Opinion on the Welfare of Farmed Fish

February 2014

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FAWC Opinions

FAWC Opinions are short reports to Government[1] on contemporary topics relating to farm animal welfare. They are based on evidence and consultation with interested parties. They may highlight particular concerns and indicate issues for further consideration by Government and others.

The Farm Animal Welfare Committee is an expert committee of the Department for Environment, Food and Rural Affairs in England and the Devolved Administrations in Scotland and Wales. It was established on 1 April 2011. The Committee and its predecessor Council (1979-2011) both use the acronym FAWC.

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Welfare of farmed and park deer, 2013
Welfare implications of breeding and breeding technologies in commercial livestock agriculture, 2012
Contingency planning for farm animal welfare in disasters and emergencies, 2012

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Osteoporosis and bone fractures in laying hens, 2010
Welfare of the dairy cow, 2009
Policy instruments for protecting and improving farm animal welfare, 2008
Welfare of farmed gamebirds, 2008
Enriched cages for laying hens, 2007
Beak trimming of laying hens, 2007

[1] Where we refer to "Government" we are addressing the Department for Environment, Food and Rural Affairs in England, the Scottish and the Welsh Governments, and other responsible Government Departments and Agencies.

Opinion on the Welfare of Farmed Fish

Scope

1. Since the 1996 FAWC Report on Farmed Fish, the considerable expansion of fish farming, introduction of new technologies, changes in understanding of fish welfare and changes to the national and European regulatory and legislative context, mean that updated comment is now necessary. Welfare at killing and during related operations will be considered in a separate Opinion.

2. This Opinion is mainly restricted to species of fish farmed in Great Britain for human consumption: Atlantic salmon, rainbow trout and lesser numbers of other species including brown trout, sea bass, halibut and tilapia. Wrasse are mentioned for their use on salmon farms as a method of sea lice control and also because they have their own welfare needs. Species differences are often ignored by people unfamiliar with the subject but many are profound.

3. This Opinion is concerned with farmed finfish, as vertebrates covered by the animal welfare legislation, and not crustaceans or molluscs. Ornamental fish, angling and wild capture fisheries are also beyond the remit of FAWC so are not specifically covered.

4. FAWC has reviewed the scientific literature, conducted a written consultation, met with experts and visited farmed fish production systems in Great Britain. Current industry codes of practice and welfare accreditation schemes have been reviewed against the FAWC 1996 report to assess whether practices have been improved.

5. Objectives of the Opinion:
   a) To question whether there is adequate, science based understanding of the welfare issues relevant to the priority topics highlighted in the text and identify any gaps in scientific investigation.
   b) To assess whether current welfare standards are sufficiently defined to accommodate any concerns raised.
   c) To identify if there are any gaps in the legislation, codes of practice, or welfare accreditation schemes where poor welfare practices may remain.

Background

6. Awareness and understanding of and concern for finfish welfare have continued to grow since 1996. The European Food Safety Authority (EFSA) concluded in 2009[2] that 'The balance of evidence indicates that some fish

[2] European Food Safety Authority 2009. General approach to fish welfare and to the concept of sentience in fish.

species have the capacity to experience pain' (see Appendix 5). These include commonly farmed species. There is also increasing evidence for other forms of suffering covered in the Five Freedoms such as hunger and fear. While there is debate on whether these feelings can be interpreted as conscious, there is increasing consensus that such feelings should be a matter of concern to people responsible for fish and FAWC agrees with that view. This is consistent with FAWC's precautionary principle that animals should be given the benefit of any reasonable moral or scientific doubt about their welfare.

7. Concern for welfare does not only depend on demonstration of negative feelings. The Five Freedoms include freedom from physical problems (injury and disease), and freedom to express normal behaviour. In many species of fish there is increasing scientific evidence for behaviours that require quite complex cognition, such as learning from positive reinforcement. This is relevant to FAWC's belief that all animals should have 'a life worth living' and that as many as possible should have 'a good life.' Allowing fish freedom to perform behaviour of this kind in captivity may be challenging but requires consideration.

8. There is increasing understanding of the factors most important to fish welfare, primary among which is water quality. This has many components, including concentrations of necessities such as oxygen and harmful solutes, and factors such as pH and temperature. Many of these components are interdependent, with optimal ranges affecting each other and also varying between species of fish. There used to be emphasis on specifying maximum stocking densities (including in our 1996 report). It is now understood that water quality is more important, although high density may have an impact on water quality as well as on other welfare issues such as fin damage, disease transmission and social behaviour (e.g. feed competition, displacement of subordinate fish). Low stocking density can cause different problems, such as territoriality, but there is incomplete understanding of other needs such as those for the physical structure of the environment.

9. Many factors important to welfare are also important to production, notably avoidance of bacterial and viral diseases, parasites and physical skin damage, so both welfare and production benefit from these factors being controlled. However, some procedures negative for welfare are integral parts of the production process, for example, crowding before and during transport and handling fish out of water. It is appropriate to find ways to reduce such impacts, even if these conflict with production priorities.

10. Some fish species have been kept in captivity for centuries, for example carp, which have been selectively bred for reduced mortality, growth and appearance. Other species have been farmed only relatively recently; for example, salmon have been farmed for between 3 and 15 generations from their wild ancestors. These fish may be considered semi-wild, similar to other non-domesticated, farmed species such as gamebirds and deer.

11. Fish have fundamental differences from terrestrial farm animals. They:

- Live in water (and salmon and some trout transition between fresh and salt water); this has many effects, for example on importance of water quality, delivery of oxygen, maximal stress response on removal from water and vulnerability to diseases and parasites;
- Have a reproductive strategy of producing very large numbers of eggs, from which free living forms emerge at an early developmental stage;
- Inhabit a three dimensional environment that is typically only visible from the water surface, with challenges for visibility, identification of individuals, monitoring, handling and movement of animals;
- Are poikilothermic (cold blooded), which has many effects; for example, they are likely to be more affected by ambient temperature, but less affected by feed deprivation than homeotherms (warm blooded animals);
- Are particularly vulnerable to skin damage, especially when overcrowded or handled, with implications for disease susceptibility;
- May control their physiology by selecting environmental conditions, and production systems reduce this choice;
- Are developmentally labile; for example, maturation is affected by temperature, day length and feeding, while gender can be changed in many species;
- Include many carnivorous species;
- Include naturally migratory species (salmon and trout).

These differences have important implications for farming methods and for welfare. For example, fish are often kept in very large groups and in simple pens or tanks, although to the fish environmental complexity of currents and other water variables may be more important than the structural environment.

12. Despite the differences between fish and terrestrial animals, including the fact that some operations necessitate two activities that invoke the maximal stress response in fish (crowding and removal from water), it is widely accepted that fish (and specifically salmonids) are suitable for farming and food production purposes, and that some degree of stress is unavoidable, although it should be minimised through good husbandry practices and operating system design.

13. Brief overviews of the life stages and farming of salmon and trout are given in Box 1. Other species may be very different. Many websites provide details of life cycles and production systems for farmed fish species, for example the Food and Agriculture Organization of the United Nations[3]. Other terms are in the glossary (Appendix 3).

[3] http://www.fao.org/fishery/culturedspecies/Salmo_salar/en

Box 1. Overviews of life stages and farming.

Atlantic Salmon, *Salmo salar*

- **Broodstock**: Age 2-3 winters at sea or in shore-based salt water tanks, weight 10-20kg. Generally held in shore-based, fresh water tanks prior to stripping of eggs and sperm. Anaesthetised before stripping and not allowed to recover. ~1500 eggs/kg of fish.
- **Eggs**: mixed with sperm in the hatchery. Infertile eggs removed. Kept in fresh water of the highest available quality. Up to 510 degree days to hatch.
- **Young stock**: called successively alevin, fry and fingerlings/parr.
  - **Alevin**: Young with yolk sac attached, 0.1 to 0.3g. Kept in fresh water in indoor trays/tanks, in the dark. Loss of yolk sac just prior to first feeding. Time to first feeding depends on temperature.
  - **Fry**: Kept in indoor tanks. First sorted by size ('graded') at around 5g.
  - **Fingerlings/Parr**: Transferred to larger tanks indoors, outdoors or in fresh water lochs for 6 to 12 months, depending on conditions.
- **Smolt:** the stage of adaptation to salt water, alternatively:
  S0: Smolting at 6 months induced by photoperiod and/or dietary constituents (e.g. increased salt content).
  S1: Smolting at 10-12 months, 75-120g.
  S2 (unusual): Smolting at 12-24 months, up to 400g.
  Transferred to sea pens or seawater tanks.
- **Grilse/'One sea-winter salmon'**: Matured after one year at sea, 3-4kg.
- **'Two sea-winter salmon'**: 18-20 months at sea (longer for broodstock), 5-10kg.

Rainbow Trout, *Oncorhynchus mykiss*

- **Broodstock**: Kept in fresh water. May have photoperiod manipulated to control timing of reproduction. Females may be masculinised by hormone treatment. Eggs and sperm are manually stripped after anaesthesia.
- **Eggs:** Incubated ('laid down') in trays, typically at 10°C. Called 'green ova' until eyes are visible around 16d, then 'eyed ova.' Around 85% are all-female, produced by sperm from masculinised females, and around 15% are triploid produced by heat or pressure shock after fertilization.
- **Alevin:** Young with yolk sac after hatching around 30d post-fertilization. Kept in indoor trays.
- **Swim-ups:** Stage of first feeding, around 20d post-hatch.
- **Fry**: Transferred to nursery/fry units: troughs, tanks or raceways, typically indoor or covered, with bore or spring water. 0.6-10g (1.5–4 months). First graded at around 5 g.
- **Fingerlings:** 10-40g (4-7 months). Transferred to fresh water on-growing systems at 25-40g (5-7 months): raceways, earth ponds, tanks or pens/cages in lakes/lochs.
- **Grow-ons for slaughter:** Killed for the table market at >300g (12-15 months) before sexual maturity (all females).
- **Grow-ons for restocking**: Transferred to angling waters at >500g (>15 months). Triploids preferred for larger size and sterility.
- **Grow-ons for seawater transfer:** Transferred to nets/pens in seawater at >100 g (9 months). Slaughtered at 3-4kg after 1-2y in seawater.

