Module 24
Welfare of Farmed Fish and Aquatic Invertebrates (Fish Welfare Part 2)

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:

This lecture will outline the welfare concerns in farmed fish, and describe how to assess fish welfare.

It will also cover welfare issues regarding fish in angling, fish kept as companions and for show (ornamental fish).

Finally, we will look at emerging welfare concerns for invertebrates such as crabs, lobsters, prawns and molluscs which are farmed and caught for human consumption.

Slide 3:

To review what we covered in the previous fish welfare module (Module 23): first, 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 of the ways that birds and mammals are.

Second, fish meet the criteria for the capacity to perceive pain and suffer.

Third, thousands of millions of fish are caught and killed for human consumption each year. Some of these fish are wild-caught, others are farmed. Each category has welfare concerns.

With wild-caught fish, the concerns relate to their capture, landing and slaughter.

We shall now look at the welfare concerns in farmed fish and at how we might assess their welfare.

Slide 4:

Potential or actual welfare concerns may be identified using the Five Freedoms. However, in many cases, there is no scientific data demonstrating the extent to which fish may be affected by any of the potential concerns. More research is needed on behavioural and physiological measures. Until that research has been carried out, however, we must be aware of all potential concerns and not ignore the reasonable likelihood of suffering.

The slide shows a farmed Atlantic salmon, in eastern Canada, with a shortened spine and a tail deformity. These abnormalities are seen early in the fish's life in the hatchery, but affected fish continue to live and grow until some other disease or stress affects them. In the picture, the fish's shortened tail probably meant that the fish was unable to cope with currents; as a result, the fish may have brushed against the pen net more frequently than the other fish did. The resulting minor abrasions may have contributed to fin erosion, as seen in the tail and dorsal fin in this photo.

Slide 5:

The first of the Five Freedoms is freedom from hunger and thirst. Aquaculture raises several concerns here, as listed on the slide.

- Starvation before transport or slaughter: at these times, fish are starved in order to empty their gastrointestinal (GI) tract and reduce water contamination. In the wild, fish may not eat for prolonged periods, but they live in a complex environment in the wild and can satisfy other motivations. Farmed fish are accustomed to regular daily feeding and live in a relatively barren environment over which they have little control. Therefore, to starve them suddenly may cause distress.
- Anecdotal evidence suggests that farmed salmon are not obviously distressed by food withdrawal, and they react much better to handling. With almost any disease, taking fish off feed will dramatically reduce mortalities over the next few days. However, research is needed using more specific outcomes than ease of handling, to answer this question about welfare. Also, after three to five days, negative energy balance may have other effects. The Royal Society for the Prevention of Cruelty to Animals (RSPCA), through its Freedom Food scheme, and Compassion in World Farming recommend that fish should not be starved for more than 72 hours (Stevenson, 2007).
- Feed reduction/starvation to reduce the growth rate until market prices rise: In this case, farmers are not receiving a fair price for their fish. That is, a price that covers the high food intake which accompanies the fish's rapid growth rate. If market prices drop, farmers may decide to reduce feeding, or to withhold food completely from the fish, in order to slow the animals' growth rate. The farmers' hope is that, by the time the fish reach market weight, the prices will be more favourable.

However, because the animals are genetically adapted to grow rapidly, withholding food is likely to cause hunger and potentially suffering. Consequently, since 1996, the UK's Farm Animal Welfare Council has recommended that farmed salmon, for example, should only be starved as required for certain management procedures, for a minimum length of time which should not normally exceed 72 hours. For trout, the Council's maximum recommended time for withholding food is 48 hours and their guidelines specify that "Depriving trout of food prior to certain management procedures should be to achieve gut evacuation and not to adjust body composition, and the period should normally not exceed 48 hours (FAWC, 1996)."

World Animal Protection does not support the use of starvation or food reduction as a way for farmers to cope with market prices (Stevenson, 2007).

