For the pain in fish(eries)

Consequenses of pain perception in fish for catch and release, aquaculture and commercial fisheries

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Introduction

How our perception of animals has changed throughout time

Research and experiments on animals are not activities that have been performed only in recent years. Already the ancient philosophers, such as Aristoteles (384-322 BC), did anatomical and physiological studies on live animals (vivisection). This was an accepted practice since animals were not believed to have any soul and therefore could not sense pain (Rowan 1984). Also subsequent philosophers, such as Augustin (354-430) and Aquinas (1222-1274) adopted this view upon animals and found support in the Bible for their practice since God had given man superiority over animals. The perception of how animals, including fish, perceive potential harmful stimuli has therefore not changed much until fairly recently. The fact that few experiments were performed on animals during the middle ages only reflects the churches view upon animals as very different from humans. Therefore experiments on animals could not lead to new knowledge about humans (Rupke 1987).

The first laws

It was not before the beginning of the 19th century that people started to realise that animals could feel pain and discomfort. The French scientist Claude Bernard (1813-1878) stated that vivisection on animals could save lives of many humans, thereby justifying the practice (Lesch 1984). It was in this period the first laws concerning animal welfare was implemented. In in Great Britain in 1822 horses, cattle and donkeys were protected from cruelty by law. Still, it was not until 1876 that the *British Cruelty to Animals Act* was adopted as the first law concerning animals used for research (http://www.rspca.org.uk/servlet/ContentServer?pagename=RSPCA/News/NewsFeature). Still it took some years before other countries adopted similar laws, and it was not until 1921 USA adopted federal laws regulating animal welfare. However, already in the middle of the 19th century some states had adopted laws regulating animal welfare.

Laws and regulations concerning commercial and recreational fishing

In 1974 the *Norwegian Animal Rights Law* replaced the *Animal Rights Law* from 1935. The first paragraph of the *Norwegian Animal Rights Law* states which animals

the law applies for. According to this paragraph it concerns mammals, birds, frogs, salamander, reptiles, fish, and crustaceans. However, it is obvious that this needs to be stated more clearly since toads are not included together with the other Norwegian amphibians. Also the group crustaceans, which include among others *Copepoda* include species which are normally not considered by the law. The second paragraph, is probably the most important, and states that the natural instinct of all animals comprised by the law should be considered, which also includes fish. Also these animals should not be treated in such a way that they may suffer unnecessary harm. This is further specified in paragraph nine which states that killing of animals should be performed in such a way that no unnecessary pain is inflicted upon the animal. However, specific regulation applies for mammals of large commercial importance and poultry stating that these animals should be unconscious before the blood is drained. Even though this does not apply for fish, it is specified that it is not allowed to hang live fish by sticking something into or trough the fish, or to keep fish in enclosures in such a way that the may suffer unnecessary harm. So even though fish have some kind of protection trough paragraph two, we have found no laws which regulate the treatment of fish during commercial fishing except the general rules in *Animal Rights Law*.

Do fish feel pain? Views from a scientific perspective

However, this seems to be a simple yes or no question there exist scientific disagreement on whether fish can feel pain. This is also not an easy question to answer. Because in order to answer this question we first need to know what the definition of pain exactly is. According to the Webster's new twentieth century dictionary (McKechnie (ed.) 1983) we can distinguish two definitions:

1. A sensation of hurting, or strong discomfort, in some part of the body, caused by an injury, disease, or functional disorder, and transmitted through the nervous system.
2. The sensation one feels when hurt, mentally, or physically, especially distress, suffering, great anxiety, anguish, grief, etc: opposed to pleasure.

Using these definitions, the question whether fishes feel pain encompasses both neurological pain in fish ('sensing pain', definition 1), and discomfort caused by pain, fear, stress and suffering in fishes ('experiencing pain', definition 2). In scientific experiments reasonable arguments have been made both to support and refute the claim that fish are capable of sensing and experiencing pain.