Number of animals involved, duration and extent of poor welfare

14. The British farmed salmon industry is concentrated in Scotland, one of the world's three largest producers, together with Norway and Chile. Trout farms are found across Great Britain. All sites where fish are reared are registered, and there are over 750 such farms across Britain. There has been an increasing centralisation of salmon and trout enterprises with reduced numbers of companies but increased production. However, some small fish farms have been started as part of small-scale agricultural diversification.

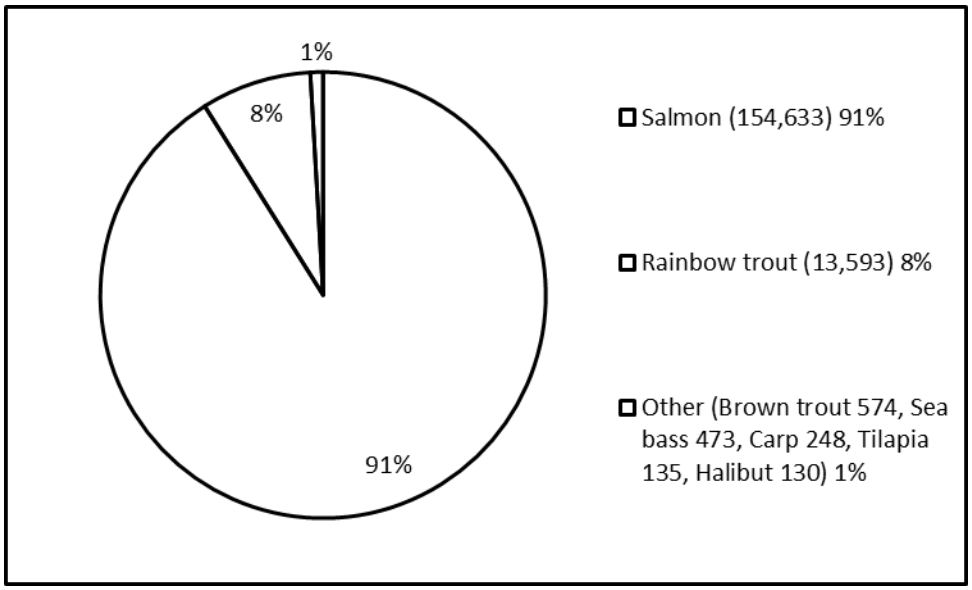
15. Approximately 180 million salmon and trout eggs are laid down each year in Great Britain (including Northern Ireland where recorded), making fish farming the largest livestock sector after broiler production. Mortality from egg to harvest is much lower than in wild fish. Calculation of mortality figures is complicated by factors such as overlap of year classes and inclusion of other losses (culls and escapes), while interpretation for welfare is difficult: for example, losses due to failure to hatch or at very early life stages have questionable impact on welfare. However, as mortality/survival is the main welfare outcome indicator available, FAWC believes that efforts to monitor losses, to distinguish between categories (death, culling and escapes), to set realistic targets, and to promote survival are all important.

16. There is variation in mortality at different life stages. In salmon the ratio of eggs laid down to smolts produced (over approximately the 1st year of life) is 1.5-2.0 (i.e. survival of 67-50%). In Scotland there is a long term trend for increased survival in fresh water, from ovum to smolt, from 22% in 1987 to 67% in 2011. Smolt to harvest survival (over approximately the 2nd and 3rd years of life) in 2011 was 83%[4]. Survival from ova to harvest was therefore 56% in 2011. Most losses are likely to have been of ova or very early life stages.

17. About 34.7 million salmon were harvested in Scotland in 2012[5]. UK farmed fish production for table and restocking in 2010 is shown in Figure 1[6]. The numbers of fish (other than salmon) grown to different weights for sale whole or filleted are not known, so it is not possible to translate production tonnages (live weight) to numbers of individuals, but for illustration a tonne of 450g whole trout comprises around 2200 individuals whilst a tonne of 3kg trout for portions comprises around 330 individuals. Production is dominated by salmon, but less so numerically than by weight, as salmon are the heaviest individual fish (up to 10kg).

[4] Marine Scotland Science Survey Report 2011
[5] Marine Scotland Science Survey Report 2012
[6] Cefas FinFish News summer-autumn 2012

Figure 1. 2010 UK farmed fish production for table and restocking (tonnes).



18. Production cycle length in some farmed fish is longer than most terrestrial farm animals, e.g. salmon can be grown for as long as three years and halibut for five. Chronic welfare issues might therefore have a higher welfare impact.

19. There are discussions about development of sentience in fish during their lives and at what stage their welfare can be assessed, e.g. at alevin or 2cm fry stages. Home Office legislation on the protection of animals used for scientific purposes applies to fish from the point of first independent feeding, but this is probably for practical reasons rather than a reflection of developing sentience. The Animal Welfare Act 2006 and the Animal Health and Welfare (Scotland) Act 2006 apply to all vertebrates other than foetal or embryonic forms. While new-hatched fish are extremely small, often called 'larvae' and are more similar in many ways to foetal than new born birds and mammals, many factors in their treatment affect their survival and development, and therefore affect their welfare either at the time or later or both. FAWC therefore suggests that it is valid to consider welfare from hatching, but that it is also appropriate to use first feeding as a working basis for the stage from which more attention might be given to their welfare. In salmon this is about 300 degree days after hatching, for example one month at 10ºC.

20. The number of fish involved in farming is very large. There are also often very large numbers of fish in individual holdings: a tank may contain more than 100,000 fry and the largest sea pens (also known as sea cages) can house nearly as many 5kg salmon. There are many challenges in control, management, environment, inspection and individual identification. Systems are very diverse, including on-shore tanks (which may re-circulate water), fresh water systems and sea pens. Potential welfare issues raised during consultations

include environmental conditions (especially water quality, including pollution events and stocking density), genetics, nutrition, movement/handling, transport (which happens to most farmed fish), diseases and parasite infestation (where mortalities can be extremely high).

Legal context (GB and Europe)

21. The Animal Welfare Act 2006 and Animal Health and Welfare (Scotland) Act 2006 cover fish (as vertebrates) that are commonly domesticated in the British Isles, under the control of humans, or are not living in a wild state. These Acts do not apply to any animal in the foetal or embryonic form (i.e. before hatching/birth), but in principle protect them at all other stages of development. This offers farmed fish protection against unnecessary suffering and places a duty on the person responsible for the fish to ensure their needs are met. Nothing in the Act applies to fishing (interpreted as any legitimate form of fishing, including angling).

22. European Council Directive 98/58/EC concerning the protection of animals kept for farming purposes (including fish), requires that *"owners or keepers take all reasonable steps to ensure the welfare of animals under their care and to ensure that those animals are not caused any unnecessary pain, suffering or injury".* This requirement is covered by the Animal Welfare Acts. However, the Directive excludes fish from the detailed provisions set out in its Annexes. The definition of farmed animal under the Welfare of Farm Animals (England) Regulations 2007 (and similar legislation in Scotland and Wales), which apply Directive 98/58/EC, explicitly excludes fish. Fish are, therefore, not offered the more detailed welfare protection afforded to most terrestrial farm animals.

23. The Welfare of Animals (Transport) (England) Order 2006 (and equivalent legislation in Scotland and Wales) applies to all vertebrate animals, including fish; applying Council Regulation (EC) No 1/2005 on the protection of animals during transport and related operations. Under this legislation drivers of animal transporters (and attendants) need to be trained and certified. Not all of the detailed provisions are best suited to the transport of fish, for example that:
"(g) sufficient floor area and height is provided for the animals" and
"(h) water, feed and rest are offered to the animals at suitable intervals."

24. As an explanatory parallel, the Animals (Scientific Procedures) Act 1986 (and impending legislation to implement EU Directive 2012/63/EU on the protection of animals used for scientific purposes) applies to fish from the point of first independent feeding, or earlier if factors have an effect later in life. Such a factor might be temperature in the hatchery: it has been suggested that increased temperature to promote faster growth might increase spinal deformities. This legislation does not apply to farmed fish *per se.*

25. Provisions for fish health and disease control are contained in the Aquatic Animal Health (England and Wales) Regulations 2009 (and similar legislation in

Scotland). Other legislation with relevance for the treatment and welfare of farmed fish includes the Veterinary Medicines Regulations (VMR) 2011. The term "animal" is only loosely defined under Section 27 (1) of the Veterinary Surgeons Act 1966. Fish are not specifically included. Practitioners have interpreted this to mean that clinical investigation and diagnostic interpretation of fish disease issues do not legally need to be undertaken by a qualified veterinary surgeon. The reality in the industry is that diseases in farmed fish are routinely diagnosed by fish biologists and other specialists who are not vets. This includes notifiable disease investigations done by Marine Scotland Science (MSS) and the Centre for Environment, Fisheries and Aquaculture Science (Cefas) staff. This situation has probably arisen because relatively few vets were involved as the industry developed. However, the prescribing of Veterinary Prescription Only Medicines (POM-V) is regulated by the VMR and must be undertaken by a qualified veterinary surgeon, who is also regarded as having those fish "under his/her care".

26. Environmental legislation has an impact on the treatment of fish disease and parasite conditions in terms of allowable discharge of medicines into fresh and sea water. Restrictions on numbers of treatments or the amount of medicine used can make treatment less effective.

