Vitenskapskomiteen for mattrygghet
Norwegian Scientific Committee for Food Safety

# Risk Assessment of Catch and Release

## Opinion of the Panel on Animal Health and Welfare of the Norwegian Scientific Committee for Food Safety

**17.03.10**

**ISBN: 978-82-8082-376-2**

**VKM Report 2010: 06**

# RISK ASSESSMENT OF CATCH AND RELEASE

Rolf Erik Olsen
Tor Fredrik Næsje
Trygve Poppe
Lynne Sneddon
John Webb

# CONTRIBUTORS

Persons working for VKM, either as appointed members of the Committee or as *ad hoc* experts, do this by virtue of their scientific expertise, not as representatives for their employers. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

## ACKNOWLEDGEMENTS

The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) has appointed an *ad hoc*-group consisting of both VKM members and external experts to answer the request from the Norwegian Food Safety Authority. The members of the *ad hoc*- group are acknowledged for their valuable work on this report.
The panel also wishes to thank Eva B. Thorstad, of the Norwegian Institute for Nature Research – NINA, for her valuable contributions and comments to the report.

The members of the *ad hoc* group are:
*VKM members:*
Rolf Erik Olsen (Chair), Panel on Animal Health and Welfare
Brit Hjeltnes, Panel on Animal Health and Welfare

*External experts:*
Tor Fredrik Næsje, Norwegian Institute for Nature Research
Trygve Poppe, the Norwegian School of Veterinary Sciences
Lynne Sneddon, University of Liverpool & University of Chester
John Webb, Marine Scotland – Marine Laboratory

## ASSESSED BY

The report from the *ad hoc*-group has been evaluated and approved by Panel on Animal Health and Welfare of VKM.

Panel on Animal Health and Welfare:
Wenche Farstad (chair), Bjarne O. Braastad, Knut E. Bøe, Arne Flåøyen, Brit Hjeltnes, Kristian Hoel, Tore Håstein, Rolf Erik Olsen, Espen Rimstad, Rune Waagbø and Olav Østerås

Scientific coordinator from the secretariat: Ingfrid Slaatto Næss

# SUMMARY

The Norwegian Ministry of Fisheries and Coastal Affairs and The Norwegian Environmental Authorities have expressed a wish of assessing whether catch and release as a management principle should be acceptable for Norwegian salmonid fish in rivers with depressed population density.

The Norwegian Food Safety Authority (NFSA) has accordingly requested the Norwegian scientific Committee for Food Safety (VKM) to conduct an assessment of the welfare implications of catch and release compared with traditional angling and killing for the anadromous life stages of the following native salmonids: Atlantic salmon (*Salmo salar*), sea trout (*Salmo trutta*) and Arctic char (*Salvelinus alpinus*) in Norwegian rivers.

To gather and summarize the scientific background documents necessary to answer the questions posed by the Norwegian Food Safety Authority, the VKM Panel on Animal Health and Welfare established an *ad hoc*-group consisting of six national and international (UK) experts.

The report was produced during most of 2009, and gives a state of art overview of current knowledge on the effects of catch and release practices on these fish species' welfare, using accessible and peer reviewed published literature as basis for the assessment. Anecdotic and non-published reports have been used to a limited extent as they are regarded as untested or containing unverified statements. The Panel on Animal Health and Welfare discussed the full report in a meeting on the 9th of December, and gave its support to the conclusions drawn by the *ad hoc*-group.

The report has concentrated on the literature on the aforementioned three species. Transfer of knowledge from other species has only been undertaken to a limited extent as general physiology and responsiveness to stress and handling, may or do, differ significantly among species and may lead to erroneous conclusions.

In order to produce a report most accurate with reference to the request, the *ad hoc* group has concentrated on the impacts catch and release fishing has on the anadromous life stages of these fish. Furthermore, the request has been to evaluate additional welfare issues with catch and release that are not seen in retention fishing. As the main difference occurs from landing onwards, the catch process itself has not been the subject to exhaustive discussions. Finally, the ethical aspects of catch and release are not within the remit of VKM and have thus not been considered.

The report gives a brief overview of the history of catch and release, the three species' general biology, and current population status in Norwegian rivers. An introductory section describing current knowledge on pain sensation, fear and stress responses has also been added for reader's information. The main body of the report has been designed to give an outline of current knowledge associated with each of the questions asked by the Norwegian Food Safety Authority, leading up to an answer. The summary responses are as precise as possible. The subjects cover the factors that may affect fish welfare during capture and handling, and the report also includes a section on criteria for humane killing. The effects of various designs of hook and bait types is discussed. The recovery process following release is also discussed, including sections on wound infections, mortality rate, impact on reproductive fitness, predation risk and likelihood of recapture. If catch and release is to be introduced, then the final chapter summarises some possible ways to ameliorate the effects on welfare. The reader will notice that while there is extensive information on some of these subjects for Atlantic salmon, comparatively little is known about the impact of catch and release on anadromous sea trout and Arctic char. Furthermore, in some areas, it has also been difficult to give conclusive answers, partly because there are many interrelated factors that could affect fish welfare that should be taken into account but are beyond the scope of this report, and partly because there is a lack of experimental data. Further progress in these fields can only be accomplished through directed research activities. Based on the review of literature, the panel concludes that catch and release has the potential to harm the fish. During playing and handling of the fish, it will be subjected to stress and other disturbances that may impair the fish's welfare. These have the potential to cause damages leading to increased mortality (fish with excessive injury and low likelihood to survive should be killed and not released), secondary infections and impacts on reproduction. However, for the anadromous life stages of the species in question (virtually no information for trout and char), available and published scientific literature does not indicate catch and release has any long lasting welfare implications after release. For example, catch and release of Atlantic salmon in rivers at water temperatures less than 17-18 °C have been reported to result in low mortalities (0 - 6 %). The numbers of reliable studies conducted under natural conditions at high water temperatures are few, and to determine reliable mortality levels for catch and release at water temperatures above 17-18 °C more studies should be performed. Given that the catch and release procedures involve subjecting fish to significant stress and other disturbances it is likely that the fish's welfare is impaired. Welfare issues including survival can be improved by selection of correct fishing tackle, handling procedures, and training of anglers and guides.

## KEY WORDS

Catch and release, anadromous salmonids, Atlantic salmon, Arctic char, sea trout, fish welfare

# NORSK SAMMENDRAG

Fiskeri- og kystdepartementet og natur- og miljøvernmyndighetene ønsker å vurdere om fang og slipp bør innføres som en måte å regulere fiskebestanden på i norske lakseelver med lav populasjonstetthet.

På bakgrunn av dette har Mattilsynet bestilt en vurdering fra Vitenskapskomiteen for mattrygghet (VKM) om velferdsmessige konsekvenser for fisk som fanges i fang og slipp-sportsfiske sammenlignet med tradisjonelt sportsfiske der fisken avlives. VKM er bedt om å vurdere de tre laksefiskartene laks (*Salmo salar*), sjøørret (Salmo *trutta*) og sjørøye (*Salvelinus alpinus*) når disse befinner seg i det anadrome stadiet, det vil si når fisken vandrer opp i elver for å gyte.

For å skaffe en oversikt over den vitenskapelige bakgrunnen for slikt fiske og gi grunnlag for å svare på spørsmålene fra Mattilsynet, nedsatte VKMs faggruppe for dyrehelse og dyrevelferd (dyrevern) en *ad hoc*-gruppe bestående av seks nasjonale og internasjonale (Storbritannia) eksperter.

Rapporten ble til gjennom flere møter i *ad hoc*-gruppen i 2009 og gir en oppdatert oversikt over aktuell kunnskap om hvilken effekt fang og slipp-fisket har på velferden til de tre omtalte fiskeartene. *Ad hoc*-gruppen har hovedsakelig benyttet vitenskapelig og fagfellevurdert litteratur. Uoffisielle rapporter, brosjyrer eller annet populærvitenskapelig materiale er benyttet i mindre grad, da informasjonen i disse ikke er kvalitetssikret. Faggruppen behandlet rapporten fra *ad hoc*-gruppen på sitt møte den 9. desember 2009 og ga da sin tilslutning til rapporten.

Vurderingen har konsentrert seg om litteratur om de tre nevnte fiskeartene. Overføring av kunnskap til eller fra andre fiskearter har blitt gjort i meget begrenset omfang etter som generell fysiologi og spesielt fysiologisk respons på håndtering og stress ofte varierer vesentlig mellom ulike arter. Kunnskap fra andre arter har dermed begrenset overføringsverdi og kan lede til uriktige konklusjoner.

For å kunne besvare oppdraget fra Mattilsynet mest mulig presist, har VKM konsentrert seg om å beskrive risiko for dårlig dyrevelferd når de tre artene befinner seg i det anadrome stadiet. Videre har Mattilsynet særlig ønsket at det settes fokus på dyrevelferdsrisiko knyttet til fang og slipp som ikke forekommer ved tradisjonelt sportsfiske. Ettersom hovedforskjellen mellom fang og slipp og tradisjonelt stangfiske opptrer etter innfanging av fisken, er selve kjøringen av fisken ikke blitt nøye vurdert. Videre er den etiske siden av fang og slipp ikke blitt vurdert, fordi dette ligger utenfor VKMs mandat.

