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Science-based assessment of welfare: aquatic animals

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Summary

Terrestrial animal welfare has been a matter for exploration for many years. In contrast, approaches towards improving the welfare and humane treatment of aquatic animals are relatively new, as is the thinking behind them. Several issues complicate the process of addressing the welfare of aquatic animals in a consistent manner. These include the following:

– the huge diversity among aquatic animals, the majority of which are poikilothermic vertebrates and invertebrates
– understanding the practices involved in fisheries, aquaculture and aquatic animal production, and their purpose
– the relative paucity of scientific information
– understanding the philosophical approaches, policies, guidance and regulations that may influence the provision of optimal welfare and humane practices for aquatic animals.

In this paper, the authors attempt to provide an overview of all these elements, relating what is known and understood about these issues for the primary group used in aquaculture and fisheries, finfish, and exploring the factors that may influence the concepts and practices of aquatic animal welfare. These factors seem to be the foundation of all welfare approaches and include:

– ethical and moral concepts of animal welfare and humane treatment
– whether animals experience suffering from the potentially adverse practices used in their maintenance, management and use
– the public and institutional understandings of these issues and their results.

These are discussed with the hope that future developments in, and approaches to, aquatic animal welfare will be of use to society, industries and the public.

Keywords

Aquaculture – Aquatic animal – Cephalopod – Crustacean – Decapod – Ethics – Finfish – Harvest fishery – Humane practice – Ornamental – Welfare.

Introduction

Animal welfare deals with the humane treatment of animals. Addressing the welfare or well-being of aquatic animals is possibly one of the more complex and challenging tasks for science, as this involves several factors unique to aquatic animals. In contrast to terrestrial production animals, aquatic animals encompass extremely diverse, divergent and distantly related taxonomic groups, of greatly varied phylogenetic ages and linkages. They range from highly developed marine mammals to lower invertebrates, all with very different anatomies, physiologies and behaviour. For example, the evolutionary history of finfish stretches back over 450 million years (96) and more than 28,500 species currently exist (52). Invertebrate groups have even greater evolutionary age, adaptations and diversity. These animals are used in a number of different ways and for a variety of reasons, including food and other commodities, exhibition, recreation, research, etc.

Furthermore, there is a relative dearth of scientific information for evaluating and addressing the optimal humane care and welfare of most aquatic animal species. The majority of documented information refers to finfish (41). This scarcity also applies to the ethical theory on which aquatic animal welfare can be founded. Unlike those approaches dealing with mammals and birds, aquatic animal welfare is in its infancy.

In general, aquatic animal welfare involves philosophical and ethical interpretations of humane practices. Public understanding of these issues also influences humane treatment of aquatic animals, and the resulting opinions or policies expressed by many organisations. Sentience, that is, the conscious awareness of the animal to favourable or adverse conditions, is usually considered a precondition for animal welfare concerns and is thus an important question. The principles of animal welfare have emerged primarily in terrestrial animals, many of which have similar anatomies, physiologies and behaviours (which are often also shared by humans). Most animal welfare principles are based on the assumptions that these similarities indicate that animals are sentient (i.e. are cognisant and feel comfort and discomfort), and that it is unethical to purposefully, or through neglect, inflict or allow animals to experience discomfort. However, with the exception of marine mammals (which will not be dealt with here), aquatic animals are poikilothermic (cold-blooded) vertebrates or invertebrates and their physiology is likely to result in different levels of sentience.

One practical problem for science is how to deal with the large numbers of individuals handled in aquaculture, as the welfare of the individual animal must be protected and monitored.

The development of approaches to aquatic animal welfare issues is likely to be influenced by many factors. These include the following:

– ethical and moral philosophical concepts and principles which relate to the humane treatment of all animals

– scientific evidence that animals are capable of perceiving and responding to human intervention and practices (i.e. sentience)

– public understanding of these factors and perceptions of human-animal interactions and sub-optimal husbandry practices

– opinions expressed through the policies adopted by governmental and non-governmental organisations, which may result in legislative and regulatory decisions or guidance.

These influences and constraints, along with a limited number of publications dealing with animal welfare, restrict an extensive discussion on all aquatic animal species and welfare issues. This paper will therefore attempt to provide an overview of the principles of animal welfare that may apply to poikilothermic aquatic animals, with an emphasis on finfish. Where applicable, the authors will also refer to decapods. This discussion will focus on the scientific evidence for the ability of aquatic animals to perceive, process and respond to positive or negative conditions imposed by human intervention. Such evidence is usually considered fundamental in developing approaches to optimise animal welfare and humane treatment. The authors will also attempt to relate these approaches to the current predominant practices used in aquaculture, harvest, capture and wild fisheries.

Aquaculture, harvest and capture fisheries

The greatest number of human-aquatic animal interactions fall principally into three broad categories:

– aquaculture fisheries

– harvest fisheries

– capture fisheries.

Aquaculture and harvest fisheries primarily involve using animals for food and these industries rival or exceed terrestrial animal agricultural production (Fig. 1). However, captured aquatic animals may be cultured or farmed and later consumed, and aquatic animals are also captured or bred for exhibition and other reasons, such as recreation and sport. Finfish, crustaceans and molluscs constitute the predominant species harvested from the wild or cultured (101). It is the largest group, finfish, that will be the primary topic here. Many aquatic animals are also used as companion animals or 'pets' (ornamentals) in private and public displays, and in research. Although few species are truly 'domesticated', they have been managed or cultivated for many millennia (14).

The capture, breeding and care of aquatic animals has a long tradition in society. Aquaculture is defined here as the purposeful culture, farming or management of aquatic animal populations for the benefit of humans or the environment.

This definition includes the following:

– private and public, commercial and non-commercial systems which have been specifically constructed (e.g. tanks, ponds, etc.) to house aquatic animals

– impounded natural areas (e.g. net-pens, cages, etc.) of readily motile animals (e.g. finfish)

– areas of naturally occurring habitats of sessile animals (e.g. oyster and clam beds or reefs).

