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ARTICLES

Finfish Aquaculture: Animal Welfare, the Environment, and Ethical Implications

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Abstract The aim of this review is to assess the ethical implications of finfish aquaculture, regarding fish welfare and environmental aspects. The finfish aquaculture industry has grown substantially the last decades, both as a result of the over-fishing of wild fish populations, and because of the increasing consumer demand for fish meat. As the industry is growing, a significant amount of research on the subject is being conducted, monitoring the effects of aquaculture on the environment and on animal welfare. The areas of concern when it comes to animal welfare have here been divided into four different stages: breeding period; growth period; capturing and handling; and slaughter. Besides these stages, this report includes a chapter on the current evidence of fish sentience, since this issue is still being debated among biologists. However, most biologists are at present acknowledging the probability of fish being sentient creatures. Current aquaculture practices are affecting fish welfare during all four of the cited stages, both on physical and mental levels, as well as on the ability of fish to carry out natural behaviors. The effect fish farming has on the environment is here separated into five different categories: the decline of wild fish populations; waste and chemical discharge; loss of habitat; spreading of diseases; and invasion of exotic organisms. There is evidence of severe negative effects on the environment when looking at these five categories, even when considering the difficulty of studying environmental effects, due to the closely interacting variables. The ethical arguments and scientific evidences here reviewed have not all come to the same conclusions. Nevertheless, the general agreement is that current aquaculture practices are neither meeting the needs of fish nor environment. Thus, the obvious environmental and

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animal welfare aspects of finfish aquaculture make it hard to ethically defend a fish diet.

Keywords Aspects of animal welfare in fish · Ethics and animal welfare · Aquaculture · Fish sentience · Environmental impact of aquaculture · Humane slaughter

Introduction

The amount of fish killed for food each year is steadily increasing, as the consumer demand for fish, as well as the world's human population, is growing rapidly. As the populations of wild fish are decreasing due to unsustainable fishing, the number of fish reared in farms has increased greatly the last decades. From previously answering for 9% of the total of fish killed for human consumption in the middle of the 1980s, aquaculture systems produced 46% of the consumed fish in 2008 (Food and Agriculture Organization of the United Nations 2010), although this percentage is lower in the developing countries. The rising consumer demand for high quality fish meat, as well as increasing public concern for fish welfare and environmental sustainability, has led to an increased demand for improvements of fish farm practices (Lambooij et al. 2004). In addition, the increasing public concern regarding fish welfare in aquaculture (Huntingford et al. 2006), has resulted in a substantial amount of research the last decade.

The term welfare is used in a broad sense, and can be defined in various ways. However, there are three wide definitions often used: the feeling-based, the function-based, and the nature-based definition (Duncan 1996; Broom 1996; Fraser et al. 1997). Furthermore, a fourth integrity based definition can be identified (Lund and Röcklinsberg 2001). In short Fraser and colleagues mean that the welfare of the animal can be assessed either in regards of its own subjective feelings, emotions and mental state; its physical functioning, health and capacities; or by the ability the animal has to express its natural behavior and lead a natural life (Fraser et al. 1997). In order to assess fish welfare, it is possible to either use one of these definitions, or to combine them for a more complete assessment. However, in many cases of fish welfare, all three definitions are related and they all lead to the same conclusion, since poor welfare defined by one approach often leads to poor welfare according to the other two (Huntingford et al. 2006).

Considering that the various species of fish reared in farms have evolved differently to adapt to their natural habitats, in aspect of salinity, temperature, depths etc., they differ with respect to behavior and needs. Previous research regarding fish welfare has almost exclusively handled teleost fish, i.e., finfish (Huntingford et al. 2006), and although the term "fish" includes other species than the teleosts, this paper will in general focus on these species.

In contrast to other species of animals in agriculture, there has, until recently, been very little research on the capacity to feel pain and psychological stress on fish species farmed for meat (Chandroo et al. 2004; Algers et al. 2009) even though the number of fish that are being killed for meat each year probably exceeds the number of all other animals reared for meat put together. The actual number of fish being killed each year is unknown, since, in statistics, fish are being measured in weight instead of in individuals, which might be considered as an indication of the status fish have in today's society. Also, farmed fish, as other production animals reared in large populations, is often regarded and spoken of, not as animals to care for, but as crops to harvest (Lund et al. 2007).

The aim of this investigation is to review and discuss the potential risks of aquaculture practices, particularly in regards of fish welfare, but also concerning the environmental impacts of these practices. In addition, the ethical implications for animal welfare and environmental issues will be examined, since the cases of animal and environmental protection are the primary subjects of ethical discussion concerning aquaculture.

Aspects of Animal Welfare

The potential risks for impaired welfare in farmed fish caused by humans occur under different phases of the production. Here they will be divided into four different stages: breeding; growth period; capturing and transportation; and slaughter. Important aspects of fish welfare regarding these stages will be discussed, and we consider the question of fish sentience and ability to feel pain to be a relevant starting point for discussion, so this is our initial approach to investigate the term welfare in fish.

Sentience

The existence of pain and suffering in fish has been widely studied and debated in recent years, with some conflicting results. These studies are important since they may determine whether animal welfare should be considered at all concerning fish and fish production. Science has not yet, with certainty, come to an agreement whether fish can feel pain or experience suffering, though in recent years most scientists do acknowledge that fish can experience at least something similar to the mammalian experience of pain (Rose 2002; Algers et al. 2009).

If fish can feel pain, they need to be regarded as sentient creatures. Their reactions to stimuli would therefore probably not only be a physiological response but also cause an associated psychological experience that requires cognitive capabilities (Chandroo et al. 2004).

Although finfish have nociceptors (receptors with ability to perceive painful stimuli), hence should be able to at least acknowledge pain, there still is a debate concerning the ability of fish to have an actual cognitive experience of pain (Algers et al. 2009). It has been proposed that the similarities between fish and mammals do not only include some aspects of neuro-anatomy, but also other anatomical, physiological, and behavioral similarities, and therefore, fish are creatures that should be taken into consideration regarding animal welfare and humane treatment (van der Vis et al. 2003; Lambooij et al. 2004; Huntingford et al. 2006; Lund et al. 2007). It can be concluded that fish have the sense organs and neural system acquired to react and respond to painful stimuli, and most likely to experience a subjective feeling of pain, as well as other mental states such as suffering. Thus, for the remainder of this paper, fish will be regarded as sentient creatures.

Breeding

Their breeding contains aspects that are critical to the fish welfare, and these are genetic aspects (including genetic variation and covariation and selection practice) as well as, reproductive practice (e.g., environmental effects during hatching and larvae feeding). There are a number of different malformations of the spine that are common in farmed fish, they have been observed in most farmed fish species, and they are considered to be effects of both hereditary factors, e.g., inbreeding; and environmental factors, e.g., nutrition imbalance, especially vitamin deficiency, or inappropriate temperatures (Afonso et al. 2000; Imsland et al. 2006; Anonymous 2009; Olesen et al. 2010). Gjerde et al. (2005) found that the incidence of vertebral deformities in Atlantic salmon (*Salmo salar*) varied from 2.3 to 21.5% during 1992–1995 and that this was determined by a substantial additive genetic component, but it was not correlated to high genetic growth potential. A study of Atlantic cod (*Gadus morhua*) by Imsland et al. (2006) found evidence implying that the feed regime during the larval stage had major implications for anatomical development and occurrence of skeletal deformations. Similar finding has been made by Kolstad et al. (2006), who found that spinal deformity showed a higher degree of environmental sensitivity in cod.