- High protein requirement of carnivores: carnivorous fish, such as salmon, have a high requirement for protein and polyunsaturated fatty acids. They are therefore fed fish meal from other fish which have to be caught and killed and are likely to suffer in the process, as we discussed in the previous module. However, vegetable diets may be deficient and cause malnutrition.
- Aggression: when fish compete for food, they may or may not fight (fighting is a large cost to both fish), but they will show non-physical aggressive interaction. The losers tend to become less active and eat less. Where food is localised and fed automatically, dominant fish may prevent other fish from feeding.
- Malnutrition: more and more species of fish are being farmed, but not all their nutritional requirements may be known. Micronutrients are a particular concern. A lack of these results in high mortality rates, reduced immunity, poor feeding and slow growth.
- Water quality: it is essential to ensure that water is the correct quality for the fish being stocked, including appropriate salt content. For example, if juvenile salmon are moved into sea water too early, they become very dehydrated.

Slide 6:

Here we move to the next freedom: freedom from pain, injury and disease.

- Handling: can be stressful if farmers are not experienced.
- Injuries: these can occur in densely crowded cages.
- Diseases: fish can suffer from many infectious diseases. High stocking density, poor water quality and low feed intake can increase the risk of disease. We cannot give a full clinical account here. However, external parasites are especially significant because they attach around the nares (nostrils) and eyes, and can affect the fish's sensory capacities, locomotion, foraging and ability to compete. As farm conditions already restrict fish considerably, the additional constraints caused by ectoparasites may affect welfare more than they would in the wild.
- Vaccination lesions: injectable, oil-adjuvanted viral and bacterial vaccines are more effective than vaccines given by immersing the fish in treated water. Vaccines are injected into the peritoneal cavity. This can cause adhesions between viscera, which may interfere with organ function. The picture shows a young salmon being vaccinated.

- Vaccination is stressful and can lead to reduced food intake lasting up to two weeks. The vaccine adjuvants may be more of an influence here than the stress caused by handling the fish for the vaccination.
- Morphological abnormalities: rapid growth rate and restricted movement have been said to result in smaller and weaker hearts with more fat around them, and to cause large fish to have difficulty coping with husbandry procedures such as handling and grading. However, it is not clear that growth rate is the cause of developmental abnormalities of the heart. Research suggests that environmental or social stress on female salmon is the cause of morphological abnormalities in their offspring. Fish with these deformities have poorer growth, lower survival rates on farms and do not cope as well with routine husbandry events.
- Overcrowding: this can lead to increased physical injury, spread of disease and competition over food, as described earlier. However, you may recall from Module 23 that high stocking densities are not necessarily bad for fish, as the flow of water may be more important than the relative volume.
- Algal blooms and jellyfish: the growth of algae in sea cages can cause stress and disease. Jellyfish can also be toxic. In the wild, the fish would be able to avoid these threats, but because they are confined and at high stocking densities, they cannot avoid them.

Slide 7:

Freedom from discomfort:

- Lack of shelter: fish held in pens at sea are protected from birds and marine predators such as seals and other mammals. However, when these barriers fail, the fish cannot escape from them as they might in the wild. Also, even with barriers, if fish can see or otherwise sense the presence of predators, even if they are protected, they may become very distressed.
- Farmers have a strong and legitimate incentive to ensure their stock are adequately protected, and most farmers do everything they can to avoid predators. Underwater sonic devices are sometimes employed, especially in high risk areas/times: it is not clear how these affect potential predators and other wildlife. Some farmers may shoot marine predators such as seals, which is also a concern.
- Water quality: fish are very vulnerable to fluctuations in water quality. Water temperature, flow rates, pH, oxygen, etc. must be carefully monitored and all equipment kept in good working order. High stocking density may also affect the extremes of water quality that fish are exposed to. If water quality is not controlled and monitored, this is an important welfare concern because fish are unable to escape to other bodies of water.

The picture shows a water recirculation system for farmed Atlantic salmon. Recirculation reduces exposure to pathogens or predators: the incoming replacement water is usually from a well so there are no wild fish in the incoming water.