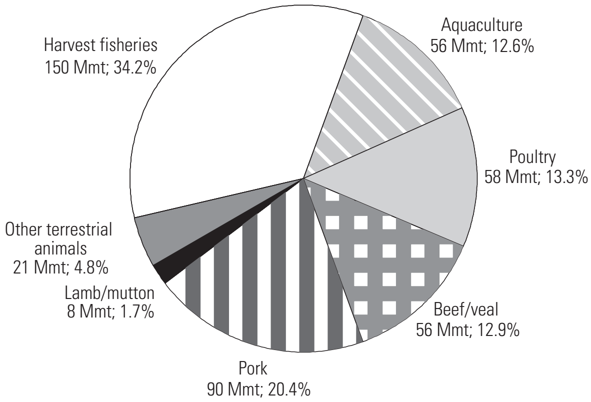


Fig. 1
Current estimated global production from aquaculture and harvest fisheries (primarily finfish, crustacea and molluscs), in comparison to terrestrial animal agriculture commodities
Quantities shown in millions of metric tons (mmt) of protein
Sources: Bruinsma (24), FAO (47, 48, 49) and Rana (101)

It also includes hatcheries that release large numbers of fish for restocking purposes and animals held for exhibition. In all aquaculture, optimal survival, growth and maximal fecundity are the primary objectives. Optimising the conditions that meet these objectives is the primary reason for improving the welfare of the animals.

Commercial harvest fisheries rely on capturing wild animals primarily for food. Some of these stocks may have been produced through aquaculture and subsequently released to the wild. Non-commercial fishing or angling is typically for personal food consumption and occurs frequently throughout the world to sustain families or local communities.

Many wild populations are managed through harvest or catch limitations, usually imposed by government regulation, to maintain ecologically stable or sustainable populations (46). In all other ways, however, wild aquatic animals are subject to the variable conditions of the environment with no human control over their welfare except humane treatment during their harvest and processing.

Today, the production and trade of ornamentals is a large and continuously developing industry (60, 61, 92), with a very high monetary value (31). Traditionally, these aquatic animals are captured from the wild and kept in home aquaria or large public displays; however, the propagation and culture of these animals over many generations is increasing rapidly. In some countries, the popularity of ornamentals as companion animals in homes rivals the numbers of traditional 'pets' (3, 5). To satisfy welfare issues in the ornamental fish trade, as in aquaculture, wholesalers and aquarists must have sufficient knowledge of the basic needs of these fish for water quality, feeding, genetics and disease management.

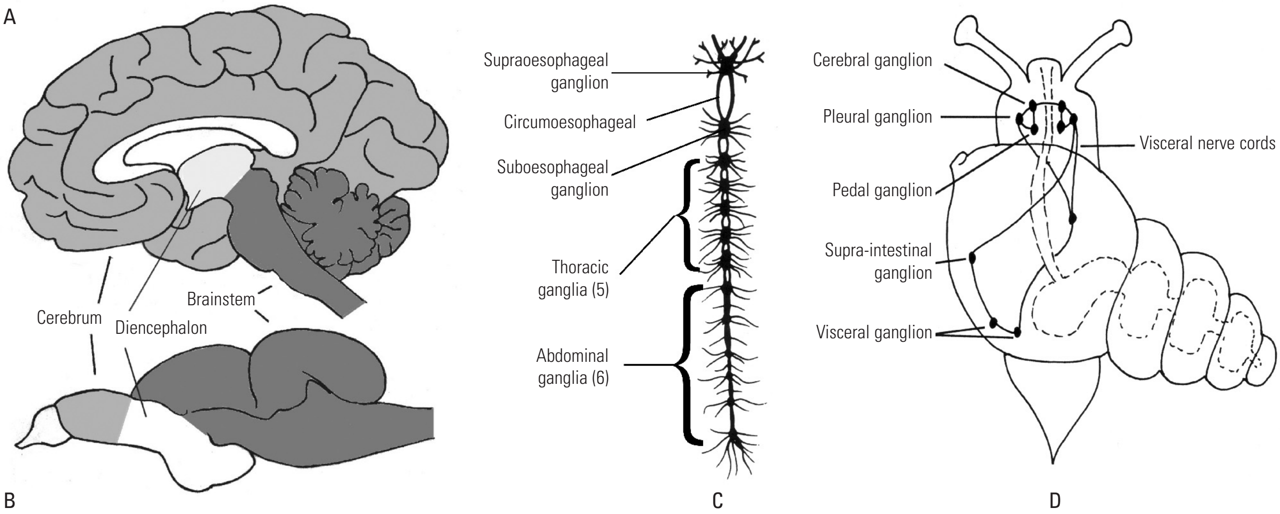
Aquatic animals: their cognisance and perception of conditions affecting their welfare

Applying the principles of ethics and animal welfare to poikilothermic aquatic animals involves supplying the things necessary for sustaining life, optimising health and minimising visible discomfort (e.g. pain, stress and fear). Evidence demonstrating that these animals have sufficiently high cognitive ability to be fully aware of their surroundings and the conditions that affect them (8) is pivotal to animal welfare. However, the mechanisms for providing such evidence are still highly controversial, even in humans (9).

This higher level of cognition, frequently referred to as 'sentience' (27, 28) and typically attributed to the neocortical functions in mammals, must result in conscious awareness (including perception, memory, judgement and possibly emotional responses to conditions), not merely reflex actions to internal or external stimuli. Evidence on cognitive abilities is therefore most frequently inferred from neuro- and endocrine physiology findings, and as expressed through behaviour. However, an objective scientific assessment requires avoidance of anthropomorphic logic – i.e. attributing human characteristics and emotions to animals without a sound scientific basis.

Much of the information on the ability of finfish to consciously perceive, experience and respond to conditions and situations comes from their neuroanatomy and neurophysiology, particularly the neocortex. There is no doubt that the central nervous systems (CNS) of mammals and poikilothermic vertebrates and invertebrates are very different (Figs 2 and 3). However, higher-level cognitive ability cannot be inferred from neuroanatomy alone.

It has been suggested that the supraoesophageal ganglion of crustaceans (17) and the cerebral ganglion of molluscs function as 'brains' to co-ordinate and integrate somatosensory and motor functions. Nevertheless, there appears to be no information linking these organs to true cognitive abilities. Indeed, some authors (30) suggest that this lack of neural complexity indicates that invertebrates cannot be cognisant of noxious stimuli and, therefore, are unable to experience pain, fear or suffering.