Sensing pain

To be able to understand the ability of fishes to sense pain we have to go back to the evolution of sensory function in vertebrates. Although fishes like all other vertebrates have a nervous system, their brain is quite elemental when related to the mammalian brain (Butler & Hodos 1996; Nieuwenhuys et al. 1998). Central in sensing pain is nociception. This term refers to the detection of noxious stimuli by the nervous system (Sneddon et al. 2003). The peripheral nervous receptors we call nociceptors sense stimuli and report to the central nervous system where motor responses are initiated and the sensation of pain is perceived (http ://www.vet.ed.ac.uk/ animalwelfare/Fish%20pain/ Pain.htm).

Nociceptive reactions to noxious stimuli are a universal characteristic of animal life, even in simple invertebrates that have no brains, a fact demonstrating that reactivity to noxious stimuli does not imply conscious awareness (Rose 2002).

In all vertebrates, including humans, innate responses to nociceptive stimuli, such as limb withdrawal, facial displays, and vocalizations are generated by neural systems in subcortical levels of the nervous system, mainly the spinal cord and brainstem (Rose 2002). Studies carried out on sharks and rays (Cameron et al. 1990; Leonard 1985; Snow et al. 1993) suggest a lack of nociception, and thus of sensing pain. On the other hand a study carried out on rainbow trout does provide evidence of nociception (Chervova 1997; Sneddon 2002; Sneddon et al. 2003). However, this means only that, at least some, fishes are capable of sensing noxious stimuli; it provides no evidence for the psychological experience of pain (http://www.vet.ed.ac.uk/animalwelfare/ Fish%20pain/ Pain.htm).

Experiencing pain

To suggest pain perception ('experiencing pain'), it must be shown that any behavioural or physiological responses are not merely reflexive. Therefore an animal should be able to perceive the adverse sensory stimulus and, second, that it reacts both physiologically (e.g. inflammation, cardiovascular changes) and behaviourally (e.g. move away from stimulus, cessation of normal behaviour) (Zimmerman 1986). Experiencing pain therefore has to be associated with a 'feeling' or negative perception (Broom 2000).

According to Bermond (1997) the highly developed neocortex of the human cerebral hemispheres is responsible for our ability to experience emotions and sensations such as pain. The fish brain, however, is dominated by brainstem components and features very primitive cerebral hemispheres that lack neocortex. Humans require this neocortex for basic sensory functions as it is thought to be responsible for interpreting the sensory information received and processed by our brainstem and spinal cord. In fish, a higher level of cortical sensory interpretation appears nonexistent, since fish behaviour is unaffected by cortical damage (Rose 2002). If we assume, as Rose (2002) and Bermond (1997) do, that the neocortex is necessary for pain sensation, then we must admit that sensation of pain in any animal lacking an analogous structure is unlikely. Fish would therefore lack the neurological capability to experience the negative psychological sensation of pain.

Clearly any animal could not be successful unless it featured both a mechanism for detecting potentially harmful stimuli and a kind of negative or unpleasant psychological or subjective state or experience with which it could associate such stimuli. Fish, it appears, may have remarkably different systems of nociception and brain function from mammals and therefore may not experience the precise sensation of pain that humans do but this does not mean that fish are incapable of experiencing a negative psychological state analogous to human pain in response to noxious stimuli (http://www.vet.ed.ac.uk/ animalwelfare/Fish%20pain/Pain.htm). Fish brains lack the neocortex, so fish clearly cannot suffer in exactly the same way as we do. However, other parts of the fish brain are well developed and are used to produce complex behaviour, so lack of a neocortex does not mean that fish cannot experience some kind of suffering (Erdmann 1999; FSBI 2002). Recent studies suggest that fish have the capacity to perceive painful stimuli and that these are strongly aversive. It has already been demonstrated that fish can learn to avoid noxious events such as electric shock (e.g. gold fish, Ehrensing et al. 1982; Davies & Klinger 1994), hooking during angling (e.g. carp and pike, Beukema 1970a, b) and acid (rainbow trout, Sneddon et al. 2002; Sneddon 2003). Also disruptions in behaviour after angling have been shown (smallmouth bass, Kieffer et al. 1995). Although experiments suggest that pain sensitivity in fishes varies (Chervova 1997), they are capable of suffering and experiencing stress (Klausewitz 1989). Consequently, injury or experience of other harmful conditions is a cause for concern in terms of welfare of individual fish (FSBI 2002).