27. Defra announced work on planning for sustainable growth in English aquaculture with a consultation in January 2012[7]. The Welsh Government has recently announced an aim to double Wales' annual finfish aquaculture output (from 1,000 to 2,000 tonnes) by 2020[8]. The Scottish Government has enacted the Aquaculture and Fisheries (Scotland) Act 2013[9], and is committed to help the industry to increase farmed finfish production substantially but sustainably by 2020.

Fish disease regulation

28. EU legislation to protect farmed (and wild) fish from serious notifiable diseases was revised in 2006 (Council Directive 2006/88/EC) and has been transposed into British legislation as The Aquatic Animal Health (England and Wales) Regulations 2009 (and similar legislation in Scotland). These regulations require:

- finfish farms to be authorised by the responsible body (i.e. the Cefas Fish Health Inspectorate (FHI) in England and Wales and the MSS FHI in Scotland) and to farm according to stipulations on species, holding facilities and location;
- finfish farms to operate in accordance with a documented and approved bio-security plan, maintain medicine and health surveillance records, maintain

[7] http://www.defra.gov.uk/consult/files/120112-aquaculture-consult-doc.pdf
[8] http://wales.gov.uk/newsroom/environmentandcountryside/2013/131126marine/?lang=en
[9] http://www.legislation.gov.uk/asp/2013/7/contents/enacted

mortality records for each epidemiological unit, and notify the FHI or nominated veterinarian of any increased or unusual mortality;
- specialist aquatic animal transporters to be registered and finfish farms to maintain records of movements of aquatic animals.

29. FHI field inspectors are appointed under this legislation, empowered to act under the authority of the competent authority, and can enter fish farms and issue enforcement notices.

30. The FHIs perform regular inspections of farms to audit compliance and inspect stocks for clinical signs of notifiable diseases. The frequency of site inspections is risk based, but is at least once a year in England and Wales and biennially in Scotland. Site inspections may be pre-arranged or unannounced. The FHIs also conduct risk-based programmes of sampling and testing for notifiable diseases, investigate disease outbreaks, enforce statutory disease controls and implement controls on the import and export of live fish.

31. The FHIs also operate on behalf of the Veterinary Medicines Directorate (VMD) under The Animal and Animal Products (Examination for Residues and Maximum Residue Limits) Regulations 1997. This involves: inspecting fish farm medicine records, sampling farmed fish for veterinary medicines residues and investigating any positive results. The FHI in England and Wales also undertakes inspections on fish farms holding veterinary medicines mixing licences under the VMR, on behalf of the VMD.

32. The FHI in Scotland undertakes additional inspections for containment (prevention of escapes) and for sea lice to assess compliance with The Aquaculture and Fisheries (Scotland) Act 2013. This may include audit of records (for containment, sea lice monitoring, medicines use, staff training and site procedures), inspection of stock and facilities, audits of staff conducting sea lice counts and administering treatments, making independent sea lice counts and collection of samples.

Fish welfare inspection and enforcement

33. Animal Health and Veterinary Laboratories Agency (AHVLA) and local authority inspectors (such as Trading Standards Officers) have official responsibility for enforcement of existing animal welfare legislation on fish farms (i.e. Animal Welfare Acts, Welfare of Animals (Slaughter or Killing) Regulations and Welfare of Animals during Transport Orders) but do not routinely visit fish farms.

34. FHI field inspectors have an on-farm presence when inspecting, auditing and collecting fish samples and will discuss fish welfare concerns with farm staff and, if appropriate, collect evidence of welfare issues. However, the official enforcement remit of the FHIs is restricted to fish health, medicines and

containment and does not extend specifically to fish welfare if not connected to disease. The FHIs therefore relay unresolved welfare concerns to Defra (in England and Wales) or direct to AHVLA staff (in Scotland).

35. In England and Wales, the FHI has been involved in occasional welfare cases, to avert the potential abandonment of stocks. However, it is striking that it appears that no enforcement actions or prosecutions under welfare legislation have ever been taken against finfish farmers within England and Wales. It is not clear whether this suggests that the industry is judged to maintain acceptable standards (welfare being a prominent part of assurance schemes), or that the official enforcement authorities lack a presence on fish farms or lack confidence in proceeding with actions for welfare (because fish farming presents particular challenges to gathering evidence for welfare enforcement actions), or a combination of these. Action under the Animal Welfare Acts could potentially be supported by evidence of failure to comply with a code of practice, produced by either industry or government.

36. In Scotland, AHVLA and Scottish Government vets have been involved directly on-site with cases of poor welfare reported to them and have sought satisfactory resolution of cases where they have been involved. A number of AHVLA vets have also recently been trained to prepare them to deal with such cases as they occur in future.

37. Non-governmental animal welfare organisations (e.g. SSPCA, RSPCA) may instigate legal actions under the Animal Welfare Acts. There are media reports of the SSPCA investigating individual fish farm managers in Scotland following deaths of salmon during chemical treatments for sea lice[10].

38. Where potential welfare cases concern large scale mortality or relate to the use of veterinary medicines, other agencies such as the Environment Agency, Scottish Environmental Protection Agency or VMD may become involved.

Potential for specific fish welfare legislation

39. There is currently no legislation specifying conditions under which fish should be kept. However, the Animal Welfare Acts place a duty on the person responsible for the fish to ensure their needs are met, to the extent required by good practice. “Needs” are defined to include a suitable environment, diet, ability to express normal behaviour and protection from pain, suffering, injury and disease. “Good practice” has been established for terrestrial farmed species in the form of the statutory Codes of Recommendations for the Welfare of Farmed Livestock (although the statutory basis of these Codes is under review in England at the time of writing). Codes of this sort could be developed for farmed

[10] http://www.fishupdate.com/news/fullstory.php/aid/14778; http://www.fishupdate.com/news/fullstory.php/aid/14058/SPCA_probe_salmon_deaths__.html

fish, drawing on the existing industry codes of practice, but in the absence of statutory codes the industry codes can be used for guidance on accepted good practice. Failure to comply with these codes could be used as evidence to support a prosecution or when taking other enforcement action.

40. General requirements of the sort included in the Welfare of Farmed Animals Regulations concerning the competence of staff, record keeping, inspection frequencies, construction of facilities and arrangements for maintenance and testing of automatic equipment could be extended to farmed fish. If these points are covered suitably in industry codes for the species concerned, they can be considered as accepted good practice (see paragraph 47 onwards) and it should be possible to enforce them using the Animal Welfare Acts as previously described. However, industry codes are at different stages of development for different species and have not yet been produced for some more recently farmed species. It therefore seems appropriate for legal requirements, with suitable modifications, to be extended to farmed fish so that there is a clear legal basis for enforcement. This will be particularly relevant for new enterprises with species that have not previously been farmed.

41. Although recommendations in statutory codes might be perceived to carry greater weight in a prosecution, they do need to be kept up to date with changes in legislation and technical developments. There may therefore be a good argument for encouraging the development and updating of recommendations in industry codes instead, with some form of government endorsement, as a more flexible alternative to statutory codes.

42. For terrestrial species, a person specifically qualified in animal welfare is required to be present during transport and in slaughterhouses and this has provided welfare benefits[11]. This approach could also be applied throughout the aquaculture industry, including on farms, where site managers may already fulfil this role but often not explicitly. Such a nominated person would need sufficient authority and technical competence to provide relevant guidance to farm personnel.

International considerations

43. In 2005 the Council of Europe published a general recommendation concerning farmed fish[12], which was initiated by FAWC's 1996 Report. The Standing Committee of the European Convention for the Protection of Animals Kept for Farming Purposes was working on species-specific texts for fish, but its work was suspended in 2010.

[11] European Council Regulation 1099/2009 on the protection of animals at the time of killing
[12] http://www.coe.int/t/e/legal_affairs/legal_co-operation/biological_safety_and_use_of_animals/farming/Rec%20fish%20E.asp

44. The OIE *Aquatic Animal Health Code*[13] makes recommendations that cover: Introduction to recommendations for the welfare of farmed fish; The welfare of farmed fish during transport; The welfare aspects of stunning and killing of farmed fish for human consumption; and Killing of farmed fish for disease control purposes. This guidance is a baseline for farmed fish production on a global basis.

45. In 2008 EFSA published several Opinions on the animal welfare aspects of husbandry systems for farmed Atlantic salmon, trout, carp, eel, sea bass and sea bream. In 2009 EFSA published Opinions on the general approach to fish welfare and the concept of sentience in fish, and on knowledge gaps and research needs for the welfare of farmed fish. These will influence any future proposals that might emerge from the EU Commission on the welfare of farmed fish.

46. It is difficult to quantify imports of farmed fish products but these come from a wide variety of species (e.g. salmon, sea bass, sea bream, tilapia, pangasius) and production systems with a range of welfare issues. Retailers' supplier standards and Aquaculture Stewardship Council standards are likely to be the only sources of assurance of production standards for imported products.

Commercial and other codes and recommendations

47. The UK salmon and trout industries have adopted universal codes of practice that go beyond legal minimum standards, at least partly in response to the 1996 FAWC Report. These codes of practice include those of the main industry bodies – the Scottish Salmon Producers Organisation (SSPO) in conjunction with government and others (Code of Good Practice for Scottish Finfish Aquaculture[14]) and the British Trout Association (BTA)(Quality Trout UK[15]) – and the welfare standards developed by the RSPCA[16] and implemented by its Freedom Food assurance scheme. Other relevant standards include organic standards, GlobalG.A.P., and Aquaculture Stewardship Council. Focus on fish welfare within these schemes is variable. Of course, any standard requires good implementation, inspection and compliance to be effective.

