Module 23
Welfare of Wild-Caught and Farmed Fish (Fish Welfare Part 1)

Lecture Notes

Slide 1:

This lecture was first developed for World Animal Protection in 2006 with extensive contributions from by Dr Larry Hammell of the Atlantic Veterinary College, Canada. It was revised by World Animal Protection scientific advisors in 2012 using updates provided by Dr Caroline Hewson.

Slide 2:

As public concern grows about the effects humans have on animal welfare, fish are becoming included. However, because they are at a much earlier point of domestication (farmed fish) and the large-scale industries are relatively new compared to agriculture, we have relatively less knowledge about fish welfare, but the potential to make fewer errors and false assumptions than has been the case in agriculture.

There are two lectures in this series that introduce you to the ethical and welfare issues relating to the human consumption of fish and invertebrate aquatic animals, and our use of ornamental fish as companions and wild fish for sport (recreational angling) and entertainment.

This module will teach you the basics of fish biology in relation to welfare, e.g. evidence for sentience and memory and the practical implications therein.

At the end of this lecture the student should be able to:

- recognise that fish comprise a large and diverse group of animals.
- understand the welfare implications of fish biology, including for sentience
- understand the welfare implications of the ways in which fish are managed for human food
- construct a general approach to assessing the welfare of fish
- identify welfare concerns in farmed fish.

The picture shows grouper in Malaysia.

Slide 3:

This module and the following one will examine welfare issues that arise in commercial fisheries, aquaculture (farmed fish and invertebrates) and in ornamental fish and recreational angling.

Slide 4:

We start with some statistics. Most of the world's fish consumption is in South-East Asia. However, concern in Europe and North America about eating red meat has contributed to an increase in the consumption of fish there too.

The fish we eat are derived from wild stocks (commercial fisheries and, to a much lesser degree, angling) or from farmed stocks (aquaculture). This slide shows the relative numbers of agricultural animals eaten globally each year, compared to the much greater number of fish killed. For example, you can see that there are approximately 57 billion (i.e. 57 thousand million) poultry killed for food each year.

It is difficult to estimate accurately the numbers of individual wild fish who are killed globally by the commercial fisheries. However, based on FAO data of the weight of wild fish caught globally in 2009, and assuming an average weight of between 280g and 5 kg, a report by Mood (2010) estimated that there may be upwards of 970 billion wild fish killed each year – perhaps as many as 2.7 trillion (2.7 million million). That includes those killed for food, and those killed for other uses – including feeding to farmed fish and other farmed animals. It is noteworthy that two of the main farmed fish species, salmon and trout, are carnivorous, and fishmeal derived from wild fish is a major part of their diet.

Please take a moment to read the figures on the slide.

Slide 5:

Note that fish comprise an old (in evolutionary terms) and very large group (c.f. the coelacanth – a 'living fossil'). Each species is adapted to a particular ecological niche and has its own species-typical behavioural, morphological and physiological traits. For example, fish range from Antarctic species living in water of 0°C to –1°C their entire lives, to tilapia identified in water of 30°C or more in Africa.

Today we shall consider only bony fish, not sharks and other cartilaginous fish.

Slide 6:

Examples include the salmonid group which live in temperate waters. They are a varied group that includes:

- Atlantic salmon, *Salmo salar*
- brown trout, *Salmo truttia*
- rainbow trout, *Oncorhynchus mykiss*
- Arctic charr, *Salvalinus alpinus* (niche market).

Salmon and rainbow trout are the most commonly farmed fish in Canada and northern Europe. Rainbow trout are indigenous to western North America but were moved everywhere in the world (including the European Union (EU), Mexico, Kenya, southern Asia, etc.) by anglers in 1870s. Farming of rainbow trout occurs in the EU, Chile, Eastern Canada (Newfoundland), etc.

Slide 7:

Cichlids live in tropical waters. The group includes tilapia and sea bream.

Farmed tilapia: these fish have been grown for food for a very long time. However, they have only been farmed intensively in the past 20–30 years, following technological improvements in water recirculation in hatcheries. Farmed tilapia production is rapidly expanding in many parts of the world.

Slide 8:

As you know, fish obtain oxygen from the water, through gills which are covered by opercula. The effect of the operculum is to create a ventilation pump. Carp can breathe air through their mouths.