Pain and welfare

Though what is quite apparent from both of the arguments outlined above is that our current body of knowledge about the neurophysiology of fish is inadequate for either argument to be entirely convincing. Therefore it is particularly relevant in this case to remember that ‘absence of evidence is not evidence of absence’ (Sherwin, 2001). We must remain open-minded and recognize that our ability to answer the question ‘do fish feel pain?’ with confidence is limited by the constraints of our own anthropocentric perception.

Catch and release

History and practice

The method of catch and release is used mainly in recreational fishing, when a fish is caught on a hook and released alive into the water with allegedly no permanent harm having been inflicted on the fish. In management catch and release has been viewed as a means by which recreational salmon fishing could continue with little or no associated mortality when stocks were low (Dempson et al. 2002). Catch and release has been practiced in different ways, both as a total band on killing any fish and by restrictions on the fish that can be killed. In the United States catch and release has been practiced with bag limits (restricted number of fish allowed to be killed) and in some cases there has been a slot limit (only fish within a size group can be killed) (Barnhart 1989).

A first example of catch and release as a management tool is from Maine, Penobscot River, where it was advocated in the beginning of the early 1800's. The acceptance for catch and release as a management tool in the US and Canada is a recent phenomenon, which started to become more common in the 1980's (Eastern Canada, Fisheries and Oceans). Catch and release is now being commonly used as a management tool in North America and is gaining increased acceptance in Great Britain, Russia and Scandinavia (Thorstad et al. 2001). In Norway the extent of the catch and release fishing is unknown, but in some rivers (Sautso, Alta) it has been used to protect certain size groups of salmon or protect salmon in rivers with extended fisheries for sea trout and Arctic charr (Thorstad et al.2003).

Mortality

There are strong disagreements on the impact catch and release has on the fish population. A study done by Muniz (1997) showed that the mortality related to catch and release varies from 0-40%. The mortality of Atlantic salmon and brown trout released is around 0 to 5 %. According to Muniz the variation in mortality can often be attributed to fishing methods and tools, and live bait gives the highest mortality as the fish has a tendency to swallow the bait whole and the hook will then cause internal bleedings. Treble hooks can often lead to a long handling time and increase the stress and discomfort for the fish (Muniz 1997). It is assumed that fishing with fly gives a

lower mortality in general, than using live bait or spinning bait, as it gives less wounds on vital organs than do the others.

It is also of vital importance that the fish is being handled correctly as air-exposure, high water temperatures (above 20°C) and playing time increases the post-angling mortality (Tufts et al. 2000). It is a well known fact that high water temperatures leads to high mortality, though the reason for it is unknown (Muniz 1997), and in some Canadian rivers the fishing is stopped when temperatures reach high temperatures. The longer the fish is being played before it is landed influences the physiology of the fish negatively (Thorstad et al. 2000), as a response to the stress is increased levels of corticosteroid hormones in the blood plasma which in turn may inhibit the reproduction processes (Muniz 1997). Thereby the recreational fisher's line of action is crucial for post-angling mortality of the fish, and also for the degree of discomfort the fish will feel.

The ethical discussion

The fish may feel discomfort when caught on a hook and it will struggle against it by all means, though the sense of discomfort is unavoidable whether it is being released or killed afterwards. In Norway, the debate of catch and release has not so much been dominated by arguments whether fish feels pain, but more focusing on the conflicting goals of catch and release compared to the traditional Norwegian view of fishing as a mean to harvest food.