48. As assurance schemes develop in breadth and depth, the issue of communicating such standards to the consumer becomes more significant. Labelling adds value to the final product by modifying consumer buying behaviour, but some current claims may not be meaningful, such as that fish are 'farmed to the highest welfare standards.' Experience with other food labels suggests that fish producers should ensure that welfare related labelling (including logos or husbandry related terminology) clearly reflects the standards

[13] http://www.oie.int/en/international-standard-setting/aquatic-code/access-online/
[14] http://www.thecodeofgoodpractice.co.uk/cogp/preface-to-the-2010-edition
[15] http://www.qualitytrout.co.uk/
[16] http://www.rspca.org.uk/ImageLocator/LocateAsset?asset=document&assetId=1232731074670&mode=prd

achieved and allows both identification of standards and comparisons between products. In that way demand can drive up standards in the whole industry[17].

49. The Freedom Food scheme requirements for salmon (the RSPCA standard) are detailed and prescriptive. They were initially partly based on the 1996 FAWC report and have since been refined further. The Scottish Finfish Code reflects general practice and is less detailed and specific. All these codes and standards recognise that water quality is key to fish health, welfare and production and contain general requirements to monitor and maintain water of good quality. Most view stocking densities largely in relation to their impact on water quality, although Freedom Food sets upper limits for salmon stocking at different production stages, which are readily and objectively auditable. There is also other variation and sometimes contradiction between standards, for example in their requirements for smolting, fasting, removal of dead fish and use of medicines.

50. As already mentioned, there is no legislation that specifies requirements for the welfare of farmed fish during production and therefore no statutory code of practice. However, there is high take-up of both the Code of Good Practice for Scottish Finfish Aquaculture and of the Freedom Food assurance scheme for salmon (the latter covering 60% of Scottish salmon production in 2012[18], with the expectation expressed in 2013 that this will rise to 90% in the next two years[19]). An RSPCA welfare standard for trout is due for publication in 2014.

51. The Aquaculture and Fisheries (Scotland) Act 2013 uses the Code of Good Practice for Scottish Finfish Aquaculture as its source of guidance for the industry on fish welfare and many other aspects of farmed fish production.

52. We were informed during our consultations that ‘good welfare is good business’. Research and training (both vocational and academic) have apparently improved the welfare of fish and the acceptance of animal welfare considerations and practices in the industry over the last 20 years. Industry has been proactive in developing and implementing standards of good practice and information exchange is supported by industry organisations. One of the most common concerns voiced by industry was the lack of or risk to availability of veterinary medicines to treat disease and parasite conditions in farmed fish, and possible restrictions on existing treatments such as formalin (see Appendix 4).

[17] Farm Animal Welfare Committee. Report on Education, Communication and Knowledge Application Related to Farm Animal Welfare, 2011
[18] Freedom Food Impact Report 2012
[19] Scottish Salmon Producers Organisation Website 2013

Fish welfare issues

53. The increasing understanding of, and concern for, welfare of fish in aquaculture applies both to factors causing welfare problems such as disease, parasitism and feed deprivation and competition, and to outcomes such as skin damage, fin erosion, other injuries, hunger, pain and fear. The emphasis here will be on factors and outcomes that FAWC considers important but that have had less consideration in other reports.

Monitoring and consideration of groups and individuals

54. Most consideration of, and action on, fish welfare is at the group level, and monitoring is often limited, partly because it may be difficult to see individual fish. Good stockpeople assess group behaviour at feeding and at other times, and may notice changes in behaviour, such as 'flashing' – reflected light off the shiny ventral surface as fish roll in the water or against a substrate. Fish are more visible in some production systems than others, and in some species than others. Underwater cameras are sometimes used, but monitoring thoroughly and following up problems systematically with either visual or camera observation is often difficult. Camera output can, though, also be used retrospectively, to understand a problem after it has occurred.

55. One activity focussed on individuals is removal of dead fish, but this may not be done regularly, for example because of sea state or risk of disturbance of the population. Individuals from some groups are sampled for growth, diseases or parasites, but most action taken subsequently is at the group level. There is sometimes doubt about the reliability of sampling, because the condition of the fish may affect which individuals are caught. Monitoring of various welfare indicators would be necessary, both behavioural and physical (e.g. fin damage, deformities, morbidity), as well as of mortality, to assess improvement in fish health and welfare.

56. Some methods are being developed or implemented for automatic or remote monitoring, including submersible remotely operated vehicles. However, these will not remove the need for stockpeople to assess the fish and intervene if necessary. Numbers of fish managed by each stockperson are growing as pen sizes and automation increase.

57. Farmed fish are rarely treated individually except, for some of the animals, when vaccinated by hand, tagged and slaughtered (this is not unique to aquaculture but fish farming systems can make monitoring and intervention particularly difficult). Sometimes suffering results: for example, while in some systems sick fish can be caught with a dip net, it may be impossible to catch a sick fish in a sea pen, and problems like this may become more difficult as pens of larger size are used. Catching and culling sick fish can have an adverse impact on the behaviour and perhaps welfare of the rest of the population, but

leaving them can be a disease risk. The issue of monitoring will come up several times below. However, consideration of individual fish welfare is important whether or not they can be monitored.

58. Issues important for welfare and how these are currently addressed are considered below, primarily for salmonids, under the headings of Environment, Husbandry and Problems/solutions, although these categories overlap.

Environment

59. Many environmental factors are important for welfare. The intention here is to highlight some of those that are less obvious or emphasised elsewhere. First, choice of site and water supply may be critical. For example, water from a borehole may carry fewer fish pathogens than river or lake water, have less variable temperature and be free from chlorine (beneficial for fish health), but be high in carbon dioxide (deleterious).

60. Division of the farming process into distinct stages (hatchery and various growing stages) allows provision of conditions that are appropriate to those stages, and could potentially allow more monitoring of both groups and individuals when they are moved from one stage to the next. However, that movement may itself be disruptive or traumatic and, as it generally involves movement of a whole group, it means that subgroups may be given less than optimal conditions.

61. Similarly, farm systems such as ponds, raceways, tanks and pens are simple in design and tend to provide fairly uniform conditions throughout. It is questionable whether this allows sufficient variation for the needs or preferences of individual fish. For example, it has been shown experimentally that fish with certain diseases will choose a different place in a temperature gradient than healthy ones, yet the opportunity to do so in commercial conditions is generally lacking. It has also been shown in sea pens that fish show individual variation in choice of position and response to light levels and food delivery. This is not to say that provision of more varied, complex or enriched environments would be easy; factors such as enrichment may encourage territoriality and increase aggression.

62. Above all, fish need good water quality. This is complex, as water properties interact in their effects on fish. Thus a concentration of one solute that is safe at one time may become unsafe as other conditions change, e.g. concentrations of other solutes, temperature, pH, etc. For example, higher temperatures decrease the concentration of oxygen in water but increase the fishes' demand for it. Water quality is also affected by water flow and stocking density.

63. Carbon dioxide concentrations in water depend on pH and hardness of water; oxygen concentrations depend largely on temperature. Adding extra oxygen to fresh water can result in carbon dioxide levels from the fish increasing to detrimental concentrations. Water recirculation systems or heavily stocked tanks can also allow carbon dioxide concentrations to rise detrimentally.

64. Temperature and light also have important effects, such as influencing feed intake. Photoperiod is sometimes manipulated, even extended to continuous illumination. It is not clear what impact this has on fish welfare, even though some salmonids encounter 24h light (and 24h dark) in the wild. Some studies suggest that continuous illumination may cause eye damage, and periods of darkness are needed in some species. However, manipulation of light can be positive for welfare both directly (e.g. helping to synchronise smolting) and indirectly (e.g. allowing visibility of fish). Hatchery conditions may have an impact on later life, e.g. incubation temperature may affect cardiac and skeletal development.

65. There are at least two important conclusions on water quality. First, there should be safety margins and monitoring of the environment, including important parameters such as solute concentrations and temperature in combination with stocking density and water flow. Second, there should be direct monitoring of the fish to determine their welfare and the impact of water quality. Management procedures to address likely problems should always be available, such as providing supplementary oxygen or reducing stocking density.

66. Where farming systems rely on automatic equipment for environmental control and monitoring, alarms are needed to indicate failure or problems and contingency plans to deal with those are needed, including back-up supplies of water, power, oxygen, etc. Contingency plans are also needed for other emergencies, such as pollution events or severe predation[20].

67. Extreme weather events, such as changes in temperature and rainfall, storm surges and storms affecting sea-states, may have strong effects on fish farms, so farms need to be aware of the possibilities and plan for them. FHIs will seek assurances about farm planning to mitigate risk from extreme weather as part of their approval process.

Husbandry

68. Around half the eggs used in British aquaculture are imported, with salmon eggs coming from Norway and trout eggs from Denmark and the US. Imported stock may not always be bred specifically for British conditions so there is potential for mismatch of genotype to environment. Disease resistance and

[20] Farm Animal Welfare Council. Opinion on Contingency Planning for Farm Animal Welfare in Disasters and Emergencies. March 2012

flesh colour are among the traits genetically selected. Growth is more dependent on water temperature than genetic selection.

69. Sexual maturation is considered undesirable in farmed fish populations because energy from food is diverted from production of flesh to development of gonads, physiological changes can result in poor performance and condition, and sexually mature male fish may become more aggressive. Sexual maturation can be avoided by harvesting fish before they mature, altering environmental cues (e.g. daylength) to prevent maturation, and manipulation of karyotype (sex chromosomes). Karyotype manipulations include production of all-female and triploid populations. Female fish typically mature at a larger size than male fish, and triploid fish are sterile. Single sex populations and triploids are not allowed under organic or Freedom Food standards for salmon.

70. Most farmed rainbow trout are all-female populations, which are harvested before they mature. Triploid rainbow trout are also produced when larger fish are required, e.g. for stocking waters for angling. The Environment Agency has a policy that brown trout farmed for restocking should be triploid (or the progeny of local brood-stock) to preserve local gene pools[21].