Rapporten gir en kort oversikt over historien til fang og slipp-fisket, de tre artenes biologi og deres populasjonsstørrelse i norske elver. En innledende seksjon som beskriver aktuell kunnskap om evne til å føle smerte, frykt og stress hos fisk er inkludert. Hoveddelen av rapporten er en gjennomgang av oppdatert kunnskap knyttet til hvert av spørsmålene som er stilt i Mattilsynets bestilling, og spørsmålene er besvart ut fra dette. De summariske svarene er så presise som mulig ut fra foreliggende vitenskapelige litteratur og erfaringsbasert kunnskap.

Temaene dekker en gjennomgang av faktorer som kan påvirke fiskevelferden ved innfanging og håndtering, og rapporten inneholder også et avsnitt om human avlivning av fisk. Effekten av ulike typer kroker og agn er diskutert. Restitusjonsprosessen etter slipp er også diskutert i avsnitt som omhandler dødelighet på grunn av alvorlige sårinfeksjoner og økt predasjonsrisiko. Sannsynligheten for gjenfangst og betydning for reproduksjon er også omtalt.

Et viktig forbehold ved konklusjonen i vurderingen er at mens det for laks er god tilgang på vitenskapelig baserte data, er tilgangen svært begrenset for de to andre artene sjøørret og sjørøye. Videre har det innenfor noen områder vært vanskelig å gi konsise svar som bunner ut i en konklusjon, fordi det er mange faktorer som påvirker dyrevelferden, men som det ville føre for langt å diskutere i dette begrensede mandatet. Til dels er det også slik fordi det ikke foreligger tilstrekkelige eksperimentelle data om emnet. Videre framdrift innenfor disse områdene kan bare oppnås dersom en gjør målrettede vitenskapelige forsøk.

Basert på en gjennomgang av tilgjengelig vitenskapelig litteratur, konkluderer faggruppen med at fang og slipp har utfordringer ut over vanlig fiske der fisken avlives etter innfanging: Fisk blir skadet ved kroking, den kan utsettes for stress og andre påkjenninger når den dras inn, noe som kan påvirke fiskens velferd negativt, og det er usikkerhetsmomenter knyttet til dødelighet, sekundærinfeksjoner og effekter på reproduksjonen hos fisken som slippes ut igjen (fisk med store eller alvorlige skader skal ikke slippes ut igjen, men må avlives umiddelbart). Til tross for velferdsutfordringene som beskrives over, peker imidlertid ikke den vitenskapelige litteraturen på langsiktige velferdsproblemer etter slipp når de omtalte artene befinner seg i det anadrome stadiet, selv om det må understrekes at det foreligger lite informasjon for sjøørret og sjørøye. Under forhold der temperaturen i elvevannet er under 17-18 ºC, er det for eksempel funnet lav dødelighet (0-6 %) etter slipp hos atlantisk laks. Det foreligger imidlertid få vitenskapelige studier der mortalitetsundersøkelser er gjort under naturlige forhold ved vanntemperaturer høyere enn 17-18 ºC. For å fastsette pålitelige mortalitetsnivåer for fang og slipp under disse vanntemperaturene, bør det derfor utføres flere studier.

Gitt at prosedyrene ved fang og slipp medfører at fisken utsettes for mer stress og andre påkjenninger enn ved vanlig sportsfiske, er det sannsynlig at metoden medfører negativ påvirkning på fiskens velferd. Velferdsutfordringer knyttet til fang og slipp kan imidlertid møtes gjennom krav til fiskeutstyr, håndteringsprosedyrer for fisken mens den holdes fanget, og ved opplæring av sportsfiskere og fiskeguider.

Dersom fang og slipp skal benyttes som forvaltningsprinsipp, inneholder rapporten et etterskrift som oppsummerer rutiner, som kan forebygge at dyrevelferden kompromitteres.

# CONTENTS

# BACKGROUND

Recreational retention fishing for Atlantic salmon and other anadromous species in Norwegian rivers is a very popular pastime, and the income from fishing licences can represent large sums. When properly performed and followed by quick and efficient killing of the fish immediately after landing, such fishing is considered justifiable and acceptable from an animal welfare point of view. In contrast to the situation in many other countries, catch and release has not been commonly practised in Norway. However, as many populations of Atlantic salmon are now seriously reduced in many rivers, there is an increasing demand for catch and release (C&R) to be practised also in our country. However, in response, a number of related animal welfare issues have been raised.

According to the Norwegian Animal Welfare Act of 1974, section 2 "*animals shall be treated well, and consideration shall be given to the instinctive behaviour and natural needs of animals, so that there is no risk of causing them unnecessary suffering*". The Norwegian Food Safety Authority has upheld a statement issued by the previous governmental agency (the Norwegian Animal Health Authority) on March 24th 2002, where it was concluded that "*fishing based on catch and release involves subjecting individual fish to the stress, exhaustion and danger of injury associated with being caught purely for entertainment and outdoor recreation and involving no element of food supply*". However, it is also stated that: "*Catch and release for selective pressure on stocks and sizes may be acceptable pursuant to the Animal Welfare Act provided that the proportion of fish released is small, and the fish are not seriously damaged or exhausted*".

The Norwegian Ministry of Fisheries and Coastal Affairs and The Norwegian environmental authorities have expressed a wish of reassessing whether catch and release as a management principle for salmon in rivers with low stock levels could be acceptable. According to the ministries' comments to the Animal Welfare Act Draft, referred to the Parliament on the 28 November 2008, a general ban on such practice is not considered practical. However, each incident must be acceptable from an animal welfare point of view, and specific regulations may be relevant (Ot.prp. 15 (2008-2009) 2.2.19.4).

Against this background the Norwegian Food Safety Authority (NFSA) requested the Norwegian scientific Committee for Food Safety (VKM) to conduct an independent assessment of the welfare implications of catch and release compared with traditional angling and killing of fish.

To prepare the scientific background necessary to answer the questions from the Norwegian Food Safety Authority, the VKM Panel on Animal Health and Welfare established an *ad hoc*-group consisting of 6 national and international experts. The international experts (2) came from the United Kingdom. The group was chaired by Principal Scientist Rolf Erik Olsen from the Panel on Animal Health and Welfare.

# TERMS OF REFERENCE

The main topic of the request is to conduct an assessment of how catch and release affects the welfare of the fish compared with ordinary angling where the fish are killed (retention angling), and an assessment of the factors that are important in safeguarding the welfare of the fish during catch and release. The assessment shall include the anadromous life stages of the salmonids: Atlantic salmon (*Salmo salar*), sea trout (*Salmo trutta*) and Arctic char (*Salvelinus alpinus*), and the catch and release fishing of these species in rivers. The assessment shall include effects on both the individuals involved and their offspring.

All acute, delayed and long-term effects of catch and release not associated with ordinary retention fishing should be considered. Where relevant, differences between the three species and between fish of different ages, sizes and developmental stages should be addressed. The influence of different angling practices as to type of tackle (rods, lines), hooks (without or with one or more barbs, circle, J-style etc.), kind of bait, playing of the fish and handling practices (net, hands) should also be taken into account.

The following points should be addressed:

1) Playing of fish for landing: How will playing of the fish affect the fish's welfare and survival rate after release?

2) Handling: Does handling of the fish during catch and release differ from handling during retention fishing? If so, what are the potential welfare implications of any differences? How will different types of handling affect the welfare: Beaching, handling in nets or with bare (dry/wet) hands, handling in water and out of water, duration of handling out of the water and handling to remove hooks? Is it possible to undertake any of these handling procedures safely and efficiently without removing the fish from the water? Is it possible to restrict the maximum handling time out of water to e.g. 15 seconds?

3) Humane killing: What kinds of conditions will due to welfare considerations require that fish are killed and not released?

4) Hook types and removal of hook: Are certain hooks more aversive to fish, and do any hooks cause more lesions? Will the additional use of live bait or other types of bait cause additional tissue damage? Does the removal of the hook cause any additional suffering? Will the removal of deeply embedded hooks or certain types of hooks imply higher risks of suffering?

5) After release: Which factors will affect the recovery rate, including those mentioned above and any additional factors, such as environmental variables (eg. water or air temperature)?
    a) How long will it take for the fish to recover and resume normal physiological body functions and behavioural patterns?
    b) Will released fish be more prone to wound infections or infectious diseases?
    c) Will the fish be more susceptible to increased predation? If yes, how large a percentage of the fish might be expected to die due to predation?
    d) Is the fish' reproduction affected? If so, in what way?

e) What is the mortality rate of released fish caused by the catch and release procedure, and how long will it take before they die? Are there types of injuries or physiological or behavioural reactions that will always be lethal to the fish?

6) Possibility of recapture: What is the risk that released fish will be repeatedly captured? Will any learned avoidance behaviour depend on certain factors, such as type of fish hook used and/or the use of different types of bait?

7) Possible procedures to ameliorate effects on welfare: Is it possible to reduce or eliminate any suffering or avoid further impairment of fish welfare after release, by using certain hooks, types of equipment or certain practices for angling and handling of the fish?