Slide 8:

There are many factors in fish farming which can cause fear and distress, and these were described earlier. The picture illustrates handling: it shows juvenile salmon fish being vaccinated.

- Overcrowding: crowding of fish is likely to cause social stress; stressed fish will try to avoid the others, if the environment permits that. If it does not, this will increase stress. This is a particular concern at times of short-term overcrowding such as when fish are caught in a dip-net and held for vaccination or other procedures (see picture). Thus, even though a high stocking density may not necessarily cause physical welfare problems, it may cause varying degrees of social stress. It may be difficult to evaluate this if the fish are distressed, if they are crowded or if they are moving rapidly. Also, it is not clear what behavioural signs indicate social stress.
- Escapees: fish who escape into open water are called 'escapees'. Escapees are not adapted to the conditions in the wild. They have been reared in an environment with ample food and, usually, no predators. This early experience reduces the ability of escapees to respond to predators and to feed – they are not used to foraging for food so often stay at the farm site looking for feed. It is not clear whether the escapees' lack of experience of predators causes them to suffer more fear and distress than wild fish do when they are attacked. A further concern is that escapees compete with wild stock for food and mates and may spread disease. In addition, escapees may reduce the fitness of the wild stock by interbreeding.

Slide 9:

Aquaculture creates several problems for fish in the freedom to express normal behaviour category (Huntingford & Adams, 2005).

First is the need for environmental complexity/control.

- Confinement and high stocking densities prevent fish from performing their full range of normal behaviours. Conditions of confinement also provide little environmental complexity or environmental control, i.e. no environmental enrichment (EE).
- Note that, for fish who live in schools, having too low a stocking density may be distressing. Also, the environment does not allow them to express other behaviours such as seeking shelter to get away from aggressive conspecifics, or nesting.

Next, abnormal behaviours such as repeated swimming in vertical or circular patterns may be 'stereotypies' and reflect an inadequate environment.

- Knowledge of each species' behaviour in the wild is an essential starting point to understand the significance of abnormal behaviours.
- In some cases, factors such as light and feeding delivery have been contributory causes of stereotypies.

Assisted reproduction: the reproduction of farmed Atlantic salmon and rainbow trout is not allowed to occur in the natural way, but is done under anaesthesia to remove the egg and sperm.

Farmed Atlantic salmon are prevented from locating spawning substrates (gravel in freshwater streams) and never engage in spawning behaviours. It is not clear whether fish suffer from being prevented from showing normal courtship behaviour or spawning behaviour. However, handling for anaesthesia is stressful, and the procedure of extracting eggs and sperm is invasive.

Slide 10:

An additional and significant concern in the welfare of farmed fish is that genetic engineering is becoming more widely used in a range of farmed species to produce fish who grow quickly, are resistant to disease, tolerant of low levels of oxygen in the water, etc.

For efficiency, producers want fish who grow faster and larger, converting feed into flesh more efficiently. Depending on the species, the potential is for growth rates several times faster than normal, and animals who are up to 14 times bigger. However, this is associated with health and welfare problems, including higher growth being associated with reduced tolerance to disease and stress, and with abnormalities in the cranium and operculum due to excessive cartilage deposition. This in turn causes feeding and breathing difficulties.

Also, transgenic fish who escape could either displace wild fish through their superior ability to secure food, or breed with them and, by introducing characteristics unsuited to the local environment, undermine the wild fishes' genetic make-up, producing fish less able to survive in the wild.

Slide 11:

The methodology for assessing welfare in farmed fish is not yet well defined because the most valid measures for this still need to be established.

Some important environmental indicators of potential welfare problems are:

- water flow rate: if the rate of flow is low and the stocking density is high, this may lead to disease, poor water quality and other related problems
- quality: the colour and clarity of water are affected by phytoplankton and by the weather. The pictures show grouper on a farm where there has just been a lot of rain. The water is extremely cloudy because sediment from the bottom of the ponds has been stirred up. If turbidity persists:
  - the suspended sediment can cause gill damage
  - bacteria in the suspended sediment can use up oxygen in the water
  - light levels in the water are reduced and may reach the point where fish may not be able to see food.