71. Although triploidy is rarely used in salmon, it is an active research area. Use of triploid salmon has been proposed on environmental grounds because it would prevent escapees interbreeding with native wild stocks. Triploid salmon may also benefit the industry and fish welfare, because triploids may grow faster, the production cycle would be shortened, and the impact of sea lice may be reduced. Conversely, triploidy may have some negative effects on salmon welfare, e.g. increased incidence of deformities, but evidence for these is incomplete.

72. Identification of individuals is not common in commercial fish farms but experimentally and in some breeding populations fish are individually tagged. A number of identification methods are permitted under the Mutilations (Permitted Procedures) Regulations 2007 in England and Wales, and the Prohibited Procedures on Protected Animals (Exemptions) (Scotland) Regulations 2010. These include: insertion of subcutaneous tracking devices; tagging; chemical branding; freeze branding; micro-chipping; removal or perforation of parts of fins, adipose fins or fin rays. These will have different impacts on welfare. Experimentally, some fish have been fitted with passive integrated transponder (PIT) tags in the abdominal cavity (under Home Office licence) to monitor their movements, and computerised tracking of fish by their individual skin-spot patterns may also become possible.

73. Since 1996 there has been more automation of feeding, including capture of uneaten feed, which prevents wastage and pollution and allows monitoring of consumption by a group. Automated methods tend to reduce competition and

[21] http://www.environment-agency.gov.uk/research/library/publications/39903.aspx

aggression, but there may still be a minority of fish that get less feed than they require.

74. Feed is withdrawn before handling and transport to reduce metabolism (and hence ill-effects of stress), oxygen demand and defaecation. This improves water quality during crowding and transport, and food hygiene during post slaughter processing. Negative effects on welfare are probably less than in warm-blooded animals (wild fish may go for long periods without feeding). Sudden feed withdrawal may reduce welfare because aggression may increase. Maximum periods of feed withdrawal are detailed in most codes and standards, following a recommendation in the 1996 Report. There is still little scientific basis for these precise figures, but where they are given in degree days this seems more appropriate than absolute time.

75. Feed restriction is sometimes practised for management purposes, for example to slow the growth of some fish to meet a required delivery date. Again, negative welfare effects are probably less than for warm-blooded animals, but this practice may be protracted. There are situations when a whole pen will be subjected to the feed restriction practised prior to harvesting, but only a proportion will be harvested.

76. Smolting is the physiological change necessary for salmon to move from fresh to salt water. It is a managed process in farmed salmon and is an example of fish being treated as a population rather than individuals because they are moved as a group. Those fish that are not physiologically ready to move suffer major problems in salt water, and often die, but the group cannot be held back until all are ready, because some then adapt back to fresh water. However, the industry has made considerable progress in managing smolting, including by environmental and dietary manipulation that increases uniformity of fish and reduces losses after transfer to sea water.

77. All the following operations may cause physical damage through abrasion or contact with other fish and a high stress response: crowding, moving by pump, net or other method, grading, handling and transport. There has been progress in reducing the impact of all of these, for example by:

- Carrying out crowding in several stages, with time at highest density minimised;
- Moving fish in scoops with water rather than in nets;
- Reducing frequency of grading, which because it involves fish passing through machinery can be especially stressful and injurious, while recognising that sorting fish by size may be important for welfare, particularly that of the smallest fish in a group; and
- Development of mechanised handling in water.

Indeed, it is a priority for welfare to avoid removing fish from water, and if this is not possible to keep them partly immersed (to promote movement and to keep the gills submerged if possible) and to minimise the time involved.

78. More information is needed on the effects of those operations and procedures on fish, to assess current problems and to encourage and track improvements. FAWC was told that some farms collect quite a lot of data of this kind, but that there is little compilation or sharing of such data across the industry or with regulatory bodies.

Problems and solutions

79. While biosecurity has generally improved, disease and parasites are still major problems and are considered the greatest fish welfare problems by some. Effective treatments are lacking for some diseases (see Appendix 4), while for other diseases treatments are aversive, have significant side effects or are limited in their use by environmental controls. In some cases disease is increased by poor husbandry and environment because stress compromises the immune system. Sea lice are a variable but still sometimes major concern in salmon production and welfare; in 2013 the SSPO started to publish a quarterly report on prevalence of sea lice and on the management strategies undertaken. Use of wrasse and other cleaner fish to control sea lice will be considered in the next section.

80. In the last few decades, different diseases have arisen and have had to be addressed in turn. However, there is more proactive work occurring on fish health and welfare to try to reduce the threat of new problems, including breeding for disease resistance.

81. It is generally recognised that as far as practicable, biosecurity and husbandry methods, such as isolated sites, appropriate cleaning and disinfection of equipment, and all-in all-out production, should be used to reduce the risk of disease occurrence and thereby minimise the use of therapeutic medication. Medication should not be used to compensate for poor management or excessive stocking rates. Where new sites are being considered, most standards require that veterinary input be obtained in the veterinary health plan, preferably early in the design and planning stages, to reduce the risk of disease issues associated with inappropriate site selection or equipment design.

82. The 1996 FAWC Report raised the issue of availability of veterinary medicines. It is apparent that there is still only a limited number of medicines licensed for use in fish (Appendix 4). Where there are no licensed medications for a species, or for a disease condition, veterinary surgeons are permitted to prescribe medications licensed for another use or non-licensed medications to food producing animals under the terms of the Prescribing Cascade, provided the product is not prohibited for use in the intended species, and has a maximum residue limit, as listed in the Annex to Commission Regulation EU 37/2010[22].

[22] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:015:0001:0072:EN:PDF

83. Medicines (such as antimicrobials) are often administered at the level of the population, rather than to the individual, typically via the feed or via water "bathing". This approach is also commonly used for vaccination, although individual injection is also used in salmon and trout. In-feed therapeutic medication may create a number of issues, such as: sick animals may not ingest sufficient medication, as they may be inappetant, and will be inadequately treated; and outwardly normal animals are medicated, despite apparently not needing treatment for clinical signs. Sub-clinically affected animals, that are otherwise eating well, will be effectively treated and are likely to continue to grow well compared to more severely affected animals. This may increase size variability in the population, which may contribute to other welfare issues, such as competition. However, for some diseases the population medication approach does have the benefit of reducing the level of infectious organisms in the environment, and thus reducing the risk of a wider disease outbreak.

84. Furthermore, the effective therapeutic use of medicines and other substances may be prevented or restricted because of environmental/pollution concerns, potentially creating short term welfare issues and longer term efficacy issues. Formalin is one treatment that may be in this category, but is currently still available under the Cascade.

85. Morphological abnormalities are sometimes frequent, such as eye cataracts, heart problems and spine deformities, but an increasing amount is known about their causation and prevention. As already mentioned, it was considered that using higher temperatures to accelerate early development could increase skeletal abnormalities, so this practice is now restricted.

86. Similarly, injuries are sometimes common, but methods of avoiding them are improving. This applies both for injuries caused by the physical environment (reduced by, for example, use of knot-free nets) and for those inflicted by other fish (when fin damage occurs it is mostly caused by biting, and is less prevalent if high stocking density is avoided).

87. The value of a written health plan, already established for other farm animals, is increasingly recognized in fish farming. The Freedom Food scheme includes a requirement for a written Veterinary Health and Welfare Plan, agreed between producer, stockpeople and a vet familiar with the farm who can ensure that the plan addresses issues specific to the farm. The Plan should cover, as a minimum, biosecurity, fish management, monitoring and control of disease and physical injury, strategies for dealing with major common diseases, contingency plans to deal with disasters, recording and classification of the causes of mortality, and training of personnel. The Freedom Food scheme gives significant weight to the requirement for training in areas including recognition of signs of poor welfare and disease, investigation of health and welfare problems, administration and recording of the use of animal medicines, vaccination, sea lice monitoring, monitoring fish health, and management of procedures including

handling, crowding, grading fish, culling and humane slaughter. Other standards also require veterinary health plans, including the Code of Good Practice for Scottish Finfish Aquaculture, which is also comprehensive in the aspects that need to be covered. One important issue here is the availability of vets experienced in fish health.

88. Predators such as otters in fresh water systems and seabirds and seals in sea pens can have major welfare impacts, causing fear, stress, trauma and death. Exclusion or deterrence is preferable to methods that injure or kill predators, especially as some research on culling of seals found little effect on losses, but sometimes, for some categories of predators, killing is necessary and effective. Predation by cormorants on some fish farms was successfully reduced by selective killing of individuals that proved to be resident on the sites. Such culling requires licensing from English Nature, Scottish Natural Heritage or Natural Resources Wales.

89. The Scottish Fish Farm Production Surveys published annually by Marine Scotland Science have included data on escapes since 1999. The data (for salmon in fresh water, salmon in seawater and rainbow trout) are based on self-reporting by the industry, and reflect incidents when escapes occurred when rearing units failed or were damaged (e.g. due to weather, predators, accidents). The number of fish escaping from the three sectors varies markedly between years and no trends over time are apparent. The median between 1999 and 2011 was 190,000 per year (range 38,000 to 886,000). These figures exclude any losses that occur outwith reported incidents, and escapes elsewhere in GB. More recently, incidents of failure or damage are also recorded even if no escapes are confirmed.

90. Some escaping fish survive (as reported by anglers); the majority are likely to experience poor welfare. It is believed that escaped salmon and rainbow trout feed poorly on wild prey, lose condition, and most die prematurely. Recently there has been a drive to improve containment in Scottish aquaculture to reduce potential interactions with wild stocks[23]; this will also benefit fish welfare.

91. Land-based farms are required to screen water intakes and outflows to retain any fish that escape from the rearing units (tank, raceway or pond). If efforts are not made to recapture such fish they may reside within the water circulation channels on the farm, where they are not usually fed directly. These fish are a potential disease reservoir.

