

Chapter 1

A Brief Look into the Origins of Fish Welfare Science



Tore S. Kristiansen and Marc B. M. Bracke

Very little of the great cruelty shown by men can really be attributed to cruel instinct. Most of it comes from thoughtlessness or inherited habit. The roots of cruelty, therefore, are not so much strong as widespread. But the time must come when inhumanity protected by custom and thoughtlessness will succumb before humanity championed by thought. Let us work that this time may come.

Albert Schweitzer, Reverence for Life

Abstract Every year, humans kill or injure trillions of fishes in fisheries, recreational fishing, aquaculture, and through the destruction or contamination of their habitats. However, until recently fish welfare has been paid little attention. The recent, at least partial, inclusion of fish within the moral circle can be seen as a natural/logical consequence of the increased attention paid to animal welfare in general, and in particular to the welfare of farmed fish in the rapidly growing intensive fish farming industry. The concern for fish welfare was first raised by animal protection groups in the early 1990s, and by the end of that decade, fish welfare had started to receive attention from scientists, food authorities, politicians, and the aquaculture industry. After the turn of the millennium, fish welfare blossomed into a research topic and became a prioritized and integrated part of animal welfare legislation in Europe. This chapter tells the story about the rise of animal welfare as a topic of concern, and especially fish welfare science, including the controversy concerning pain and consciousness in fish.

Keywords Animal welfare · Five freedoms · Welfare definitions · Moral circle · Pain · Welfare research · Laws and regulations

T. S. Kristiansen (✉)
Institute of Marine Research, Bergen, Norway
e-mail: torek@hi.no

M. B. M. Bracke
Wageningen Livestock Research, Wageningen, The Netherlands
e-mail: Marc.Bracke@wur.nl

1.1 Introduction

Fishing is an ancient practice dating back at least 42,000 years (O'Connor et al. 2011), and the domestication of fish species began more than 4000 years ago (Beveridge and Little 2002). Humans have probably had a strong relationship to fish for several thousand years, but we know little about people's attitudes towards fish through time. A quote from the seventh century Chinese poet Du Fu (杜甫) expresses his compassion for fish and that others should be compassionate too:

I see shining fish struggling within tight nets, while I hear orioles singing carefree tunes.
Even trivial creatures know the difference between freedom and bondage. Sympathy and
compassion should be but natural to the human heart
Du Fu (712–770 AD)

Another example can be found in the earliest biography of Saint Francis of Assisi, commissioned by Pope Gregory IX and completed in 1230, which tells us that:

He was inspired by the same fatherly affection towards fish. When they were caught, and he had the opportunity, he threw them back into the water alive, instructing them to take care not to be caught again.
Thomas de Celano, First life of St. Francis

Maybe these men were exceptions to the rule, since until recently fishes have mostly been kept outside of the moral circle of animals that we consider to have interests or sentience (Lund et al. 2007). The recent, at least partial, inclusion of fish within the moral circle can be seen as a logical consequence of the increased attention being paid to animal welfare in general, and in particular to the welfare of farmed fish in the rapidly growing intensive fish farming industry.

Fish and fisheries are of great importance to human trade and welfare, and cultures, cities, and nations have been based on them (Hart and Reynolds 2002). Millions of people are directly or indirectly involved in catching and processing fish, which are a very important source of proteins, minerals, and unsaturated fatty acids for humans and their domestic pets and livestock (FAO 2016). Every year, humans kill or injure trillions of fishes in fisheries, recreational fishing, aquaculture, and through the destruction or contamination of their habitats (Lymer 2002). However, until recently fish welfare has been paid little attention. Concern for fish welfare was first raised by animal protection groups in the early 1990s (Lymer 1992) and during that decade the topic of "fish welfare" started to appear in a few scientific journals, at aquaculture conferences, and in calls for research funding. By the end of the 1990s, fish welfare had started to receive attention from scientists, food authorities, politicians, and the aquaculture industry. Both EU and national research funding institutions began prioritizing fish welfare, and various European authorities e.g. the European Commission and the European Food Safety Authority (EFSA), put fish welfare on the map. Thus, at least in Europe, farmed fish have started to enter the moral and legal circles, but in most parts of the world, fish are still lacking legal protection.