The Norwegian board of animal ethics has voiced their opinions against the practice of catch and release as they can not find it ethically defendable. They are concerned that allowing catch and release is a step towards removing our society away from the nature. They view that hunting and fishing should be done on sustainable populations and should be done as part of harvesting food. Norway may have a different view on catch and release compared to Great Britain. In Norway fishing is generally about harvesting fish, but catch and release makes fishing a sport and a challenge and may therefore be viewed as anti-ethical by some groups. In Great Britain fishing has long traditions as being about both sport and harvesting fish and therefore, catch and release is more accepted as means to reduce the impact anglers has on the fish population (Aas 2002). The Norwegian ministry of Agriculture has recently stated

that they are working with new laws to restrict the use of catch and release for commercial purposes in recreational fishing.

For other groups arguing for catch and release, it is both an ethical and conservative approach to resource utilization. They argue that this approach is consistent with the fishery management goal of sustainability in situations where many waters are under pressure. They argue that from the pain perspective there are no strong arguments against catch and release, as shown by Rose (2000) that the ability of fish to feel pain in the sense humans define pain is very limited.

A paradox in the discussion of whether the fish feels pain or not, is that it only applies for certain species of fish like Salmon or Trout, while there is very little concern for the way unwanted fish are caught and killed. The Ørekyt at Hardangervidda is an unwanted species which are caught in fish traps and then left on shore to die in large numbers. This species has a more developed brain and nervous system and is probably more prone to fell pain than the salmon do when caught on a hook. (http://www.forskningsradet.no/nyheter/pressestoff/vedlegg/170902etiske_utfordringer.html).

Aquaculture

The aquaculture production of salmon and trout in Norway has increased from 7 500 tons in 1980 to 490 000 tons in 2001. In the rest of the world aquaculture has been an important business for a long time, with roots in China two thousand years ago. The focus on fish welfare in aquaculture has changed a lot during the last years. This change in probably just as much based on the understanding that fish welfare is important for economical success, as concern and new knowledge about the fish being able to feel pain.

The development within aquaculture in Norway, with more focus on fish welfare, has clearly led to a decrease in the percentage of fish experiencing pain during the production. But if we consider the larger number of fish that are produced today, compared to 20 years ago, the number of individuals experiencing pain is probably higher today.

In recent time, several groups in society have set focus on fish welfare in aquaculture. Animal rights groups, consumers, veterinarians and people from the aquaculture industry itself have all been striving for increased fish welfare. The motives for emphasizing this within these groups are most likely different. Animal rights groups focus on the individual fish, which are suffering and caused pain in the intensive aquaculture production (www.dyrebeskyttelsen.no/artikler/004_5.shtml; www.dyrevernalliansen.org/fakta/f_05.php, Lymbery 2000)

These groups are confident that the fish are able to feel pain. Within the consumers that are buying the fish, there is a strong trend towards wanting to know how the fish they buy has been reared. They want documentation that the fish has been reared in a good environment, and that it has been treated well. Veterinarians focus on fish welfare from a pathological point of view; they supervise the production and want it done in a way that leads to as little diseases as possible. People working in the industry have increased focus on fish welfare because the consumers require it, and because they have realized that better fish welfare leads to higher production and profit.

By looking at how the production of salmon and trout is done practically, we can get an idea of where the challenges concerning fish welfare are lying.

Smolt production

Smolt production involves the time from eggs to fish ready to be put to sea at 50 - 200 grams. Several steps of the smolt production can potentially cause stress and pain to the fish. It has not been documented how fish welfare is affected by these factors.

The production water is heated to 12-15°C during start feeding in February, to make the fish grow faster. This temperature is maintained until the natural water temperatures rises to this level in May/June. Too high temperature in this stage can give more deformities like "hump backs" (korthaler). Hump backs are fish with shortened spine, little is known whether these fish experience pain because of this disorder. Hump backs often constitute 2-7 percent in fish groups, so a considerable number of individuals have this deformity.

During smolt production the fish are exposed to an artificial light regime, which differs considerably from the natural light regime (Hansen 1998). This is done to make the fish grow faster, avoid sexual maturity and control the time of smolting. Little is known if this artificial light regime works as a chronic stress factor to the fish.