Other important aspects of water quality are levels of carbon dioxide (CO_2) and chemicals such as nitrite and ammonia.

Slide 12:

Bird activity over ponds: bird activity increases if fish are coming to the surface, e.g. because of low oxygen in the water. However, some bird activity may be normal, as in the picture. These gulls are gathered around a cage of farmed Atlantic salmon in eastern Canada. The birds eat the excess feed that is caught on the netting, and they make a mess, but they do not interfere with or harm the salmon. Anecdotal evidence suggests that the fish are not distressed by the birds' presence.

Slide 13:

The following animal-based measures can be made relatively easily.

- Colour: skin and eyes change colour in response to stress. Also, cataracts are commonly seen now in farmed fish such as salmon and sea bass. Cataracts have been associated with changes in temperature and with toxins and disease.
- Ventilation rate: increased opercular beats or flared opercula. Caused by stress, gill disease, or poor water quality.
- Behaviour: immobility, increased swimming, escape attempts, rubbing. 'Mouthing' at the surface of the water because of low oxygen in the water. 'Flashing' (when a fish turns on its side and swims in a semi-circular motion, scratches, or appears briefly at the surface of the water) because of parasite infection.
- Food intake: this is affected by many things, such as temperature and social stress, as well as normal changes in appetite, e.g. with reproductive status.
- Body condition: this is affected by food intake. So is mucus production, which is affected by disease and handling.
- Growth rate: this is affected by food intake and stress levels. Chronic stress (social, environmental, disease) may lead to slow growth.
- Mortality rate: this can routinely be 20 per cent or more – much higher than occurs or is accepted in farmed mammals (Stevenson, 2007). The low cost of individual fish, the large size of fish farms, and a lack of recognition that fish are sentient may contribute to the acceptance of high mortality rates.
- Morphology: such as abnormalities associated with triploidy in salmon.
- Injury: to fins and tail; scars – this may reflect poor holding facilities, bad handling, or overcrowding, or aggressive fish. See next slide.
- Disease: this may affect behaviour, e.g. rubbing to dislodge parasites; clinical signs such as cataracts. It is important to know the diseases and their clinical signs.

- Reproductive performance: failure to breed when feed, temperature and light are optimal.
- Stocking density: related to water flow rate; optimal density varies with species.

Slide 14:

Other researchers have produced an integrated welfare index that combines the condition of body and fins with plasma glucose and plasma cortisol, in farmed Atlantic salmon. The index gave the same results as the assessments of fish farmers, and the index varied in the way expected with factors such as stocking density.

The previous lecture detailed the many welfare concerns relating to wild-caught fish. If audits were performed at slaughter using the criteria for farmed fish detailed there and repeated above, it is likely that many commercial fisheries would fail completely.

Much more work is needed to ensure humane slaughter methods under commercial fishing conditions.

Slide 15:

We now move to the welfare of fish killed for recreation.

Slide 16:

First, we give some background. It is thought that about 12 per cent of people globally engage in recreational angling. The types of recreational angling are:

- leisure
- competitive
- game fishing
- specimen fishing (e.g. trying to catch particularly large fish).

Within these categories, fish may be caught and killed (note that the term used is ‘harvested’. This may reflect cognitive dissonance, which we discussed in Module 30 on human–animal interaction whereby we adapt our language to help us feel better about conflicting internal feelings – in this case, killing fish for recreation when they are not needed for essential nutrition).

Alternatively the fish may be caught and released – the assumption here is that released fish will survive to be caught again in future. In some countries release is required and is seen by conservationists as an ecological way to practise the sport. For example, Canadian government guidelines for recreational angling describe ‘catch-and-release’ as part of responsible fishing. They include tips on how to release fish, and information about times of the year when certain species of fish may only be caught by catch-and-release, and may not be kept and killed (Fisheries and Oceans Canada, 2011). However, some countries do not permit the release of fish as it is thought to be worse for their welfare. For example: since

2008, Switzerland has prohibited the intentional release of fishes caught by anglers (Arlinghaus et al 2009).