The Norwegian Food Safety Authority asks for an assessment of the scientific data in the form of a written report. Any lack of knowledge and need for further studies should be highlighted.

# INTRODUCTION

## A) DEFINITION OF CATCH AND RELEASE

Catch and release refers to the process of capturing fish by using hook and line, and then releasing live fish back to the waters where they were captured, presumably to survive unharmed (Arlinghaus et al., 2007).

Catch and release is a relative term and implies a gradient from catch and release only, - to catch and kill angling with release of a proportion of the catch alive. It can be a voluntary action or the result of harvest regulations (i.e. mandatory). Over time, the use of the term has broadened from a principle where all captured fish are released, to include the use of special regulations that force anglers to release part or most of their catch. Such regulatory catch and release includes release based on length limitations (i.e. all fish smaller or larger than the specified size limit must not be retained), protected (closed) seasons, bag limits, protected species (e.g. some species are protected and cannot legally be retained) and protected life stages (e.g. release of Atlantic salmon kelts). Voluntary catch and release usually refers to the voluntary decision on the part of the angler to release fish.

The motivation for releasing a fish after capture may therefore be driven by both ethical considerations and fishery management objectives. However, for the purposes of this report when attempting to evaluate the impact of such procedures on the individual fish themselves, including stress, pain and mortality, it is not important whether the fish was voluntarily released or released as a result of fishing regulations. However, an exception to this may be circumstances when management regulations require anglers to release fish (e.g. if an individual of a protected species or population is captured during angling for other species) irrespective of the condition of the fish.

## B) THE HISTORY OF CATCH AND RELEASE

A brief outline of the history of catch and release is given below. For more comprehensive reviews, readers are advised to consult publications by Arlinghaus et al. (2007) and Thorstad et al. (2008a) from which much of the following information is sourced.

Fishing techniques that involve hooking fish (angling) were invented at least 50,000 years ago, primarily to catch fish for food (Sahrange and Lundbeck, 1992). Recreational fishing that is not motivated by personal consumption, sale, or trade is also likely to be a very old activity. There are many Egyptian tomb scenes, drawings, and papyrus documents that suggest fishing being pursued as a pastime. The oldest interpretation of this originates from a 3,290 year old Egyptian image displaying a fishing nobleman (Pitcher and Hollingworth, 2002).

England seems to be the origin of voluntary catch and release. For the fifth edition of *The Compleat Angler* (1653 onward), Izaak Walton asked Charles Cotton to write a section on fly fishing, which contains a specific reference to voluntary catch and release: “This is a diminutive gentleman, e`en throw him in again, and let him grow till he be more worthy your anger.” In the reign of George II (1727–1760), size limits for roach (*Rutilus rutilus*) were imposed, and it was illegal to take, possess, or sell any undersized fish or fish caught out of season (Policansky, 2002). As fly fishing became more regimented in 19th century England, writers increasingly mentioned releasing a portion of one’s catch voluntarily. Revered by millions of boys worldwide, the founder of the Boy Scout movement Lord Baden-Powell preached the gospel of catch and release wherever he fished (Precourt, 1999). He wrote of the need to let fish go so that other anglers might have good sport, that fish might grow and reproduce, and that the reason for recreational fishing is to renew and recreate more than it is to catch fish. The British were therefore probably the first to practice voluntary catch and release as an ethical principle and during fishing competitions. The British also developed the so-called coarse-fishing ethics, voluntarily releasing almost every non-salmonid fish (North, 2002). Late in the 20th century, the British coarse-fishing ethics received considerable support in Europe, with many highly committed anglers and angler groups practicing voluntary catch and release (Policansky, 2002; Arlinghaus and Mehner, 2003).

Regulatory catch and release relates to the implementation of the first fishing regulations throughout Europe. However, European catch and release has a variety of origins and traditions (Aas, 2002). In mainland Europe, the view that catch and release is “an unethical and reprehensible fishing practice” is much more common than in the UK and North America, although there are some who view catch and release as “both an ethical and conservative approach to resource utilization” (Aas, 2002). The need for anglers to release a portion of one’s catch was advocated in America as early as 1864. Concerns for conservation in America during the 19th century led to acceptance of catch and release as a means of preserving stocks of fish, contrasting the continental European tradition of fish as a source of food.

Regulatory catch and release, particularly of undersized or otherwise protected fish, is presently almost universally accepted as a “good idea” to conserve fish stocks and fishing opportunities. Voluntary catch and release in Europe and elsewhere seems to be growing with the spread of the British so-called coarse (i.e., non-salmonid) fishing ethics and the so-called “specimen hunting” practiced by many of the highly committed and often species-specialized angler groups. They strongly adhere to voluntary, often total catch and release, as do some of the competition or “match” anglers across Europe (North, 2002). This is accepted in some cultural environments, but less popular in others. Subsistence thinking prevails particularly in Eastern Europe, northern Scandinavia (Aas and Kaltenborn, 1995), northern North America (e.g. National Research Council (NRC), 2005), and in most marine recreational fishing areas outside the English-speaking world.

## Magnitude of catch and release today

Globally, millions to billions of fish are released after capture by recreational anglers every year. Rough global release rate estimates are about 60 % (Cooke and Cowx, 2004). In the United States alone in 2000, an estimated 11 million anglers participated in 78 million marine fishing trips and caught 445 million fish, of which 253 million or 57 % were released (Bartholomew and Bohnsack, 2005). The proportion of caught and released fish has increased from 34 % of the total catch in 1981 to 59 % in 1999 (Bartholomew and Bohnsack, 2005). However, there is considerable diversity in catch and release rates in different cultures, institutional environments and, situations involving many different species.

## Catch and release of salmonids

Members of the salmon family, mainly salmon, trout, and char, have been important recreational species for centuries. Since the middle of the 20th century there has been an increasing, although not uniform, acceptance of catch and release fishing for these species, most notably for brown trout and rainbow trout. In contrast, for Atlantic salmon, which has a long history of being killed when caught, this acceptance has tended to come later.

The extent of acceptance of catch and release angling for Atlantic salmon varies between countries within the species' distribution range. Catch and release angling for Atlantic salmon has the longest history in North America, being advocated as early as the 1880s (Wydoski, 1977). A hundred years later, in 1981, the first catch and release-only fisheries were introduced on some Canadian rivers (Tufts et al., 2000). In Eastern Canada, anglers have been required by law to release all Atlantic salmon ≥ 63 cm since 1984, and faced with declining populations are actively encouraged to voluntarily release smaller salmon to maintain recreational angling. However, within Canada, catch and release as a management tool has not been widely accepted in Newfoundland (Dempson et al., 2002).

Until the 1990s, few anglers in the United Kingdom released salmon other than kelts (spawned fish) or fish very close to spawning. Since then, catch and release has become widely practised and promoted. In recent years, over half the recorded rod catch has been reported as being released (Environment Agency, 2006; Fisheries Research Services, 2004). While most fish are released voluntarily, it has been compulsory since 1999 to release salmon caught before June 16th in England and Wales because of depleted runs of spring running salmon.

In Northwest Russia, recreational fisheries in the Murmansk Province began developing in 1989, with foreign anglers releasing most of their catch. In recent years more than 80 % of the total catch taken by anglers has been reported to have been released (ICES, 2009).

The International Council for the Exploration of the Sea (ICES) receives catch and release reports from eight countries (Denmark, Canada, Iceland, Ireland, Norway, Russia, UK and the USA) (ICES, 2009). The proportion of the total catch being released has increased over the last decade, and varies between 19 % in Iceland to 100 % in the USA (2008). Altogether, 204,000 Atlantic salmon were released in these countries in 2008.

### C) THE PRESENT CATCH AND RELEASE OF SALMONIDS IN NORWAY

In Norway, there has been a traditional culture for fishing and killing fish for consumption. Until recently, there has been little tradition for classic catch and release angling for salmonids, that is, with the intention to fish target specific individuals or species and then release them. However, in the past years there has been an increasing debate about whether catch and release can be used as a management tool to regulate exploitation of declining fish populations of anadromous salmonids. At present, catch and release of salmonids is not illegal (including voluntary release), but restrictions have been put in place to limit the extent to which it can be used as a mandatory measure to regulate river fisheries. In statements from Department of Environment (dated 28.01.2008) and the Directorate for Nature Management (dated 30.01.2008) it is stated that release of anadromous salmonids as a regulatory measurement should not be increased from the present day level.

There has been little knowledge with regard to the extent of catch and release of anadromous salmonids in Norwegian rivers. The first time catch and release data appeared in official statistics was 2008, with the number of Atlantic salmon released amounting to 5,512 (ICES, 2009). However, it is not known what proportion of fish caught and released Atlantic salmon are subsequently reported in the official statistics, so this number should be regarded as a minimum, with the actual number possibly being higher.

On the other hand, releasing fish after they have been caught unintentionally has been practiced in Norway for a long time. For example, the statutory requirement to release of undersized fish (30/35 cm for anadromous salmonids) has been in existence for many years. The release of a species such as Atlantic salmon caught outside its legal season, when fishing for other species, has also been frequently practiced. More recently, the imposition of bag-limits or protection of particular size groups of fish, such as large female salmon, has been introduced; fishermen having to release any fish not allowed to be caught according to the regulations. The release of Atlantic salmon kelts, (i.e. spent fish) in the spring is also mandatory in many watercourses, and wild specimens that are accidentally caught, during deliberate intensive fishing for escaped farmed salmon, are also released.