The natural spawning can be intervened in aquaculture by procedures that enhance the gonad maturation process. This can either be done by altering the photoperiod, or by hormonal injections (Donaldson 1996), which can have impact on fish welfare. Especially the hormonal injections appear to have negative effects of the animals' wellbeing, as the fish has to be handled and the hormone is injected through the skin (Grigorakis 2009).

Aspects besides handling procedures in the spawning process may have negative effects on fish. For example, breeding fish for productive features, such as fast growth and high feed conversion efficiency, has had some unexpected welfare consequences. Due to genetic and/or environmental factors, conditions such as deformities of heart, swim bladder, spine, jaw, and lips are not uncommon in farmed fish, and impair welfare through poor health and impaired swimming ability, as well as capacity to compete for food (Imsland et al. 2006; Ashley 2007). Affected fish show decreased stress resilience and have increased mortality rates compared to others (Ashley 2007), indicating impaired welfare. In addition to the hindering of competitive and swimming abilities, it is likely that such malformations are painful for the individual fish, although research on this subject is lacking.

In intensive aquaculture, feed for larvae compose mainly on rotifers, but in comparison with zooplankton, led to three times the incidence of skeletal malformations, with an average of 14.2% versus 4.1% (Imsland et al. 2006). An introduction of zooplankton as feed in commercial fish farms might be difficult however, since the plankton are only accessible under a limited part of the year (Imsland et al. 2006). Yet this study points out an urgent matter for intensive aquaculture, namely that current breeding and feed practices may be efficient enough regarding fish production, but mostly not concerning fish health and welfare.

Growth Period

The growth period is the longest stage for most fish in aquaculture, hence possibly the most important one from a welfare perspective. Some of the potential risks for fish welfare during this stage include crowding, handling, diseases, aggressive behavior causing injuries or food deprivation, poor water quality, and starvation before transportation or during disease treatment. The intense rearing conditions commonly seen in commercial fish farms is often causing poor water quality; reduced growth, stress, and distress; and mortality (Håstein et al. 2005). This is certainly a concern for fish welfare and closely interacts with other issues of concern in subsequent sections.

Disease

To prevent and control spreading of disease among fish in aquaculture, knowledge of the interaction between pathogen, fish, and environment, is required (Toranzo et al. 2005).

Outbreaks of infectious diseases that are not substantially inflicted by stress and poor living conditions, leads to suffering (Huntingford et al. 2006), hence it should be treated properly and prevented if possible. There are numerous infectious and non-infectious diseases farmed fish can be exposed to, thus a thorough assessment is beyond the scope of this paper. Vaccination for preventing diseases has increased and a reduction in infectious diseases has been observed in concerned farms (Håstein et al. 2005). The vaccinations themselves though, pose a threat for fish welfare through increased handling, causation of inflammation in the body part injected, and occasional subsequent deformations of the spine (Håstein et al. 2005).

Physiological responses to chronic stress in fish includes immunosuppression, hence repeated occurrences of diseases and high mortality rates can be an indication of a poor environment for, and impaired welfare of, farmed fish (Huntingford et al. 2006). Causes for chronic stress associated with disease susceptibility can for example be fin abrasions, aggressive social interactions, and crowding (Ashley 2007).

Aggression and Abnormal Behaviors

Fish species with hierarchal social orders can, particularly in cases of improper housing conditions such as high densities and deficient feeding methods, express aggressive behavior that leads to social stress, especially for the subordinates (Ashley 2007). For low ranking individuals, this may lead to immunosuppression, food competition with decreased growth, decreased swimming activation, and food deprivation, alongside fin and eye injuries with infections and increased mortality as results (Ashley 2007). Furthermore, social traits such as increased aggression can be partially caused by unintentional selection, since behavior is influenced by genetic, as well as environmental factors (St-Cyr and Aubin-Horth 2009).

Rearing of Atlantic cod (*Gadus morhua*) in fish farms is problematic, since highly aggressive behavior and cannibalism is common among juveniles (Höglund et al. 2005). Though Höglund et al. (2005) acknowledge that hierarchal and aggressive behaviors are important parts of the juvenile Atlantic cods behavioral repertoire, the authors suggest a use of feed supplement (L-tryptophan, or TRP) that is aggression suppressing, since "[…] by changing the behavior of the fish instead of altering the social and/or physical environment, TRP-supplemented feed could be more cost-effective and less time-consuming than other manipulations aimed at decreasing cannibalism." Other manipulations of the environment for farmed cods named by the authors are feeding strategies and usage of optimal stocking densities. The freedom to express natural behavior would hereby be compromised, not only by rearing fish in improper conditions, but also by feeding them supplements that essentially alter their behavior. The reason given this is that altering fish behavior is less costly and time-consuming than changing the inadequate rearing system, where subordinate individuals have little chance of escaping aggression from dominant ones. Although it is reassuring that aggressive behavior of farmed fish is regarded as a concern for scientific research, it may be viewed as incautious or unethical to manipulate the natural behaviors of fish to solve issues of improper production practices.

Besides aggression, abnormal behavior in farmed fish, such as atypical swimming, is a potential symptom of threatened welfare. These behaviors can be the results of suppression of behavioral needs, indicative of exposure to stressors and potentially poor welfare, as the animal makes unsuccessful efforts to alter its situation (Ashley 2007). In other cases, fish abnormal behavior can derive from injury, disease, or other health conditions (Ashley 2007). Whichever, the abnormal behavior of fish should be taken into concern, evaluated, and handled.

The lacking comprehension of behavioral needs for farmed fish, both social and individual, represents a serious risk for fish welfare (Håstein et al. 2005). Regarding fish as sentient creatures with individual needs besides physical health is a critical step towards treating fish in a morally acceptable way. Further scientific evidence is needed to fully realize the welfare implications fish farm conditions have on fish behavior and welfare.

Stocking Density

The impact of stock density on fish welfare is difficult to assess, due to the interaction between environmental factors, such as water carrying capacity, as well as the diverse physiological and behavioral requirements of different species (Håstein et al. 2005; Ashley 2007). For instance, solitary living fish may be stressed by, and turn aggressive in high densities, while for fish that naturally live closely together with others in large numbers, too low a density may be stressful (Ashley 2007).