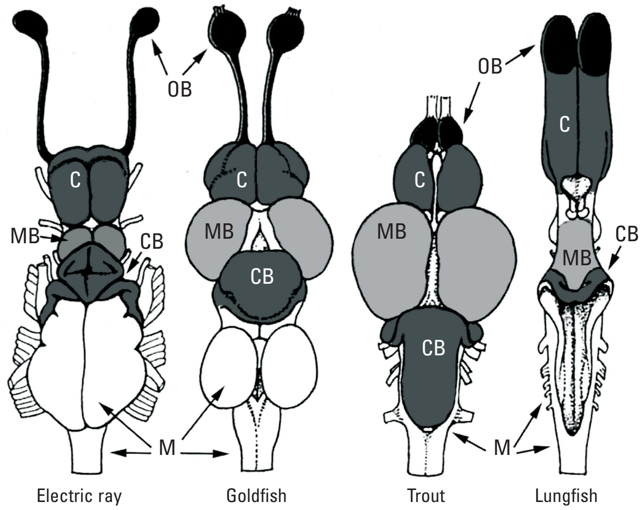


A: mammal
B: teleost (trout)
C: crustacean (lobster)
D: mollusc (snail)

Fig. 2
Comparative complexity of the central nervous systems of the primary aquatic animals used in aquaculture and harvest fisheries, in comparison to that of a mammal
Sources: A and B from Rose (107), C and D from Sømme (121)

While this belief may be justified for most mollusc groups, cephalopods (octopuses, squid, etc.) have the most complex and well-organised brains of all invertebrates. Their CNS are well developed and include giant axons. Furthermore, their eyes are the most complex of all invertebrate eyes (140). They can solve maze puzzles and remember the solutions, they have complex behaviour patterns and they appear to show strong emotions that are signalled by profound changes in colour. In many respects, cephalopods appear to exhibit the higher-level cognisance necessary to suggest they may be sentient. Boyle (20) suggested that, 'the neural and behavioural complexity of the cephalopods is similar to that of the lower vertebrates, and it is felt that their needs and welfare merit similar consideration'. However, evidence for cephalopod sentience is equivocal for, as stated by Williamson and Chrachri (140), 'there is surprisingly little known about the operation of the neural networks that underlie the sophisticated range of behaviour these animals display'. In addition, Sømme (121), in a comprehensive review of invertebrate sentience, concludes that, while it is unlikely that most invertebrates are sentient, and, 'although octopuses have a high level of cognition and great ability to learn, it is not definitely known if they can experience pain' (one criterion thought to indicate sentience).

There is continuous debate (7, 107) on whether finfish are sufficiently cognisant of noxious stimuli (119, 120) to perceive these as pain or fear and thus experience emotional responses akin to suffering. Southgate and Wall (122) and others (119, 120) demonstrated that fish have nociceptors (receptors capable of sensing noxious stimuli). Many also suggest that, because A-delta and C fibres are present in the trigeminal and afferent somato-sensory neural pathways, similar to those found in mammals, fish may have some ability for a certain level of cognitive neural processing. It is also suggested that A-delta and C fibres present in the peripheral nerves simply modulate pain (71). Furthermore, substance P, which is implicated in pain transmission in mammals, has been found in the hypothalamus and forebrain of fish (74). However, Rose (107) argues that nociceptive-based behaviour of fish can occur in the absence of pain, and that these behaviours are not dissimilar to the adaptive reflex behaviour of all animals, including protozoans which simply avoid noxious stimuli. The discussions of Chandroo *et al.* (27, 28) complicate this still further. Using information from other studies, Chandroo *et al.* speculate that fish may have neuro-functional similarities to other animals that suggest sentience and an appropriate level of cognisance, which may indicate that fish are capable of suffering. However,



C : cerebral hemisphere
CB : cerebellum
M : medulla
MB : midbrain (the optic tectum is the only midbrain structure visible in this dorsal view)
OB : olfactory bulb
Structural specialisations are most pronounced in the brainstem, which consists of the medulla, cerebellum and midbrain. The elasmobranches, represented by the ray *Raja clavata*, have a large electromotor nucleus on the dorsal surface of the medulla (shown by the upper arrow pointing to the medulla). Among the more highly evolved teleosts (bony fishes), brain anatomy varies according to dominant sensory systems. For example, the goldfish *(Carassius auratus)* has a large vagal lobe (upper arrow pointing to the medulla), due to its extensively developed chemosensory system for taste, while the rainbow trout *(Oncorhynchus mykiss)* has a relatively large optic tectum of the midbrain, due to its visual specialisation, and the South American lungfish *(Neoceradotus forsteri)*, regarded as an unspecialised species, has a slender brain lacking structural exaggerations

Fig. 3
Comparative anatomy of the brain of four diverse finfish types, illustrating both the basic similarity of brain structural organisation and striking differences related to predominant sensory functions, making comparison of neurosensory and cognitive abilities difficult
From Rose (107)

evidence for the cognitive ability of fish to interpret noxious stimuli as pain or discomfort is equivocal and subjective (21, 108), and must undergo rigorous examination. Similarly, as no neurological or other evidence is available concerning the higher-level cognitive abilities of lower invertebrates, such as crustaceans and molluscs, that would identify them as being sentient (121, 140), more in-depth research is also needed in this area.

Nevertheless, as has been suggested by Cawley (26) and others, and eloquently articulated by Rose (108), 'the improbability that fish can experience pain in no way diminishes our responsibility for concerns about their welfare. Fish are capable of robust, unconscious, behavioural, physiological and hormonal responses to stressors, which if sufficiently intense or sustained, can be detrimental to their health'.

Applying the principles of ethics and welfare to poikilothermic animals

The philosophical and ethical principles that apply to the well-being of all animals are fundamental to the development and application of welfare standards for aquatic animals. Ideally, they should underlie the policies, guidance and regulations established by both governmental and non-governmental bodies.

Animal welfare science is emerging as a research field in its own right (82). It explores how animals are affected by their environment, and qualitatively and quantitatively assesses conditions imposed on them that may affect their welfare. The concept of animal welfare also has an ethical dimension (50, 127), which deals with the underlying values involved in the relationship between humans and animals. Animal ethics asks whether humans have any moral responsibilities towards animals and, if so, what the quantity and quality of animal welfare practices provided by humans should be. This approach requires some brief remarks.

A basic question is whether animals deserve any welfare considerations at all. This is a central issue in relation to poikilothermic aquatic animals. Concerns about animal welfare are very often based on the belief that it is wrong to inflict pain or suffering on other sentient beings (117). From this point of view, the welfare of poikilothermic animals must be considered only if they are sentient. Hence, the question as to whether they can experience mental states is crucial. However, it is a matter of debate whether the existence of a subjective state such as animal suffering can actually be proven by science (70, 87). Philosophers have also articulated arguments on grounds other than that of suffering, offering further reasons for handling poikilothermic animals humanely. One such ground is that animals, when domesticated, become part of the 'moral community'. That is, they become included among those to whom humans have a special responsibility (83). This view also makes it relevant to consider the welfare of farmed fish.

A third argument for considering animal welfare can be found in the proposed Norwegian animal welfare ordinance. This ordinance, which includes aquatic animals, states that animals have intrinsic value and, therefore, should be handled with 'care and respect for the animals' distinctive character' (90). Furthermore, many aspects of this thinking, specifically related to aquaculture, are articulated in the Holmenkollen Guidelines (125), which suggest that ethical principles ensuring the health and welfare of fish, including humane slaughter, should govern the industry. While the concept of intrinsic value has been applied within the policies and legislation of several countries, and is often referred to in the public debate about higher animals, it is still the subject of much philosophical debate (36), and may also be less intuitively appealing when applied to lower animals, such as poikilothermic animals.