The practice of catch and release seems to have increased in many Norwegian rivers in later years, possibly due to two factors. Firstly, catch and release is now a common practice in many other countries and foreign fishermen have brought this practice to Norway when fishing, especially for Atlantic salmon. Many foreign anglers also now view catch and release as an important conservation practice, which is advocated among their Norwegian colleagues. Secondly, declining stocks of wild salmonids requires the development of new management strategies and associated regulations. As an alternative, or in addition to reduced/closed fishing season and bag-limits, catch and release has been suggested as a means of maintaining fishing activities in rivers whilst maintaining important sources of income to the fishing right holders and other stakeholder benefits (e.g. angling tourism), and to protect the remaining fish stock from poaching. There is also an argument that these activities will act to preserve the culture of angling and interest in anadromous salmonids among local people.

As an example of the positive effects of catch and release on salmon production, the studies of the Atlantic salmon in the River Alta can be used. The development of hydro power in 1987 had serious negative effects on the fish production in the upper 5 km of the Atlantic salmon stretch (closest to the dam), where the salmon production in the mid 1990s declined to approximately 20 % of pre-development levels. The consequence was that the number of spawning females dropped to a level that was too low to maintain juvenile recruitment in the area. As an alternative to closing the area for fishing, voluntary catch and release was introduced in 1997 (Ugedal et al., 2007). This change in management strategy has been suggested as an important factor for the tenfold increase in the number of female spawners, from approximately 10-25 in 1996-1997 to approximately 150-250 after 2005 (Ugedal et al., 2007; T. Næsje, NINA, unpubl.). The area is now fully recruited with juveniles (Hindar et al., 2007).

## D) DESCRIPTION OF THE SPECIES

### ATLANTIC SALMON (*SALMO SALAR*)

Atlantic salmon are naturally distributed along the east and west coast of the North Atlantic Ocean (MacCrimmon and Gots, 1979). Most Atlantic salmon populations are anadromous, although some populations are freshwater residents (Klemetsen et al., 2003). The Atlantic salmon populations display considerable phenotypic plasticity and variability in life-history characters (Fleming et al., 1996; Klemetsen et al., 2003). They spawn in rivers in the autumn, and the eggs hatch in the following spring. The juveniles (parr) remain in freshwater for 1-8 years, most usually 2-5 years (Klemetsen et al., 2003), before they transform physiologically and morphologically into smolts and migrate to sea to exploit the rich feeding opportunities (Wedemeyer et al., 1980; Høgåsen, 1998). At sea, Atlantic salmon are distributed over large areas in the North Atlantic Ocean (Hansen and Quinn, 1998). Adult salmon mature after 1-5 winters (usually 1-3) in the sea and return to freshwater to spawn (Klemetsen et al., 2003). A varying proportion of male juveniles may not migrate to sea, but become sexually mature ‘precocious parr’ being capable of successful reproduction with adult females (Dalley et al., 1983; Myers and Hutchings, 1987).

Atlantic salmon return with a high level of precision to their home river for spawning (Hasler, 1966; Harden Jones, 1968). Moreover, Atlantic salmon apparently return to the same area of the river where they spent their pre-smolt period, and ecological and genetic differences among subpopulations within rivers are also documented (e.g. Heggberget et al., 1986; Summers, 1996; Primmer et al., 2006). Salmon populations differ both ecologically and genetically (Hindar et al., 1991; Klemetsen et al., 2003; Verspoor et al., 2005).

The International Council for the Exploration of the Sea (ICES) refers to 600 different salmon stocks in North America and 1500 in the Northeast Atlantic (www.ices.dk). In Norway only, there are 452 salmon rivers (**Table 1**).

During their upstream migration, Atlantic salmon do not feed, and their energy reserves are used for body maintenance, gonad growth and migration (Jonsson et al., 1997). Some Atlantic salmon may spawn repeatedly, up to five times during their lifetime (Jonsson et al., 1991a; Klemetsen et al., 2003). However, post-spawning mortality is often high (particularly among males) and most individuals spawn only once or twice. The survivors, kelts, migrate downstream to sea shortly after spawning, or during the following spring or early summer (Jonsson et al., 1990; Halttunen et al., 2009).

Atlantic salmon typically enter coastal home waters and rivers from the sea several months prior to spawning, and timing of the run is highly variable both within and among populations (Fleming et al., 1996; Klemetsen et al., 2003). Most Atlantic salmon in Norway and Canada enter the rivers from May to October (Klemetsen et al., 2003), with a general tendency for large multi-sea-winter salmon to enter the rivers earlier in the season than smaller one-sea-winter fish (Power, 1981; Jonsson et al., 1990). Water discharge appears to be an important proximate factor stimulating adult Atlantic salmon to enter rivers from the sea, but in combination with other environmental factors (reviewed by Banks, 1969; Jonsson, 1991).

Across the whole distribution range, many Atlantic salmon populations are in decline, despite reductions in marine fisheries (ICES, 2004; Klemetsen et al., 2003). Several factors have contributed to this decline, and human impacts such as overexploitation, acid deposition, transfer of parasites and diseases, aquaculture, freshwater habitat degradation, hydropower development and other in river impacts seem to be important contributors (Johnsen and Jensen, 1991; Anonymous, 1999b; Committee on Atlantic salmon in Maine, 2004; ICES, 2004).

According to a recent survey of the population status in 452 Norwegian watercourses containing Atlantic salmon, 10 % of the watercourses had lost their populations, while 33 % of the watercourses were categorized as threatened, vulnerable or reduced (**Table 1**). In 54 % of the watercourses, populations were moderately or little affected. However, in 46 % of these the fishery managers had some concerns about the status of populations. Fifty-two salmon stocks were affected by acidification (Directorate for Nature Management). The parasite *Gyrodactylus salaris* has now spread to 46 river systems, and 10 salmon stocks are regarded as lost. One third of the salmon rivers are regulated, which has been identified as a significant negative factor for a total of 85 salmon stocks. The Norwegian Scientific Advisory Committee for Atlantic Salmon Management (Vitenskapsrådet for lakseforvaltning) has given advice that harvest rates should be reduced in 63 % of the 151 largest salmon rivers (Anon., 2009).

**Table 1.** Population status of Atlantic salmon in 452 Norwegian rivers categorized by the Norwegian county governors in 2007 (Directorate for Nature Management, http://www.dirnat.no).

| Category | Number of populations | Percent |
|---|---|---|
| Lost populations | 45 | 10.0 |
| Threatened or vulnerable populations | 83 | 18.4 |
| Reduced populations | 65 | 14.4 |
| Moderately to low affected populations with special concerns | 208 | 46.0 |
| Moderately to low affected populations without special concerns | 38 | 8.4 |
| Uncertain status | 13 | 2.9 |

## SEA TROUT (*SALMO TRUTTA*)

The brown trout is indigenous to Europe, North Africa and western Asia (MacCrimmon et al., 1970; Elliott, 1989). The anadromous brown trout, which in the following is termed sea trout, is not as extensively distributed as freshwater resident populations. Sea trout are mainly found in Iceland, Scandinavia, rivers draining into the White Sea and Cheshkaya Gulf as well as the Baltic, North Sea and Bay of Biscaya (Frost and Brown, 1967). Within the same gene population some individuals may be resident while others are anadromous (Jonsson and Jonsson, 1993). Anadromous behaviour is more frequently exhibited among females than males. In a study of 17 small coastal streams in south and middle Norway, Jonsson et al. (2001) showed that approximately 50 % of the males and 96 % of the females were anadromous. Trout may, like some Atlantic salmon, have reproductive success as small non-anadromous males. These small “precocious parr” do not compete directly for females, but opportunistically dart into the nest to fertilize eggs at oviposition (Jonsson, 1985; Fleming, 1996).

Similar to Atlantic salmon, brown trout usually spawn in rivers in the autumn and the eggs hatch the following spring (Klemetsen et al., 2003). The smolt ages in Norwegian populations range between 1 and 7 years (usually 2 to 4 years), and the smolts are 10 to 23 cm in length (Jonsson, 1985, 1989; L'Abée-Lund et al., 1989). The average age of smolts increases towards the north, from 2.1 years at 54 $^{o}$N to 5.6 years at 70 $^{o}$N (Jonsson and L'Abée-Lund, 1993). This variation in smolt age with latitude is suggested to be an effect of water temperature; fish in the northern populations on average grow more slowly due to the colder water (L'Abée-Lund et al., 1989). Anadromous fish can be found in rivers and brooks of all sizes, and small rivers may be abandoned under hostile conditions, such as low water during winter.

