the case of commercial sea fishing, the fish are not humanely killed as is required in most land-based **slaughterhouses** processing domesticated animals. While alive and conscious, fish may be eviscerated, packed in ice and otherwise processed. Demersal fish (bottom feeders), in particular, have been shown to take up to 40 min or more to die following evisceration and packing in ice (Robb and Kestin, 2002).

Besides commercial fishing, the scale of sport fishing should not be underestimated. For example, the 2006 National Survey of Fishing, Hunting and Wildlife-Associated Recreation (US Census Bureau, 2006) shows that in the USA there are 30 million anglers (approximately 13% of the population) spending US$42.2 billion on their sport each year. In part due to depletion in fish stocks from overfishing, there has been a dramatic increase in aquaculture, producing fish for the table. Within Europe, aquaculture has been the fastest growing animal production sector, with an increase in both the number of species farmed and the total amount of fish produced. Farmed fish in Europe alone now include such diverse species as carp, salmon, trout, tilapia, catfish, sea bream, sea bass, eel, turbot, halibut, barramundi and cod. The farming of each new species requires the development of specialized knowledge and associated techniques if potential welfare problems are to be avoided. For example, mistakes in water quality, temperature or feeding when rearing from eggs through larval stages can lead to deformity and **abnormality** of almost all the fish in batches containing hundreds of thousands of animals. Fish may be reared at high stocking densities under highly constrained conditions, affecting their ability to carry out normal behaviours such as feeding, shoaling and **predation/parasite** avoidance. Factors such as these are thought to be the reason why the majority of farmed salmon and trout suffer high levels of fin erosion and why injuries, especially of the eyes, are more prevalent than in wild populations.

Other potential welfare problems in aquaculture include increased exposure to disease, poor water quality and the effects of husbandry procedures such as handling, grading, **transport** and harvest. The majority of fish are not stunned after harvest and death can be prolonged. Many fish are allowed to asphyxiate, often on ice or in an ice slurry. Salmon are frequently exsanguinated by gill cutting, a method which leads to death only after several minutes. A full review of **slaughter** methods is given in Robb and Kestin (2002), in which the majority of methods are found to be unsatisfactory. Electric stun/kill of fish at harvest has been shown to be effective, and methods are beginning to be developed for a range of farmed species and to be adopted by industry, often with support and encouragement from large buyers such as the supermarkets (see, for example, Lines *et al.*, 2003).

Fish are used in scientific research and for toxicity testing of products and of, for example, water supplies. Of the 3.2 million scientific procedures licensed to be carried out within the UK, 10% were carried out on fish (Home Office, 2008). Fish in research may be subjected to deliberately imposed treatments that may have a variety of adverse effects on growth, behaviour and physiology. Fish are also kept for private and public display. Ornamental fish are often captured from the wild using sublethal doses of poison and may undergo extensive transport. In captivity, as in aquaculture, their care depends on owners providing an appropriate environment. It is not uncommon to find predator and prey species kept within the same enclosure, a practice generally frowned upon in, for example, a terrestrial **zoo**.

Potential welfare problems exist only if fish have the ability to suffer. At present the evidence either way is not entirely satisfactory. Rose (2002) puts forward a strong argument that fish are unable to 'experience' **pain** and are unable to suffer, stating 'the reactions of fishes to noxious stimuli are nociceptive and without conscious awareness of pain'. His argument is in the main part based upon a comparison between the neural structures present in fish and those present in mammals, with particular reference to man. An alternative view is summarized in Huntingford *et al.* (2006), which they relate only to adult fish. They draw on the current literature showing that, of those investigated so far, several fish species are capable of learning and integrating information and that this requires processes more complex than simple associative learning. Based on this evidence and supposition they state that 'where there is evidence of fish species with sophisticated cognitive and behavioural processes, the experience of suffering may be a real possibility'. A strong piece of work in support of Huntingford *et al.* (2006) by Sneddon *et al.* (2003) found that when rainbow trout were administered bee sting venom around the mouth they suspended feeding, showed a greatly increased rate of opercular beat and moved to the bottom of the tank to rock gently from side to side. Current research in this area is turning to functional and structural magnetic resonance imaging (MRI) techniques to help investigate **brain** functioning and remodelling during **aversive** episodes. Whatever the eventual outcome of the argument, for the time being it is suggested that the '**precautionary principle**' is adopted. (TK)