The stock density of farms rearing the commonly brought up species rainbow trout, varies among farms, which are often guided by the farmers' own experience, since there is not always legislation controlling fish density. Usually the density varies between 15 and 40 kg/m^3 in Europe, North America and Australia, but both higher and lower densities are in practice (Ellis et al. 2002). According to Ellis et al. (2002) animal welfare in fish farms has become a central issue, since there are indications that the meat quality and fish health are closely linked to the welfare of the animals. Although there are conflicting results, studies have shown that an increase in density leads to an increase in gill and fin injuries, as well as mortality of farmed rainbow trout (Ellis et al. 2002), and that the overall welfare is impaired (Ashley 2007). Others studies have shown that a low density can lead to increased fish mortality, since the aggression of rainbow trout can be triggered by low densities, and this can raise the susceptibility of disease and infection due to the damage inflicted (Ellis et al. 2002). In high density farms as well, an associated problem seems to be an increased disease occurrence, which could be explained by poorer water quality, easier spread of pathogens, and that the immune system of the fish could be impaired by the stress crowding inflicts (Haya et al. 2001; Ellis et al. 2002). Studies have shown that feed intake decreases with increased density in fish farms, and studies have also shown that feed conversion efficiency decreases with increased densities (meta-analysis by Ellis et al. 2002), which clearly demonstrates that animal welfare issues are important not only for the reared fish and concerned consumers, but also have an economic importance to the farmers.

To assess the fish welfare implications of high fish density in rainbow trout, Ellis et al. (2002) state that more research is needed. They found that the scientific studies of fish density had conflicting results and did not clearly show that high density is a stressor that will impair fish welfare. Ellis et al. (2002) do conclude though, that there are signs suggesting that the welfare of the animals is at risk with high densities, as well as with too low densities. The increase in gill and fin damage, as well as the increased mortality in at least part of the high density farms studied are, according to Ellis et al. (2002), suggesting that high fish density in rainbow trout farms are likely resulting in a poorer welfare for the animals. The authors further discuss the welfare implications of decreased food intake and growth rate in high density farms, and argue that to be sure of impaired welfare for these fishes, it has to be shown that the fish are suffering from hunger, stress, or other discomforts associated with decreased food intake or growth rate, since these effects do not mean impaired welfare per se. However additional studies (Ellis et al. 2002; Vazzana et al. 2002; Håstein et al. 2005), have shown that increased stress levels and mortality, inhibited swimming behavior, and decreased ability to digest food are results of high densities for farmed fish. Other aspects of high density in fish farms that could impair welfare are that the behavioral needs for the fish might be made impossible to meet, and that the water quality is often poorer in high densities, due to more intense use of the water for metabolic reactions and that increased fish movement will hinder the particles in the water to settle (Ellis et al. 2002). This may lead to stress, aggressive behavior and damages to the gills and fins due to collisions (Ellis et al. 2002; Håstein et al. 2005). This evidences illustrate that high density is undoubtedly a matter of welfare concern.

The implications of high stocking density for farmed fish varies among different species, and are, as mentioned, interconnected with other rearing conditions, such as water quality and food availability (Turnbull et al. 2005; Ashley 2007). The difficulty to assess welfare, due to lack of research, with the wide range of different species reared in aquaculture further complicating the matter, lead to difficulties for development of appropriate densities recommendations (Turnbull et al. 2005; Ashley 2007). However, in a study of Atlantic salmon (*Salmo salar*), Turnbull et al. (2005) found that high density impair welfare if above a threshold density of 22 kg m^3, when body and fin condition, as well as plasma concentration of cortisol and glucose was measured. The water conditions regarding temperature and oxygen levels during the study was for the most part within the recommended ranges, and should therefore not have influenced the results. The authors conclude though, that a recommended threshold density for farmed fish does not guarantee fish welfare, since there are a number of factors connected to density that affects the animals' well-being. This means that, for some farms, a density of 22 kg m^3 would be appropriate, but for others a decreased density would be required due to differences in farm practices and conditions. Ashley (2007) suggests behavioral observations of on farm fish as important measures animal keepers can take to see indications of poor welfare due to improper stocking density.

Capturing and Transportation

Fish are mainly captured and transported when transferred to pens for growth or in connection with slaughter. Although the duration of these stages are comparably short compared to the growth period, they are vital stages in regards of welfare, since they can cause numerous potential stressors for the animals. Examples of such are crowding, handling during capture, poor water quality with low oxygen levels, food deprivation, exhaustion, injuries, as well as increased aggression and spreading of diseases. When moved to the new environment of the growth pen, acclimatization to this environment regarding water composition, temperature, and light levels, needs to be considered and assured (Ashley 2007). The handling and transport itself to the growth site is stressful for the juvenile fish, thus their ability to cope with the transfer can be subsided, with increased mortality as a result (Ashley 2007).

Before slaughter, when captured and transported, the fish are subjected to a number of stressors, such as crowding with skin abrasions, as well as low oxygen and high ammonia levels in the water as results of the crowding (Poli et al. 2005; Gatica et al. 2008). Any handling of fish before slaughter, such as capturing or transfer from transport vehicle to holding pens before slaughter, is a stressful experience for fish (Håstein et al. 2005), due to crowding and struggling, and the poor water quality crowding leads to (Poli et al. 2005; Gatica et al. 2008). This exhausts the fish, and as they are most often not given the opportunity to recover before the slaughter (Poli et al. 2005), it also affects their ability to handle the actual stress of being stunned and slaughtered. Since the struggle decreases the pH in the fish musculature, and the animals are not allowed to recover, this is shown in the meat quality after slaughter (Poli et al. 2005; Gatica et al. 2008). To avoid this poor meat quality such as off-flavor, fish are often starved several days or even weeks before slaughter, for sake of water quality during transport and so that the animals' energy reserves are emptied and they do not have the energy to struggle during capturing (Poli et al. 2005; Gatica et al. 2008). Hence the pH does not drop in the muscles, however the procedure is sure to be further stressful to the fish (Poli et al.

2005; Gatica et al. 2008). There is evidence though, that indicates that the food deprivation itself not necessarily is a source of impaired welfare, thought mainly to depend on the fact that fish are ectothermic (Huntingford et al. 2006). The starvation has, however, an impact on their energy reserves and therefore the all total condition of the fish, and furthermore results in stress and possible behavior changes, such as increased aggression, or "eye snapping" (Håstein et al. 2005; Ashley 2007), which may lessen their ability to cope with other sources of stress during this stage.

When the fish are captured they usually get loaded onto the boat by pumps and then again transferred by pipes from their resting cages or directly from the boat to slaughter (Gatica et al. 2008). The pumps and pipes transferring the fish stress the animals and can cause injuries and skin abrasions, therefore they should be well constructed and the duration of transfer in pipes should be as short as possible (Ashley 2007; Gatica et al. 2008). The overcrowding that occurs in the resting cages is also stressful for the animals and can lead to aggressive behavior and injuries (Ashley 2007; Gatica et al. 2008). The stress caused by capturing, handling, and transport should be minimized by, ideally, slaughtering the fish directly after capturing, and if that is not possible, by improving the practices used in handling and transport to slaughter (Gatica et al. 2008). Handling and other disturbances in the pre-slaughter process are also associated with stress for the fish (Håstein et al. 2005; Poli et al. 2005; Ashley 2007; Gatica et al. 2008). Being taken out of water is a severely stressful situation for fish; giving an emergency response leading to high plasma cortisol levels and behavior indicating acute stress, such as excessive struggling and attempts to escape (Håstein et al. 2005). Manual handling can cause skin abrasions, along with scale and mucous coat removal (Ashley 2007). The mucous coat serves as a protection from infections, and if damaged the fish is much more susceptible to diseases, as well as weakened in locomotion and osmoregulation abilities (Ashley 2007). Thus, handlers should always take precautions when handling fish, such as using appropriate nets, gentle and wet hands, and keeping the fish out of water for as short a time as possible (Håstein et al. 2005; Ashley 2007). Continuous or multiple stressful situations for fish are additive and exhaust the animals, making them less capable of handling further stressors (Ashley 2007; Gatica et al. 2008).