However, for most fish, being out of water is extremely stressful because of the lack of oxygen. For this reason, World Organisation for Animal Health (OIE) guidelines state that fish should not be removed from water.

Moving on to stress generally, fish show physiological and behavioural responses to acute and chronic exposure to stressors.

Physiological stress response:

Fish have a hypothalamo-pituitary axis that mediates stress responses, and also involves the release of catecholamines from inter-renal tissue.

When sensory input is processed by the brain as a stressor, corticotrophin-releasing factor is secreted by the hypothalamus. This factor acts on the pituitary gland, causing corticotrophic hormone to be released. This in turn results in the secretion of cortisol from inter-renal tissue – fish do not have an adrenal gland *per se*.

The inter-renal tissue also secretes catecholamines when the sympathetic nervous system is activated.

Cortisol and catecholamines have similar physiological effects in fish as in mammals, with increased muscle activity, depletion of glycogen stores, and lactate increase due to anaerobic glycolysis.

Cortisol levels return to normal following brief exposure to stressors, but remain elevated if exposure is longer, and may take weeks to return to normal. Chronically elevated cortisol suppresses immunity and leads to increased infection with and death from fungal and bacterial disease.

Cortisol can be measured in the blood, but is affected by the stress of handling and taking blood; faecal cortisol provides a more stable measure and is useful for measuring chronic stress.

Glucose, lactate and opercular breathing rate are also measures of stress.

Behavioural stress responses of farmed fish to daily experiences are less well studied than physiological ones. They include:

- shoaling to escape predators
- hiding to escape predators or attack by conspecifics
- altered speed and direction of swimming.

As with mammals and birds, individual fish vary in both their level of cortisol response and behavioural responses to stress.

Slide 9:

There is growing acceptance that fish are sentient. This is reflected by the World Organisation for Animal Health, which represents 178 countries, having specific guidelines on humane handling, management and slaughter of farmed fish in their Aquatic Code.

Some individual countries also have strict standards of slaughter, reflecting fishes' sentience.

Not all scientists – and others – agree that fish are sentient, however. In particular, some emphasise that fish do not have a neocortex, a recent (in evolutionary terms) part of the cerebrum that (where it exists) is involved in cognitive processing. The neocortex is very highly developed in primates and is present in other mammals and birds.

However, neither that anatomical information nor even the presence of pain receptors is sufficient grounds for knowing whether an animal can have the conscious aversive experience of pain. This slide shows some criteria to consider when deciding whether fish can feel pain. The first is nociception: can fish perceive adverse stimuli?

Research on rainbow trout (Sneddon et al., 2003) showed that they have receptors on their face and head that respond to pressure, high temperatures (over 58°C) and noxious chemicals. These receptors serve as nociceptors, as well as mechanochemical and mechanothermal receptors, and they are the same type as exist in birds and mammals. The associated nerve fibres are in the trigeminal nerve and are myelinated A-delta fibres and unmyelinated C fibres, both of which are also involved in nociception in mammals and birds.

The next is: do they show protective behavioural responses to aversive stimuli?

When acetic acid or bee venom was injected into the lips of trout, they rubbed their lips on the tank, rocked, and took twice as long to resume eating as the control group (who had received a saline injection). The responses of the fish in these experiments were more than short-term reflex responses, and suggested that the fish knew which part of their body hurt and were seeking to relieve it.

Physiological responses included increases in respiration rate, faecal cortisol and dilated pupils.

Next is avoidance learning: research on different species of fish in the wild and in laboratories shows that they can learn, remember and show complex behaviours that are consistent with higher-order processing such as cognition (Yue et al., 2004). For example, rainbow trout learned to move into a different chamber to avoid a threat (a dip-net). The reward for that behaviour was escaping from the threat. Then, when the threat was preceded by a light, the light triggered fear, and the fish responded to the light by moving into a different chamber. When the fish were tested again with the light seven days later, they showed the same avoidance response, showing that they remembered the light's significance.

A further criterion is: can an animal make trade-offs between pain responses and other motivations such as hunger?