References and further reading

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Fission–fusion social system

This is a type of social **grouping** in which all individuals belong to a parent group that can fracture (fission) into smaller subgroups or individuals to seek out dispersed resources, such as forages or mates, but afterwards return to the larger parent group (fusion), often using contact calls to facilitate this fusion. There can be fluid movement of individuals between subgroups and even between different parent groups, such that group composition and size are frequently changing. In order for a **social group** to be spatially coherent, its members need to synchronize their activities. However, synchronization can be costly to individuals if it causes them to put off an activity that would benefit them more than what the group is doing. This will occur more in groups comprised of different ages, sexes and sizes, since optimal time allocation is likely to differ between these individuals. Thus, division into smaller subgroups can facilitate **synchronization of behaviour** in individuals with similar requirements. Species that have a fission–fusion social system tend to have very large **brains** relative to their body size, suggesting that this type of system may be cognitively demanding (**see: Intelligence – comparative**), perhaps relating to the difficulty of managing social relationships with individuals which are out of contact for long periods of time. (LMD)

Fitness

In **evolution**, success is defined by the persistence of genes in a population. There are three ways to do so and, together, they define an individual's inclusive fitness. First, survival and doing things that help an individual survive maximize personal fitness. Secondly, **reproduction** and doing things that help an individual reproduce maximize direct fitness. Thirdly, helping relatives survive and reproduce, since kin share common genes (see: **Kinship**), maximizes indirect fitness. (DTB)

See also: Dominance; Individual fitness; Sexual behaviour

Five freedoms

The basis for the five freedoms was first documented in the **Brambell Report** in 1965, but not formalized as such until later. They comprise:

- Freedom from thirst, **hunger** and **malnutrition** (by ready access to fresh water and a diet to maintain full **health** and vigour).
- Freedom from physical and thermal discomfort (by providing an appropriate environment including shelter and a comfortable resting area).
- Freedom from **pain**, **injury** and **disease** (by prevention or rapid diagnosis and treatment).
- Freedom to express most patterns of normal behaviour (by providing sufficient space, proper facilities and company of the animal's own kind).
- Freedom from **fear** and **distress** (by ensuring conditions and treatments that avoid mental **suffering**). (DBM)

See also: FAWC; Laying hen housing; Measuring welfare

Further reading

Brambell Report (1965) *Report of the Technical Committee to Enquire into the Welfare of Animals Kept under Intensive Livestock Husbandry Systems*. Chairman: Professor F.W. Rogers Brambell. Cmnd. 2836, December 1965. Her Majesty's Stationery Office, London.

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Flehmen

The term flehmen was introduced by Schneider in 1930 and refers to a conspicuous behaviour performed by ungulates and members of many other taxa in response to **pheromones** from other animals, usually **conspecifics**, but also other species. Pheromone is the term used for a chemical that transmits messages between animals. The flehmen response involves a characteristic **posture**: the animal stands erect, extends its neck, raises its head, flares the nostrils, opens its mouth slightly and curls the upper lip, often exposing the upper gum (performs a 'grimace'; see Fig. F.5).

Flehmen is generally performed in response to the smelling and/or licking of **urine** and/or the anogenital region of another animal. It is often performed repeatedly to the same stimulus and may be maintained for a minute or more. The behaviour is thought to facilitate the transport of relatively non-volatile compounds to the **vomeronasal** (or Jacobson's) **organ**, which is a chemoreceptor organ located in the vomer bone between the nasal passages and the mouth. Thus the vomeronasal organ appears to be used for the perception and analysis of pheromones, allowing the animal performing flehmen to gain information about the animal emitting the pheromones.

Generally, flehmen is performed by a male to the urine of a female, is often seen in a sexual context and, thus, one function of flehmen may be to allow a male to determine the reproductive status of a female. However, this cannot be the only function, as it occurs interspecifically, and in some species it is performed during female–female and male–male encounters. There are also reports that, in some species, females perform flehmen to neonates and amniotic fluid. Thus it may be that

Fig. F.5. Sable antelope (*Hippotragus niger*) showing flehmen to urine (image courtesy of, and reproduced with the permission of, Kaci Thompson, University of Maryland, College Park, Maryland).