Therefore, for sake of the fishes' welfare, they should not be starved longer than enough for the stomach to empty, so that the water quality during transport and pre-slaughter is not further lowered by waste, and the fish in that same aspect need to be rested and free from skin abrasions, muscle bruises, or other injuries (Poli et al. 2005; Ashley 2007; Gatica et al. 2008).

Slaughter

The very moments leading up to death for fish in aquaculture may be short in terms of life span, but as discussed below, is often associated with severe stress and pain for the animals. There has been a substantial amount of research in slaughter of farmed fish recently, perhaps due to the poor meat quality of stressed and exhausted fish, but probably also because of the increased public concerns regarding current slaughter procedures. Slaughter techniques are often adjusted to assure efficiency, not fish welfare (Ashley 2007), and there are various different methods used in commercial fish farms worldwide, most of them described below. Methodology used to assess sensibility, consciousness, and reactions to stimuli in fish is also briefly described.

Ability to confirm unconsciousness, and therefore insensibility, in fish depends on adequate methodology, since behavioral observations alone may be misleading due to the immobility that can occur without loss of consciousness (van der Vis et al. 2003; Lambooij et al. 2004). Other ways to assess the stress response and sensibility of fish, such as electroencephalogram, or EEG; electrocardiogram, or ECG; plasma hormonal levels; somatosensory evoked responses; and visual evoked responses, are available as a complement to the behavioral parameters (van der Vis et al. 2003; Lambooij et al. 2004; Ashley 2007). The somatosensory evoked responses is brain responses to painful stimuli (such as a scratching with a nail), and visual evoked responses is brain responses to stimuli in form of a flashing light directed at the eye. Insensibility is concluded when the brain responses do not occur, this due to brain disruption or brain failure (van der Vis et al. 2003; Lambooij et al. 2004). The occurrence of visual or somatosensory responses does not make it possible to automatically assume conscious awareness of light or pain stimuli, though it is a sign of intact pathways to higher brain centers and implies remained sensibility (Lambooij et al. 2004).

There are different methods of stunning and killing farmed fish in practice, both forceful methods that quickly render fish unconscious, and methods that slowly decrease the level of consciousness in the animals. With certainty, handling, stunning, and slaughter are highly stressing moments for farmed fish whichever method being used, and the more stressful it is, the lower the meat quality, which makes it measurable (Poli et al. 2005). Poli et al. (2005) view the relative fast working methods of some types of stunning (e.g., knocking and spiking) generally as less stressing for the fish than other methods, though they point out that these methods are not always practical, for example with large numbers of smaller sized fish. Following methods of slaughter is currently being used on farmed fish in Europe: asphyxia, carbon dioxide narcosis, ice stunning, spiking (though used mostly on an experimental level), knocking, exsanguination through gill cutting or decapitation, salt bath in combination with evisceration (i.e., gutting), and electrical stunning (e.g., van der Vis et al. 2003; Lambooij et al. 2004; Poli et al. 2005). The following section deals with these different slaughter methods.

Asphyxia

The oldest method of fish slaughter is asphyxia, which essentially means suffocation through taking fish out of water, and has been shown (for example in plasma cortisol levels and meat quality) to be associated with high occurrence of stress reaction in the animals (Poli et al. 2005; Ashley 2007). The duration until fish lose consciousness varies widely among different species, depending on how resistant the species is to hypoxia, and ranges from about 5 min to over an hour (Poli et al. 2005). Behavioral studies of fish being slaughtered in this manner also indicates that this experience is highly stressful, based on observations of attempted escapes and other avoidance behavior, and this method is thought to mean prolonged suffering before unconsciousness occurs (van der Vis et al. 2003; Poli et al. 2005; Ashley 2007).

Stunning by Ice Water Immersion

Cause of death when fish is being immersed in ice water is anoxia and the time until stunning varies among species also in regard of this method (Poli et al. 2005; Ashley 2007), from 12 min (in eel) to up to 198 min (in trout) (Poli et al. 2005). This method has been concluded to be inhumane due to behavioral observations of vigorous movement, and because of the length of time from immersion to unconsciousness (van der Vis et al. 2003; Poli et al. 2005; Ashley 2007), although in some species of fish that are adapted to warm water, the level of stress seems to be relatively low, in for example plasma glucose and lactate levels, as well as the behavioral reaction of the fish with little or no violent reactions (Poli et al. 2005). In comparison with asphyxia, this seems to be a less stressful experience for the warm water adapted species of fish (Poli et al. 2005), but is still considered inhumane due to the duration until stunning (Ashley 2007).

Exsanguination

Death by gill cutting, without previous stunning is not considered to be a humane method of slaughter, and has been banned in e.g., Norway. Studies have found that the behavior of Atlantic salmon, such as vigorous movements, indicates occurrence of sensibility at least for the most part of the time from cutting until death (Robb et al. 2000). van der Vis et al. (2003) found that the visual evoked responses to light stimuli were not lost directly after the cut, further indicating the method’s welfare implications for fish. Lambooij et al. (2004) studied ECG and somatosensory evoked responses in African catfish following gill cutting without stunning, and found that although the ECG patterns depressed after 2–5 min, the somatosensory evoked responses lasted 15 min in all fish tested, at which time the tests were aborted and the fish killed. Gill cutting as a method of slaughter is yet in practice in countries such as United Kingdom and Norway (Robb et al. 2000). In comparison, decapitation is a way of slaughtering eels in the Netherlands, although rarely used except by retailers, since it is not practical when slaughtering eels in great numbers (van der Vis et al. 2003). This is for certain not a humane treatment of eels: tests have shown that the animals do not lose their visually evoked responses for an average of 13 min after the cut (van der Vis et al. 2003) and eels can stay alive for up to 8 h after decapitation (Verheijen and Flight 1997). Therefore this method is detrimental from an animal welfare perspective.

Electrocution

Electrocution can be an effective, and more humane, method of stunning considering that it can lead to an immediate loss of consciousness, as well as reduced handling, transportation, and taking fish out of water, when carried out in water (van der Vis et al. 2003; Ashley 2007). Electricity can either be applied over the whole body, or across the head only, if done on individual fish (van der Vis et al. 2003). Without using a high enough electrical current, immobilization without lost sensibility may result, hence becoming a threat to welfare (Ashley 2007).

