time to lose brain function.

Decapitation

Decapitation consists of the complete separation of the head from the rest of the body. In the EU it is typically used for eels but it may be used elsewhere for larger fish. Loss of conscious-
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Fish can be rendered insensible by replacing oxygen with carbon dioxide. This is a relatively common method used in aquaculture where it has been mechanised and applied to fish on a batch basis. By contrast, it does not appear to be currently used in wild capture fisheries. Saturating water with CO₂ creates an acidic and oxygen-deficient environment that places fish in a narcotic state (EFSA, 2004). CO₂ immobilises the fish; however, there can be a delayed loss of consciousness which may result in them being slaughtered before becoming insensible. If used for prolonged periods, this technique can potentially cause death by acute hypoxia.

In response to CO₂ 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, strenuous activity was observed with fish keeping their mouths and gill covers closed, followed by collisions due to vigorous swimming (Rahmanifarah et al., 2011). Some fish, such as eels and sturgeon, appear to be more resistant to CO₂ saturation and were reported to show escape and aversive behaviour for more than an hour. Activity during exposure to CO₂ can lead to scale diffusion, increased mucus secretion, and gill haemorrhaging (Marx et al., 1997; Robb and Kestin, 2002; Roth et al., 2002).

The combined effects of live chilling and moderate CO₂ narcosis have been tested in Atlantic salmon and reported to be superior to narcosis alone (Erikson et al., 2006). 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 CO₂ saturated water for up to ten minutes before slaughter, which in effect means that fish are exsanguinated or gutted while still conscious (Yue, 2008). As it is also probable that CO₂ causes acute discomfort or pain, it is not considered an acceptable method of stunning fish before slaughter, either with or without simultaneous chilling.

Electrical stunning

Electricity can be used to render fish insensible by electrical stunning or kill them by electrocution. The principle of electrical stunning is to pass sufficient current through the brain, stimulating higher nerve centres to cause their dysfunction. This may be conducted dry, where fish are passed over an electrified surface out of water, semi-dry, where an electrical current is applied directly into the fish, or 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 a humane killing procedure for some species of farmed fish (World Organisation for Animal Health, 2019), 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 involving seizures. Behaviour of fish during these phases varies between species, and increased intensity and duration of application can cause physical injuries. 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 application is prolonged. If fish are not killed by the electrical process, they can recover consciousness gradually. Various studies have led to the formulation of some
minimum requirements for effective electrical stunning (Kestin et al., 1995). Insufficient current, voltage, or duration can lead to immobilisation 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 via a club, hammer, or semi-automatic percussive stunning device (EFSA, 2009b). When a heavy blow is delivered correctly over the brain, cranial pressure massively increases causing disruption of normal electrical activity. Percussive stunning in Atlantic salmon was found to cause cerebral concussion leading to seizures and instant reduction or loss of consciousness. Induced brain haemorrhage may then impair the blood flow, ultimately leading to death (EFSA, 2004; Lambooij et al., 2010).

However, if the blow is inaccurate or not forceful enough, fish do not lose consciousness but may not display normal behaviours, can become immobile without losing consciousness, or sustain injuries. For some species, increasing percussive force to bring about instant insensibility also caused broken jaws and burst eyes (Roth et al., 2007). Other species such as sea bream are unsuited to percussive killing due to their anatomy (van de Vis et al., 2003). Percussive stunning also requires air exposure and individual handling of fish. In wild capture fisheries, this method could only be used for manual 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, also known as pithing. It requires individual handling and restraint of fish and can be done manually or by using a pneumatically operated pistol. It is most commonly used for larger fish such as tuna and salmon and, when spiked correctly, immediate brain death occurs (Poli et al., 2005). Perforation of the hindbrain produces an instant tonic reaction of a few flaps of the tail and minor muscle tremors 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 method originating in Japan, which follows spiking with insertion of a flexible pithing rod or wire along the spinal cord. Captive needle stunning involves pneumatically firing a needle into the brain, followed by injection of compressed air. In African catfish, inserting compressed air into 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 (Lambooij et al., 2002). If fish brains are small or the spike misses the target area, fish may not be effectively stunned and will suffer until death occurs.

**Additional welfare concerns related to commercial fishing**

In addition to procedures that directly involve fish being intentionally caught, commercial fishing is also associated with other activities that affect the welfare of fish and marine animals. Three of these are described in the following.

**Discards and bycatch**

Discards are the part of the catch that is returned to the sea, either dead or alive. Discarding may occur because fish are too small, or due to economic factors such as insufficient market demand, or due to fishing rules. Discards may include one or many species, and they can be thrown away on purpose, or fall through fishing gear by accident (FAO, 2011).
Discarding of live fish, which may be injured, carries a range of consequences for their survival and well-being. Releasing live unwanted caught fish can expose them to additional stress associated with onboard handling, air exposure and physical injuries. Some fish 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 (Campana et al., 2009).

Discarding of fish may therefore result in ‘hidden mortality’. Post-release mortality rates have been recorded for some species and some fishing methods – e.g. in skate caught with bottom trawlers, the overall short-term survival was 55% (Enever et al., 2009) 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% (Milliken et al., 2009) and their survival rate was affected by depth, temperature, and de-hooking.

Sea turtles may be caught as bycatch during bottom trawling for shrimp, and as they are air breathers they will drown if they are unable to return to the surface. Turtle excluder devices (TEDs), incorporating a grid within the trawl net to prevent larger animals passing to the back of the net, and an escape opening, can be used to reduce turtle bycatch. Debris from the water can reduce the efficiency of TEDs and larger turtles may be too big to fit through escape hatches. As TEDs can reduce the efficiency of a catch, fishers may circumvent them by tying the escape opening shut.