In a world of limited resources, one crucial question is how much welfare it is reasonable to provide. It may be difficult or very costly to avoid all of the negative consequences of aquaculture for animal welfare. Often, it is argued that these consequences must be accepted to provide people with food. In ethics, such dilemmas are often dealt with by arguing that different interests or rights can be weighed against each other. Thus, an infringement upon the interests of animals may be accepted if humans have strong reasons for it. Production of the food necessary for human sustenance may qualify as a reason for certain infringements. Which compromises are morally acceptable depends on the philosophy being applied (113). For example, fishing for subsistence might be acceptable, while angling, including 'catch and release', may not be.

Although there is general agreement that animal welfare concerns the quality of life for the animal (112), there has been considerable debate among scientists and philosophers about how this concept should be understood in practice. The following three general approaches have emerged:

– one approach focuses on the feelings of the animal, such as pain, pleasure or suffering (33, 37)

– another approach considers welfare as being of a sufficient standard when the biological systems of the animal are functioning satisfactorily and it can cope with its environment (23)

– the third approach defines welfare as being dependent on the ability of the animal to express natural behaviour and live a natural life according to its genetically encoded nature (106).

Although there is considerable overlap among these definitions, this is to be expected in an ethical discussion of what constitutes a good life for the animal. As in most philosophical approaches, there is no absolute 'right' or 'wrong' answer. What is important is to be explicit about the choice of definition. The 'Five Freedoms' of Brambell (22), in the World Organisation for Animal Health (OIE) principles of animal welfare (91), can be seen as a complex approach which tries to combine all three of the above approaches, with the emphasis on biological functioning. However, there has been little discussion of how to understand the concept of welfare in relation to aquatic poikilothermic animals.

The definition of animal welfare is important because it determines how welfare should be measured and what indicators should be used. For example, if feelings are considered essential for defining welfare, methods for registering and quantifying pain and discomfort must be developed, whereas choosing biological functioning as a criterion of welfare may only require health and production records to reveal welfare status.

A major difficulty when trying to develop welfare standards for aquatic animals is how to understand and quantify the concept of 'a good life' for animals which are so different that any analogies with any human understanding of welfare seem to have little relevance. However, Fraser *et al.* (51) described two types of welfare problems in animal production:

a) challenges for which animals lack adaptations

b) adaptations that no longer serve an important function.

Welfare problems are reduced when the discrepancy between the adaptations of an animal and its environmental conditions is as small as possible. This approach may possibly form the foundation for welfare guidelines in aquaculture systems, until more sophisticated knowledge on aquatic animal needs has been gained.

Current conditions and practices in aquatic animal production

The conditions experienced by aquatic animals used in aquaculture and harvest fisheries, and those captured for ornamental or display purposes, which are relevant to their welfare are outlined below. Many have been previously addressed by Håstein (62) and others, and the examples mentioned are intended only to briefly illustrate some issues of possible importance to welfare. These include the following:

a) environmental conditions, such as water quality

b) predominant industry practices, including:

– stocking densities

– handling, grading and tagging individuals

– nutrition

– genetic selection and modification

– occurrence of and responses to diseases

– capture techniques

– trade in ornamental fish

– transportation and shipping

– methods of slaughter and euthanasia, with an emphasis on finfish.

Conditions and practices that may indicate physiological, behavioural or other stresses are also emphasised, as in Conte (30). These may be useful as indicators or indices for assessing and evaluating optimal or sub-optimal animal health and welfare. However, it should be emphasised that all of these elements probably interact in complex ways, as indicated in Figure 4, and that the overall stressors affecting the health and welfare of aquatic animals are multifactorial.

Environmental and water conditions

Aquatic species are physiologically well adapted to specific ecological niches, defined by the physical, chemical and biological parameters of the water in which they normally live, with preference and tolerance limits for temperature, salinity, pH, dissolved oxygen, organic and inorganic substances, light, etc. Conditions outside the optimal preference or tolerance ranges may result in stress, distress, impaired health and mortality, all of which are often associated with the intensive rearing conditions that cause poor water quality (130, 136). The deterioration of water quality is directly proportional to biomass and animal metabolism, with the resulting oxygen, carbon dioxide and nitrogenous waste levels, and water volume or turnover. Thus, careful observation of animal behaviour and water quality is required to maintain optimal conditions for health and welfare.

Chronic stress from poor water quality may result in loss of homeostasis, reduced growth and reduced disease resistance (89). Reduced water circulation may induce aggression, heterogeneous growth and increased susceptibility to disease (122, 136). Photoperiodicity and artificial light, used to increase production and observe the animals, often result in a reduced feed uptake in Atlantic salmon (*Salmo salar*) during the first 6 to 12 weeks after the lighting change, suggesting stress. Power failure and sudden transitions from light to dark may induce stress responses, panic reactions and mortality (85). The position of the lighting influences swimming depth and fish density, and darkness may result in crowding, sub-optimal oxygen levels and fin erosion (72).

Stocking density and social stress

Stocking density affects productivity and economic returns, and excess density beyond a biological optimum may negatively affect health and welfare. However, this area is complex and depends on many interrelated factors (40), the mechanisms of which are only partly understood and appear to be species-specific.

Behaviour and water quality are important elements in this specificity. Bottom-dwelling species, such as halibut (*Hippoglossus hippoglossus*) and turbot (*Psetta maxima*), require a larger surface area but lower volume, whereas, for pelagic schooling species like cod (*Gadus morhua*), volume is important. High stocking densities are known to reduce