Lambooij et al. (2004) studied head-only stunning with electricity and subsequent gill cutting on African catfish. Two out of seven fish responded to noxious stimuli up to 5 min after 1.2 s of electricity applied and gill cut, even though a relatively high current was being used. According to van der Vis et al. (2003), 1 s of application across the head only leads to sufficient stunning in one out of ten sea bream tested, and the fish with brain disruption regained consciousness after only 37 s, when visually evoked responses were observed. Ten seconds of electricity applied across the head was more efficient with six out of ten fish stunned for at least 10 min and the fish were assumed to be dead, though one of the ten sea breams tested did not lose visual evoked responses at all, and three of the stunned fish recovered within 16 s. For these results, the current used varied and the fish who was sufficiently stunned received relatively high currents (over 400 mA) (van der Vis et al. 2003). The low currents often being used in commercial farms is explained by the violent muscle contractions the electrocution leads to, which can leave blood spots in the muscles, as well as broken bones, and in that sense give decreased meat quality (Poli et al. 2005; Ashley 2007). However, with an optimized current and insurance that death will occur before regained consciousness, this method can be quicker and less stressful to fish than most other methods currently used in commercial fish farms (van der Vis et al. 2003; Lambooij et al. 2004; Poli et al. 2005; Ashley 2007).

Carbon dioxide Stunning

A widely used method of stunning of farmed fish is carbon dioxide stunning. The fish are stunned by immersion in water with added carbon dioxide, CO_2, which decreases the pH-level in the blood and intoxicates the brain, leading to narcosis (Poli et al. 2005; Ashley 2007). When carbon dioxide is added to water, it dissolves to carbonic acid, H_2CO_3, which is highly aversive to mucous membranes, and causes intense avoidance behavior in fish, such as frantic swimming and attempts to escape the water (Rollin 1993). The duration until stunning varies, but although immobility is reached within 30 s to 4 min, sensibility remains up to 5 min, often up to being bled by gill cut (Håstein et al. 2005; Poli et al. 2005). It has been concluded by a number of authors that this method is not humane (e.g., van der Vis et al. 2003; Håstein et al. 2005; Ashley 2007), yet still it is an internationally common practice in finfish aquaculture.

Percussive Stunning

For larger fish, insensibility by a blow to the head using a club can be used as a stunning method, leading to concussion, a disruption of the brain and immediate unconsciousness or death (van der Vis et al. 2003; Poli et al. 2005). If done correctly this is, therefore, one of the more humane methods (van der Vis et al. 2003; Poli et al. 2005), though to hit this relatively small target in the correct way requires trained, focused, and rested personnel (Poli et al. 2005; Ashley 2007). In practice, the first hit is often not accurate enough to disrupt the brain, leaving the fish with remained sensibility, and it therefore needs to be hit more than once before stunning (van der Vis et al. 2003; Poli et al. 2005). The repeated hitting leads to suffering for fish, since consciousness is not lost immediately. Although, this method is one of the least stressful, if quick and proper stunning can be assured.

Another fast method associated with less stress reactions than others is spiking, used mainly on tuna and salmon (Poli et al. 2005). A spike is inserted into the brain and unconsciousness is immediate, if done correctly (Poli et al. 2005). The spike must hit a specific point to ensure stunning, and if it misses the small target inside the skull, it is painful, leaving the fish with full consciousness and tissue damage caused by the spike (Poli et al. 2005). Automatic stunning equipment may thus represent an improvement of this method, since it is more accurate and minimal handling is possible (Ashley 2007), although care must be taken to use the appropriate pressure and size adjustments to ensure successful stunning before exsanguination (Håstein et al. 2005).

Salt Bath and Evisceration

For eels, one method of slaughter being used, mainly in the Netherlands, is through immersion in a salt bath, in combination with evisceration (van der Vis et al. 2003). The eels are exposed to sodium chloride (NaCl) in a dry tank for desliming for about 20 min, and then eviscerated and bled to death (van der Vis et al. 2003). The whole procedure takes approximately an hour, and the eels might have maintained consciousness under the entire process (Ashley 2007), and eels have even shown signs of life for up to 18 h after initiation of the procedure (Verheijen and Flight 1997). This is not considered to be a humane method, also because of the behavioral signs of severe stress, and the attempts of eels to escape the tank for at least 3 min after addition of salt to the tank (van der Vis et al. 2003).

The stress levels of fish before slaughter can be so severe, due to pre-slaughter procedures, that the positive effects of a more humane method of stunning no longer shows any significant differences in physiological measures (Poli et al. 2005). Therefore, although slaughter methods are important for fish welfare purposes, cautious handling in the capturing and pre-slaughter procedure cannot be over-emphasized.

Ethics in Concern of Animal Welfare

It is but recent that fish ethics has become a real issue of discussion. Other animals in human care have been of interest for research and public concern for decades, and it would seem that fishes are the last to be included in the moral debate. This is likely due to more than one reason, one worth mentioning is the lack of human-fish interaction. Humans have had relationships with other animals for a long time, building strong emotional bonds. With fish however, bonds are hard to make, due to the obvious water–air boundaries, as well as the difficulty for humans to communicate with fish; we are not capable of interpreting fish body language and facial expressions, and they make no human receivable sound to indicate their mental states (Lund et al. 2007). Although fish do not evoke feelings of empathy in most humans, does this mean that it is right to exclude them from moral concern? Lund et al. (2007) argues that (1) sentient animals should be of moral concern, (2) fish are most likely sentient, thus (3) fish should have the right to be morally treated. Hence, the level of empathy alone, that humans have for fish, should not determine the treatment received.

Although the moral significance of animals is essentially an ethical issue, such ethical reasoning is often based on scientific research of animals' ability to experience suffering or pleasure, as well as on which conditions or situations that inflict such experiences (Lund et al. 2007), to enable sound ethical conclusions. Mainly the animal's cognitive abilities has been the focus of animal ethics, making fish a group of animals largely neglected in one sense of moral concern of the individual animal (Lund et al. 2007), since the cognitive abilities of fish is questioned and debated. However, the substantial amount of new research in this subject has led to an increased interest in welfare of the individual fish from scientists, as well as the public (Lund et al. 2007). Hopefully, this will lead to a shift in human attitudes towards fish, making them regarded as animals of moral concern, and no longer as crops to be harvested.

In the debate regarding fish sentience and the actual experiences fish have of pain, fear, and suffering, authors (e.g., Ashley 2007; Lund et al. 2007) advocates giving fish the benefit of the doubt. Since it is not possible for science to fully comprehend the subjective emotional states fish are capable of (nor of any other animal), to say that welfare issues should be including fish seem to be the morally just approach. Lund et al. (2007) state that the lack of scientific evidence of fish sentience should not lead to the presumption that sentience is absent in fish, and make moral concern of fish insignificant. In addition the authors suggest that a risk assessment would speak in favor of giving fish the benefit of the doubt, since the consequences of treating fish as sentient if not in case sentient is, morally, significantly smaller than treating fish as non-sentient if in fact sentient, considering the vast amount of fish reared in farms yearly and the severe implications for welfare of finfish aquaculture practices.