92. Algal blooms and swarms of jellyfish or gelatinous zooplankton are unpredictable events without obvious solutions. They can clog the gills and suffocate fish, clog nets and reduce water flow or sting fish.

[23] http://www.scotland.gov.uk/Topics/marine/Fish-Shellfish/18364/18692

Species of farmed fish

93. Species farmed in Great Britain or imported, in addition to salmon and rainbow trout, include brown trout, carp, eel, halibut, pangasius, sea bass, sea bream and tilapia. These have many differences in biology and needs. Management systems have to adapt to those differences, but sometimes knowledge about this is incomplete.

94. As one example, FAWC visited a farm rearing halibut, which are very different from salmon and trout, and so are farmed differently and have different welfare problems. They are manipulated chemically to produce single-sex groups, partly to reduce variation in growth. Varied growth is still an issue, however, and one welfare problem is that bigger fish are aggressive towards smaller ones. They are mainly bottom-living in the wild, and in farming are kept in nets with a taut base. In the absence of a loose substrate they tend to lie on top of or underneath each other. The implications of this for welfare are not known.

95. While wrasse are not farmed for human consumption, use of this and other species as 'cleaner-fish' to alleviate sea lice infections in farmed salmon seawater operations is increasing. Numbers of captive wrasse are increasing and are predicted to exceed 2 million per year within the next three years. Welfare issues include capture from the wild (which also raises questions of sustainability), predation by salmon, especially during feed withdrawal, and the lack of refuges. If demand exceeds supply re-use of wrasse has been considered, but this causes serious biosecurity risks. In this poly-culture system it is questionable whether the number of sea lice is sufficient to sustain the wrasse or, if not, whether they will eat salmon pellets, reducing feed available to the growing fish. The question remains about what to do with wrasse immediately before withdrawal of feed from the salmon prior to harvest.

Areas of poor or incomplete evidence

96. Fish farmers are increasingly keeping records of measurements, both on environmental factors and on fish, particularly where these are clearly important to productivity, but it is often unclear how these parameters should be interpreted in welfare terms.

97. Attention to individual fish welfare is important, but highlights a lack of understanding, relative to that in other farm animals, of:

- what good fish welfare is (for example, preference research has so far not shown up reliable criteria);
- how individual welfare can be monitored, with limited knowledge of variation between individuals and when in the production cycle this is important;

- which welfare outcomes are most important to fish and how they can be detected; while there has been extensive consideration of physical outcomes such as fin erosion and skin damage, and of pain (Appendix 5), there has been much less on mental outcomes such as hunger and fear;
- how observations and measures should be interpreted (good stockpeople can identify abnormal shoaling and feeding behaviour of groups or outliers given opportunity and time to do so; can this be quantified or described?);
- how what we do to fish affects them, even where there are agreed parameters for inputs or outcomes.

98. The effects on welfare of some common environmental factors are unknown, such as noise and vibration during transport by boat, road or air.

99. It is difficult to obtain information on individual fish, and to take action to protect or improve their welfare. It is possible with technology, at least in experimental conditions, to monitor individual or sentinel fish using video to assess swimming patterns or individual markings, different wavelengths of light or telemetric devices.

Critical issues

100. Difficulties in monitoring welfare and responding to problems both of groups and individual fish are growing as pen sizes, automation and numbers of fish per stockperson increase. Addressing those difficulties is likely to require increased use of technology such as video and telemetry, including automated systems to recognise situations that are out of the ordinary, combined with commitment from managers and workers.

101. Further, increased emphasis on monitoring groups and individuals might suggest a need for new and perhaps radical approaches to design and management. As just one example, it might be possible to design pens so that fish have to pass through a shallow channel (say, to reach a feeder), enabling them to be observed, and isolated if necessary. Alternatively it might be possible to carry out more checks on individuals during grading.

Ethical issues

102. FAWC believes that society should provide farmed animals with “a life worth living” and an increasing proportion with “a good life”[24]. We affirm that these provisions should extend to fish.

103. Perceptual barriers exist to giving fish full ethical consideration. Humans typically identify more closely with farmed mammals than they do with fish, due to a range of biological and habitat differences (see paragraph 11). Humans

[24] Farm Animal Welfare Council 2009. Report on farm animal welfare in Great Britain: past, present and future.

therefore feel a lesser degree of empathy with fish and are also less likely to regard fish as worthy of moral consideration on rational grounds. For these reasons the ethical issues in fish farming could, at least from a welfare perspective, potentially be viewed as insignificant.

104. In reality the ethical issues in welfare are diverse and complex. Many are similar to those in the farming of other animals. (a) At least some species, including trout, have a sensory experience of pain (see Appendix 5). (b) There are indications of a cognitive process, at least in rainbow trout, for the experience of fear, which because avoidable is unlikely to be merely a reflexive response. (c) Evidence exists from perceptual and cognitive awareness in fish for a degree of sentience. Increased understanding of these similarities with other farmed animals means that ethical issues in fish farming can no longer be viewed at the group level alone. Rather, even though dealing with individual fish is difficult, individual fish deserve ethical consideration.

105. From a legal perspective, the duty of care to fish under the Animal Welfare Acts may be taken to include provision of the Five Freedoms, insofar as these are applicable. With these in mind, greater consideration is needed of how farmed fish express normal behaviour, such as in feeding and social interaction, regardless of their capacities for pain, fear or sentience. The only elements of the Freedoms that may not be applied to fish at present are (a) thirst, although dehydration may occur if incompletely smolted fish are moved to salt water, and (b) discomfort, which to our knowledge has not been studied in fish.

106. It is widely accepted that food from fish forms an acceptable and important part of the human diet. Indeed, some analysts believe that levels of fish consumption will rise, as consumers opt for fish in preference to other meats for ethical and health reasons. In any case, commercial fish farming is relatively recent and likely to increase further. Ethical attitudes have largely developed from capture fisheries, but to reflect this new situation they now need to become more aligned with those in other farming sectors. The major welfare issues in capture fisheries, such as killing by asphyxiation, mean that aquaculture may be more ethically justifiable, as welfare standards are often higher. Nevertheless, the welfare of farmed fish at killing, including methods of killing and prior treatment, also remains a major ethical issue and will be covered in FAWC's forthcoming Opinion on this topic.

107. The welfare of wrasse and other cleaner fish used to control sea lice on salmon is a different ethical issue from the welfare of fish being reared for food production, but no less important. For example, measures should be in place to prevent predation on wrasse by salmon when they are feed restricted, such as by providing refuges, which can also be used at other times. This is a positive example of environmental enrichment in the species.

108. Although the welfare of wild fish caught in large quantities is not within FAWC's remit, the topic is relevant because very large volumes of wild fish are caught for use in feed for farmed fish. The ecological and ethical sustainability of this sector, while of great importance, is not FAWC's focus here. Angling is similarly excluded from both FAWC's remit and the Welfare Acts. Nonetheless, some fish farms also rear stocks to release into the wild for anglers. There are ethical questions about the acceptability of rearing animals to be hunted and their release from human care into the wild, as we have also commented with respect to gamebirds[25] and deer[26]. These issues, however, are separate from the welfare of fish under human husbandry.

Conclusions

109. While protection of fish welfare is challenging both in theory and in practice, FAWC recognises that many or most fish farmers and the aquaculture industry as a whole have addressed this subject seriously, within the historical and economic constraints of the systems that they use, and made many improvements that have improved the welfare of many fish.

110. In addition to the duty of care under the Animal Welfare Acts and the number of standards applied by industry and others to safeguard fish welfare, FAWC sees the need for specific legal requirements of the sort included in Schedule One of the Welfare of Farmed Animals Regulations to be extended to farmed fish to provide a baseline of management regulation. Detailed provisions for farmed fish welfare, currently contained in industry codes, need to be kept under review, as self-assessment by industry has limitations, information on compliance and enforcement is lacking, and standards need to be updated in this rapidly changing industry. FAWC concludes that Governments should consider detailed requirements as a longer term aim, informed by more scientific research on the needs of fish, and should improve enforcement if necessary.

111. For inspection and enforcement, data on welfare outcomes are needed, both from individual businesses and from the industry as a whole for comparisons. Few such data are currently collated on measures relevant to welfare. Exceptions are Marine Scotland Science's data on mortality (paragraph 16) and SSPO's reporting on prevalence of sea lice (paragraph 79). There is no industry-wide publication of data on trout.

112. Monitoring of welfare outcomes and responses to the results of such monitoring are variable at the group level. It is often difficult to see the fish, with devices to enable this (such as a simple tube to look through the water surface without reflections) unavailable or unused. Underwater cameras are quite common but are often not monitored effectively.

[25] Farm Animal Welfare Council 2008. Opinion on the welfare of farmed gamebirds.
[26] Farm Animal Welfare Council 2013. Opinion on the welfare of farmed and park deer,

113. Furthermore, there is little consideration of welfare at the level of individual fish. FAWC recognises that the ability to deal with an individual fish with a welfare problem is restricted in some systems – for example catching a sick or injured fish in a sea pen – and that attempting to do so might affect the welfare of the rest of the group. However, we believe that increased emphasis on individuals is important both for ethical and commercial reasons.

114. Understanding of environmental effects on welfare has led to improved prevention of ill-effects. However, implications of the emphasis on groups rather than individuals extend to design and management of systems and environmental factors, with systems generally providing fairly uniform conditions rather than allowing for varied needs or preferences of individual fish, and fish moved from one production stage to the next as a group with likely sub-optimal effects for some members. It may not be possible to give individual treatment to all fish, but it may be possible to provide appropriate conditions for those that need them, such as small or sick fish. Given the complex interaction of environmental factors in their impacts on welfare, monitoring of those impacts is needed but is again frequently not systematic.