Hungry fish who were given a shock while they were feeding were less likely to stop feeding and avoid the shock than fish who were not hungry. This is consistent with fish being able to process varied sensory input (e.g. pain, the probability of more pain, not feeling full, the hormones associated with hunger, and the presence of food) and make decisions.

Slide 10:

The presence of nociceptors and absence of a neocortex are not sufficient criteria to decide whether or not fish can suffer. Neural processing is more important than anatomy *per se*, and behavioural measures are also important.

There are many species of fish, and more research is needed to help us understand the neurobiology and behaviour of different species and their likely sentience. However, based on the criteria we have covered, it seems reasonable to believe that fish are sentient.

Slide 11:

Now that you are familiar with the relevant biology of fish, we shall move on to consider the welfare of wild-caught fish.

Slide 12:

The name for fisheries that catch fish in the wild is *commercial fisheries*, as distinct from fish farms.

Some facts about commercial fisheries are summarised on the slide.

An important issue is that fish do not generally die humanely (i.e. without pain, and following loss of consciousness). Instead, they die during the processes of capture, removal from water, storage and processing, including gutting, filleting, chilling and freezing.

The picture shows a very crowded net being hauled on to a boat; it illustrates the physical trauma and lack of oxygen that wild-caught fish suffer, due to being out of water (picture © Digital Vision).

On the human side, fishers have high costs from fuel, boats, chilling gear to preserve fish for subsequent shipping, and transport, often internationally. They catch fish in large numbers – the picture on the slide shows a very small operation – and they need to process the fish immediately, so that the meat is fresh. This means the focus is on processing, not on the humane death of the animals.

However, the stress experienced by many wild-caught fish reduces their meat quality, and both could be improved by better fishing methods, which would also improve the prices that fishers get for their catch.

Slide 13:

Commercial fisheries take boats out to the sea or ocean, capture wild fish, and land or haul them in the boat.

This typically brings many fish on to the boat at once, and most die from lack of oxygen, although some may be slaughtered. Others may be discarded and returned to the sea, e.g. because they are the wrong size or species.

In addition, some fish may escape during the capture process. We shall now look at each of these stages, and how they affect the fish.

Slide 14:

First, capture. Broadly, two types of equipment or 'gear' are used to capture and land: nets and hooks:

- nets may be trawled by a moving boat, or may be set in one place
- hooks are attached to lines that are either trawled or static
- both methods can create very adverse experiences for fish, depending on how long the fish are chased, or then held captive in the water – either by a moving boat, or a stationary one – before being hauled on to the boat.

The slide lists the main aspects of concern for the animals, which are:

- exhaustion because they are pursued by the moving nets
- decompression when fish are raised from the deep: the sudden alteration in water pressure can cause their swim bladders to expand rapidly and burst, and the expanded bladder may also cause the stomach to protrude from the mouth.

The nets cause several problems, including:

- they are often very full and fish may be crushed under weight of other fish
- depending on the design of the net, fish may be snared (caught in the netting) as well as very confined. This results in panic and damage to their scales and skin against the side of the nets. This is presumably painful. If some of those fish escape or are discarded, the scale damage can allow infection to set in, and the overall recovery from the physical exhaustion may take a long time, making the fish vulnerable to predators
- gill nets are designed to catch fish by the gills – their heads may be stuck in the net for hours or days before the net is landed. Those fish suffer injuries to the gill area, from struggling, and are at risk of predation, e.g. by seals and by other fish.

Slide 15:

We now move on to discuss capture by hooks. The related welfare concerns are:

- the hooks may also have barbs which are thought to cause more pain
- fish may be caught on hooks through the mouth or gills and can be held like that for hours and days if long-line' baited hooks are used – these may be many metres long, and may not be hauled in immediately
- the hooks are also used to spike fish as a way to pick them up
- some fish are used as live bait on the hook, to catch other fish. This may be humane for the target fish, if it is hauled up and slaughtered, but it is not humane for the bait fish.

A further welfare concern with wild-caught fish is the by-catch – these are the non-target fish and other species who are caught in the process. For example:

- long-lines also catch and can injure sea birds, turtles, sharks, and non-target fish species
- it is well known that nets sometimes catch dolphins, and adapted nets are widely used to prevent this. However, those nets may instead catch high numbers of shark, turtles and juvenile fish
- when sharks are caught in this way, they may have their fins cut off because these are a desirable human food in some countries, and the sharks are then thrown back into the water. The process is painful and very debilitating, as the sharks will suffer infection and

have a high risk of dying by predation.