Slide 17:

The three main welfare concerns for fish caught in recreational angling are as follows.

- Physical injuries: these may not be fatal but seem likely to cause significant pain. Hooks may go through, e.g. eye, jaw, throat, gut. However, it is not clear what the long-term impact of such injuries is. For example, an eye injury might be expected to impair the fish's ability to find food or a mate or to avoid predators. Jaw injuries could interfere with social displays, feeding and respiration if the opercula and gills are affected. Other fishing gear can also cause injury. For example, once fish are caught they may be taken up in a net; some nets cause fin abrasion and skin injury which are probably painful and may affect mobility if the fish are returned.
- The second welfare concern is the effect of the stress response incurred during the catching process as the fish struggles. The full effect of this is unknown and we cannot say that it is generally severe. However, research on farmed fish indicates that prolonged stress reduces immunity. In fish caught by angling, it has been shown to reduce the survival of offspring, following spawning.
- The third welfare concern is mortality in released fish. Again, we do not have enough data and figures have ranged from 0–89 per cent (Cooke & Sneddon, 2007). However, some studies do not follow the fish over the longer term, and it is thought likely that some proportion of released fish are likely to die, but not immediately after release, as a result of the multiple stressors of the angling process. In addition, the methods of killing the fish who are harvested may not always be humane, e.g. fish being held out of water for a photograph, etc., and thus starting to asphyxiate. This is not comparable to the asphyxiation and delay in death that occurs in commercial fishing; however, similar concerns apply.

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To improve the welfare of angled fish, we need to:

- minimise duration of angling
  - use appropriate strength of line and land fish as quickly as possible
- minimise air exposure and improve handling
  - land by hand if possible, not a net
  - if using a net, it should be one without knots
  - hold fish in coolers with good quality water, rather than in nets in the body of water (lake, etc.)

- gear is also important, e.g.
    - barbless hooks
    - the optimal design of the end of the hook is not certain – some may penetrate less, but be more difficult to remove
    - bait should not be other live fish
- water temperature is very important and can be very varied under certain weather conditions. Pulling a fish through it can be extremely stressful for the fish, and may lead to the fish's death. So it is best not to fish if the water temperature is very variable
- deep-sea fishing: here, if fish are pulled up quickly from deep water, the pressure differential may cause their swim bladder to expand or even burst. If it has not burst, piercing it with a needle to release air may be a stress, but would enable fish to swim down again, on being released. However, we do not know how stressful and problematic that would be in the longer term
- finally, as you know from earlier slides, fish should be stunned before being killed, and not left to asphyxiate or be killed by decapitation.

Slide 19:

We now move on to consider the welfare of ornamental fish.

Slide 20:

First, some background: it is estimated that more than 350 million ornamental fishes are traded annually within the aquarium industry. There are more than 1,000 species available. The ongoing provision of these fish may create problems relating to wild capture with its associated high mortality and adverse impacts on the remaining wild populations. These issues are covered in more detail in the modules on wildlife (21 and 22).

Meanwhile, although farmed fish have increasing protection internationally, ornamental fish have little protection in most countries.

Although there is a large body of carefully observed, anecdotal information about the best way to keep fish in aquaria, there has been very little actual scientific research on this. Consequently, while there is much useful information in magazines for fish owners, we do not yet have much formal scientific knowledge about the welfare of ornamental fish, so there are no scientifically-determined guidelines on appropriate mixtures of species or stocking densities for ornamental fish.

A further point is that fish can be very long-lived – many can live for decades in good captive conditions, and some for more than a century.

Fish medicine is a specialisation within exotic animal medicine or zoo medicine, so clinically we have some knowledge of optimal conditions and disease prevention in some species.

However, a vet in general practice would not generally be well equipped to advise or deal with ornamental fish. This lecture cannot teach the clinical principles, but we will outline the main welfare concerns.