The fish density in fish tanks often reaches 60 kg/m^3. If the current or the feeding is not correctly administered, such a density could lead to aggression between individuals, with fin biting and eye snapping (www.fiskforsk.norut.no/Info6_n.htm). This behaviour surely will cause pain to some of the fish in the tank.

The use of water in smolt plants varies with the available amount. And available water will vary greatly between plants. In dry periods too little water may be used in the fish tanks. This will lead to pourer water quality, with accumulation of faeces, ammonia and carbon dioxide in the water. Carbon dioxide in high concentrations is anaesthetic to fish, it is not known what medium concentrations do to the fish, but it is

thought to alter the blood pH and change oxygen affinity properties (Root and Bohr effect).

The fish are vaccinated before they are put to sea. It is important that the vaccination is performed under good hygienic conditions, under correct water temperatures and that the people who vaccinate know exactly where to put the needle (Ellis 1988). Vaccine disorders are among the largest groups of deformities in aquaculture today. The disorders turn out as internal organs that grow together in the abdominal cavity and pigment spots in the filet. It is known that these accretions lead to reduced growth in fish that suffer severely from it. On the other hand, vaccination has revolutionized fish health. Several diseases that were common some years ago, and that caused great pain, are now almost absent. Vaccination has also lead to a decrease in the use of antibiotics, from 50 000 kg in 1980 to 750 kg in 2001.

When the fish are to be put to sea, it is important that they are completely smolted and physiologically ready to handle the marine environment (Staurnes et al. 1992). Groups of 100 000 fish are often put to sea at one time. The smolting process is controlled by light and temperature, and the size of the fish will affect this process. In a group of 100 000 individual fish, one will find considerable variation in size, so it can often be difficult to decide when to put the fish to sea. Fish that are not properly smolted will encounter great osmotic problems in seawater, and might even die from this.

Production at sea

Animal rights groups claim that a too high fish density in the net cages is detrimental to fish welfare. Large density can lead to aggression between individuals. It can also lead to pour water quality in the net cages, especially if the nets are grown with algae. If the water exchange is too low, this can be seen by measuring the oxygen level inside the net cages. These are factors that affect growth and feed uptake, and aquaculturists therefore want to avoid them.

The fish are grouped according to size several times during the production cycle. This can be done in several ways, but most of them include pumping in fish pumps and

they include the fish getting out of the water. If these operations are not conducted in the right way, it may lead to wounds and mechanical injury.

The slaughtering of the fish most often is done by anaesthetizing the fish in water saturated with carbon dioxide and then cutting the gills. Investigations have shown that the fish fight for some time before they are sedated when carbon dioxide is used (van de Vis *et al*. 2003).

Commercial fishing industry

Norway is one of the world's leading seafood exporters and seafood is, after oil, the second biggest export commodity, bringing in earnings, in 1999, of NOK 30 billion (USD 3.3 billion). In the same year a total of 2 800 000 tons of different species were fished commercially (The Directorate of Fisheries http://www.fiskeridir.no). It is expected that a growing share of the world's need for food will be provided by the sea. About 90 per cent of the total quantity of fish which is brought to land in Norway is exported (ministry of Fisheries http://www.fid.dep.no).

In Norway, there is an increasing awareness of the huge potential that lies in the development of marine resources, and the intention is that fisheries and aquaculture are to play an increasingly important role in the country's industrial sector. The earnings from the marine sector can be a vital element of the Norwegian economy when the oil and gas resources start to dwindle. For Norway it is of major importance that the production of Norwegian seafood shall comply with the strictest requirements to health and hygiene and be based on a sustainable and environmentally friendly production and harvesting methods (http://www.fid.dep.no).

Since time immemorial, people in Norway have made a living from fishing, whaling and sealing. This has been the very basis of life and culture on the coast. Efforts to steadily improve the management of marine resources have had high priority, in order to ensure that commercial fishing and aquaculture remain a major industry in Norway for all time. The reason fisheries have always been such a central component of Norwegian business and industry is that Norway controls some of the richest fishing grounds in the world. The North Sea, Norwegian coast, Barents Sea and the polar front in the Norwegian Sea are all highly productive areas, and major fish resources spawn right outside the coast of Norway (http://www.fid.dep.no).