But even if wild fish theoretically enjoy the same legal protection as farmed fish and other vertebrates, in practice this is ignored also in Europe. Recreational fishing

Fig. 1.1 Young hunter.
Fish are still not killed and
treated like mammals



is a very popular activity performed by millions of people (Arlinghaus et al. 2007a, b; Cooke and Sneddon 2007). It is seen as a relaxing recreational activity, associated with positive experiences of nature, including excitement and the satisfaction of catching your own food. We even let small children catch fish and some play with live fish on land (Fig. 1.1). “Catch and release” fishing, where the aim is to experience the joy of catching the fish but not use it for food, has become increasingly popular (Arlinghaus et al. 2007b). In contrast, catching and killing most other vertebrate animals by hand is something most people find aversive and have never done. Fishing is the exception! In our experience, almost all of us become excited and happy when they catch a fish on a hook—perhaps releasing our old predatory instincts? When it comes to removing the hook and killing the struggling fish, we are reluctant to cut its throat the first time, but soon most of us get convinced by more experienced fishers that this is an acceptable and normal thing to do. In traditional fishing cultures there is usually little or no consideration for the suffering or welfare of fish, and, if anything, the primary management goal has been to optimize sustainable harvests. Accordingly, fish are “harvested” from the sea and the catches are quantified in terms of weight and not numbers. In this sense, fish tend to be treated more like vegetables than animals. However, the quote above from Albert Schweitzer reminds us that long-lasting traditions do not necessarily mean that our actions are ethical and should continue.

During the past few decades aquaculture has been the fastest growing animal production industry in the world; in Norway, for example the value of farmed fish

now surpasses by far the value of landings of wild fish (Torrissen et al. 2011). Whilst fisheries have stagnated world-wide and many fish stocks are overexploited, aquaculture is expected to continue to grow (FAO 2016).

With the introduction of intensive fish farming, we became responsible for the whole life cycle of the fish, and the farmer must care well for his animals if they are to survive, grow, and stay healthy (Chap. 14). We have, therefore, moved from a hunting culture to a culture of care, which also raises new ethical concerns and responsibilities about how we handle the fish and how well the fish fare through life. In this chapter, we present a brief history of how the relatively young fields of fish welfare science and legislation have emerged, and explore their concomitant challenges and controversies.

1.2 The Origin of Animal Welfare Science

The concern for the welfare of intensively produced mammals and birds prepared the ground for concern for fish welfare (Fraser 2008; Phillips 2009; Broom 2011). After the Second World War, efficient intensive livestock production with large numbers of animals living at high stocking densities became increasingly common in the United States and Europe. This also led to more public concern about animal welfare. It has been claimed that Ruth Harrison's book, "Animal Machines" published in 1964, initiated the animal welfare movement and the science of animal welfare. Harrison raised questions such as:

How far have we the right to take our domination of the animal world? Have we the right to rob them of all pleasures in life to make more money more quickly out of their carcasses? Have we the right to treat living creatures solely as food-converting machines? (Harrison 1964, p. 37)

She argued for better standards for animal welfare and described vividly how animals were reared in "factory farms". The book resulted in a public outcry, and only 6 weeks after its publication the British government appointed a commission, chaired by Professor F.W. Rogers Brambell, "*to examine the conditions in which livestock are kept under intensive husbandry and advise whether standards ought to be set in the interest of their welfare, and if so what they should be.*" (Brambell 1965, page 1)" After several farm visits and expert interviews they published their report in 1965: "*... to enquire into the Welfare of Animals Kept under Intensive Livestock Husbandry Systems*". It was the first systematic evaluation of animal welfare in intensive farming systems, and it included many recommendations for improvements (Brambell 1965). In an appendix to the report, we find an essay by Professor W.H. Thorpe of Cambridge University, on "The assessment of pain and stress in animals". He formulated important questions that formed the agenda for the study of animal welfare in the decades that followed (Thorpe 1965).