Slide 16:

The main welfare questions in relation to capturing and landing fish are:

- Is the gear specific to the target species, given the range in size, depth, etc?
- Can any distress be reduced?
- Once fish have been landed onto the boat, are they killed in a humane way?
- Are non-target species, or any fish who escape from the gear, harmed by it?
- Can the discarding of fish ('by-catch') be reduced?

Slide 17:

As we have noted, wild-caught fish are rarely put through a humane slaughter process. They are caught in very large numbers, and typically left on deck to die. This can take between one and four hours.

Meanwhile, workers must process the catch by removing their viscera, removing the muscle from the bone, chilling them and freezing them. Many fish undergo all of this while they are conscious but asphyxiating. On average, in that case, they are on deck for 25–65 minutes before being gutted.

Slide 18:

The majority of fish who escape during capture or who are discarded are damaged and have poor survival rates because of injuries and sub-lethal pathology caused by stress and infection. However, those who do not have such damage survive.

Note that some species are hardy, so relatively more of them survive after escaping. This may then disrupt the local balance of species.

Slide 19:

The welfare problems caused by commercial fishing create moral unease about whether we should consume wild-caught fish.

In *aquaculture* (farming fish) concern is especially with the welfare of the individual, because those fish are dependent on human care throughout their lives. However, in commercial fisheries, concerns have been of a wider nature, as noted on the slide.

Broadly, not only do fish suffer but there can be significant effects on some species as a whole, which risk extinction, with consequences for the entire ecosystem in which they live, e.g. those animals who feed on them, and the balance of other populations and species.

A further concern is that commercial fisheries focus on the chasing, catching and slaughter of wild animals and so represent a form of hunting. In the common utilitarian or rights ethical framework applied to farmed animals, the suffering of individuals in commercial fisheries is of special concern. However, the prevailing ethic around commercial fisheries is, rather, that hunting is part of a wider ecological system in which all living beings are food for some others. Thus, wild fish have the experience of life and, in exchange, are killed to feed, in this case, human beings.

Compared to the welfare of farmed terrestrial species, these ethical issues with wild-caught fish are poorly developed, and there has been little collective discussion of them. There are environmental, human and animal points to balance such as:

- sustainability of the species, and local fish populations, is important for its own sake and because commercial fishing may deplete the fish available to local human communities to eat and to trade locally. Often those communities may already be poor and vulnerable to the impact of commercial fishing. On the other hand, commercial fishing provides widespread global employment and food
- many wild-caught fish are used as livestock feed, and this is seen as problematic, given the lack of humane slaughter at present
- wider environmental considerations regarding shipping the catch to markets around the world, chilled, to provide fresh fish in countries where the catch is not local or native
- the issues of sentience and welfare which we have just described
- the local ecological impact of by-catch.

Slide 20:

It is unlikely that commercial fishing will diminish in the near future, however, and improvements in animal welfare are essential.

One way of looking at improvements is through the '3 Rs', developed for minimising harm to animals used in research. Module 19 describes them in detail. Two of these are *refining* the procedures to minimise the suffering and harm to the animals involved, and *reducing* the number of animals involved.

This slide illustrates how those principles apply to commercial fishing.

Refinements include:

- not using live fish as bait
- reducing the time fish are held in gear and on the deck
- reducing injury and stress during capture and hauling onto the deck
- the type of net used – there are different designs and materials, e.g. a knot-free net causes less damage overall
- whether hooks have barbs, and how fish are removed from hooks

- humane slaughter techniques (percussive/electrical stunning) may be adapted for use on the boat.

Reductions mean catching fewer fish. For example:

- fishers can modify gear to minimise by-catch, and avoid catching juveniles
- if fishers only catch large mature fish, only one will have to be caught and die to provide the same amount of meat as several immature, smaller fish. For example, using a single line and hook to catch one large tuna ensures that the animal can be caught, landed and humanely killed relatively quickly, and the meat is of high quality because of this. It is a method that is being used and is both more humane and more profitable than catching larger numbers of tuna in nets, with possible by-catch.