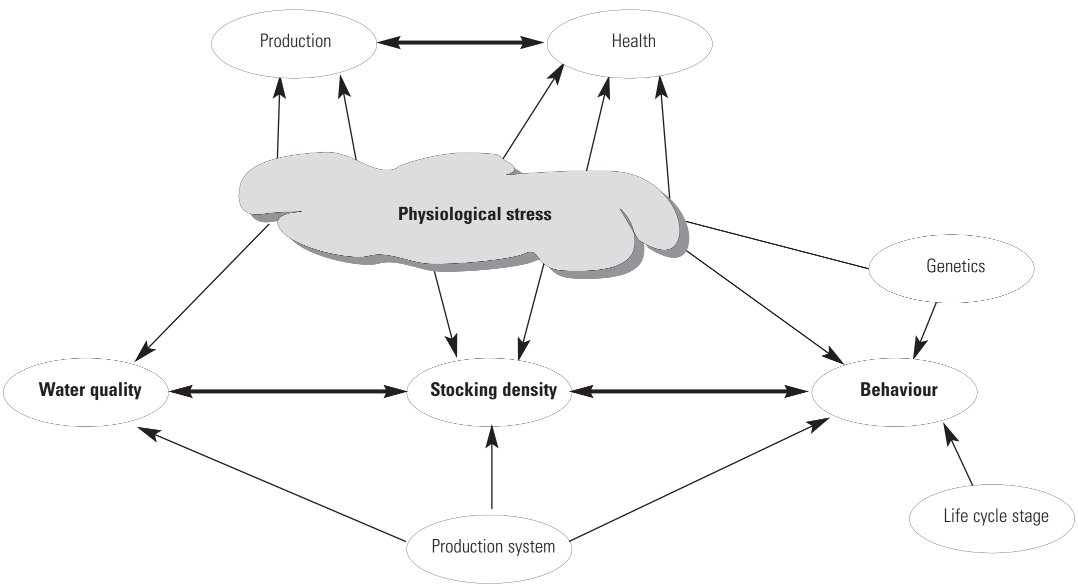


Fig. 4
Factors influencing the appropriate stocking density of fish in cages and tanks

growth and increase stress levels (77, 134). Skin or fin damage may occur from aggression or abrasion, resulting in possible infections and disease. High stocking rates may constrain swimming behaviour (16), feed intake and the ability to digest food (40). In some species, such as rainbow trout (*Oncorhynchus mykiss*) and African catfish (*Clarias gariepinus*), low densities encourage territoriality. In intensive systems that use cages or tanks without acute corners, high feed levels and higher densities induce schooling behaviour (13, 64) and decreased aggression. Understanding such behaviour is therefore important in developing fish farming systems and equipment. Tank colour should mimic the natural environment of the species. For example, in species adapted to dark surroundings, bright colours will induce stress, associated with a higher risk of predation.

Handling, grading and tagging

Handling during grading, tagging and other maintenance or management operations usually requires concentrating and removing animals from the water, and escape attempts, struggling and other behaviours suggest acute stress. The degree of stress is dependent on the life stage (fry or adult) of the animal, handler skill and equipment, and, for many routine tasks, automated equipment has been designed for rapid and minimal handling of animals. Many of these routine tasks are necessary for optimal production and animal health and welfare, but have disadvantages. For example, in hatcheries rearing salmon and other species, cannibalism is common if fish are not graded by size; however, handling during grading is not only stressful but may cause skin damage (6). Stressful handling of the female may increase fry mortality and deformities and reduce growth. Tagging to identify individuals is becoming more important for a variety of reasons, including health and disease surveillance, and several methods are used, including fin clipping, a variety of different metal or plastic external and internal tags, and thermal branding. Internal tags require minor abdominal surgery and external tags, which penetrate the skin, may result in chronic wounds and secondary infections. External tags may also physically disrupt swimming and other behaviours.

Feeding and nutrition

Farmed fish rely heavily on rations that are specifically formulated and include omega fatty acids, usually from fish meal. Nutritionally imbalanced feeds or food not natural to the species may result in malnutrition and nutritional deficiencies. Phosphorus deficiency results in scoliosis and other skeletal deformities (11) and rancid feed may cause fatty liver syndrome and liver degeneration. Immune systems are often impaired before malnutrition affects growth (135). Using dry feed at low temperatures may result in 'water belly' (ascites) and mortality, as the fish are unable to maintain fluid and electrolytic balance.

Improper feeding routines and technology may induce stress and aggression. Starvation and/or reduced feeding are occasionally used to reduce growth to adjust to market demands and improve flesh quality (39). While the welfare aspects of stress from reduced feeding have not been fully investigated, aggression increases among fish that are fed sub-optimally and some fish show behavioural abnormalities ('eye snapping' or 'bum eye disease'). Tail biting, cannibalism and physical fin or eye damage may occur (59).

Genetics

Genetic selection and improvement of farmed fish have mostly focused on improving production, including:

– growth rate

– feed conversion rates

– flesh quality

– genetic disease resistance

– fecundity.

Genetic manipulation has been conducted on a wide variety of aquatic species for production purposes, including the development of transgenics (2), for sex reversal, and polyploids, which result in sexual sterility and increased growth rates. High reproductive capacity, short generation times and high survival of offspring in hatcheries have allowed rapid selection of phenotypes and genotypes. For example, over four generations of breeding, the feed conversion in farmed salmon increased by 80%, when compared to that of wild salmon (56), due mainly to higher feed intake and better feed use (129). It is not known if these changes will challenge the biological limits of the animals, become stressors and consequently cause welfare concerns, but selective breeding has been shown to have positive welfare effects. Selective breeding of Norwegian Atlantic salmon and rainbow trout has produced less-aggressive, less-excitable fish, which are better adapted to artificial rearing conditions and handling. Selection has also produced fish that are resistant to several diseases, including the following:

– vibriosis (57, 102)

– furunculosis (58)

– infectious salmon anaemia (102)

– infectious pancreatic necrosis (T. Åsmundstad, personal communication)

– sea lice infestation (75)

– *Saprolegnia* toxicity (88).

The effects of genetic engineering on welfare depend on the genes which are modified. There is some concern about unforeseen phenotypic consequences (109), including cranial, jaw and opercular deformities in transgenic coho salmon *(Oncorhynchus kisutch)* (35) and carp (*Cyprinus carpio)* (29, 38), that affect feeding and respiration. Altered allometry in transgenic coho salmon results in reduced swimming ability (44, 80, 93) and some behavioural changes have also been reported (1, 34).

Disease problems related to farming

Intensive farming conditions may physiologically stress fish, increasing their susceptibility to disease (122, 124), and a close relationship has been observed between husbandry practices and disease incidence (116). Diseases associated with aquacultural production include skeletal or soft tissue malformations, eye lesions, etc. (10, 19, 25, 42, 76, 98, 100), and increases in the number of such deformities suggest sub-optimal conditions (11) that may affect the welfare of the animals. The so-called 'gaping jaws' syndrome, an abnormality caused by infection during development, is a common problem in cultured halibut larvae (86). It causes the fish to be unable to close their jaws adequately and feed properly, and can also result in head abrasions with additional secondary infections of bacteria and fungi (86).

Cardiac anomalies, including total or partial lack of *septum transversum*, hypoplasia and *situs invertus*, have been reported in farmed Atlantic salmon (73, 97, 98), leading to reductions in size and tolerance to stress, and heart failure. Cataracts causing blindness are reported to be an increasing problem (19, 137, 139), some of which may result from organophosphate treatment or ultraviolet light (78).