As a direct result of the Brambell Report, the UK government appointed a Farm Animal Welfare Advisory Committee (FAWAC; called the Farm Animal Welfare

Council (FAWC) from 1979). However, in the course of the following years few of the recommendations in the report or FAWAC were followed up (Broom 2011). In a 1979 press release, FAWC gave a list of five essential conditions that all farm animals should be provided with. This list was later refined and named the “Five freedoms” (Webster 2005) (Box 1.1). These have been widely acknowledged and adopted by professional groups and animal protection NGOs, as a framework for animal welfare assessment and legislation (Welfare Quality 2009).

In his essay on “The history of animal welfare science” Professor Donald Broom writes: “In the 1960s, the emphasis of discussions was on what people should do, i.e. on animal protection rather than on animal welfare. In the 1970s and early 1980s, the term animal welfare was used but not defined and not considered scientific by most scientists” (Broom 2011). During the 1970s, the animal welfare area consisted of two branches: an ethical and philosophical branch, which may be labelled “animal ethics”, by and large initiated by the moral philosophers Peter Singer and Tom Regan (Singer 1975, 1981; Regan 1983). These philosophers discussed *inter alia* whether or not animals had moral rights, or intrinsic value, over and above their subjective experiences constituting welfare. Their writings inspired a range of animal welfare/animal protection initiatives, and NGOs and (often more extreme) animal rights groups. The other branch, which may be called welfare science, was more science and ethology based. Animal welfare scientists mostly came from university zoology departments (Broom 2011), but also from animal science groups at agricultural universities and some from veterinary faculties. Whilst animal ethicists have been concerned about moral/ethical (i.e. prescriptive) issues (concerning what is acceptable), such as questioning our moral “rights” to kill or use/exploit animals, animal welfare scientists have historically been concerned with the descriptive questions (about what is de facto the animal welfare situation). A problem for welfare science has been how to define and measure welfare. Since subjective experiences cannot be measured directly, welfare scientists have often adopted a pragmatic approach, for example by studying measurable biological parameters that were assumed to correlate with welfare as actually experienced by animals (Broom 2011; Lund et al. 2007). Some scientists have taken this one step further by more or less equating animal welfare with some measure of physiological functioning. A problem for such a definition of animal welfare is that it misses the relationship with the ethical questions that are associated with animal welfare and animal suffering (Dawkins 2006; Diggles et al. 2011; Torgersen et al. 2011; Mellor 2016). New knowledge about motivational systems, animal decision-making, and basic and behavioural needs has been contributing to a gradual change in the scientific views of animals from instinct-driven “automata” to goal-directed agents that have needs that can be satisfied or frustrated (Dawkins 1980, 1990; Broom 2011). New knowledge about stress physiology, behaviour, and health is, of course, relevant for animal welfare (Moberg and Mench 2000), even though at that time (the 1970s and 1980s) veterinarians were reluctant to talk about animal feelings (Broom 2011).

Box 1.1 The Five Freedoms

- (1) freedom from thirst, hunger or malnutrition;
- (2) appropriate comfort and shelter;
- (3) prevention, or rapid diagnosis and treatment, of injury and disease;
- (4) freedom to display most normal patterns of behaviour;
- (5) freedom from fear.

In a press statement FAWC (1979) published five demands for farm animal welfare conditions (see list above). They have since been refined and labelled “the five freedoms” (Webster 2005). On its web page, FAWC states: “The welfare of an animal includes its physical and mental state and we consider that good animal welfare implies both fitness and a sense of well-being. Any animal kept by man, must at least be protected from unnecessary suffering. We believe that an animal’s welfare, whether on farm, in transit, at market or at a place of slaughter should be considered in terms of ‘five freedoms’”.

The “five freedoms” are often said to originate from the Brambell report (e.g. Broom 2011), but those referred to were the following five very modest minimum requirements for the ability of calves to move their body in industrial housing systems: “the animals should at least have the ability to stand up, lie down, turn around, groom themselves and stretch their limbs”. This has later been referred to as “Brambell’s Five Freedoms”, even though they were not labelled “five freedoms” in the Brambell report.