After entering the sea, the sea trout feed in fjords and coastal waters usually over the summer, for two and more year (Jensen, 1968; Nordeng, 1977; Jonsson and Jonsson, 2002). Sea trout in northern and southern Norway may also stay in coastal waters during winter (Jonsson and Jonsson, 2002; Knutsen et al., 2004; Rikardsen et al., 2006; Jensen and Rikardsen, 2008). They may migrate up to 100 km from their home river, but generally less than 40 km, depending on the length of the fjord where their home river drains (Fiske and Aas, 2001). Sea trout are seldom found far offshore in the Atlantic (Klemetsen et al., 2003) and survival can be as low as 25 % during the first summer at sea (Fiske and Aas, 2001).

In the southern part of its distribution range, sea trout may begin to sexually mature after one summer at sea (Jonsson and L'Abée-Lund, 1993). Further north, for example in northern Norway, fish often spend two to three summers at sea before spawning for the first time.

Sea trout are multiple spawners, and more than 50 % may spawn more than once (Fiske and Aas, 2001). The number of repeat spawners, however, seems to decrease towards the north, being about 60 % in the south and 30 % in the north, but with some variation (Klemetsen et al., 2003). Males usually mature at a younger age than females (Jonsson, 1989).

The size of mature sea trout varies between 25 and 100 cm (0.15 and 15 kg), but is most usually 30 – 50 cm (0.3 – 1.5 kg) (Fiske and Aas, 2001). Within the same population, males are more variable in size than females (Jonsson, 1989). The longevity of both males and females increases with increasing latitude (50 % from 58 to 70 $^{o}$N), and decreases significantly with increasing sea and river temperatures. However, body size was not correlated with latitude (Jonsson et al., 1991b).

According to a classification of the population status in 1161 Norwegian watercourses with anadromous sea trout in 2007, 2 % of the watercourses had lost their populations (**Table 2**). Further, 30 % of the populations were categorized as threatened, vulnerable or reduced, while 57 % of the populations were moderately or little affected. However, in 52 % of these watercourses, fishery managers had concerns about the population status.

**Table 2.** Population status of anadromous brown trout in 1161 Norwegian rivers categorized by the Norwegian county governors in 2007 (Directorate for Nature Management, http://www.dirnat.no).

| Category | Number of populations | Percent |
|---|---|---|
| Lost populations | 28 | 2.4 |
| Threatened or vulnerable populations | 104 | 9.0 |
| Reduced populations | 238 | 20.5 |
| Moderately to low affected populations with special concerns | 606 | 52.2 |
| Moderately to low affected populations without special concerns | 52 | 4.5 |
| Uncertain status | 133 | 11.5 |

### ARCTIC CHAR (*SALVELINUS ALPINUS*)

The Arctic char has a circumpolar distribution through the Holoarctic region, and more than 50,000 populations are found worldwide (Maitland, 1995; Klemetsen et al., 2003). It is the northernmost of all freshwater and anadromous species. Although non-migratory and anadromous populations exist, the most common Arctic char habitats are oligo- or ultraoligotrophic coldwater lakes containing few other fish species. Indeed, in northern or alpine lakes, it is often the only fish species present. The phenotypes and ecology of Arctic char are more variable than in most other freshwater fish species. For example, the size of mature females may vary between 3 and 12,000 g (Klemetsen et al., 2002; Klemetsen et al., 2003). The anadromous form is only found in the northern areas of its distribution range (Northern Norway, Northern Russia, Northern Canada, Iceland, and Greenland). In Norway, anadromous Arctic char is found in the northern counties (Nordland, Troms and Finnmark) and Svalbard. The southern limit is in Bindalen in Nordland. However, occasionally, anadromous Arctic char have been reported caught in some of the southern rivers in Norway. Most often anadromous char is found in watercourses which also support populations of Atlantic salmon and sea trout. The proportion of anadromous individuals in a population may vary among watercourses (Klemetsen et al., 2003).

Arctic char populations may consist of both resident and anadromous individuals. Among anadromous fish, both immature and sexually mature fish undergo coastal sea migrations during the summer months (Nordeng, 1983; Johnson, 1989). Most migrants, (including immature fish) return to freshwater every year, usually earlier than sea trout. The general assumption is that most anadromous Arctic char stay in freshwater during the winter. However, the occurrence of arctic char in estuaries and fjords during winter has recently been documented (Jensen and Rikardsen, 2008).

The largest Arctic char migrate first to sea, often in April or beginning of May, and have the longest sea period (Berg and Berg, 1989). Individuals seldom migrate further than 20 to 30 km from their home river. The coastal feeding migrations usually last for 30 to 50 days, which is shorter than for sea trout (Berg and Berg, 1988, 1993; Finstad and Heggberget, 1993; Rikardsen et al., 1997, 2000; Jensen and Rikardsen, 2008). The reason for this difference in behaviour is not known (Rikardsen et al., 2004).

Arctic char are multiple spawners. When suitable habitats are present and accessible, anadromous char will most frequently spawn in lakes in the autumn. The eggs hatch in the following spring. In lake populations smoltification usually occurs at 4 to 6 years (16 – 22 cm), while in river populations smoltification usually takes place at 2 to 3 years and at a smaller size (Fiske and Aas, 2001). In general, faster growing individuals will smolt at an earlier age and smaller size than slower growing fish, and northern population's smolt at older average age than southern populations.

After completing their marine feeding (typically after two years), many individuals in the Norwegian populations mature at approximately 25 cm for males and 30-35 cm for females (Svenning et al., 1992; Kristoffersen et al., 1994; Rikardsen et al., 1997; Fiske and Aas, 2001). Most anadromous Arctic char usually weigh less than two kilos, but may in some rivers grow up to 4-5 kg. Levels of marine mortality can be high and is highest for smaller individuals. Only 15 to 30 % of the fish may survive the first season in the sea, while among larger and older fish 75-85 % may survive (Jensen and Berg, 1977; Fiske and Aas, 2001).

According to a classification of the population status in 107 Norwegian watercourses with anadromous Arctic char undertaken by the Norwegian county governors, 3% of the watercourses had lost populations (**Table 3**). Further, in 9 % of the watercourses, the Arctic char populations were categorized as threatened, vulnerable or reduced. In 80 %, the populations were moderately or little affected. However, in 49 % of these watercourses the managers had some concerns about their population status.

**Table 3.** Population status of anadromous Arctic char in 107 Norwegian rivers categorized by the Norwegian county governors in 2007 (Directorate for Nature Management, http://www.dirnat.no).

| Category | Number of populations | Percent |
|---|---|---|
| Lost populations | 3 | 2.8 |
| Threatened or vulnerable populations | 3 | 2.8 |
| Reduced populations | 7 | 6.5 |
| Moderately to low affected populations with special concerns | 52 | 48.6 |
| Moderately to low affected populations without special concerns | 34 | 31.8 |
| Uncertain status | 8 | 7.5 |

## E) DESCRIPTION OF PAIN AND SUFFERING IN FISH

### Nociception in fish

Nociception and pain are terms which are often applied interchangeably in the published literature on animal pain; however, these are quite distinct in their definition. Nociception is merely the detection of a noxious stimulus that can or does cause injury, and is usually accompanied by a reflex withdrawal response. All animals are considered to be capable of nociception; however, pain perception is more difficult to demonstrate. The widely used definition of human pain is "An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" (IASP, 1979). From this definition, a negative affective component combined with a sensory aspect constitutes pain. This conscious experience comprises of feelings of suffering or discomfort such that individual welfare is reduced. Pain assessment is therefore difficult, and depends upon direct verbal communication from the individual that experiences pain.

To determine if an individual unable to communicate verbally is in pain, a note was added to this definition that stated: "The inability to communicate verbally does not negate the possibility that an individual is experiencing pain". Other measures are used to determine whether infants are in pain and these have been applied to animals who also cannot communicate their internal state. Measuring the negative affective component in animals which can be described as discomfort and suffering is difficult. We cannot know how an animal "feels" but robust indirect measurements can inform our assessment of the potential for pain. Prolonged, adverse changes in behaviour that last longer than an instantaneous reflex response, and deleterious changes in physiology in response to a noxious, painful event can indicate to what degree the animals' normal behaviour and physiology are affected. If these responses are reduced by the administration of analgesia, then, one can include that the animal is experiencing a negative affective state due to the potentially painful event. Definitions of animal pain are therefore founded upon behavioural and physiological responses rather than emotional states that an animal cannot communicate.

Animal pain is defined as the sensory perception of tissue damaging, noxious stimuli or an aversive sensory experience (see Zimmerman, 1986; Molony, 1997). A reflex withdrawal away from that stimulus should occur almost instantaneously, and any injury should be associated with vegetative responses (e.g. inflammation and cardiovascular responses). Further, the animal should learn to avoid that noxious stimulus and prolonged changes in behaviour should be expected to occur that are not simple reflexes. There are a few studies demonstrating hook avoidance in pike and carp (Beukema, 1970a, 1970b). These behavioural changes should have a protective role to reduce further injury and pain, prevent the injury occurring again and to enhance healing and recovery. Additional criteria, such as the possession of a nociceptive system similar to that found in mammals, relevant brain areas to process pain or nociceptive information, pathways from the periphery to these brain areas, and the existence of opioid receptors and endogenous opioids, must also be met to determine whether an animal can perceive pain (Bateson, 1991; Sneddon, 2004). The robust and easily measured criteria as listed above can be used to assess whether a procedure that causes tissue damage does result in an animal possibly experiencing pain.