In the wild, fish are exposed to a number of different stressors that can lead to suffering, including starvation, injuries as a result of predation, difficult environmental conditions, and diseases. In regard of this, it can be presumed that fish are accustomed, hence adapted, to handle stressful situations. According to Huntingford et al. (2006), this does not mean that humans should expose fish under human care to such situations, since there is a moral distinction between the impaired welfare caused by natural incidents or conditions, and that caused by humans, especially in human imposed confinement. The authors continue to define the difference by suggesting that the stressors fish are exposed to in natural conditions are often avoidable and of short duration, while human imposed stressors are often constant and unavoidable. This is objected to by Arlinghaus et al. (2007), through the view that humans are a part of nature that should interact with other species, and through the argument that for the individual fish, if stressors are imposed by humans or otherwise it is of no importance. A possible response to these arguments could be that, like Huntingford et al. (2006) state, there is a difference in stressors that could be, at least, attempted to escape from, and stressors that are unavoidable because of confinement. Another argument could be that there is a difference for us humans if it is we who are exposing others to possible suffering, rather than if it is induced by natural elements. Furthermore, the stressors caused by human interaction with fish are often not instead of, but in addition to, nature invoked stressors, hence they should be of importance for the individual fish.

Arlinghaus et al. (2007) are further challenging the "emotion-centered feeling-based" view adopted by Huntingford et al. (2006), in terms of assessing fish welfare. They argue that since the science-based evidence of the mental states of fish is inconclusive, concepts such as suffering should not be applied to fish. Instead, they are advocating a function-based assessment of fish welfare, meaning that good welfare is when the fish is "in good health, with its biological system functioning properly and not being forced to respond beyond its capacity." This would mean that good fish welfare could be acquired without allowing fish to perform their natural behaviors, and without the possibility for fish to be in good mental states.

Arlinghaus et al. (2007) continue by saying that since the individual experiences of fish are impossible to fully comprehend and measure, biologists should focus on signs of poor or good welfare; not the existence or non-existence of fish sentience, or ethical discussions of moral attitudes towards fish, because the focus of biologists should be on that what is objectively measurable. A different view is possible though, namely that of the significance of science to be a part of ethical discussions. Science should take its place in society, not as all-knowing, but as a voice in the on-going discourse that is essential for evolvement. Taking a stand and openness for possibilities should be encouraged in science, not disregarded as insincerity. Kaiser and Stead (2002) also acknowledge a need for scientists to be a voice in the debate by themselves, and are stating that participation in relevant discussions should be adopted more widely. Although, or perhaps just because, research often is inconclusive, with more investigations required to prove hypothesis to be fact, a discussion of appropriate measures that should be taken on the base of currently available research is necessary.

Balcombe (2009) welcomes the approach of science to animal sentience research, pointing out that research on the individual experiences of animals deserves serious regard, both in science and in animal ethics, since ethical deliberations require scientific bases. However, the author points out a lack in current animal sentience related literature; the absence of the concept of animal pleasure. Instead, the focus on animal sentience research seems to be on negative states; such as pain, distress, and suffering. Although Balcombe (2009) grants that the negative states are of higher moral significance, it does not mean that pleasure is a negligible aspect of animal welfare. This since this is the case, there are numerous indicators that, in many different groups of animals, there is a willingness to work for rewards (e.g., play, tasteful food, comfort, and touching or sexual behaviors), and not only to avoid pain- or stressful situations (Balcombe 2009). One example related to fish is the interaction between cleaner fish and their "clients." The clients let the cleaner fish clean them from parasites, loose skin, and fungal infections; showing signs of anticipation (Potts 1973), this probably not only of the benefits health, but also of the pleasure clients get from the actual tough (Balcombe 2009). Fish, as well as other animals, kept in captivity, can be deprived of pleasure in two ways: by keeping them enclosed in impoverished conditions, unsatisfying their behavioral, mental, or physical needs; and by the killing of healthy animals, hence denial of the future pleasures a full life could give (Balcombe 2009). In that sense, the concept of fish pleasure has moral significance and therefore should be treated as a vital aspect of animal welfare research and animal ethics discussions. Balcombe (2009) concludes that when viewing animals as motivated not merely by pain avoidance, but also by pleasure seeking, the human inflicted deprivation of freedom and taking of lives, for gains such as human entertainment or gastronomic matters, is in essence an immoral practice.

Whether you are of the view that ethical treatment of animals means that animals have the right to their own lives and freedom, or of the view that it is morally just to kill animals for meat, but that they should be treated humanely until and during slaughter, the review of current literature in the previous section clearly implies that the treatment of fish in aquaculture is at present not to be regarded as ethical.

Aspects of Environmental Impact

Aquaculture's impacts on the environment includes: decline of wild fish populations; waste and chemical discharge; loss of habitat; spreading of diseases to wild fish populations and invasion of exotic organisms (Naylor et al. 2000; Costa-Pierce 2003; Dempster and Holmer 2009). In the following section, these issues will be briefly addressed.

Decline of Wild Fish Populations

Wild fish populations have declined rapidly, due to the over-fishing of fisheries, leading to the substantial growth of fish reared in aquaculture (Naylor et al. 2000). Although these fishes are reared and not a part of the wild fish populations, aquaculture is still partly responsible for the decline of wild fish in the world's oceans (Naylor et al. 2000). This actual negative influence on the status of fisheries' stocks is in contrast with the presumed effect of the rapid growth of aquaculture production, which was thought to be a decline in catches of wild fish (Naylor et al. 2000). To explain this, Naylor et al. (2000), point out that wild fish are being used as feed, in form of fish meal and fish oil, in aquaculture as well as other forms of meat production, and fish from intensive systems formerly have been fed fish protein that equals 2–5 times the fish protein produced on-farm. During recent years the ratio of wild fisheries inputs to farmed fish output has fallen, from 1.04 (1995) to 0.63 (2007) for the aquaculture sector as a whole, but remains as high as 5.0 for Atlantic salmon. (Naylor et al. 2009). Carnivorous fish species are commonly farmed and are in the Western society more demanded than herbivorous or omnivorous species, making the decline of wild fish populations accelerate (Naylor and Burke 2005). However, the rearing of omnivorous species has expanded in recent years (Naylor et al. 2009), which, together with the increasing feed efficiency rates, shows that measures are being taken to preserve the wild fish populations. A future development of alternative sources for fish feed, such as animal by-products, plants, and products from microorganisms may contribute to a more sustainable production of carnivorous fish (Gillund and Myhr 2010).

The drastic decline of wild fish in the world's oceans is not just a moral issue in itself, but also a critical environmental issue, since fish play an vital protective role of their ecosystems (Holmlund and Hammer 1999). The services to ecosystems made by fish include: predation on other organisms; food web maintenance; regulation of sediment processes and flow of carbon and nutrients; and acting as feed for other aquatic, terrestrial, or aerial species, hence in addition providing services to other ecosystems than their own (Holmlund and Hammer 1999).