<http://webarchive.nationalarchives.gov.uk/20121010012427/http://www.fawc.org.uk/freedoms.htm>

1.2.1 The Welfare Definition Problem

“Animal welfare” is a concept used by people involved in the protection of animals, and most people probably agree that welfare is related to the quality of life as experienced by the individual animal (Bracke et al. 1999). In order to implement welfare standards and welfare monitoring schemes, we need to know how it can be measured. However, despite the growing importance of animal welfare and a common understanding of what is meant by the term, the concept of animal welfare has been surprisingly difficult to define scientifically, and there is still no consensus (Duncan 1996; Webster 2005; Fraser 2008; Lerner 2008; Phillips 2009; Broom 2011).

The Brambell report did not define welfare, but described it as follows:

Welfare is a wide term that embraces both the physical and mental well-being of the animal. Any attempt to evaluate welfare therefore must take into account the scientific evidence available concerning the feelings of animals that can be derived from their structure and functions and also from their behaviour. (Brambell 1965 (p. 9), also cited in Duncan 2006)

This view is probably close to what most animal welfare scientists still believe today.

One of the first and widely used definitions of animal welfare was presented by Professor Donald Broom (1991): “*The welfare of an individual is its state as regards its attempts to cope with its environment.*”, where coping means “*having control of mental and bodily stability and that welfare is poor when coping ability is low*”. Broom’s definition has been said to identify animal welfare with some sort of physiological functioning, but Broom later stressed that aversive feelings, such as pain and fear, and hedonic feelings, such as pleasure and comfort, are parts of an evolved coping strategy, and that feelings are essential parts of welfare (Broom 2011, see also Chap. 13).

There are three common ways of defining animal welfare: in terms of *physiological functioning*, of *natural living* and of *feelings* (Fraser 2008, 2009). An important controversy has centred around the questions of whether animal welfare should primarily refer to biological functioning or to feelings (Duncan 1996; Turnbull and Kadri 2007; Torgersen et al. 2011; Mellor 2016) and whether animal welfare should be restricted to conscious animals only. Broom (2011) held that all animals could fit in his definition, whilst being conscious was more relevant to deciding which/when animals should be protected. Many biologists have argued that feelings and subjective experiences are not accessible to scientific enquiry, and they have therefore proposed restricting welfare to physiological functioning, e.g. related to health and other measurable parameters (Arlinghaus et al. 2007a; Diggles et al. 2011). Animal rights activists have emphasized that a natural environment and natural species-specific behaviour should be important aspects or components of animal welfare, and have questioned the ethics of killing and restricting animals’ freedom of expression of normal behaviour (Regan 1983). Besides, Singer’s preference utilitarianism (greatest good for the greatest number) (Singer 1975, 1981), and Regan’s rights views (animals are subjects of a life with inalienable rights), the field of animal ethics also encompasses the telos concept proposed by Bernard Rollin, referring to an animal’s “nature” and its right to live according to its nature (Rollin 1989).

Some scientists have claimed that fishes lack the essential brain structures that enable them to consciously experience pain or other feelings (Rose 2002; Rose et al. 2012; Arlinghaus et al. 2007a; Key 2016). The consciousness issue has therefore persisted for much longer in relation to fish compared to other higher vertebrates (in which consciousness is nowadays generally accepted, Chap. 8). This “fish pain controversy” will be discussed in more detail below.

The main criticism of defining animal welfare in terms of feelings is that animals’ subjective experiences are not accessible to us. However, this problem can be solved if we can use proxies like behaviour, appearance, and health indicators as correlates of welfare. To be able to experience pleasure and pain, an animal needs to have some kind of conscious qualitative experience and we are not attributing welfare to organisms believed to lack consciousness, e.g. fungi or plants. This is because if we agree that unconscious organisms, like bacteria, experience welfare, the concept loses its meaning, as well as its moral, political, and social implications (Torgersen et al. 2011).

1.3 Emerging Concerns for Fish Welfare

Fish have been a part of animal protection legislation for a long time, even before the concept “fish welfare” was used. The first *Cruelty to Animals Act*, which prohibits painful experiments on *all animals other than invertebrates*, was passed in the United Kingdom in 1876, and was followed by the *Protection of Animals Act* in 1911, which defined “domestic animal” and “captive animal” as any animal “of whatsoever kind or species, and whether a quadrupled or not”, including birds, fish, and reptiles.