Much of the debate upon the ability of fish to experience pain surrounds brain anatomy, and it has been suggested that because the fish brain is smaller and does not have the enlarged neocortex of humans, fish are incapable of suffering (Rose, 2002). However, critics do agree that fish are capable of nociception, and can exhibit the simple detection and reflex withdrawal response to noxious stimuli. However, there is disagreement as to whether fish experience the negative feelings associated with pain (Rose, 2002; Sneddon, 2004, 2006). If one accepts the critic argument, then this means that only primates and humans will suffer from pain. This premise defies the laws of evolution since no function suddenly arises in the absence of a primitive ancestor (Bekoff and Sherman, 2004). If we accept this opinion, then we agree that cats, dogs, birds etc are unable to experience discomfort and suffering. Perhaps animal pain should be considered as a primitive, rudimentary experience on a phylogenetic sliding scale (Bekoff and Sherman, 2004). In terms of phylogeny, humans experience the most advanced, complicated pain and suffering whereas fish possess a relatively primitive form of pain, however, it is no less important.

### Fear in fish

Fear can be defined as "the activation of a defensive behavioural system that protects animals or humans against potentially dangerous environmental threats" (Fendt and Fanselow, 1999). These behavioural responses are usually combined with activation of the autonomic nervous system (LeDoux, 2000). This includes increased heart rate (Black and deToledo, 1972), release of endogenous opioids (Bolles and Fanselow, 1980), and the release of several hormones such as cortisol (Tomie et al., 2002). During fear humans experience the subjective state of fear (Bradley et al., 1993; Jones, 1997). Again, when investigating fear in animals robust behavioural and physiological parameters can be measured to give an indirect assessment of fear. Three main criteria can be used to determine whether animal fear occurs

(Fendt and Fanselow, 1999). Firstly, the brain areas and systems that control the fear response should be similar with a common neuronal basis to those that control human fear. Secondly, threatening, fearful stimuli should generate a consistent suite of behaviours that shield the animal from the threat. Thirdly, drugs that reduce human fear should also reduce fear responses in the animal.

Classical conditioning using negative reinforcement or fear stimuli is an important component of defensive behaviour and the amygdaloid and hippocampal regions of the mammalian brain are crucial. In fish these responses are also innervated by homologous limbic brain regions in the telencephalon. The mammalian amygdala has long been known to be important in motivational state and fear (Carter, 1996; Maren, 2001). The dorsomedial (Dm) telecephalon in fish is involved in this emotional learning and is homologous to the amygdala (Bradford, 1995; Butler, 2000; Portavella et al., 2004). The mammalian and avian hippocampus is involved in memory and also the learning of spatial information and the dorsolateral (Dl) telencephalon in fish that is homologous to the hippocampus (Bradford, 1995; Butler, 2000; Portavella et al., 2002, 2004). Therefore, even though the fish brain is different in structure to the mammalian brain there are homologous regions controlling the expression of fear.

Fish display escape behaviours when confronted by potentially threatening stimuli (Chandroo et al., 2004; Domenici and Blake, 1997; Yue et al., 2004), including erratic movement (Cantalupo et al., 1995; Bisazza et al., 1998) and freezing and sinking to the bottom of the water body (Berejikian et al., 1999, 2003). These behaviours may have a protective role and reduce the threat (Ashley and Sneddon, 2007).

Alarm substances are released from damaged fish skin and alert conspecifics to danger. Innate behavioural fright responses are displayed by fish when this substance is added to the water, however, these are species specific with individuals only responding to the alarm substance of conspecifics (Smith, 1992; Lebedeva et al., 1994; Brown and Smith, 1997; Berejikian et al., 1999; Asley et al. 2009). Crucian carp, *Carassius carassius*, given alarm substances reduced feeding and exhibited alarm behaviours (Hamdani et al., 2000). Dashing, vigorous movements in the substrate, and fast swimming towards refuges were performed for some time after the substance was provided. These behaviours are often linked to predator avoidance (Hamdani et al., 2000; Ashley et al., 2009). Fish perform a clear behavioural response to alarm substance and a physiological stress reaction with increased plasma cortisol and glucose (Rehnberg et al., 1987; Ashley et al., 2009). Research into learned avoidance in fish demonstrates that a consistent repertoire of behaviour is elicited by fearful stimuli that are not merely a reflex response. Rainbow trout can learn to associate a light cue with a fearful stimulus and respond solely to the light cue by exhibiting avoidance behaviour (Yue et al., 2004). Fear of an aversive stimulus motivates the animal such that it quickly acts to avoid this negative experience.

Studies in anti-anxiety drugs are few in fish but they have shown similar receptor sites for benzodiazepines in the brains of fish in areas comparable with mammals (Nielsen et al., 1978; Hebebrand et al., 1988; Rehnberg et al, 1989). Administration of a benzodiazepine drug reduced aggression between male Siamese fighting fish, *Betta splendans* (Figler et al., 1975). Other research has suggested these drugs given to fish modulate their behaviour to reduce fear (Rehnberg et al., 1989). Fish given a fearful stimulus exhibited reduced exploratory behaviour but this was not seen in anti-anxiety drug treated fish (Rehnberg et al., 1989).

## Stress

Stress can be defined as a condition in which an animal is challenged by a threat (environmental or behavioural) and cannot maintain a normal physiological state. The stress response, therefore, attempts to maintain the normal functioning of the animal or homeostatic balance. Stress can be thought of as a stimulus which challenges homeostasis (Wendelaar Bonga, 1997). Primary physiological responses to stress involve two endocrine pathways: the adrenergic (or sympathetico-chromaffin) and the hypothalamic-pituitary-adrenal/inter-renal (HPA/HPI) axes. Fish do not possess adrenal glands but instead have inter-renal cells in the head kidney; however, the stress response in fish is very similar to that in mammals (Wendelaar Bonga, 1997). Catecholamines, including adrenaline and noradrenaline, are released as a result of adrenergic stimulation (Sumpter, 1997) and affect blood flow and oxygen transport (Nilsson, 1984). The HPI response is a hormone cascade leading to the synthesis of corticosteroids, primarily cortisol in fish (Fagerlund, 1970; Wendelaar Bonga, 1997). A plethora of studies have measured stress in fish. Acute stress results in the physiological responses above which relatively quickly return to normal, however, chronic stress can lead to secondary effects such as impaired immune function, reproductive failure, anorexia and decrease growth (Wendelaar Bonga, 1997). From the catch- and- release studies, it would seem that many fish recover quickly from the stress, i.e. within 4 hours (e.g. Suski et al., 2007) and this short stress response will assist to returning the fish to normal function. However, mortality has been recorded in some studies where it was linked to play or emersion duration (Meka and McCormick, 2005; Danylchuk et al., 2007).

# ASSESSMENT

## 1. PLAYING OF FISH FOR LANDING

As a group, salmonids are highly adapted to both endurance and rapid-burst swimming.

In contrast to other factors, comparatively little research has been undertaken on the effect of playing time (retrieval time between hooking and capture for the purposes of unhooking and release). There are no detailed published studies on the relationship between playing time and subsequent fitness post-release; most studies have tended to focus on the cumulative impact of hooking, playing and subsequent handling (including unhooking) prior to release on subsequent survival and behaviour.

The period over which salmon and trout are played by anglers varies considerably and is influenced by such factors as environmental conditions (e.g. water height and temperature), season, fish size and condition, angler experience and the type of angling equipment being employed (Thorstad et al., 2003a).

The physiological effects of exhaustive exercise on fish are well documented (for review see Wood, 1991; Kieffer, 2000). Prolonged, rigorous swimming to a state of exhaustion results in a series of metabolic, acid-based and ionic changes. Typically, plasma lactate levels may increase in both blood and tissue, and sodium/chloride levels may be disturbed. Mortality among severely exercised fish has been attributed to the intracellular acidosis within the white muscle (Wood et al., 1983) Following experimental exhaustive exercise, salmon recovering in soft water (neutral pH) may experience greater levels of physiological disturbance than fish in acid or soft water (Bielak, 1996; Rossiter et al., 1996).

Direct studies on the physiological impact of capture and handling associated with angling catch and release are rare. Prolonged playing times increase levels of physiological stress (Wood et al., 1983) particularly when combined with high water temperatures (Wilkie et al., 1996). Thorstad et al. (2003a) report of increased levels of physiological disturbance among angled Atlantic salmon with increasing playing times. This finding supports some circumstantial evidence from similar studies indicating that fish played and retrieved as quickly as possible tended to resume normal migratory behaviours more rapidly than fish played for extended periods (Webb, 1998).

Playing time was also loosely correlated to fish size. However, fish size *per se* is not a good predictor of physiological disturbance. Nevertheless, among mature salmon angled late in the season, physiological disturbance was shown to be less among multi-sea-winter (MSW) salmon than smaller grilse (1SW) (Booth et al., 1995). The capacity for exhaustive exercise, magnitude of post-angling disturbance and the likelihood of mortality following angling were all greater for fresh run (‘bright’) salmon that had recently entered freshwater than fish that had been in freshwater for some time and spawned (kelts) (Brobbel et al., 1996).