Slide 21:

As with farmed fish, important aspects of husbandry include:

- water quality, especially ammonia which is produced by uneaten food, animal waste, and decaying organics
- ammonia is broken down in the water to nitrite and then nitrate, but if ammonia and nitrite levels build up they can rapidly cause toxicity. Water temperature and pH contribute to that build-up happening
- nutritional needs vary – again, note that there are 1,000 species of ornamental fish. Some are herbivores, others piscivores
- some owners feed the latter frozen fish. However, freezing allows the build-up of thiaminase in some species, which in turn leads to thiamine deficiency in the ornamental fish
- iodine deficiency and hepatic lipidosis are other common dietary diseases; the lipidosis seems to be caused by excessive consumption of polyunsaturated fats.

Slide 22:

As we noted, there is little scientific data on the social aspects of the mixed groups of tropical fish which are kept worldwide. A recent study (Sloman et al., 2011) looked at whether the presence of angelfish altered the behaviour of a mixed group of three other species: white cloud mountain minnows, neon tetras and tiger barbs.

The researchers also looked at whether group size affected behaviour and welfare.
They found that:

- angelfish were good for the welfare of small, shoaling species
- for white cloud mountain minnows and neon tetras, larger group sizes resulted in increased natural behaviours (i.e. a tendency to shoal)
- in that study, the aquarium had environmental enrichment: a plastic plant and a plastic shelter at the back of the tank, placed on either side of the outflow. The data indicated that the benefits of environmental enrichment depended on the species and the size of the group overall. This affected whether individuals used the enrichment and, if so, whether they sheltered there to get away from others, or instead defended it aggressively as a resource or territory
- The study illustrates the complexity of social interactions, and indicates how little scientific evidence we have in that area, given the numerous possible combinations of species that people may choose to keep in aquaria in the home. As vets in practice, you may need to rely on the considerable experience of some fish owners and on the articles by such people

in pet magazines as to what ornamental fish need for good welfare. Those owners' long experience and careful observation have value. However, still keep in mind that scientific evidence is needed to provide the highest level of professional advice regarding how to give ornamental fish a life worth living.

Slide 23:

We now move away from husbandry and its disease and behaviour outputs to other diseases that are common in ornamental fish. Briefly, they are:

- infection with mycobacteria; note this is the same genus as tuberculosis and leprosy, and there is some evidence that some may be zoonotic. There is no cure, and diagnosis cannot be made absolutely *in vivo*
- cataracts can be common in outdoor fish, and many are caused by a parasite – the trematode (fluke), *diplostomum*. There may also be environmental causes. Surgery can be carried out to remove the cataracts
- older fish are prone to tumours. There is a body of information about them which can help with diagnosis, derived from laboratory fish who are used regularly to detect and study effects of mutagenic pollutants or compounds. Surgery and chemotherapy are possible
- euthanasia can often be a humane option for sick fish. To do this:
  - sodium pentobarbital may be injected
  - based on OIE (2011) guidelines for farmed fish, carbon dioxide is not recommended because it is probably aversive
  - the anaesthetic agent tricaine methanesulfonate (MS-222) can be used at 300 ppm dissolved in water. It is acidic and should be buffered at a 1:1 or 1:2 ratio with sodium bicarbonate. When opercular movements cease, the fish should remain in the anaesthetic bath for an additional 20–30 minutes. Monitor the heart rate and check for withdrawal reactions or painful response. The heart may continue to beat for several hours after death because the fish's heart has pacemaker cells that are independent of central vagal control (Weber, 2010).

Slide 24:

We will now discuss the welfare of aquatic invertebrates, including molluscs and crustaceans.

Slide 25:

We will end this lecture by considering the welfare of aquatic invertebrates. That is:

- molluscs, which include some shellfish, squid and octopus
- crustaceans, e.g. prawns, crabs, lobsters and crayfish.

It has been known for some time that octopuses in particular have relatively advanced cognitive abilities and should be considered to be sentient. For example, octopuses show learning in response to both visual and tactile cues, and have a working memory of foraging areas that they have used in the recent past.