The first report that specifically concerned fish welfare was probably the “*Report of the panel of enquiry into shooting and angling*”, commissioned by the RSPCA (Medway 1980). The Medway report concluded that: “*In the light of evidence . . . , it is recommended that, where considerations of welfare are involved, all vertebrate animals (i.e. mammals, birds, reptiles, amphibians and fish) should be regarded as equally capable of suffering to some degree or another, without distinction between ‘warm-blooded’ and ‘cold-blooded’ members*” (p. 52). It suggested “*that every angler should review his appreciation of the sport in the light of evidence presented on the perception of pain. Panel members believe that many anglers are concerned to promote the welfare of fish and will welcome advice on methods of lessening the likelihood of suffering among fish (p.53)*”. The report further discusses the welfare consequences of angling and gives several suggestions as to how to mitigate these, e.g. through the use of barbless hooks.

During the 1980s, the intensive farming of Atlantic salmon started to grow into a significant industry in Scotland and Norway, and by 1990 the industry was experiencing major problems of bacterial diseases and sea lice. In a 1992 report on “*The Welfare of Farmed Fish*”, Peter Lymbery, on behalf of the NGO Compassion in World Farming, was the first that raised concern about the poor welfare conditions in the salmon farming industry, especially the slaughter process, and argued that urgent action was needed to stop the widespread suffering of farmed fish (Lymbery 1992). Two years later, the RSPCA also showed concern for fish welfare in a report written by Steve Kestin on “*Pain and stress in fish*” (Kestin 1994). This attention to fish welfare and pain raised ethical questions about human activities that harm fish. In response, the Angling Governing Bodies Liaison Group and the British Field Sports Society ordered a second opinion from Dr. T.G Pottinger. His “*Fish welfare literature review*” (Pottinger 1995) was intended to “*assess the current state of knowledge regarding two areas of key importance in fish welfare: physiological stress and pain perception, with particular reference to the relationship between angling practices and fish welfare*” (p. 7). By 1995 several studies had already been performed on the responses to stress, performance, and health of fish produced for aquaculture and stock enhancement. These studies showed that the stress physiology of fish was very similar to that of mammals (Pickering 1981; Schreck 1981, 1990; Barton and Iwama 1991). However, at that time there were very few anatomical, biochemical, or behavioural studies regarding pain in fish, and Pottinger concluded: “*There is no information available in the literature at present which provides firm*

evidence that fish perceive pain as mammals apparently do or, conversely, that they cannot perceive pain as mammals do. On balance, it seems unlikely that fish experience pain as understood by humans. The problem of assessing exactly what a fish perceives when exposed to stimuli considered to be noxious or unpleasant in human terms may prove to be intractable.” (p. 5).

In 1996, the British Farm Animal Welfare Council (FAWC 1996) also addressed fish welfare in a “*Report on the welfare of farmed fish*”, covering Atlantic salmon (*Salmo salar*), rainbow trout (*Oncorhynchus mykiss*), and trout (*Salmo trutta*), with “*brief comments on carp (Cyprinus carpio) and those species of wrasse which are used for parasite control during salmon farming*”. A FAWC working group carried out an extensive consultation exercise, obtained oral and written evidence from experts in salmon and trout production, and carefully examined scientific data. A number of fish farms in the United Kingdom (and a few in Norway) were visited, a seminar was held with invited experts from industry and research institutes, and opinions were collected from animal protection societies. FAWC interpreted the available scientific information somewhat differently from Pottinger, and concluded: “*we do not know what fish feel but the evidence available makes it very likely that at least some aspects of pain are felt by fish. In addition to any effect of pain, injury to a fish results in poor welfare where there is impairment of function or increased susceptibility to disease*” (p. 2). This report also made recommendations for the fulfilment of needs related to rearing, husbandry practices, and slaughter.