The process of retrieval and capture by the use of ‘hand-tailing’ or ‘beaching’ may require the fish to be played to a greater level of physical exhaustion than those landed via a landing net (Webb, personal observation).

*How will playing of the fish affect the fish' welfare and survival rate after release?*

Both catch and release and retention catch (catch and kill) involves a certain time of playing and possible air exposure. Likewise, the fish is either netted or drawn towards the angler to be caught. With similar playing time, catch and release does not impose significantly higher stress-levels than conventional retention catch. However, the combination of playing of long duration and significant air exposure may lead to exhaustion and poor condition of the fish. The condition of the fish is therefore likely to be affected by the duration of prior playing.

Under ideal conditions Atlantic salmon and other salmonids can probably cope with the effects of exhaustive angling. It is very difficult to establish the effects of playing time by anglers *per se* in isolation from other potential stressors (e.g. associated handling). Consequently, there is comparatively little data and information on the specific impact(s) of the duration and intensity of playing time on fish welfare and subsequent survival. Nevertheless, there is some circumstantial evidence that physiological disturbance is related to playing times and that fish that are retrieved quickly resume normal behaviors more quickly following release. As a general advice, anglers should a) reduce playing time to a minimum, and b) use equipment that facilitates rapid retrieval and capture (i.e. strong fishing line and a net).

*Figure 1: A gillie can be of great help during catch and release (Photo: T. Næsje).*

## 2. HANDLING

Catching of fish for retention differs markedly from that of catch and release. For retention fishing, the goal is to land the fish efficiently for killing. This may include beaching or pulling the fish aboard a boat, being dragged or lifted head-first fully or partially onto the shore by pulling the fishing line, using tail grasp (grasped by the base of the tail), or body/head grasp (the fish is brought the hand and grasped tightly, fingers may be temporarily inserted into the mouth, gills or eyes to prevent escape), being netted (scooped up with a 'landing net' in the water – which is then usually hoisted or carried out of the water to the shore or into a boat) and/or gaffed (a large metal hook is drawn quickly into or through the fish's body). Following landing, the fish are killed via a blow to the top of the head, often by use of an instrument called a priest. At this stage salmon are also often bled immediately by cutting the gills. The time between capture to final dispatch can vary from seconds to minutes.

Handling during catch and release may be quite similar to that used in retention fishing. However, in retention fishing, if the fish is removed and killed quickly it is unlikely that it will experience prolonged pain, fear or stress after landing since it is dead. Catch and release fish may experience, therefore, extended periods of handling and as such increased stress (Thorstad et al., 2003a; Suski et al., 2007; Thompson et al., 2008). Handling of fish during capture, hook removal and practices such as weighing, netting, holding fish in keep nets do result in significant physiological stress (Cooke et al., 2003b; Thorstad et al., 2003a; Butcher et al., 2008; Thompson et al., 2008; Whiles et al., 2009) which is exacerbated by higher temperatures (Meka and McCormick, 2005; Millard et al., 2005). Therefore, handling time should be significantly reduced in catch and release.

Handling in air has a significant effect on stress and mortality post-release since this leads to collapse of the gills as well as metabolic impairments due to reduced oxygen availability (e.g., rainbow trout, Ferguson and Tufts, 1992; rock bass, *Ambloplites rupestris*, Cooke et al., 2001; smallmouth bass, *Micropterus dolomieu*, Cooke et al., 2002; largemouth bass, Suski et al., 2004; Thompson et al., 2008). Different species vary in their sensitivity to air emersion (Arlinghaus et al., 2007). For some species, being held in air for less than a minute may cause increased mortality in exercised fish (e.g. rainbow trout mortality: air 0 seconds, 12 %; air 30 sec 38 %; air 60 sec, 78 %, Ferguson and Tufts, 1992). Fish are often seen to struggle and gulp trying to draw water into the mouth. Keeping fish in the water for the maximum amount of time possible would alleviate these effects. The use of a suitable net enables a fish to be unhooked while still in the water, involving less or no air exposure and the fish is recovering during the unhooking process.

Often landing fish involves the use of a landing net. Net abrasion can occur when knotted nets are used, so those that do not abraid the fish such as knotless nylon or rubber net are preferable, particularly with small diameter mesh (Barthel et al., 2003). Nets fitted with large mesh sizes may serve to increase the likelihood of damaging the fins, so landing nets used for catch and release should have a large enough opening for the whole fish but have small enough mesh size such that parts of it's body does not protrude through the net. Handling fish with wet hands may also reduce abrasions to the skin and removal of mucus. Gloves (abrasive) may damage the mucus layer, and should not be used.

Alteration of equipment and procedures used in catch and release angling may improve the welfare of individual fish. Rapid removal of hooks or cutting the fishing line when hooks are deeply embedded and cannot be easily removed, are also recommended. Recommendations have been made by Canadian and Australian angling groups (Schupplid, 1999; http://www.freshwatersanglers.com.au, cited in Cooke and Sneddon, 2007) but they are difficult to regulate. Norwegian recommendation brochures made by Norske Lakseelver and Norges Jeger- og fiskerforbund and an instruction video has also been produced (www.lakseelver.no; www.njff.no). Diodati and Richards (1996) and Meka (2004) reported higher fish mortality among inexperienced catch and release anglers than experienced demonstrating that training and experience lowers the risk to fish welfare.

Weighing of the fish should be avoided because of the increased handling time and increased chance of damage to the fish, e.g. fins, mucus and body when weighing. Length can be measured while still in water (the fishing rod can be used as a tape measure). There is a table in the Norwegian catch and release handling brochure, referred to above, where the angler can find the fish weight corresponding to the fish length. If weighed, it is possible to weigh fish in containers of water rather than in air.

Effective training and information dissemination is an important factor in improving the efficiency of angler's treatment of fish since experienced anglers cause fewer injuries to caught fish than novice anglers (Meka, 2004).

*Does handling of the fish during catch and release differ from handling during retention fishing? If so, what are the welfare implications of these differences? How will different types of handling affect the welfare: Handling with nets or with bare (dry/wet) hands, handling in water and out of water, duration of handling out of water and handling to remove hooks? Is it possible to do any of these handling procedures without removing the fish from the water? Is it possible to restrict the maximum handling time out of water to e.g. 15 seconds?*

In retention fishing, fish is landed by any means available and killed shortly afterwards. In contrast, fish subject to catch and release may experience extended periods of handling and the associated risks of increased stress and injury. Handling of fish during capture, hook removal and practices such as weighing, netting, and holding fish in live wells or keep nets do result in significant physiological stress which is exacerbated by higher temperatures.

Hooks should be removed while the fish remains in water – ideally contained within a large knotless net. Fish should be handled with wet hands and handling times minimised. Under normal circumstances, (especially if the angler is assisted by another person) hook removal can be done with long-nosed pliers while the fish is still in water, and the fish can be released without taking it out of water at all. If the hook is deeply embedded, the fish's head can be supported out of water for a few seconds while removing the hook or the line is cut. Hence, maximum handling time out of water can be restricted to 0-15 seconds, even when a photo is taken. This is achieved by letting the net fall away and holding the fish just above the water surface for a few seconds while taking the picture. If so, it is important to hold the fish horizontally with the combination of a gentle supporting grip around the base of the tail and support under the front part of the belly. Fish should not be held vertically (via the head or the tail) as this may damage the spine. The practice of weighing live fish should be avoided. Changes to equipment and handling procedures may improve the welfare consequences for individual fish subject to catch and release. However, relatively little research has been conducted in this area to fully validate the approaches outlined.

*Figure 2: If the fish has to be taken out of the water, hold it horizontally with a combination of gentle grip around the base of the tail and support under the front part of the belly. The fish on the picture has been tagged for a scientific study (Photo: T. Næsje).*

## 3. HUMANE KILLING

Humane methods of killing fish are proposed for fish used in experimental studies and in some countries for harvesting and slaughter of farmed fish yet little has been recommended for fish caught by angling (European Commission DGXI, 1996). Of course, catch and release results in the release of the caught fish so humane killing may not be considered important. However, in some circumstances fish otherwise destined to be released may be judged to be excessively injured or unlikely to survive, killing may be necessary.

In the case of excessive stress or injury, humane killing should be adopted (European Commission DGXI, 1996; American Veterinary Medical Association (AVMA), 2001). The Norwegian Animal Welfare Act (1974 and 2009) advises that animals should be treated well with no risk of causing unnecessary suffering and should be conducted by someone with the skill to humanely kill an animal using an appropriate method. The Act also specifies the need for immediate unconsciousness to reduce possible suffering but does not recommend a particular method of killing fish.

Euthanasia should be applied where deep hooking injuries are sustained to the gullet or extensive damage occurs to the gills (Arlinghaus et al., 2008). Excessive bleeding has been linked to high mortality (Millard et al., 2005; Arlinghaus et al., 2008) and, therefore, fish exhibiting high levels of blood loss may also be candidates for euthanasia, together with fish struggling to return to equilibrium, since this indicates a high level of stress (Danylchuk et al., 2007).