In addition, the traditional treatment of crustaceans such as crabs and lobsters has long caused concern for many consumers, e.g. killing them by boiling them, or pulling off their legs while they are alive. However, attention is now being paid to whether they too might be sentient, and the significance that this has for us.

Slide 26:

So, what are the implications of sentience in terms of numbers of aquatic invertebrates killed for human consumption?

We saw in the first fish welfare module (Module 23) that, whereas we kill approximate 57,000 million farmed birds every year, for food, we may kill as many as three trillion (three million million) farmed and wild-caught fish.

We kill similarly huge numbers of invertebrates for food. For example, 12 per cent of all crustaceans eaten annually are tiger prawns. It is estimated that, in 2008, we ate 214 billion of them: that is, 12 per cent of our total crustacean consumption represents more animals than our farmed fish consumption.

This means that in total we may consume 1.7 trillion (1.7 million million) crustaceans each year. That does not include the molluscs – mussels, clams, squid, etc. As you can see, the numbers are vast, and similar in magnitude to the numbers of vertebrates.

However, there is not yet acceptance that aquatic crustaceans are sentient. Scientists who agree that fish are sentient are not necessarily persuaded that crustaceans may be too. Less research has been carried out into this area than into fish.

Slide 27:

This slide reviews some of the points we considered that supported the idea that fish are sentient, and applies the same criteria to aquatic crustaceans. Most of the reported research there has concerned various species of crab, and it was summarised at a conference on humane slaughter in 2011 (Elwood, 2012).

First, like fish, crustaceans do not have a neocortex. However, we have seen that anatomy alone is not a sufficient criterion for sentience, and pain in particular (Sneddon et al., 2003). Using the criteria that we applied to fish:

- nociception: can crustaceans perceive adverse stimuli?
  - nociceptors and associated nerves have not been described in crustaceans
- do they show protective behavioural responses to aversive stimuli?
  - glass prawns: when acetic acid was painted on one antenna, they rubbed it against the tank and increased grooming compared to controls given water
  - hermit crabs who had left their shells and were given an electric shock on the abdomen showed persistent grooming. These findings are very similar to those in fish who rubbed their lips on the tank and rocked when acetic acid was injected into the lips.

Related to this is the criterion of showing physiological responses to aversive stimuli: crustaceans do not produce cortisol but their equivalent is called crustacean hyperglycemic hormone (CCH). In a study where some crabs had one leg pulled off, and controls did not, there was a marked rise in glucose and lactate in the damaged animals. This is consistent with the tissue damage being stressful, at the least.

Our next criterion is avoidance learning and memory: various studies on crabs and crayfish indicate that they rapidly learn to avoid aversive stimuli such as electric shocks, and that they remember this. For example, in one study crabs learned to hold one leg out of the water to avoid getting a shock. In another crabs quickly learned to discriminate between a shelter where they would receive a shock, and one without an electric shock.

You will recall that another criterion is if an animal can make trade-offs between pain responses and other motivations such as hunger. Hungry fish appeared to ignore pain in order to feed. Studies on crabs show similar results. For example, hermit crabs have a long, soft abdomen which is not covered by their shell. Each one therefore lives in a gastropod shell which is larger than they are. The crab can withdraw completely into the shell and this enables them to avoid predators. As the crabs grow they seek larger shells, and they have strong preferences for certain species of shells (Elwood et al., 1979).

Research has been done on these crabs to see how they balance competing demands for important resources such as (i) avoidance of pain caused by electric shocks, (ii) the avoidance of predators, and (iii) the retention of preferred gastropod shells. In one study (Elwood et al., 1979), the crabs were each given a shell of varying degrees of preference. They were all exposed to a single electric shock that, based on other studies, was thought to be just below the voltage which would make them leave their shells. More crabs evacuated the less preferred shells than evacuated the more preferred shells. This suggests that the crabs were more motivated to experience discomfort or pain in exchange for the safety and "ownership" of a more preferred shell, but would rather leave the less preferred shell than undergo much discomfort.