Another mechanism for reduction relates to the fact that wild-caught fish are processed to provide omega-3 fatty acids as a supplement for humans. If plant-based sources of the appropriate fats could be manufactured, this would reduce the need to use wild-caught fish for the purpose.

Similarly, wild fish are used to feed farmed fish, but this could perhaps be avoided by feeding invertebrate protein.

Slide 21:

We now move on to the welfare of farmed fish.

As the global human population grows, there has been associated over-fishing of wild fish, therefore many wild fish stocks are decreasing. Fish farming is partly a response to this.

The picture on the left shows cages on a salmon farm in Canada.

The picture on the right shows a fish farm in Thailand, with laying hens over a catfish/tilapia pond. The chicken faeces (and some excess feed) help to seed the pond with phyto- and zooplankton, which feed the fish. The farmer produces eggs, chickens and fish, and also rice because the water fertilises a rice field.

Slide 22:

We will now highlight the aspects of fish biology that are most pertinent to the welfare of farmed fish.

The first is water quality.

This is very important for all fish. Water flows continuously over the gills in a unidirectional flow. Fish have a good chemosensory system, to help them to avoid water with low oxygen levels, high levels of ammonia, etc. If water has low oxygen or increased pollutants, fishes' ventilation rate (opercular beats) increases, or the fish seek a location with more oxygen (e.g. they cluster near where the water enters the tank).

Light levels can indirectly affect water quality. If salmon juveniles have low levels of light through the night, they tend to stay more evenly distributed in the water column. This promotes even circulation of water and exposure of all fish to well-oxygenated water. However, if lights are turned off at night (i.e. an artificial light that is turned off, or on and off when someone wants to check on them), the population tends to cluster, which often results in oxygen problems and gill disease and decreased feeding.

In over-stocked ponds, there is excess fish waste in the water. This causes excess ammonia in the water. With over-stocking, there is incomplete breakdown of ammonia, and nitrite accumulates in the water. The nitrite is absorbed through gills and oxidises the haem ion (methaemoglobin), which then cannot carry oxygen (methaemoglobinaemia). As a result, the fishes' blood has a brown tinge.

Flushing out the water with new water that contains no ammonia or nitrite will solve the problem (either through converting ammonia to nitrate, or by increasing the amount of new water).

Slide 23:

Feeding: this depends on the species, ecological niche and environmental conditions. Among salmon in intensive conditions with a localised food source, aggression and competition over food are higher than in the wild where food sources are dispersed.

It appears that genetic selection for rapid growth of farmed salmon has favoured 'bold' fish who are successful at getting food from a localised source. Those fish who are less competitive over food are likely not to get enough food.

Slide 24:

Moving on to fish husbandry, the most important factors for basic physical welfare are water quality (temperature, oxygen content, osmolarity, etc.) and good stockmanship. The picture shows fish farmed in high densities in a fish farm in Selangor, Malaysia.

Farmed fish are usually bred in captivity, either from wild-caught stock or from fish who have already been domesticated for several generations. The fish are kept in specially constructed facilities. They are fed and closely monitored. They are protected from many of the negative influences that affect wild fish. The facilities may take the form of large net pens in natural bodies of water such as bays or oceans; in that case, it is difficult to adjust water quality. Alternatively, the fish may be kept in land-based farms: they are held either in specially built ponds, or in tanks (see picture).

If the ponds have a low stocking density, no water exchange is needed: water quality is maintained by the phytoplankton in the pond and by careful feeding regimens. At higher stocking densities, machinery is needed to adjust the flow and oxygenation of the water.

However, tanks require water recycling, or fresh-water flow-through.

Note that, with these farmed systems, and unlike wild fish, a relatively constant environment is imposed on the animals.

Slide 25:

With these different farm systems, stocking density is important. However, fish biologists have argued over whether the weight of fish per unit volume of water (kg/litre) is as important as the quality of that water. In fact, weight per unit flow of water (kg/litre/minute) may be a more useful measure. This is because water flow reflects water exchange.

In general, optimal stocking densities have not been well defined because they also depend on water quality and flow rates. Also, recommended stocking density assumes a uniform distribution of fish throughout the available space, while in reality fish are not so evenly spread.