While the use of vaccines for treating bacterial disease is increasing (63), and effectively reducing infectious disease, adjuvants may cause local inflammatory responses and granulomas. Intra-abdominal vaccination may result in peritoneal adhesions and other side effects, such as growth retardation and spinal deformities (18). In some cases (e.g. Atlantic salmon), severe vaccination-related reactions are reduced when fish weigh at least 70 grams and the water temperature is 10°C or below. Ultimately, the goal is to develop vaccinations which produce good immunity with few side effects (84).

Treatment against parasites such as sea lice in salmonids is important as infestation can lead to scale loss and skin lesions that cause osmotic disturbances. Damage to the head may be so severe that the skull bones are exposed – a condition referred to by Lymbery (79) as 'death crown'. Using ballan wrasse (*Labrus bergylta)* to control lice infestations may also involve welfare considerations in regard to the biological needs of the wrasse (131).

Capture fisheries

The history of fishing for wild fish is about as long as the history of humankind. In recent years, questions have been raised regarding aquatic animal welfare and human-animal interactions. The question of whether fishing for pleasure through 'catch and release' is ethically acceptable has also been raised. For welfare purposes, the use of wild fish can be divided into two categories, as follows:

– fish caught to be killed

– fish caught to be kept alive for further rearing.

Traditional commercial fisheries and 'put-and-take' fishing (angling on private farms for a fee, based on what is caught) come into the first category, while capture-based aquaculture and catch-and-release fishing belong to the second.

When fish are caught to be killed, the aim from a welfare point of view must be to kill the animals as quickly and painlessly as possible. Depending on the method of capture, the process of killing and exsanguination may take from a few minutes to 24 hours or more.

In commercial 'Danish seining' (also known as 'Scottish seining' and Japanese 'bull-trawling'), which uses trawls, purse seines and hooks, death may typically take one hour (trawls), from one to four hours (seines), and from four to six hours (hooks), depending on the species, while nets may take up to 24 hours (I. Huse, personal communication, 2004).

At present, there is no knowledge to judge whether crowding, choking or hooking is the most painful procedure for the fish. Although welfare issues should be considered, even for capture fisheries, it will take time and probably political incentives to introduce alternative catching methods.

Capture-based aquaculture, in which young fish are caught and reared in pens or enclosures, is an old tradition for several fish species, such as cod, eel (*Anguilla anguilla)*, groupers (*Serranidae)*, tuna (*Thunnus* spp.) and yellowtail *(Seriola quinqueradiata)* (68). However, it has been shown that the catching methods used involve stress, as well as external and internal lesions in the fish and subsequent mortality (67, 126). It is clear that some equipment, particularly nets, causes mortality due to choking because of impaired gill movement. Mortality figures are usually lower when fish pots or hooks are used, but the latter do wound the fish. The use of trawls and Danish seining, in which the fish are heavily concentrated as the nets are hauled in, results in squeezing, choking and gill irritation from particles adhering to the gills. When cod are captured at depths of 15 metres to 30 metres or more, nearly 100% of the swim bladder of the animal will rupture from pressure de-compensation and possible eversion of the peritoneum in the vent region (68). The lesions are normally reported to heal within one week and the fish will start feeding within four weeks (68). However, in some fish, gas may be trapped in the abdominal cavity when they surface and these fish will subsequently die, unless a needle is used to drain the gas. Exophthalmia from pressure de-compensation has also been reported.

Danish seining is recognised today as the method of choice for capture-based cod aquaculture, while trawling is recognised as unsuitable from a welfare point of view. In trawling, studies have shown that, even though the fishing gear used does not cause mortality, discarded fish may die later due to behavioural impairment, resulting in increased predation (32, 110).

Although the fish in 'put-and-take' fisheries are killed quickly and humanely, immediately after capture, the practice has welfare implications. Catch-and-release fishing has become increasingly common in many countries in recent years, not only for sport but also as a tool to reduce the pressure on fish stocks in rivers with small and vulnerable local populations. Being caught probably inevitably results in stress and pain, suggested by the production of lactic acid and increased cortisol levels. Although a high proportion of fish may survive, high mortalities are occasionally reported. Factors such as temperature, catch-and-release time and handling methods are important to the survival rate. In some countries, catch-and-release fishing is prohibited since it is not considered to fulfil animal welfare criteria.

Factors affecting welfare in ornamental fish

Breeding and caring for ornamental aquarium fish has a long tradition and these days the production and trade in ornamentals is a rapidly developing sector. With industrial-scale production of ornamentals, welfare issues related to breeding, transportation and killing for disposal are of concern. It is reported that, in some cases, less than 50% of bred fish survive the first six months, while wild captured ornamentals may suffer losses as high as 75% between capture and retail sale (99). To satisfy welfare issues in the ornamental fish trade, wholesalers and aquarists must have sufficient knowledge on the basic needs of these fish with regard to water quality, feeding, genetics and disease management. The attention given to welfare in the ornamental fish industry must be similar to that given in aquaculture.

Transportation of fish

Transportation routines for live fish depend on the reason for shipping, size of consignment and species to be transported. For restocking purposes, buckets and/or sealed plastic bags with excess oxygen are used. Sealed bags are also the most common method for compartmentalising ornamental fish, traded over long distances.

Lorries or well boats are the most common way of transporting fish from hatcheries or nurseries to grow-out farms. The type of vehicle used depends on whether the fish are bound for sea-water cage-culture or inland pond-farming.

Containers for transporting fish must be designed to eliminate harm to the fish during transportation. Adverse conditions during movement, such as overcrowding or unacceptable water quality due to low oxygen, may result in irreparable damage to the fish and mortality.

Transportation of coho salmon yearlings by truck has been reported to cause a marked physiological stress response and reduced relative fitness, as well as a lower survival rate and reduced ability to tolerate any additional stressing agent (69, 114, 123). Conditioning has been shown to improve the ability of juvenile chinook salmon *(Oncorhynchus tshawytscha)* to withstand transportation stress (115). Mortalities in large captive broodstock of milkfish *(Chanos chanos)* can be minimised if the fish are transported and handled in sealed oxygenated bags with chilled sea water (53). Sedation combined with a recovery period appears to lessen the stress burden associated with hauling and transport (111).

Slaughter and euthanasia

As in terrestrial animal production, aquatic animals are purposefully killed for two main reasons:

– for animal or human food

– to control or eradicate devastating diseases in both wild (managed and unmanaged) and farmed populations.

Secondary purposeful human activities, such as sport fishing, may result in the death of animals. However, sport fishing frequently combines this recreation value with harvesting animals for human consumption, or the control of animals unsuitable for consumption.