1.4 Fish Welfare in Politics, Laws, and Regulations

During the 1990s politicians too became increasingly concerned about animal welfare. In the European Union, animals were granted the status of “sentient beings” through the Treaty of Amsterdam (European Parliament 1997). In 1998, the EU issued *Council Directive 98/58/EC concerning the protection of animals kept for farming purposes*, which also included fish. Article 3 stated that: *Member States shall make provision to ensure that the 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*. The directive was later implemented in national legislation, and animal welfare, including fish welfare, became a priority research topic funded by the European Commission.

The Holmenkollen Guidelines for Sustainable Industrial Fish Farming from the Norwegian National Committee for Research Ethics (Sundli 1999) were amongst the first international protocols to suggest that ethical principles aimed at ensuring the health and welfare of fish, including humane slaughter, should govern the aquaculture industry. The World Organisation for Animal Health (OIE) later identified animal welfare, including fish welfare, as a priority area in its Strategic Plan (2001–2005) (Lund et al. 2007). In 2005, the Council of Europe adopted a recommendation on the welfare of farmed fish and in 2008, the OIE adopted [guidelines](#) for fish welfare.

The European Food Safety Authority (EFSA) also played an active role. EFSA aims to gain an in-depth understanding of the factors affecting animal welfare in general, and to provide a science-based foundation for European policies and legislation. In 2004, EFSA's independent Panel on Animal Health and Welfare (AHAW) issued scientific opinions regarding the transport and stunning/killing of farmed fish (EFSA 2004), and in 2008–2009 the panel published eight “scientific opinions” on the welfare and husbandry systems of Atlantic salmon (*Salmo salar*), carp (*Cyprinus carpio*), European sea bass (*Dicentrarchus labrax*), gilthead sea bream (*Sparus aurata*), rainbow trout (*Oncorhynchus mykiss*), European eel (*Anguilla anguilla*) (EFSA 2008a, b, c, d, e), and stunning and killing of turbot (*Scophthalmus maximus*) and Atlantic bluefin tuna (*Thunnus thynnus*) (EFSA 2009a, b). In 2009, this was followed by a *General approach to fish welfare and to the concept of sentience in fish* (EFSA 2009c). EFSA's scientific opinions focus on helping risk managers to identify methods to reduce unnecessary pain, distress, and suffering, and to increase animal welfare wherever possible.

Fish welfare is also considered in national legislation and recommendations, e.g. the New Zealand Animal Welfare Act (1999), the Australian Capital Territory Animal Welfare Act (1992), the Queensland Government Animal Care and Protection Act (2001), the Norwegian Animal Protection Act (1974), and the Norwegian Animal Welfare Act (2009). The Norwegian legislation gives fish a level of protection that is similar to that of other vertebrates. These laws were also followed by a range of regulations that specify both functional and specific demands regarding the individual stages of fish production.

International organizations have also issued recommendations and guidelines regarding fish welfare, and codes of practice adopted by the industry include measures to safeguard fish welfare. The Code of Conduct issued by the Federation of European Aquaculture Producers (FEAP) built on these documents and had a strong focus on fish welfare. Other standards and certification schemes for sustainable aquaculture that include fish welfare have been issued by the Aquaculture Stewardship Council (ASC), GLOBALGAP aquaculture standard, Best Aquaculture Practices (a division of the Global Aquaculture Alliance), and the RSPCA Assured (Freedom Food) (see also Chap. 13).

1.5 The Rise of Fish Welfare Science

Drawing on all branches of biology, including behavioural ecology and neuroscience, the science of animal welfare asks three big questions: Are animals conscious? How can we assess good and bad welfare in animals? How can we use science to improve animal welfare in practice?

Marian Stamp Dawkins (2006, p. 77)

Before 2000, the concept of “fish welfare” was not used much by fish scientists. A search in Google Scholar for scientific publications containing the phrase “fish welfare” produces only 16 papers and reports published before 1990, and 51 in the

period 1990–1999, most of which were not really about fish welfare. However, after the turn of the millennium, “fish welfare” gradually came to be used by more and more scientists working in aquaculture and fish farming. This is illustrated by a rise to 1120 “fish welfare” papers and reports between 2000 and 2009, and 4940 hits between 2010 and 2019.