As you see from the data listed above; the fishing industry in Norway is huge! While searching after these data on the internet from the ministry of Fisheries and The directorate of Fisheries I have been reading about quality, health and hygiene for fish, but the aim was to find anything about fishes and pain. In such a big industry should it

not be taken some strategic decision about pain since almost 3 000 000 tons of fishes are being fished from the ocean each year?

The *Norwegian Animal Health Authority* also have fish under their legislation and § 2 of the *Animal Rights Law* states that animals must be taken care of so they do not suffer more than neccessary and in § 9 the law states the same when killing an animal. Since there is a certain scientific element of uncertainty about fish and pain, the *Animal Health Authority* says that management should regard fishes as being capable of suffering and feeling pain (http://www.dyrehelsetilsynet.no).

There are *relatively strict* laws in the aquaculture industry about health, fish quality and killing as listed above, but in the commercial fishing industry the same laws and regulations are hard to find. Only in Quality Regulations relating to Fish and Fishery products laid down by the ministry of Fisheries 14th of June 1996 pursuant to the act of 28th of May 1959 no. 12 relating to *Quality Control of Fish and Fishery products* I found in § 2 Life fish, section 1; Fishing and towing . *During fishing and towing, care must be taken to ensure that the fish are not killed or unnecessarily reduced in quality* (http://www.lovdata.no) So except for the *Norwegian Animal Health Authority* § 2 and § 9, combined with § 2-1 in *Quality Control of Fish and Fishery products* there are no laws and regulations that aims to reduce the pain and suffering in commercial fishing industry in Norway.

Concluding remarks

So even though fish have some kind of protection through paragraph two, we have found no laws which regulate the treatment of fish during commercial fishing except the general rules in *Animal Rights Law*. From an ethical point of view, this means that we should be very conscious about welfare in the use and treatment of fish in commercial fisheries, aquaculture, angling and scientific experiments (Sneddon 2003; Sherwin et al. 2003). Although the evidence is blurred, avoidance of potentially injurious stress responses is an important issue in considerations about welfare of fishes (FSBI 2002; Rose 2002; Sneddon 2003). Therefore the *Norwegian Animal Health Authority* (Dyrehelsetilsynet) has taken the stand that in problems related with animal welfare in fish, management should regard fishes as being capable of suffering and feeling pain. (http://www.dyrehelsetilsynet.no/ dyrevern/tema/dbaFile6659.html). The discussion still continues, but with the department of Agriculture having signalled that catch and release is not an ethical accepted method of management in areas with low fish populations and recreational fishing, they are introducing a new era in the way we perceive fishing.

As is seen, the welfare of fish in aquaculture and commercial fisheries is dependent on many factors. A crucial factor to obtain good fish welfare is knowledge of the factors mentioned above, and many others. The sedation before slaughtering is a point that will have to be further investigated (van de Vis et al. 2003; Robb et al. 2002). Historical attitudes and practice have lead to a lower focus on welfare among fish in aquaculture, as compared to other animal groups in agriculture. In the future, the pressure on the aquaculture business towards higher focus on fish welfare, from animal rights groups and customers in common, is bound to increase. More knowledge on the fishes ability to feel pain, might also increase the focus on fish welfare.

References

Aas, Ø. 2002. Controversy over Catch-and-Release Recreational Fishing in Europe. Recreational Fisheries: Ecological, Economic, and Social Evaluation. *Fish and Aquatic Resources Series*. Vol. 8, pp. 95-106.

Anderson, W.G., Booth R., Beddow T.A., and McKinley R.S. 1998. Effects of hook-and-release angling practices. *Canadian fisheries and oceans* pp.1-7

Barnhart , R.A. 1989. Symposium review: catch and release fishing, a decade of experience. *N.Am. Fish. Managem*. 9:74-80

Bermond, B. 1997. The myth of animal suffering. In: Dol, M., Kasamoentalib, S., Lijmbach, S., Rivas, E. & vandenBos, R. (eds.) *Animal Consciousness and Animal Ethics: Perspectives from the Netherlands*. pp. 125-143. Van Gorcum, Assen, the Netherlands.