Waste and Chemical Discharge

There are various chemicals used in aquaculture practices that can affect the environment if discharged to surrounding water bodies, including different types of pesticides, fertilizers, disinfectants, antibiotics, and oxidants (Boyd and Massaut 1999; Naylor and Burke 2005). These can be harmful to natural waters through eutrophication or pollution from heavy metals, as well as having impact on wild aquatic animals, through medicines or toxins (Boyd and Massaut 1999; Naylor and Burke 2005). The environmental impact of effluents is hard to assess however, considering the variety of different practices, species, and ecosystems utilized in aquaculture, as well as the interaction between these variables (Fernandes et al. 2001). Nitrogen, in the form of nitrite and ammonia, that leaks out into nearby waters can be toxic to fish if in high levels (Naylor et al. 2000). Waste water with faeces and excess feed can lead to pollution, mostly in shallow waters and nearby coastal fish farms, in areas with restricted water exchange, or in areas with high occurrence of intensive aquaculture (Ervik et al. 1997; Naylor et al. 2000; Fernandes et al. 2001). Especially benthic environments under and around fish farms seem to be affected, through sedimentation of feed and faeces, which can lead to anaerobic conditions, methane or hydrogen sulphide exposure, pathogen spreading, and increased risk of bacteria resistance in case of antibiotics or other anti-bacterial agents additives in the feed (Ervik et al. 1997). Since 1987, the use of antibacterial drugs in Norwegian fish farming has been reduced from about 48 tonnes to approximately 1 tonne annually, and the 649 kg active substance prescribed in 2007 corresponds to approximately 0.03% of the produced biomass being treated once with an antibacterial drug (Midtlyng et al. 2011).

The poor water quality and crowding conditions in intense aquaculture may impair the immune system of fish, leaving them more receptive to diseases, thus more medical treatments are required (Haya et al. 2001). There are a number of different chemicals used in aquaculture, and there is little knowledge of the quantity of these chemicals used (Haya et al. 2001). Since the industry has grown rapidly the last decades, the usage of medicines and other chemicals (for example feed additives) are probably in many regions influencing the environment, the indigenous species, and their habitats (Haya et al. 2001). One example of the consequences common fish farm medicines may have on the oceanic environment is the anti-parasitic drug used on Atlantic salmon in the case of sea lice infestation. The pesticide is toxic, even lethal, to lobsters and shrimps that are subjected to it in high enough concentrations (Haya et al. 2001). Mortality of shrimps and lobsters were observed by Haya et al. (2001); half of the lobsters tested did not survive if exposed to the pesticide an hour in the concentrations being used in current bath treatment practices of salmon, and spawning failure was observed in both shrimps and lobsters tested. However, they proposed that it is not certain how wild lobsters and shrimps are affected by the sea lice treatment of salmons, since the concentration of the pesticide will decrease when released into the surrounding waters, although mortality and reproductive failures are likely to increase (Haya et al. 2001). More recent research show that the pesticide effect in sea lice treatment probably is more complex and harmful to lobsters in different life stages than previously thought (Burridge et al. 2008).

Loss of Habitat

The usage of natural habitats for wild fish as sites for aquaculture can have detrimental effects for wild fish, as well as the environment. It is mainly coastal habitats that are being exploited. One example of this is the cultivation of mangrove forests for fish farming, leading to loss of nursing grounds and shelter for fish, and leading to sediment transport to downstream coral reefs (Naylor et al. 2000). This threatens the survival of a number of aquatic species, and has been reported to cause climate change through decline of rainfall (Garrett et al. 1997). Another effect aquaculture can have on habitats is that of clearing of land to make saltwater ponds. This increases the salinity of the ground, making it an irreversible alteration of the natural environment (Diana 2009).

Along the coastline of the Pacific outside of Chile, aquaculture production of salmon has led to a loss of benthic biodiversity of an average of 50% on farm sites, due to sediment changes, generated by organic matter discharge, decreased oxygen levels, and copper deposition (Soto and Norambuena 2004). Hazardous algal blooms have also increased, as has the pollution of nitrogen from intensive salmon farms, giving raised mortality rates of aquatic species (Buschmann et al. 2006).

Spreading of Diseases to Wild Fish Populations

Diseases spreading between wild and farmed fish are problematic from an environmental point of view in the sense of threats to fish populations. The spread of pathogens often originates from wild fish, though due to crowding and intensity, it can often turn into epidemics when spreading to fish farms (Naylor and Burke 2005). In regions where aquaculture is common and concentrated, it is thought that diseases and parasitic infections that are relatively uncommon in natural waters, can spread more easily and become a severe hazard to wild fish (Naylor and Burke 2005). Another source of spread seems to be contaminated feed, in form of wild fish products that is imported from different parts of the world (Naylor and Burke 2005), as well as interaction between infected escaped farmed fish with wild fish populations (Naylor et al. 2005). Interbreeding of wild and farmed fish may also pose a risk regarding disease spread, through weakening of the immune system of wild fish (see subsequent section), hence enabling spread and prevalence of pathogens and diseases (Naylor et al. 2005). For example, there now is evidence suggesting that current high levels of sea lice outbreak in wild fish populations is closely linked to the high concentration of aquaculture (Krkošek et al. 2005; Naylor et al. 2005). Regarding salmon farms, spreading of parasites from farmed to wild fish mainly takes place during the juvenile stage of the wild fish, when they are most vulnerable due to their small size and recent transition to salt water conditions, and since they are, under natural conditions, spared from parasites associated with adult salmon (Krkošek et al. 2005). Moreover, the influence of a single salmon farm may result in a four to five fold increase in infection pressure, compared to natural levels, and if near a wild salmon migration route, can cause severe damage to wild populations through high mortality rates on juveniles (Krkošek et al. 2005; Krkošek et al. 2006), in addition to the welfare implications of sea lice infestation for the individual fish (Ashley 2007). The effect seen on juvenile salmons is most likely not restricted to salmons; other species of fish might be at risk of similar parasitic development, with especial high risk for fish species with migratory behavior, as aquaculture is expanding internationally (Krkošek et al. 2006).

Diseases spreading between farmed and wild populations of fish often occur, though it is problematic to assess these spreads due to their complexity (Naylor et al. 2000). To reduce disease spread from farmed to wild fish however, it is recommended to make serious attempts to decrease stress that can suppress the immune system in farmed fish, as well as careful filtering of used water before discharge (Naylor and Burke 2005).

Invasion of Exotic Organisms

It is not unusual that fish in aquaculture production escapes, becoming a part of the ecosystem (Naylor et al. 2000), either through frequent low scale escapes, or occasionally through mass escapes due mostly to weather conditions such as storms (Naylor et al. 2005). Effects on the ecosystem and wild fish populations include competition for food or mates with fish of the same or another species; predation; introduction of pathogens; and impaired fitness through interbreeding (Naylor and Burke 2005; Streftaris et al. 2005). More than once, exotic species of fish have competed out the indigenous fish, resulting in exotic fish displacing other species, leading to a decrease in biodiversity (Diana 2009). A common type of farmed salmon, the Atlantic salmon, frequently escapes and constitutes about 40% of the wild fish of this species caught in the North Atlantic Ocean (Naylor et al. 2000), and outnumbers Atlantic salmon with wild origin returning to streams by far (Naylor et al. 2005). Ford and Myers (2008) found in a meta-analysis that a reduction in survival or abundance of wild populations of more than 50% per generation on average where wild populations were associated with salmon farming. Competition for food or mates between wild and farmed fish may have serious implications, especially since farmed Atlantic salmon are selected for fast growth, and unintentionally have become more aggressive and risk-taking than their wild counterparts, which means that wild salmon may be stressed by the competition (Naylor et al. 2005). Furthermore, the spread of parasitic diseases is harmful to the wild fish populations, and may even lead to rapid collapse of, e.g., pink salmon (Oncorhynchus gorbuscha) in Western Canada (Krkošek et al. 2007).