However, even if not labelled “fish welfare”, the rapidly growing fish farming sector, together with a long tradition and growing practice of rearing juvenile fish for stock enhancement and sea ranching, had already led to the publication of a substantial body of studies relevant to fish welfare, including several on topics like fish production and husbandry, stress physiology, nutrition, health, diseases, and vaccines (e.g. Pickering 1981; Schreck 1981, 1990; Pottinger 1995; Wendelaar Bonga 1997; Iwama et al. 1997). Ethologists have also been studying fish behaviour for decades, addressing welfare relevant topics such as sensory biology, learning and cognition, aggression, territorial competition, and reproductive behaviour (e.g. Huntingford and Toricelli 1993; Pitcher 1992; Godin 1997; Huntingford et al. 2006).

The sharper focus in the 1990s on animal welfare in general, created a need for more scientific knowledge about fish welfare, that led to more funding opportunities from national research funds, and fish biologists willingly turned to animal welfare science. For example, in 2001 a Norwegian Strategic Institute Programme was funded to develop animal welfare competence at the two main Norwegian fisheries research institutes and the Norwegian University of Life Sciences (Damsgård et al. 2006). During the following decade, several Norwegian scientists led national and EU-funded projects on fish welfare that focused on basic research on many topics such as stress tolerance, farming environment, welfare indicators and assessment, sterile fish, coping mechanisms, individual variation, genomics, and health (Cordis 2019).

In 2002, an influential “Briefing Paper” on fish welfare was published by the Fisheries Society of the British Isles (FSBI 2002). This became an agenda and framework for scientific studies of fish welfare. The paper examined suffering and pain in fish, human–fish interactions, responses to stressors, the assessment of welfare, and much more. The authors offered no clear definition of welfare, but considered physiological function, feelings, and a natural life as different aspects of the welfare concept. However, it did not offer an opinion regarding what is acceptable fish welfare. The authors of the FSBI paper also pointed to gaps in our understanding of the concept of fish welfare, what it means and how it might be measured. The single most important gap was a lack of understanding of the mental capabilities of fish and of whether and how measurable states (such as physical injury and physiological and behavioural responses to challenge) generate subjective states of well-being and suffering. An updated version of this briefing paper was published by the same authors, plus the ethicist Peter Sandøe. The new version also included a section on “science, ethics and welfare” (Huntingford et al. 2006). In the 2000s, several review papers were published that focused on various aspects of fish welfare such as pain and consciousness (Chandross 2004; Chandross et al. 2004; Broom 2007), the welfare of farmed fish (Conte 2004; Ashley 2007), psychological

stress and welfare, (Galhardo and Oliveira 2009), animal ethics (Lund et al. 2007), welfare assessment (Håstein et al. 2005; Volpato 2009), and recreational fishing (Cooke and Sneddon 2007). In 2008, the first textbook on fish welfare was published by British fish welfare scientists (Branson 2008).

An important role in the establishment of a fish welfare science in Europe was the EU COST action network Cost 867 WELFISH (2006–2011). The network included more than 100 participating stakeholders from 26 countries, including Canada, New Zealand, and Australia (Van de Vis et al. 2012). Its main objectives were to improve our knowledge of fish welfare, to formulate a set of guidelines embodying a common and scientifically sound understanding of farmed fish welfare, and to construct a range of targeted operational welfare indicator protocols to be used by the industry. The COST Action focused on the five main farmed species in Europe: Atlantic salmon, rainbow trout, sea bass, sea bream, and carp.

1.5.1 *The Fish Pain Controversy*

In the course of the past few decades, the question “do fish experience pain?” has been receiving a growing amount of attention. This is an ongoing controversy in fish welfare science, probably since it is an essential topic for welfare concern and legislation. The accepted definition of human pain is “*An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage*” (IASP 1979, p. 247). According to this definition, pain comprises both sensory and negative affective aspects, implying it is a conscious experience. A review paper by Rose (2002) claimed that fish lack the essential brain regions and the neural basis of consciousness and pain perception, “*making it untenable that they can experience pain*”. Rose also claimed that “*Because the experience of fear, similar to pain, depends on cerebral cortical structures that are absent from fish brains, it is concluded that awareness of fear and conscious experiences is impossible for fishes*” (p. 1). If the conclusions drawn by this paper were generally accepted there would scarcely be any point in promoting fish welfare. However, Rose still had some concern for fish and accepted that fish display “*nonconscious neuroendocrine and physiological stress responses to noxious stimuli. Thus, avoidance of potentially injurious stress responses is an important issue in considerations about the welfare of fishes*”. This would appear to leave room for a definition of fish welfare in terms of “physiological functioning”.