Beukema, J.J. 1970a. Angling experiments with carp (*Cyprinus carpio* L.). II. Decreased catchability through one trial learning. *Netherlands Journal of Zoology*. Vol. 19: 81-92.

Beukema, J.J. 1970b. Acquired hook avoidance in the pike *Esox lucius* L. fished with artificial and natural baits. *Journal of Fisheries Biology*. Vol. 2: 155-160.

Broom, D.M. 2000. Evolution of pain. In: Soulsby, L. & Morton, D. (eds.). *Proceedings of the Royal Society of Medical International Congress Symposium Series on In Pain: Its Nature and Management in Man and Animals*. Vol. 246: 17-25.

Butler, A.B. & Hodos, W. 1996. *Comparative Vertebrate Neuroanatomy*. Wiley-Liss, New York, USA.

Cameron, A.A., Plenderleith, M.R. & Snow, P.J. 1990. Organization of the spinal cord in four species of elasmobranch fish: Cytoarchitecture and distribution of serotonin and selected neuropeptides. *Journal of Comparative Neurology*. Vol. 297: 210-218.

Chervova, L.S. 1997. Pain sensitivity and behaviour of fish [original title: Bolevaya chuvstvitel'nost' i povedenie ryb]. *Voprosy Ikhtiologii*. Vol. 37(1): 106-111.

Davies, R.E. & Klinger, P.D. 1994. NMDA receptor antagonist MK-801 blocks learning of conditioned stimulus-unconditioned stimulus contiguity but not fear of conditioned stimulus in goldfish (*Carassius auratus* L.). *Behavioural Neurosciences*. Vol. 108: 935-940.

Dempson, J.B. , Furey G., and Bloom M. 2002, Effects of catch and release angling on Atlantic salmon; Salmo salar L., of the Conne River, New Foundland. *Fisheries management and Ecology*, 9, 139-147.

Ehrensing, R.H., Michell, G.F. & Kastin, A.J. 1982. Similar antagonism of morphine analgesia by MIF-1 and naxolone in *Carassius auratus*. *Pharmacological Biochemical Behaviour*. Vol. 17: 757-761.

Ellis, A. E. (Ed.) 1988. Fish Vaccination. In: Academic Press, London.

Erdmann, Ch. (ed.) 1999. *The ability of fishes to feel pain and to suffer. A literature overview.* [original title: Schmerzempfinden und Leidensfähigkeit bei Fischen. Eine Literaturübersicht]. Tierärztliche Hochschole, Hannover, Germany. 46 pp.

FSBI 2002. *Fish Welfare*. Briefing Paper 2, Fisheries Society of the British Isles, Granta Information Systems, Cambridge, UK.

Hansen, T. 1998. Kap 12, Nye produksjonsstrategier. In: *Oppdrett av laksesmolt*, Landbruksforlaget.

Kieffer, J.D., Kubacki, M.R., Phelan, F.J.S., Philipp, D.P. & Tufts, B.L. 1995. Effects of catch-and-release angling on nesting male smallmouth bass. *Transactions of the American Fisheries Society.* Vol. 124: 70-76.

Klausewitz, W. 1989. Problems of sensitivity to pain and ability to suffer in fish. [original title: Über Schmerzempfinden und Leidensfähigkeit der Fische]. *Fischökologie*. Vol. 1(1): 65-90.

Leonard, R.B. 1985. Primary afferent receptive field properties and neurotransmitter candidates in a vertebrate lacking unmyelinated fibres. *Progress in Clinical Biological Resources*. Vol.176: 135-145.

Lesch, J. E. 1984. *Science and medicine in France: The emergence of experimental physiology, 1790-1855*. Cambridge, Mass. Harvard University Press.

Lymbery, P. 2002. In too deep the welfare of intensively farmed fish. In: *A report for compassion in world farming trust*.