In a different study, (described in Elwood, 2012), the researchers only used one type of shell. They then exposed some of the crabs to the smell of a predator. When all the crabs were given an electric shock, crabs exposed to the smell of the predator only left their shells at higher voltages, whereas crabs who were not exposed to the smell of the predator evacuated their shells at relatively low voltages. This suggests that the crabs were not motivated to risk exposing themselves to death by predation unless their shell became a place of high discomfort or pain.

The authors concluded that this is evidence that the animals could balance different motivations (to avoid an aversive stimulus vs. to keep an important resource), which was consistent with some cognitive processing and sentience. Note that these are only two examples of the sort of carefully controlled research that is still needed in hermit crabs and other invertebrates, before we can draw conclusions about their sentience.

We need more research in more species to understand better whether crustaceans and other lower aquatic invertebrates are sentient. However, to date the research findings parallel those of fish, and would seem to satisfy some of the criteria required.

Slide 28:

You can see that the welfare implications of sentience in crustaceans and other aquatic invertebrates are immense.

We now briefly review some particular issues.

We start with octopuses. They are caught from the wild, and the handling and slaughter process is likely to cause suffering, as they are sentient and have well developed cognitive capacities.

Research on the stress of being kept out of water for five minutes, following a 10-day period of acclimation after they had been captured, suggested that this significantly altered aspects of their immune system.

The authors concluded that stress affected catecholamine levels and immunity. However, there has not been enough research since then to understand if, as in mammals, stress may enhance the immunity of octopus in some acute circumstances, but reduce immunity if the stress is ongoing.

Next we look at the transport of live crustaceans.

Many countries farm lobsters, prawns, crabs and crayfish and these are then sold live at markets locally and internationally.

This can involve prolonged transport. It can cause significant stress in all these species – there are several within each type of animal – because of factors such as exposure to air (normally these animals live in water all the time), physical disturbance from capture and handling, and fluctuating temperatures.

Guidelines exist for transport by air and land, largely because of the loss that morbidity and mortality create for the farmers. If sentience is proven, there will be an urgent further need to refine transport. Currently recommended procedures to minimise the stress of transport include:

- chilling the animals slowly – this can cause limbs to drop off if done quickly
- using anaesthesia

Also, lobsters and crabs may fight or cannibalise each other, so their claws are fixed closed, usually with rubber bands.

We do not have time to go into further detail here on the transport of crustaceans, but in many animals transport is associated with acute physiological stress responses.

This leads us to the third area of consideration in the welfare of aquatic invertebrates, which is slaughter. We shall consider lobsters next.

Slide 29:

Traditional methods for killing lobster are still the norm worldwide, and they are a cause for increasing public concern. They include:

- drowning in fresh water
- boiling
- driving a spike through the head or chest
- splitting – this is usually done longitudinally, so that the carapace can be used to present the meat.

These procedures are conducted on the conscious animal, without stunning, because it was not thought possible to kill crustaceans in any other way. However, the animals may be chilled or frozen first.

Recommendations to avoid suffering are:

- chill the lobsters to less than 4°C before killing them
- use the specialised lobster stunner, the Crustastun. It uses electrical stunning and renders the animals unconscious within 6–12 seconds of application, after which they die. This stunner is available for batches of animals – to use for commercial slaughter – and for single animals or low usage, e.g. in a restaurant. The Crustastun is the most humane option for the slaughter of lobsters and crabs. It is manufactured under licence in different countries.

Slide 30:

You now have an overview of the welfare concerns in farmed fish, and measures that can help you to assess fish welfare. You have seen, however, that there is less information to work with compared to in the assessment of welfare in agricultural animals. During your professional lifetime, it is likely that more species-specific, animal-centred measures will become available.

You also learned today about the welfare concerns with recreational angling and ornamental fish.

Finally, you have also heard about the emerging welfare concerns for invertebrates such as crab, lobsters, prawns and molluscs which are farmed and caught for human consumption.