The term 'slaughter' will be used for terminating an animal life for immediate human consumption or use, as with terrestrial animals, whereas 'euthanasia' is applied to animals that are humanely killed but not consumed. Many of the principles underlying euthanasia are outlined in the American Veterinary Medical Association (AVMA) Report of the AVMA Panel on Euthanasia (4). However, many of the recommended methods for finfish are mainly applicable to ornamental or research animals.

To ensure ethical slaughter, acceptable methods of killing should be in place. However, since there are differences between species, establishing universal methods is difficult. While carp and eel are tolerant to hypoxia, salmonid fish are sensitive in this respect. Thus, the oxygen level in the holding units must be optimal for the particular species.

Various methods are used to slaughter fish (103) and there is no doubt that many of them can be considered totally unsatisfactory from an animal welfare point of view. Exsanguination without stunning causes aversion reactions in fish (106).

Whatever method is used for sedation, it is important that the personnel at the slaughterhouses are skilled and dedicated to their work, to reduce the levels of stress and avoid external and/or internal traumatic lesions to the animals during the slaughter process.

Slaughter for consumption

According to the Humane Slaughter Association (66), millions of fish are reared for food on a global basis and these must be slaughtered in such a way that unnecessary pain and suffering are avoided. Any handling before the slaughtering process involves an increase in the level of stress to the animal, such as the handling stress that occurs when fish are transferred from the transporting vehicle (well boat, lorry, etc.) to the holding units where they are to be kept until slaughter.

Starvation before slaughter to empty the gut is considered acceptable from a welfare point of view. The starvation period should, however, be as short as possible (122). The maximum starvation period for salmonids is normally one to three days, depending on water temperature (122, 138).

Handling and crowding can occur in the holding units before the fish are brailed (netted) or pumped into the killing facility. Rough handling during such procedures leads to additional stress in the fish and is an important welfare concern. The cortisol level of roughly handled fish may reach 700 nanograms per litre. Such rough handling may also lead to abrasions and mortality (138). It has been suggested that it is optimal if fish do not spend more than 15 seconds out of the water, whatever handling methods are used (122).

The guiding principle for optimal slaughter is to avoid unnecessary stress and pain to the animal during the slaughtering process. Thus, sedation should cause instantaneous unconsciousness lasting until death (133). Methods that only gradually result in unconsciousness may be allowed if the method does not, in itself, cause pain or stress (55).

In commercial fish slaughter, several methods have been used for sedation, as follows:

– employing CO_2

– cooling the animal down to 0°C, using ice slurry alone or in combination with CO_2

– stunning by a blow to the head

– automated percussive stunning

– electro-shocking, using the same principles as electro-fishing gear

– using approved chemicals.

All sedation methods should be followed by exsanguination.

Suffocating fish in air or crushed ice before exsanguination and slaughter may take as long as 15 minutes before trout, for example, become unconscious (79). Using crushed ice, it is possible to calm the fish and keep it alive for several hours until osmoregulatory problems and exhaustion occur. Pre-chilling fish before slaughter has been shown to be a minor stressor, compared to handling and crowding prior to slaughter, but a low chilling temperature may provoke 'water belly' (ascites), especially in rainbow trout, due to inadequate osmoregulation (118). Asphyxiation in air or chilled water is a common method for killing fish and is highly stressful (12, 103). Such methods have thus been deemed unacceptable from an animal welfare point of view (43).

Interestingly, Parisi *et al.* (94) found that ice water is the preferred method for killing edible-portion-sized sea bass *(Dicentrarchus labrax)* (of about 250 grams to 300 grams), for which individual killing is not feasible.

Sedation by CO_2, followed by cutting the gills for exsanguination, is a widely used method for commercially slaughtering salmonids. As CO_2 creates an adverse environment for the fish, they show stress reactions and erratic swimming behaviour, trying to escape before losing consciousness (106). Although the fish stop moving after 30 seconds, they may not lose consciousness until after 4 to 5 minutes and thus, if removed too early from the sedation tank, they may still be conscious when the bleeding process starts (106). The use of CO_2 is probably the best method for sedating flatfish and Parisi *et al.* (94) reported that this method was less stressful to sea bass than electrocution because of more rapid stunning. However, in general, the use of CO_2 for euthanasia is not considered humane.

Certain chemicals, including anaesthetics such as methoxypropenylphenol (isoeugenol, clove oil), have been approved in some countries for sedating fish before slaughter, with no withholding period for drug residues.

Stunning fish before slaughter is also used. The Farm Animal Welfare Council (43) suggests that stunning must cause immediate loss of consciousness that lasts until death. Percussive stunning and spiking results in a rapid loss of consciousness, without aversion reactions, if applied correctly (106), while a lesser blow to the head generally provides momentary sedation. This method is normally used on large fish. Although percussive stunning by a hand-held club is useful from a technical point of view, the method must become automated if it is to be useful for slaughter under industrial conditions. Pneumatic devices suitable for industrial conditions have been developed, but care must be taken to ensure sufficiently high pneumatic pressure or the fish may not be adequately sedated before bleeding. Different fish shapes, i.e. flat fish as compared to salmonids, may make percussive stunning of some species difficult.

Electric stunning is another possible and practical method for sedating fish (105, 132). However, effective electrocution depends on providing an electric current which is high enough to achieve complete sedation, otherwise the fish will only be paralysed. Problems may also occur if the current is too high, the most frequently observed being backbone fracture and flesh haemorrhages. Another problem which has recently come under discussion is the electric stunning of Atlantic salmon without subsequent exsanguination, to keep slaughter costs down. Since fish may have individual tolerances to electric current, some may survive the stunning procedure and suffer unnecessarily before dying of suffocation.

Whereas salmonids are relatively easy to kill, killing eels is difficult. The traditional method used (removing the mucus from the fish with ammonia or dry salt, followed by evisceration) has now been banned in many countries for welfare reasons (122). The decapitation method proposed for killing eels is also unacceptable. As spinal transection does not cause visible injuries to the brain, the eel may suffer for some time if this method is used. Thus, immediate destruction of the brain is required in the slaughtering process, if ‘neck cutting’ is to be used on these animals (45). According to van de Vis *et al.* (133), the humane slaughter of eels in fresh water is possible through the combined use of electrical stunning and nitrogen gas, which result in unconsciousness and death.

Slaughter for disposal

When aquatic animals must be killed in an organised manner to control a disease – which may be either exotic or of socio-economic importance due to mortality, infectivity or its being untreatable – welfare criteria must be considered. The methods used must be the same as those accepted for slaughter for human consumption.

To prevent the spread of disease to the environment or neighbouring aquaculture establishments, killing for control purposes should preferably occur on the site. Measures should be taken to ensure that the infected animals are collected and treated in an optimal way to prevent further spread of the disease/disease agents.