115. Similarly, there has been improvement in design and management of many husbandry operations – for example smolting and grading – but some problems still occur for groups, sub-groups and individuals. More information is needed on the effects of these operations, to assess problems and to encourage and track further improvements.

116. Disease and parasites remain major welfare problems, and there is a need for more proactive work to reduce the chance of new threats, and to increase the limited number of medicines licensed for use in fish, although medication should not be used to compensate for poor management. Methods to target medication to individuals that need it rather than groups would be beneficial, and might help to address issues such as restrictions on use of medicines for environmental reasons.

117. Farming of new or unfamiliar species often involves ‘learning by doing,’ with significant problems for welfare resulting. Considerable knowledge of biology, disease susceptibility and behaviour ought to be a prerequisite to any farming of new species.

Recommendations

118. FAWC recommends that governments should extend the requirements for terrestrial species in the Welfare of Farmed Animals Regulations (WOFAR) to farmed fish (as appropriate and with suitable modifications), so that there is a clear legal basis for enforcement of basic requirements in all farmed fish species. This would include legal requirements for the management of farming enterprises of the sort included in Schedule One of WOFAR, for example concerning the

competence of staff, record keeping, inspection frequencies, construction of facilities and arrangements for maintenance and testing of automatic equipment. However, we do not recommend creation of a statutory Welfare Code at this time.

119. Governments should also review compliance with and enforcement of the Animal Welfare Acts by AHVLA and Local Authorities, including whether inspectors are sufficiently trained and whether welfare inspections of a random sample of farms, as occurs with terrestrial species, should be introduced. If compliance and enforcement are inadequate it may be necessary to consider further strengthening the legislative framework with more detailed requirements. More research will be required to provide the knowledge base for more detailed legislative provisions for the welfare of fish.

120. Existing codes and standards include many examples of good practice, but can always be improved. As one example, it would be desirable to develop alternative approaches to the practice of feed restricting a whole pen when only some of the fish are to be moved, and to the use of feed restriction over long periods. Where relevant scientific information is available, it should be used: for example, it would be appropriate to express maximum feed withdrawal times in degree days, not days. Industry and other bodies producing codes and standards should (a) review and update them regularly, and (b) publish information on compliance.

121. As part of the duty of care under the Animal Welfare Acts, industry codes and other standards should add a requirement for farms to appoint or identify a suitable person with sufficient technical competence to be responsible for animal welfare on site, with authority to provide guidance to other farm personnel.

122. Governments should review or commission a review on the availability of (a) medicines for treating disease and parasites in farmed fish, and problems for future availability, and (b) veterinarians experienced in fish health. They should publish their findings and monitor availability on an ongoing basis; such a review could be assisted by the Fish Veterinary Society.

123. Industry should develop systematic approaches to (a) monitoring of environmental parameters and of live fish for welfare outcomes by both visual and automatic methods, (b) responding to both observed health and welfare problems and mortality, with management adjusted against expectations, and (c) compiling and sharing data across farms where this is not already done.

124. All fish farms should have contingency plans for preventing or dealing with the risks of adverse events due to weather, pollution, predation, etc.

125. Industry and research organisations, with support from governments, should give increased consideration to individual fish welfare as well as to

groups. This may require techniques hitherto used experimentally such as tagging (already done for some broodstock), telemetry of sentinel individuals and computerised video analysis. It may require provision of appropriate conditions for categories that need them, such as small or sick fish – either provided for them, or available for self-selection. It may also require new and perhaps radical approaches to design and management. Research is needed on the impacts of many aspects of husbandry, such as smolting and grading, on the welfare of individuals.

126. Individual farms and the industry as a whole should not introduce new species or systems at commercial scale without pilot studies for assessment of biology, behaviour and welfare. Such studies may have to be extensive, and if welfare is not assured the transfer to commercial practice should not take place.

127. Such research has not yet been satisfactorily completed for use of wrasse and other cleaner fish, as methods to ensure that they are fed properly and not predated are not yet adequate. Industry should complete such research urgently before commercial use of wrasse is increased. Cleaner fish should not be re-used for subsequent year-classes of salmon because of the risk of disease transmission.

128. Fish are able to detect and respond to noxious stimuli, and FAWC supports the increasing scientific consensus that they experience pain. We therefore recommend that deliberations on management and other processes should be made on this basis. To justify current practices or to decide that practices should be changed, extensive research is still needed on this and other, fundamental aspects of fish welfare, such as their needs for specific conditions (e.g. light, temperature, enrichment) or opportunities (e.g. to perform certain behaviours), the effect on them if those conditions are not met (e.g. feed withdrawal), and other important welfare outcomes and indicators. Industry, research organisations and governments should collaborate in advancing research on fish welfare comparable to that on other farmed species.

Appendix 1 – FAWC Membership, Spring 2014

Peter Jinman - Chairman
Professor Michael Appleby
Professor Richard Bennett
Professor Henry Buller
Dr Andy Butterworth
Dr Joanne Conington
Huw Davies
Mike Elliott
Professor Laura Green
Dr David Grumett
Richard Jennison
Gwyn Jones
Professor Richard Moody
Dr Philip Scott
Mark White
Steve Wotton

Former FAWC member Neil Manchester, who stood down during 2013, was a key member of the Committee that prepared the Opinion on the welfare of farmed fish.

Advisors

Charles Allan – Marine Scotland Science
Tim Ellis – Cefas
Dr Rebeca Garcia – Defra/AHVLA
Dr Sophia Hepple – Defra/AHVLA
Professor Jimmy Turnbull – Institute of Aquaculture, University of Stirling
Andrew Voas – Scottish Government

FAWC Secretariat

Richard Aram
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Brenda Rawson

Appendix 2 – Those who gave evidence and assistance

Aquaculture Innovation
Artilus Consultancy and Research
British Marine Finfish Association
British Trout Association
Centre for Environment, Fisheries and Aquaculture Science
Compassion in World Farming
Defra
Fish Vet Group
Fish Veterinary Society
Fisheries Society of the British Isles
GLOBAL G.A.P.
Humane Slaughter Association
Humane Society International/UK
LANTRA
Landcatch
Moulton College
Pharmaq
Royal Society for the Prevention of Cruelty to Animals
Scottish Government
Scottish Salmon Producers Organisation
Seafish Industry Authority
Silsoe Livestock Systems Ltd
UK Aquaculture Forum
University of Bristol
University of Stirling
World Aquatic Veterinary Medical Association
World Society for the Protection of Animals

We would also like to thank the individuals who have given evidence and the farmers and their staff who hosted visits by the Committee to fish farms.

Appendix 3 – Glossary

Alevin	Yolk-sac-carrying fry of the salmon family
AHVLA	Animal Health and Veterinary Laboratories Agency
Bathing	Chemical treatment of fish where the chemical is introduced to the water
Benthic	Living on or in sea or lake bed
Biosecurity	Prevention of disease-causing agents entering or leaving any place where farm animals are present
BTA	British Trout Association
Cefas	Centre for Environment, Fisheries and Aquaculture Science
DARDNI	Department of Agriculture and Rural Development, Northern Ireland
Degree days	A value used to estimate and predict the various stages of development. Calculated by multiplying the average temperature in Celsius by the number of days. For example, 300 degree days may be 30 days at 10^{o}C or 100 days at 3^{o}C
Demersal	Living at or near the bottom of a body of water
Developmentally labile	Open to change or adaptation during development
European Council Regulation 1099/2009	Regulation on the protection of animals at the time of killing
EFSA	European Food Safety Authority
Fingerling	Fish of about finger length, approx. 10cm
First independent feeding	First instance of fry feeding on provided feed following yolk sac absorption
FHI	Fish Health Inspectorate/Inspector
Fry	The stage of fish development between alevin and fingerling
Gelatinous zooplankton	Small, free moving jelly-like animals
Grading	Process of sorting fish for size
Homeotherms	Warm blooded animals
Inappetant	Lacking appetite or desire for food
MSS	Marine Scotland Science
NGO	Non-governmental organisation
OIE	World Organisation for Animal Health
Pelagic	Living in open water
Photoperiod	The duration of an organism's daily exposure to light, considered especially with regard to the effect of the exposure on growth and development
Poikilotherms	Cold blooded animals
Poly-culture	Culture of more than one species in the same space, in imitation of the diversity of natural ecosystems

RSPCA	The Royal Society for the Prevention of Cruelty to Animals
SSPO	Scottish Salmon Producers Organisation
SSPCA	Scottish Society for the Prevention of Cruelty to Animals
Sea lice	Ectoparasites of finfish
Sentinel fish	An animal deliberately placed in a particular environment to identify a health/welfare problem
Smolt	Young salmon at the stage when it adapts from fresh to sea water
Smolting/Smoltification	Physiological process by which a young salmon becomes able to move from fresh to sea water
Triploidy	Genetic state whereby an animal has three sets of chromosomes rather than the usual two
Veterinary Prescription Only Medicine (POM-V)	A product that may only be supplied once prescribed by a veterinary surgeon, following clinical assessment of an animal under the vet's care
VMD	Veterinary Medicines Directorate
VMR	Veterinary Medicines Regulations
WASK	The Welfare of Animals (Slaughter or Killing) Regulations 1995
WATOK	The Welfare of Animals at the Time of Killing (Scotland) Regulations 2012; and The Welfare of Animals at the Time of Killing Regulations (to be implemented in 2014 in England, Wales and Northern Ireland)

Appendix 4 – Medication

1. A number of stakeholders have asserted that the availability of veterinary medicinal products for treating farmed fish is extremely limited, constraining prevention and treatment of disease in farmed fish. This view is echoed by a number of sources including Scientific Opinions from EFSA on farmed Atlantic salmon and trout, and several positioning papers by the Federation of European Aquaculture Producers (FEAP).