McKechnie, J.L. (ed.) 1983. *Webster's new twentieth century dictionary, unabridged, second edition*. Simon and Schuster, Cleveland, Ohio, USA.

Muniz I.P. 1997 Management measures related to recreational fishing for anadromous salmonids. A literature review on the 'catch and release'-concept. *NINA Oppdragsmelding* 482:1-28.

Nieuwenhuys, R., Donkelaar, H.J. ten & Nicholson, C. 1998. *The Central Nervous System of Vertebrates*. Springer, Berlin, Germany.

Robb, D. H. F., Wotton, S. B. & van de Vis, J. W. 2002. Preslaughter electrical stunning of eels. *Aquaculture Research*, 33;37-42.

Rose, J.D. 2002. The Neurobehavioral Nature of Fishes and the Question of Awareness and Pain. *Reviews in Fisheries Science*. Vol 10(1): 1-38.

Rowan, A. N. 1984. *Of mice, models and men:a critical evaluation of animal research*. State University of New York Press. 323p.

Rupke, N. A. 1987. *Vivisection in historical perspective*. London, Routledge. 373p.

Sanford, J, Ewbank, R, Molony, V, Tavernor, WD, Uvarov, O. 1986. Guidelines for the recognition and assessment of pain in animals. *Veterinary Record*. 118: 334-338.

Sherwin, C.M. 2001. Can invertebrates suffer? Or, how robust is argument-by analogy? *Animal Welfare*. Vol. 10: 103-118.

Sherwin, C.M., Christiansen, S.B., Duncan, I.J., Erhard, H.W., Lay Jr., D.C., Mench, J.A., O'Connor, C.E. & Petherick, J.C. 2003. Guidelines for the ethical use of animals in applied ethology studies. *Applied Animal Behavioural Science*. Vol. 81: 291-305.

Sneddon L.U. 2003. The evidence of pain in fish: the use of morphine as an analgesic. *Applied Animal Behaviour Science*. Vol. 83: 153-162.

Sneddon, L.U., Braithwaite, V.A. & Gentle, M.J. 2002. Do fishes have nociceptors? Evidence for the evolution of a vertebrate sensory system. *Proceedings of the Royal Society of London Biological Sciences*. Vol. 270: 1115-1121.

Snow, P.J., Plenderplaith, M.B. & Wright, L.L. 1993. Quantitative study of primary sensory neurone populations of three species of elasmobranch fish. *Journal of Comparative Neurology*. Vol. 334: 97-103.

Staurnes, M., Sigholt, T. & Reite, O. B. 1992. Smoltifisering. In: *Fiskens Fysiologi*, Døving, K. & Reimers, E. (Eds.), John Grieg Forlag AS.

Thorstad E., Næsje T., Fiske P., Leinan I., Leinan T., and Berger H. 2001. Effects of catch and release fishing- studies of radio tagged Atlantic salmon in the river Alta in 1999 and 2000. *NINA oppdragsmelding* 713:1-19.

Thorstad E., Næsje T.F., Fiske P., and Finstad B. 2003. Effects of hook and release on Atlantic salmon in the River Alta, northern Norway. *Fisheries research 60, 293-307.*

Tufts B.L., Davidson K., and Bielak A.T. 2000. Biological implications of catch and release angling of Atlantic salmon. Edt F.G. Whoriskey & K.E Whelan. *Managing wild Atlantic salmon*. Published by the Atlantic salmon federation, St.Andrews, New Brunswick, pp. 195-225

Van de Vis, H., Kestin, S., Robb, D., Oehlenschlager, J., Lambooij, B., Munkner, W., Kuhlmann, H., Kloosterboer, K., Tejada, M., Huidobro, A., Otterå, H., Roth, B., Sørensen, N. K., Akse, L., Byrne, H. & Nesvadba, P. 2003. Is humane slaughter of fish possible for industry? *Aquaculture Research,* 34; 211-220.

Zimmerman, M. 1986. Physiological mechanisms of pain and its treatment. *Klinische Anäesthesiologische Intensivtherapie*. Vol. 32: 1-19.