Therefore, stocking density is not a reliable indicator of the welfare of fish in a confined space such as a cage or tank. At the same time, however, stocking densities are also very important for welfare, as they can cause or prevent problems such as fighting, and the spread of diseases.

The picture is of a carp farm in Malaysia with an apparently large number of fish per unit volume of water. It is not clear what the stocking density is by either of the above measures, nor what the animals' welfare is like. Other measures such as fish health, mortalities, water quality, etc. would help to indicate the welfare status of the fish.

Slide 26:

Feeding is an important aspect of fish husbandry and welfare too. Some fish are *piscivorous* (they eat other fish) and some are *herbivorous* (they eat plants). Recall that a lot of wild-caught fish are used to feed farmed fish.

The picture shows a feeding system for farmed salmon: feed is being mechanically scattered into a large Atlantic salmon cage from a chute overhead. The arrow shows the scattered food. This method of feeding may not deliver food widely enough to reach all the fish, therefore the less competitive fish may not be able to eat enough.

Slide 27:

Feeding raises welfare issues in farmed fish because of its association with aggression and competition.

We have selected farmed fish for fast growth; in addition, in many species genetic manipulation has been used to create lines of fish that express growth hormone in such a way that the fish grow very quickly. The next module will look more closely at the welfare consequences of that. For now, we can say that selection and genetic procedures may also have bred more aggressive or, at least, competitive fish who are more willing than wild fish to expend energy fighting or competing to get food. However, it is not clear that farmed fish are necessarily more aggressive over food: simply that larger fish may out-compete smaller ones by getting to the feeding area faster.

The welfare issues are that more competitive, 'aggressive' fish may be larger and have more fin injuries than others. Fish who avoid taking risks may not be able to feed, and may be more stressed and susceptible to disease. To avoid this, new feeders are being developed that deliver food according to individual fishes' appetite.

It is also important to distribute food widely so that more competitive fish cannot monopolise it. Note that farmers want as even a size distribution as possible, so they always try to maximise the feed availability to all fish in the group. It is very important to feed to satiation for the entire group: many farmers stop feeding when they see less energetic feeding activity, which does not allow the less dominant/active fish in the group to feed.

Feeding cameras (with a direct video-link to a camera pointed upwards from the bottom of the cage) have allowed farmers to identify more precisely when the entire population has stopped eating, allowing a more even growth pattern in the group.

Keeping some older, larger fish in the pen with juveniles who fight may reduce fighting. However, this risks introducing diseases and, with some species such as catfish, the larger fish might eat the juveniles – this kind of practice could introduce predator–prey stress.

Routinely in salmon hatcheries and farms, the fish are size-sorted ('graded') when the size distribution becomes too variable. In this way, the competition for feed (although it is probably occurring) is more even, so growth will be more evenly distributed.

Slide 28:

Reproductive management of farmed fish can create welfare problems. Different species have different breeding requirements, as discussed below.

- Salmon and trout: males and females are reared separately. However, mixed populations will provide more stimulus to mature.
- Tilapia: these breed readily even at high stocking densities .
- Sturgeon: they do not spawn readily, even at a low stocking density. They need to have the right substrates, and those are not provided in normal tanks. The removal of eggs for caviar is usually through some sort of surgery, but timing is crucial as the market demand is for mature eggs, just prior to being ready to be released.
- In all species, spawning is very physiologically stressful. Some species naturally die after spawning, so in farming are anaesthetised and/or killed before spawning. Those species that survive need extra care and food afterwards, to ensure they survive in good health.

The pictures on this slide show Atlantic salmon. On the left is a female brood fish; the mass of pink-orange tissue is the eggs. On the right is a mature male; the long creamy white structure under the ribs is one of the testes (indicated by the box in the photo).

Slide 29:

We now discuss the reproductive management of salmon and trout.

In Atlantic salmon, *ova* and *milt* (sperm) are removed by hand from each fish. This can be very stressful and is often done under anaesthesia.