Mutilations

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, however larger crabs probably will not live long enough to regenerate their claws, which, together with newer knowledge about pain in crustaceans (e.g. Magee and Elwood, 2016), and the ethics of declawing, suggests the practice probably should not be carried out.

Claw removal can facilitate the storage and transport of crab meat, eliminate cannibalism within storage tanks, and make crabs easier to handle. In a study using commercial techniques, 47% of Florida stone crabs that had both claws removed died afterwards, as did 28% of single-claw amputees, and around 75% of these deaths occurred within 24 hours of declawing (Davis et al., 1978). Declawing affects the ability of a crab to feed, leads to lower levels of activity, and to difficulty in attracting mates (Davis et al., 1978; McCambridge et al., 2016).

Consumer demand for shark fins has led to the practice of removing the fins of live sharks (shark finning) and returning them to the ocean. 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 and will die, either by suffocation or being eaten by predators. In an attempt to prevent this practice, many countries have introduced legislation stating that, where sharks are fished, their fins must arrive back on land attached to their bodies. The ‘fins naturally attached’ policy bans shark finning by EU vessels (Humane Society International, 2013), and by late 2021, the UK was proposing introducing a ban on the import of detached shark fins and shark fin products (gov.uk, 2021).

Ghost fishing

Ghost fishing is a term applied to fishing gear (nets, traps or hook and line) that has been lost or discarded by fishers. Ghost gear is often made of plastic and other long-lasting materials (non-biodegradable gear is predicted to persist in the marine environment for up to 600 years; Global Ghost Gear Initiative, 2018). Ghost gear can continue to passively catch fish and other
marine life, so has an ongoing negative impact on animal welfare. It may inflict physical injury or cause asphyxiation or depredation, and predators attracted by the captured prey as well as other non-target species can become trapped. Ghost fishing is an unrecorded source of fish mortality and there are concerns regarding its impact on sustainability. The Global Ghost Gear Initiative (Global Ghost Gear Initiative, 2020), comprising representatives of industry, governments, and animal protection groups, collaborates to address the problem of ghost gear worldwide.

**Recommendations to mitigate welfare hazards**

**Fishing methods recommendations**

**Recommendations common across fishing methods**
- The capture period should be minimised, minimising the tow duration during trawling and trolling, the soak time for gill and trammel nets, the deployment and drying up time of seine nets, and the time between checking of pots;
- Training should be used to increase the skills and knowledge of fishers on using fishing equipment, and on proper handling and slaughter of fish;
- Suffering and injury to fish should be minimised. Methods, handling practices, and equipment should be designed and manufactured with this goal in mind;
- Softer materials and knotless net construction should be preferred in all nets;
- The capture depth, ascent rate during hauling and 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 to reduce injuries;
- Fish should be brought onboard using fish pumps instead of by hauling;
- Catches so large that the net funnels are overwhelmed and selectivity fails, and where compression in the cod end is excessive, should be avoided;
- Bottom trawling, and especially beam trawling, should be prohibited.

**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 onboard 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 and circle hooks (circular shaped hooks with a sharply curved back, found to do less damage than J-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.
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Recommendations for fish handling between capture and slaughter

- Time spent out of water between capture and slaughter should be minimised;
- Live fish should be handled gently and in water;
- Fish should be brought onboard using fish pumps instead of by hauling trawl nets or using brail nets. Where this is not possible, the number of fish in the brail net should be limited and 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 abrasion injury;
- Handling equipment and procedures should be organised to avoid throwing fish, moving them with gaffs or picks, fish falling on the deck, getting caught on equipment or 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, with the exception of the decapitation of stunned fish;
- Practices causing thermal shock to live, non-stunned fish should be eliminated;
- Fish species that are not used to captivity should not be held alive unless 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.

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. 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 or decapitation. With smaller fish, putting them quickly on ice will usually result in death before sensibility is recovered;
- Spiking is an immediate killing method that should be used with large fish, and with smaller fish that are handled individually.

Conclusions

It is clear that the practices used in the catching, processing, and killing of wild-caught fish lead to many threats to the welfare of the fish involved, as well as to other marine species. While it is not unusual for food production to involve compromises to animal welfare, most farmed animals, including fish, are routinely stunned before slaughter; however, stunning is used rarely in...
wild-caught fish and this lack of a procedure commonly agreed to minimise pain and suffering constitutes a major threat to their welfare. Additionally, killing methods range from relatively quick to much slower and more painful and fish routinely experience suffering during catching, handling, and processing.

It is possible to mitigate these welfare hazards, however, and following the recommendations above would facilitate significant improvements to the current situation. Several companies have successfully incorporated stunning into commercial fishing operations, demonstrating that this is both possible and practical. The Dutch flatfish trawling company Ekofish uses a conveyor belt and electric dry stunner onboard its vessels to render North Sea plaice, lemon sole, turbot, and brill unconscious within one second (Ekofish Group, 2021). The Alaska-based Blue North fishing company uses traditional hook-and-line fishery to catch cod singly via a ‘moon pool’ in the centre of the boat; fish are individually brought aboard directly from the water and stunned using a semi-dry automatic stunning table, immediately followed by manual bleeding (Humane Harvest Initiative, 2021).

Ultimately, to meet consumer demand for higher welfare fish products – and to continue to raise awareness of the importance and relevance of fish welfare – product labelling should include clear information that allows consumers to make welfare-based purchase decisions. Finally, a concerted effort is required from the fishery sector and regulators to implement meaningful improvements that will not only increase the welfare of fish, but also ensure issues related to fisheries management – such as bycatch and ghost fishing – are tackled in a comprehensive way.

References


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