Crustacean slaughter and euthanasia

Although the higher-level cognitive ability (and, consequently, sentience) of crustaceans has recently been called into question (121), several different methods have been described as ‘humane’ for killing them. There are several important studies that suggest that lobsters do suffer stress (95) and that their physiology and welfare are affected by live transportation (65, 128).

Dropping live crustaceans (e.g. lobsters, shrimp crabs) into boiling water has been the most common method of killing decapods (lobsters, crabs, shrimps) for human consumption. This method is not considered inappropriate as it is questionable whether decapods have the ability to feel pain when boiled (121). Whether the vigorous whipping of the tail of the lobster when being boiled is the result of pain or a reflex reaction is still not known. However, if such behaviours do indicate stress or pain of which the animals are cognisant, it may be appropriate to make them incapable of feeling pain before boiling.

Crustaceans have been effectively anaesthetised or euthanased with chemicals and cold. An injection of potassium chloride (15), immersion in saturated sodium chloride for 1 minute or refrigeration (cooling) for at least 20 minutes are assumed to be humane killing methods. The use of commercial anaesthetics, such as tricaine methanesulfonate, methoxypropenylphenol (isoeugenol) and CO_2, have also been described (54). In giant crabs, the use of CO_2 may result in stiffness and loss of limbs. Robb, as cited by Mejdell (81), however, did not observe any effect in edible crabs after exposure to CO_2 for 1 hour.

Mechanical stunning devices used to destroy the supraesophageal ganglion in large crustaceans, such as lobsters, have also been developed for euthanasia. Robb (81) reported that electricity at 50 Hz and 240 V for 1 second immediately anaesthetises or stuns crustacea. Equipment for this purpose has been developed both for small-scale situations (single stunner) and for industrial purposes (batch stunner).

Conclusions

In summary, the authors believe that it is essential to improve the welfare of poikilothermic animals by:

– increasing understanding of the quantitative and qualitative aspects of welfare in relation to poikilothermic vertebrates and invertebrates

– increasing understanding of their cognitive abilities, motivational systems and behavioural needs, and the relationship between environmental parameters and welfare

– developing a more humane technology

– developing validated welfare indicators for on-farm welfare assessment (risk analysis, surveillance, etc.) and monitoring systems

– increasing awareness and promoting education on the welfare needs of poikilothermic vertebrates and invertebrates and humane practices for handling and managing these animals.

■

Évaluation scientifique du bien-être appliquée aux animaux aquatiques

T. Håstein, A.D. Scarfe & V.L. Lund

Résumé

Le bien-être des animaux terrestres est un sujet d'étude depuis de nombreuses années. Par contre, les approches visant à améliorer le bien-être et le traitement décent des animaux aquatiques sont relativement nouvelles, tout comme l'est la réflexion sous-jacente. Plusieurs aspects compliquent la démarche de la prise en compte systématique du bien-être des animaux aquatiques :

– l'extraordinaire diversité caractérisant le monde des animaux aquatiques, qui sont, en majorité, des invertébrés et des vertébrés poïkilothermes ;

– la connaissance des pratiques appliquées dans le domaine de la pêche, de l'aquaculture et de la production d'animaux aquatiques et leur finalité ;

– la relative rareté des informations scientifiques ;

– la connaissance des approches philosophiques, des politiques, des orientations et des réglementations susceptibles d'influer sur la mise en place de pratiques optimales assurant le bien-être et le traitement décent des animaux aquatiques.

Dans cet article, les auteurs fournissent un aperçu de tous ces éléments, en rapportant ce que l'on connaît et comprend sur ces questions concernant les poissons, le principal groupe utilisé en aquaculture et par l'industrie de la pêche, et en étudiant les aspects susceptibles d'influer sur les concepts et les pratiques liés au bien-être des animaux aquatiques. Ces aspects, qui semblent être le fondement de toutes les approches axées sur le bien-être, sont les suivants :

– le concept éthique et moral de bien-être et de traitement décent des animaux ;

– la question de savoir si les animaux souffrent des pratiques potentiellement néfastes utilisées pour l'élevage, la gestion et leur utilisation ;

– la conception du public et des institutions sur ces questions et les résultats qui en découlent.

Ces points sont examinés dans l'espoir que les progrès dans le domaine du bien-être des animaux aquatiques et les approches axées sur ce bien-être seront utiles à la société, aux secteurs industriels et au public.

Mots-clés

Aquaculture – Animal aquatique – Bien-être – Céphalopode – Crustacé – Décapode – Éthique – Pêche traditionnelle – Poisson – Poissons d'ornement – Pratique décente.

■

Evaluación por métodos científicos del bienestar de los animales acuáticos

T. Håstein, A.D. Scarfe & V.L. Lund

Resumen

Hace muchos años que se viene estudiando el bienestar de los animales terrestres. En cambio, la voluntad de aportar un mayor nivel de bienestar a los animales acuáticos y de tratarlos con decencia es algo relativamente nuevo, como lo son las ideas que subyacen a tales planteamientos. Hay varios factores que dificultan un trabajo coherente al respecto, entre ellos los siguientes:

– la enorme diversidad de animales acuáticos, que en su gran mayoría son vertebrados poiquilotermos o invertebrados;

– la insuficiente comprensión de los métodos y fines propios de la actividad pesquera, la acuicultura y la producción de especies acuícolas;

– la relativa escasez de información científica;

– la insuficiente comprensión de las concepciones filosóficas, los programas y pautas de actuación y los reglamentos que pueden influir en la prestación de un nivel óptimo de bienestar y un trato decente a los animales acuáticos.

Los autores tratan de ofrecer una visión general de todos esos elementos, exponiendo lo que de ellos se sabe y comprende en relación con el principal grupo objeto de acuicultura y pesca, que es el de los peces, y examinando las cuestiones susceptibles de influir en los conceptos y métodos relacionados con el bienestar de los animales acuáticos. Entre esas cuestiones, que parecen constituir el eje de todo planteamiento en la materia, figuran las siguientes:

– conceptos éticos y morales del bienestar animal y el tratamiento decente;

– determinación de si los animales sufren cuando se aplican sistemas de alimentación, gestión y explotación que puedan resultarles perjudiciales;

– percepción de estas cuestiones y sus consecuencias por parte del gran público y las instituciones.

Los autores examinan todos estos elementos con la esperanza de que el futuro depare mejoras técnicas y nuevos planteamientos en la materia que resulten útiles a la sociedad, la industria y el gran público.

Palabras clave

Actividad pesquera – Acuicultura – Animal acuático – Bienestar – Cefalópodo – Crustáceo – Decápodo – Especie ornamental – Ética – Pez – Práctica decente.

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