Female fish grow more quickly than males, until they start producing eggs. Several methods are used to utilise rapid growth while avoiding egg production:

- triploidy: female salmon eggs may be pressure-treated to induce *triploidy*. Triploid fish are sterile and do not produce eggs. Triploid fish grow quickly, and if they escape they cannot interbreed with wild stock. Triploids are rarely used in the production of salmon or trout because triploid cells are about 30–50 per cent larger in volume than normal cells, and are at risk of oxygen stress. Also, disease resistance is reduced
- creating all-female salmon stock: a large proportion of males mature early and are downgraded because they have undesirable meat characteristics (similar to boar taint in pigs). To help overcome this, farmers inject females with testosterone, so they become phenotypic males who produce all X sperm. These sperm are then crossed with normal female eggs, hence all-female offspring
- artificial lighting: the photoperiod may be adjusted to manage reproduction (e.g. to vary the time of spawning) and to increase growth rate. The welfare effects of this are not clear, but observation suggests that it is stressful and may reduce immunity as well as creating physiological problems because of too-rapid growth.

Slide 30:

You have now seen some of the basic aspects of housing and feeding fish on farms.

We will now look at how to catch, handle and transport farmed fish. Those needs arise, e.g. when moving fish between facilities, for slaughter, for vaccination and reproduction assistance and for grading.

Catching and handling

Nets: small ones for individual fish or large ones called *seines* are used to collect fish from ponds. They can easily damage the mucous layer on the scales, and the knots can cause injury. Lifting the net or seine can also cause damage and is very stressful.

Hands: must be wet (gloved) and movements very gentle, slow and deliberate.

Compassion in World Farming recommends that “fish should only be removed from water when absolutely necessary and should not be kept out of water for more than 15 seconds unless anaesthetised” (Stevenson, 2007).

Where possible, it is better to use water to move fish between ponds, with special fish pumps or pipes (see arrows in the picture).

The picture shows the transfer of *smolts* (juvenile salmon who are undergoing physiological change to cope with salt water, prior to migration) to sea water. Transport is very stressful, and fish can take several days to recover. However, if it is done carefully, losses should be small.

It is very important that the fish do not eat for about 48 hours prior to the handling. Otherwise, they have increased oxygen demands (due to increased metabolism) and much greater mortalities after handling.

Fish in the wild may be used to variations in food supply, but on farms the food is plentiful so it may be very distressing to have food withheld for more than three days; a maximum of 72 hours is recommended.

Slide 31:

We now come to the slaughter of farmed fish.

Slaughter methods may be divided into those that cause slow loss of sensibility (e.g. evisceration), and those that first cause rapid loss of sensibility (e.g. stunning) followed by brain death from evisceration or gill-cutting.

Slow methods of slaughter are commonly used in commercial fisheries, as we have seen. On many farms, however, slow methods are rarely used because these methods reduce meat quality.

The picture is of farmed Atlantic salmon being put into a mechanised percussive stunning machine. The fish's head is to the left.

Slide 32:

This slide shows methods causing slow loss of sensibility. OIE guidelines gives more information about them and the welfare concerns.

Asphyxiation in air: time to loss of brain function is temperature-dependent in some species (e.g. rainbow trout: in water that is 2°C, it takes 9.6 minutes; in water that is 20°C, it takes 2.6 minutes) but not others (e.g. bream: in water that is 0.1°C, it takes 5 minutes; in water that is 22°C, it only takes 5.5 minutes).

Asphyxiation in ice: fish are packed in ice slurry without water. This is commonly used for farmed fish including sea bass, rainbow trout, sea bream. Loss of brain function by cooling is reversible. May be painless (similar to hypothermia in humans) or painful (similar to the effect of ice on bare skin in humans). Causes muscle paralysis, so behaviour cannot be used to find out if it is painful. Producers say that chilling before bleeding out improves meat quality and is better than asphyxiation in air, but research has found no difference in meat quality between the two methods.

Exsanguination: gills are cut or pulled out, and the fish is put back in the water. Time taken to die is temperature-dependent.

Carbon dioxide narcosis: here, the water is saturated with CO2. Commonly used in Norway, with or without ice. Very aversive – carp, trout, eels and salmon all made vigorous efforts to escape. Fish become immobile before they lose sensibility. Most farming seems to have abandoned this practice, as it does not lead to good carcass quality following death.

Evisceration of live fish: remove either gastrointestinal tract, sometimes with liver, or heart with viscera. Death by exsanguination and asphyxiation. Death takes 20–40 minutes, depending on species.