2. The range of medicines currently licensed for treating farmed fish in the UK is listed in Table 1. If there is no suitable veterinary medicine authorised in the UK to treat a condition, the veterinary surgeon responsible for the animal may, in particular to avoid causing unacceptable suffering, treat the animal in accordance with the principle of the Cascade. The Cascade is a legislative provision in the Veterinary Medicines Regulations (VMR) that allows a veterinary surgeon to prescribe unauthorised medicines that would not otherwise be permitted. A veterinary surgeon should consider the following, in this order, when deciding on the medication to use:

- A veterinary medicine authorised in the UK for use in another animal species or for a different condition in the same species.
- If there is no such product, the next option is either a medicine authorised in the UK for human use, or a Veterinary Medicinal Product not authorised in the UK but authorised in another Member State for use in any animal species (in the case of a food-producing animal the medicine must be authorised in a food producing species) in accordance with an import certificate issued by the Veterinary Medicines Directorate (VMD). This may also apply to vaccines.
- If there is no such product, the last option is a medicine prescribed by the veterinary surgeon responsible for treating the animal and prepared extemporaneously by a veterinary surgeon, a pharmacist or a person holding an appropriate manufacturer's authorisation. In exceptional circumstances, medicines may be imported from Third countries through the VMD's import scheme.

3. In the interest of food safety, food producing animals may only be treated under the Cascade with medicines which contain pharmacologically active substances listed in the Table of Allowed Substances in EU Commission Regulation No 37/2010[27]. These are effectively products for which a maximum residual limit has been set or for which it has been concluded that no such limit is required.

4. A veterinary surgeon prescribing for, or administering a medicine to, food-producing animals under the Cascade is required to specify an appropriate withdrawal period. Unless the medicine indicates a withdrawal period for the species concerned, this should not be less than 500 degree days for meat from

[27] , EU Commission Regulation No 37/2010: http://ec.europa.eu/health/files/eudralex/vol-5/reg_2010_37/reg_2010_37_en.pdf

fish. This can make it impractical to use the medicine due to the risk of re-infection during the withdrawal period.

5. In addition to the VMR, further restrictions on the use of veterinary medicines are imposed through authorisation from environmental authorities for the use and discharge of pharmaceutical ingredients. In some cases such restrictions impose conditions which run counter to good prescribing practice, for example by making it impossible to treat simultaneously, or within a reasonable time period, all fish in one biological unit.

6. From the above it is apparent that the scope for treating infectious diseases in fish with licensed products is limited. This is especially problematic in minor species, for example although there are 7 products licensed for treating parasites there is only one for trout and none for treating fresh water parasites, which are a major disease problem. Other major disease threats such as fungal infections are limited to a single licensed product with no effective options through the Cascade and for some species there are no licensed medicines at all.

7. The provision of medicines for food animals is a complex process dependent not only on regulation but market forces; however, the provision of an effective range of medicine to treat existing and emerging diseases is essential to the protection of farmed animal welfare. Availability of medicines has a major impact on the welfare of farmed fish and should be taken into consideration by the regulatory authorities.

Table 1 Medicines listed on the VMD database for treating farmed fish in the UK (November 2013).

Product	Active ingredient	Use against	Species	Category
AquaVac FNM Plus	Bacterial vaccine	*Aeromonas salmonicida*	Salmon	POM-VPS
AquaVac Vibrio	Bacterial vaccine	*Listonella anguillarum*	Trout	POM-V
AquaVac ERM	Bacterial vaccine	*Yersinia ruckeri*	Trout	POM-VPS
AquaVac	Bacterial vaccine	*Yersinia ruckeri*	Trout	POM-V
Ermogen	Bacterial vaccine	*Yersinia ruckeri*	Trout	POM-V
Alpha Ject	Bacterial and viral vaccine	*Aeromonas salmonicida*, Infectious pancreatic necrosis virus	Salmon	POM-VPS
Birnagen Forte	Bacterial and viral vaccine	*Aeromonas salmonicida*, Infectious pancreatic necrosis virus	Salmon	POM-V
Norvax	Viral vaccine	Salmon pancreas disease virus	Salmon	POM-V
Vetremox	Amoxicillin Trihydrate	Sensitive bacteria	Salmon	POM-V
Aquatet	Oxytetracycline Hydrochloride	Sensitive bacteria	Salmon, Trout	POM-V
Florocol	Florfenicol	Sensitive bacteria	Salmon	POM-V
Pyceze	Bronopol	Fungi	Salmon, Trout	POM-V
Salmosan	Azamethiphos	Parasites	Salmon	POM-V
Excis	Cypermethrin	Parasites	Salmon	POM-V
AMX	Deltamethrin	Parasites	Salmon, Trout	POM-V
Slice	Emamectin Benzoate	Parasites	Salmon, Trout	POM-V

Paramove	Hydrogen Peroxide	Parasites	Salmon	POM-VPS
Calicide	Teflubenzuron	Parasites	Salmon	POM-V
Tricaine	Tricaine Methane Sulphonate	Anaesthetic	Fish	POM-VPS
Halothane-Vet	Halothane	Anaesthetic	All Animals	POM-V

POM-V Veterinary Prescription Only Medicine, a Veterinary Medicinal Product that may only be supplied to the client once it has been prescribed by a veterinary surgeon following a clinical assessment of an animal, or group of animals, under the veterinary surgeon's care. **POM-VPS** A veterinary medicine that may be prescribed by any Registered Qualified Person (a veterinarian, pharmacist or other appropriately qualified person). A clinical assessment of the animal(s) is not required when prescribing this category of veterinary medicine and the animal does not have to be seen by the prescriber. However sufficient information about the animal and the way it is kept must be known to the prescriber, to prescribe and supply appropriately.

Appendix 5 – A viewpoint on evidence for the capacity of fish to experience pain

1. Recent studies have demonstrated the presence of polymodal nociceptors in the facial skin of trout[28]. Nociceptors respond preferentially to physically damaging, noxious or injurious stimuli, and those found in trout have similar properties to those seen in amphibians, birds and mammals[29 30].

2. In these studies, acetic acid and bee venom (agents known to induce pain response in humans) were injected into anaesthetized trout[31]. The trout performed anomalous behaviours, including rubbing their faces into the gravel and shaking their bodies, during the period after recovery from the anaesthetic, and these behaviours were not seen in saline or control groups. Repetition of this experiment by another group produced ambiguous results[32]. Similar studies carried out in goldfish demonstrated clear behavioural changes associated with aversive stimuli[33] and this study concluded that "fish do not only respond to painful stimuli with reflexes, but change their behaviour also after the event."

3. The authors of these studies stress that pain sensation is a process with physical, perceptual and emotional elements. It is not always possible unambiguously to determine the presence of pain in an animal but pain experience may be inferred from the behavioural responses of the animal.

4. By contrast, other studies have suggested that, whilst fish may have the anatomical structures commonly associated with nociceptive capacity, they may lack the perceptual and emotional basis for pain sensation[34].

5. Thus, the scientific debate in the case of pain detection and sensation in fish diverges around the two different approaches to the analysis and understanding of pain and responses to aversive stimuli. The first of these approaches is that fish 'have the physiological and anatomical mechanisms to detect painful and damaging stimuli, and behavioural responses to remove themselves from the site of aversion'[35]. The second and opposing view is that

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[28] Sneddon LU (2003) Trigeninal somatosensory innervation of the head of the rainbow trout with particular reference to nociception. Brain Research 972: 44-52

[29] Sneddon LU, Braithwaite VA and Gentle MJ (2003) Do fish have nociceptors: Evidence for the evolution of a vertebrate sensory system. Proceedings of the Royal Society: Biological Sciences, 270 (1520)

[30] Braithwaite VA and Boulcott P (2007) Pain perception, aversion and fear in fish. Diseases of Aquatic Organisms 75(2): 131-138

[31] Op cit 23

[32] Newby NC and Stevens ED (2008) The effects of acetic acid 'pain test' on feeding, swimming and respiratory responses of rainbow trout (Oncorhynchus mykiss) Applied Animal Behaviour Science 114: 260-269

[33] Nordgreen J, Joseph P, Garner JP, Janczak AM, Ranjeim B, Muir WM and Horsberg TE (2009) Thermonociception in fish: Effects of two different doses of morphine on thermal threshold and post-test behavior in goldfish (Carassius auratus) Applied Animal Behaviour Science 119(1-2): 101-107

[34] Rose JD, Arlinghaus R, Cooke SJ, Diggles BK, Sawynok W, Stevens ED and Wynne CDL (2013) Can fish really feel pain? Fish and Fisheries DOI 10.111/faf.12010

[35] Braithwaite VA (2010) Do fish feel pain? Oxford University Press ISBN978-0-19-955120-0

despite evidence of the physiological mechanisms to detect noxious stimuli, fish may not have the neural and cognitive capacity to 'experience' pain'[36]. This has been supported by the view of some scientists that because fish lack a neocortex, they are unlikely to be able to generate 'awareness' of pain. It is interesting to note that veterinarians who perform surgical and other procedures on fish routinely use anaesthetic, anti-inflammatory and analgesic agents[37].

6. In view of the divergence of scientific opinion, and the finding that fish possess the physiological and anatomical means to 'detect painful stimuli,' it appears appropriate to give fish the benefit of the scientific doubt, and to frame deliberations with an assumption that fish are able to detect noxious stimuli or tissue damage, and to experience pain.

[36] Rose JD (2002) The neurobehavioral nature of fishes and the question of awareness and pain. Reviews of Fisheries Science 10(1): 1-38

[37] Lewart G (2001) Anaesthesia, analgesia and surgery in pet fish. Proceedings of the Atlantic Coast Veterinary Conference, Oct 9-11 2001, Atlantic City, New Jersey