The same year, however, Lynne Sneddon from the Roslin Institute in the United Kingdom published an influential study on nociception in the trigeminal nerve of the rainbow trout, *Oncorhynchus mykiss*. She documented the presence of A-delta and C-fibres that convey nociceptive information to the fish brain (Sneddon 2002). Subsequently, she showed that rainbow trout possess nociceptors that respond to mechanical pressure, high temperatures, and acetic acid, reporting greatly increased opercular beat rate and a delay in resuming feed intake after exposure to acetic acid or bee venom injected into the lip, compared to a saline injection (Sneddon et al.

2003a, b). Since then, empirical evidence and supportive arguments have been accumulating for the ability of fish to experience pain (Sneddon et al. 2003a, b, Chandroo 2004; Chandroo et al. 2004; Dunlop and Laming 2005; Dunlop et al. 2006; Sneddon 2006; Broom 2007; Brown 2015; Ashley et al. 2007; Braitwaite 2010; Sneddon et al. 2014, 2018; Woodruff 2017; see also this volume, Chap. 10). However, Rose and others have not been convinced and they have tried to refute the studies by Sneddon and others (Pen and Rose 2007) referring to their brain morphology argument (Rose 2007; Arlinghaus et al. 2007a; Diggles et al. 2011; Rose et al. 2012; Key 2015, 2016). However, neurobiologists have recently started to seriously question their logic and arguments (Merker 2016; see also many other responses to Key (2016) in *Animal Sentience* 3(1) and Chap. 10).

1.5.2 *What Next?*

In the course of the past decades, the “fish welfare” concept has become fully adopted in Europe by fish farmers, technology companies, animal advocates (NGOs), scientists, politicians, authorities, consumers, and even amongst some fishermen. The rest of the world is also following, and we can find “fish welfare” sessions in most aquaculture conferences all over the world. Many scientists are keen to include welfare measures in their field of science, perhaps also because fish welfare may increase opportunities for funding.

The growing importance of aquaculture and stronger legal protection of animals, in general, makes it reasonable to expect that concern for fish welfare will be growing in the near future. Modern aquaculture is a highly science based but still relatively young industry, and the need for more knowledge is evident. Fish welfare is a multifaceted science and consists of fields such as physiology and health, water chemistry and technology, cognitive sciences, and neurobiology, not to mention also philosophy and ethics. Fish, especially zebrafish, have become the most used research animals (Chap. 16), and fishes are also some of the most popular pets all over the world (Chap. 15), all of which points to growing awareness of and concern for fish welfare. The following chapters present a considerable amount of new knowledge about fish welfare-related topics, but they also make it clear that our overall level of knowledge about the basic welfare needs and physiological and behavioural traits and functioning of the multitude of fish species is still very limited.

As concern for fish welfare seems to be related to dwindling wild populations (Pauly et al. 1998), combined with an increase in intensive farming practices, we can now perhaps anticipate a similar pattern concerning cephalopods, crustaceans, and insects (Carere and Mather 2019; Mellor 2019). Growing concern about falling populations of some insect species and implications, for example for bird populations on farmlands, particularly pastures, together with the rise of intensive insect farming is likely to follow a similar pattern as has already taken place for common livestock species and now, apparently, for fish. These developments will pose challenging questions for science too. How are we to measure brain activity that

may be related to consciousness, for example when we stun animals before slaughter? This is a challenge in fish, and will be even more so in “lower” animals like crustaceans and cephalopods, and in due course, insects will presumably raise the same question: Are they mere automata, with or without feelings (Mellor 2019)?

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