Decapitation: used for eels, who are very hard to kill. Even after decapitation, it takes some 13–30 minutes for loss of brain function.

Anaesthetics: clove oil (eugenol, e.g. Aqui-STM) in the water sedates fish and they show much less distress before slaughter than do untreated fish. In Chile, Australia and New Zealand, it is used to sedate fish before removing them for stunning.

Salt or ammonia bath: used for eels to remove slime. It makes them immobile too, and is very aversive. This was used in Holland and Germany in particular, but has now been banned in Germany.

Electrical immobilisation: passage of a current through water (e.g. river) or through a dense pack of live fish. Causes paralysis, pain and exhaustion.

Slide 33:

Methods causing immediate loss of sensibility include:

- percussive stunning: a manual or automatic blow to the skull. Must be accurate and forceful. Fish are usually out of water for 10 seconds before being stunned. Used by fish farms but not by commercial fishers (commercial fisheries usually take fish on to the deck of the boat and then send them to a hold, on ice or salt)
- spiking: also called *coring* and *ike jime*. A spike is driven into the fish's brain. This must be accurate: the fish brain is small. The fish is out of water for 10–60 seconds before being stunned. This is used for large fish like tuna and salmon
- shooting: this is used for large fish like tuna. They must be brought to the surface first. The noise may distress other smaller fish in the nets
- electrical stunning: a current is passed across the water; fish must be of uniform size otherwise some will not be fully stunned. If the current is adequate, death follows automatically. Eels are very resistant and take up to five minutes to be stunned.

The picture shows stunned salmon emerging from the machine. The two people to the left of this picture (the arrows point to their heads; they are wearing baseball caps) identify and stun any fish who were insufficiently stunned by the automated system.

Slide 34:

OIE guidelines state that the following have been shown to result in poor fish welfare: chilling with ice in holding water, carbon dioxide (CO_2) in holding water, chilling with ice and CO_2 in holding water, salt or ammonia baths, asphyxiation by removal from water, and exsanguination without stunning.

They recommend electrical stunning, spiking and shooting.

In 2008, Norway banned the use of carbon dioxide to stun fish (Stevenson, 2007).

Slide 35:

The OIE gives three criteria for effective stunning. Their guidelines state that, while absence of consciousness may be difficult to recognise, signs of correct stunning include:

- loss of body and respiratory movement (loss of opercular activity) (we should add that fish lose consciousness before movement stops and it is important to distinguish random carcass movement from swimming)
- loss of visual evoked response – this is a measure of brain activity and requires an electroencephalogram
- loss of vestibulo-ocular reflex (VOR, eye-rolling). To test the reflex, rotate the fish from left to right on a perpendicular axis. In a dead or properly stunned fish, neither of the eyes moves
- note that the righting reflex is probably not a useful sign, although it was considered one originally. However, it is a cerebellar reflex which can occur in subconscious states and it not accepted as a useful sign of unconsciousness in other species.

Slide 36:

As with agricultural animals, you can also assess the overall effectiveness of staff at stunning fish by using audits. You would give scores for each of the five criteria shown on the slide.

To conclude, there is ongoing research into the most humane ways to slaughter the very wide variety of farmed fish available, and different stunning methods are better for some species than others.

Slide 37:

This concludes this first lecture on fish. In it, we have seen that there are many species of fish and the evidence from the species studied is that, as a class, they are sentient, in at least some ways that are similar to birds and mammals. Thousands of millions of fish are caught and killed for human consumption every year. Some of these fish are wild-caught; others are farmed. Each category has welfare concerns.

With wild-caught fish, we saw that the concerns relate to their capture, landing and slaughter, most of which does not meet the OIE's minimum standards for farmed fish, but has come about because of the large numbers of fish involved in commercial fishing.

There are several areas where suffering could be reduced, by using different gear, developing humane slaughter techniques for use on commercial vessels at sea, etc.

With farmed fish, as with other farmed animals, there is much human interference with fish. Today's lecture outlined the main husbandry and slaughter practices.

The second lecture will outline the welfare concerns in farmed fish, and describe how to assess fish welfare. It will also cover welfare issues with fish used in other ways, e.g. in angling, and will look at emerging welfare concerns for invertebrates, such as prawns, who are farmed and caught for human consumption.