Wild Atlantic salmon have greater genetic variability than farmed ones, since much of the farmed salmon come from a small number of breeders (Naylor et al. 2005). Interbreeding could alter the genetics of the native fish, making them less adapted to their specific habitats and to environmental changes, and therefore further risk depletion (Naylor et al. 2000). Hybrids between wild and feral salmon have lower survival rates than wild offspring, indicative of the effect interbreeding might have on wild populations (Naylor et al. 2005). Considering the amount of feral Atlantic salmon, the decline of wild populations, as well as the feral salmons' inability to compete, it is not unlikely that all wild salmon soon will have descended from farmed fish (Tufto and Hindar 2003; Ford and Myers 2008). This would mean a huge loss of genetic diversity that potentially will make Atlantic salmon unable to handle challenges such as changes in their environment (Naylor et al. 2005). Attempted breeding between different species is mainly unsuccessful in producing fertile offspring, thus not an issue in regards to genetic diversity, but may pose a risk to populations of fish that are declining in the wild through failed reproduction (Naylor et al. 2005). Introduction of transgenic fish in aquaculture would have an even larger impact of the concerned ecosystems, since transgenic fish have dissimilar genetic make-up compared to their wild counterparts, making the genetic influence of escapees greater in case of successful interbreeding (Naylor and Burke 2005). However, there are indications that this may not be the case as wild-reared salmons are more successful in mating than cultured growth hormone transgenic salmon in an experimental situation, although this should not directly be generalised to natural conditions (Fitzpatrick et al. 2011).

The environmental, biological, and biodiversity aspects of introduction of exotic aquatic animals require a legal framework to protect oceans from the negative effects of such introduction, especially since the scope of these effects are largely unknown to date (Streftaris et al. 2005). Notwithstanding the uncertain effects, Diana (2009) considers the introduction of exotic species or altered genotypes of indigenous species as, most likely, the largest aquaculture impact on aquatic biodiversity.

Ethics in Concern of the Environment

One claim of supporters of aquaculture is that the growing industry results in more employment opportunities for local communities, which has to be taken into account when assessing the environmental implications of fish farm practices. However, this claim can be challenged, considering the advance in technology leading to more automated production, reducing the personnel required (Kaiser and Stead 2002). In addition to this, these authors find that there are uncertainties regarding the extent to which aquaculture can continue to expand, the questions being of environmental sustainability and public consent. It is not implausible that the same practices that are the threats to aquatic environment and wildlife may also essentially be the end of the industry itself.

The significant growth of aquaculture production to date, and the continuing increase of demand for fish products worldwide, indicate what a tremendous economic role the industry has and will continue to have, not least in developing countries (Diana 2009). The developing countries produce a vast majority of the world's fish products, and the export of these products constitutes a substantial part of the economy of these countries (Diana 2009). This makes aquaculture an industry of immense economic importance for countries that are struggling with poverty, which must be taken into account when assessing the ethics of that industry's practices. However, with wild fish populations declining, the world's climate changing, and sites of fish farms becoming damaged, the question is whether an industry that is dependent on captured wild fish as feed and a healthy environment for production, should be counted on, and invested in, for future economic gain. According to Diana (2009), as a result of the decline of wild fish populations, aquaculture will soon need to depend on plant protein for feed. There may be a potential to replace carnivorous fish with extensively reared common carp (*Cyprinus carpio*) or tilapia species farming that is not dependent of captured wild-fish as feed. Considering this, to assure ability to feed the world's fast growing human population, by meanwhile considering the environmental impacts of food production, it could be claimed that investments in more energy and water efficient food production is the appropriate measure to be taken. Duarte et al. (2009) suggest production of edible macro algae and filter-feeder organisms that can lower the trophic level of aquaculture, minimize environmental impacts, and increase integration with food production on land, as a replacement for conventional aquaculture. In short, why rear fish and feed them plant protein that could be feeding humans directly, without the energy losses associated with rearing fish, as well as other animals, for meat?

Although the public's interest in environmentally sustainable aquaculture is increasing, there is a gap between ethical attitudes and consumer behavior, meaning that concern for the environment does not seem to lead to environmentally sound consumer choices, and that ethical consumption is applied only by a small part of the public (Verbeke et al. 2007). The reasons for this could be the lack of information and availability of environmentally sensible products, as well as marketing and familiarity of other products (Verbeke et al. 2007). So the question is: how to close this gap? The public is showing an increasing concern for food production, but is not generally implementing this in their consumption. There is clearly a difference between ethical concern in theory and in practice, though not meaning a lacking in importance of, and sincerity in, moral concerns. What this does indicate however, is that the moral views of the public should be a matter of policies and legislation, not of the individual choices of the consumer. Environmentally sound eating basically means eating low on the food chain, since vast energy and water losses are associated with rearing animals on feed such as grains or legumes that are suitable for humans (Goodland 1997). Rearing fish for human consumption with current practices also means, as discussed above, impact on natural waters through chemical and waste discharge, as well as damage to habitats.

Goodland (1997) expresses the view that products from environmentally unsustainable agriculture should be highly taxed, hence not preferred by consumers, leading to a shift towards more sound food consumption.

Conclusion

The research reviewed in this paper illustrates the current issues of ethical concern in aquaculture practices. They consist of animal welfare issues such as: (1) physical issues of pain, disease, immunosuppression, and skeletal malformations due to breeding, (2) behavioral issues of overcrowding, aggression, abnormal behavior, and repression of natural swimming and social behavior, and (3) stress issues of fear, exhaustion, food deprivation and starvation. Furthermore, they consist of environmental issues such as: (1) decline of wild fish population due to using wild caught fish for feed, introduction of non-indigenous species, spreading of diseases, and habitat destruction, and (2) threats to the environment through chemical and waste discharge, and destruction of ecosystems.

Finfish aquaculture is facing issues of ethical concern that seems to be essentially unattainable. The economical and nutritional gains of fish farms are not comparable with the vast environmental and animal welfare losses. In addition, the aquaculture industry has not been able to solve the issue of decline of wild fish populations, but is instead further exacerbating the decline. The ethical arguments and scientific evidences here reviewed have not all come to the same conclusions. What can be concluded, however, is that in spite of dissimilar views on animal and environmental ethics, or different results of empirical studies, the general agreement is that current aquaculture practices are neither meeting the needs of fish nor environment. Thus, the obvious environmental and animal welfare aspects of finfish aquaculture make it hard to ethically defend a fish diet.

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