Killing of the fish that would otherwise be released involves the angler making an important decision about the likelihood of the fish suffering and surviving after release and may require education and training to identify the key signs of problems and appropriate humane endpoints. Humane endpoints are normally applied to scientific studies to identify a point where minimal pain, stress or suffering has occurred but enough data has been collected to achieve the aims of that study. Ideally humane endpoints would be identified before pain or stress are experienced by the animal, however, in angling the fish has to be hooked in order to be caught.

Humane slaughter methods have been developed for the aquaculture industry which are pertinent to recreational anglers (Robb and Kestin, 2002; van de Vis et al., 2003). The main principle of these slaughter methods is that the process of killing should render fish immediately unconscious until death without exciting the fish, causing pain or suffering (van de Vis et al., 2003).

Anglers may adopt a variety of methods, however, concussion where a sharp blow to the head using a blunt instrument (priest) is often employed. This can cause brain destruction or simply stuns the fish whilst pithing or destruction of the brain tissue may be performed or exsanguination (bleeding out) where the gills are cut leading to massive blood loss. If done correctly, the concussion method followed by pithing or exsanguination is considered humane as it results in immediate loss of consciousness within seconds (van de Vis et al., 2003). Inexperience at handling and killing fish can result in that the fish is hit several times before unconsciousness and death occur, thus a period of suffering may occur (Wall, 2001). Other approved methods include cervical disruption, pitching and overdose of anaesthetics for humane killing of fish in the laboratory (AVMA, 2001; European Commission DGXI, 1996). Suffocation in air and the use of live chilling where fish are left on ice to die are not humane and should not be employed (van de Vis, 2003). The practice of despatching the fish as quickly and efficiently as possible is the most humane approach.

*What kinds of conditions will due to welfare considerations require that fish are killed and not released?*

If a fish is judged to be unlikely to survive following release, then it may be appropriate to humanely kill it. The criteria for such action may include sustained deep hooking injuries to the gullet or extensively damaged gills. Excessive bleeding has been linked to high levels of mortality and may also therefore be an appropriate justification for euthanasia together with the failure to respire normally or return to equilibrium or normal swimming.

Clear criteria should therefore be developed to avoid poor standards of fish welfare and to minimise the risks of the deliberate abuse of the right to kill fish in catch and release fisheries.

*Figure 3: Priest (Photo T. Poppe).*

## 4. HOOK TYPES AND REMOVAL OF HOOKS

Hooking location is perhaps the single most important equipment related mortality factor for angled fish (Cooke and Wilde, 2007), and hook type may play an important role for catch and release mortality arising directly from hooking injuries (Muoneke and Childress, 1994; Cook and Wilde, 2007). Hook type and design may also influence the handling time and any associated air exposure time (Cook et al., 2001). Due to different angling techniques, fish morphology, feeding ecology, behaviour, life history etc., it should be noted that results from a study of one species under certain conditions are not necessarily applicable for another species, or the same species under different conditions.

When evaluating the effect of hooks and hooking, it should be noted that many studies, including those conducted in Norwegian fisheries, indicate that catch and release of Atlantic salmon at water temperatures of less than 17-18°C results in low levels of mortality (0-6 %) (see chapter 5e). The potential to significantly reduce mortality further via changes to terminal gear may therefore be relatively limited in these fisheries.

In the recreational rod and line fisheries in Norway, Atlantic salmon, Arctic char and sea trout are mainly caught on flies, lures, and natural baits. Generally, only the use of worms, spoons, spinners, wobblers/plugs and flies is permitted (Forskrift 2003-02-25 nr 256. Forskrift om oppgaveplikt og om redskaper som er tillatt benyttet ved fiske etter anadrome laksefisk). However, at the local level, County Governors and other local stakeholders have the powers to issue more detailed restrictions. Only one bait per rod is currently permitted.

A large variety of different designs and sizes of hooks are readily available to anglers. In most cases the selection is a matter of personal choice. However, some fisheries may choose to prescribe, via a voluntary or mandatory code, the number, size and design of hooks, or the use of barbless hooks. In Norway, large hooks, 13 mm (multiple hooks) or 15 mm (single hooks) from stem to the hook point, are prohibited in an effort to reduce the risks of ‘foul-hooking’ (Forskrift 2003-02-25 nr 256. Forskrift om oppgaveplikt og om redskaper som er tillatt benyttet ved fiske etter anadrome laksefisk).

Hooks used in fly fishing may be single hooks, double or treble hooks, with or without barbs and with variable sizes. Treble hooks are also used in combination with certain types of salmon and sea-trout flies, such as tube-flies and Waddington shanks. Traditionally, one or several sets of treble hooks of variable sizes are used with artificial baits (spoons, wobblers and spinners). When fishing with worms, single hooks are most commonly used.

### One or several hooks

Comparative studies of fish mortality linked to one or several hooks have shown contradictory results. According to Muoneke and Childress (1994) single hooks may be more deeply ingested that treble hooks, but if ingested, treble hooks cause more severe injuries. Ayvasian et al. (2002) reported that treble hooks caused significantly greater mortality of tailor (*Pomatomus saltatrix*), than other hook types. In a study of striped bass (*Morone saxatilis*), Diodati and Richards (1996) found that treble hooks were associated with lower mortality compared with single hooks, which were more likely to be swallowed. In a salmonid study, DuBois and Dubielzig (2004) found that there were no differences in the frequency of serious injuries or mortalities for brown trout, rainbow trout, or brook char (*Salvelinus fontinalis*) caught with treble hooks or single hooks. Similarly, for rainbow trout, Jenkins (2003) found that single baited hooks and treble hooks were lodged in the oesophagus at the same rate. Department of fisheries and Ocean (DFO) (1998) reported that barbless double hooks produce more lesions than barbless single hooks. However, Taylor and White (1992) failed in demonstrating difference in mortality between the two hook types in non-anadromous trout.

The hook points cannot be easily manipulated and removed from tissues independently when using double or especially treble hooks. Therefore, the removal of treble hooks may require longer handling times, as demonstrated for rainbow trout (Meka, 2004). Replacing treble hooks with single hooks (or even double hooks) may be considered a means of reducing the risks of lesions associated with hook penetration and facilitating easier removal and reduced handling times (Pelletier et al., 2007). However, more studies are needed to assess whether more hook points causes higher mortality rates in catch and release fisheries for Atlantic salmon, sea trout and Arctic char.

### Hook type or size

A large number of hook designs are available on the market, but only circle hooks have had a consistent positive effect on the hooking location when compared with conventional J hooks (Cooke and Suski, 2004; Bartholomew and Bohnsack, 2005; Cooke and Wilde, 2007). Circle hooks are used mostly with live or natural baits, and are intended to penetrate and lodge in the jaw. Cooke and Suski (2004) reviewed the use of circle hooks in more than 40 studies. They found considerable variation in the mortality of fish caught with both J and circle hooks, but the overall mortality was consistently lower for circle hooks. This was also found in studies of Pacific salmonids; coho salmon (*O. kisutch*) (McNair, 1997) and Chinook salmon (*O. tshawytscha*) (McNair, 1997; Grover et al., 2002). In addition, Meka (2004) reported that the frequency of internal injuries in rainbow trout were much less using circle hooks than traditional J hooks. However, there are also some studies showing low mortalities for all studied types of hooks, including circle hooks, for example in studies of rock bass (*Ambloplites rupestris*) (Cooke et al., 2003a), bluegill (*Lepomis macrochirus*) and pumpkinseed (*L. gibbosus*) (Cooke et al., 2003c).

If hooks are deeply embedded (hook points penetrating the oesophagus and/or stomach with resultant damage to internal organs such as heart or liver), they almost certainly will result in serious injury and mortality (white seabass, *Lates calcarifer* (Aalbers et al., 2004), brook trout, (DuBois and Kuklinski, 2004), rainbow trout (Mason and Hunt, 1967), largemouth bass *Micropterus salmoides* (Pelzmann, 1978). Hook size may also affect the frequency of deep-hooking. In several species of Mediterranean fish, it has been shown that fish taken with larger hooks were seldom deeply hooked (Alos et al., 2008). This may be explained by physical limitations for the fish to swallow larger objects, and the fact that large hooks are easier to remove than smaller ones. However, Thorstad et al. (2000) found no difference in the hooking site of different sized hooks (artificial flies) used to catch Atlantic salmon in the River Alta fisheries.

*Figure 4: Treble, normal and circle hook (Photo T. Poppe).*

*Figure 5: Barbless fly hook (Photo T. Poppe).*

### Live, natural or artificial lures

Several reports compiled by Arlinghaus et al. (2007) deal with mortality in different species subjected to different angling methods. The type of bait or lure may also influence the hooking place and, hence, the level of associated mortality (Warner, 1976, 1979). Studies performed in the Rivers Kharlovka, Eastern Litsa and Ponoi, in North West Russia, (fly fishing, ICES, 2009) and in the River Alta, Norway (fly fishing, Thorstad, 2003a), documented that 5-7 % of the salmon caught were hooked in the gill arches. Hooking in the gill arches and the associated vessels may cause levels of wounding and associated bleeding that are lethal. Studies on flies versus lures and bait show that flies tend to be less injurious and have a lower chance of causing mortality (Arlinghaus et al., 2007). For example, hooking mortality in rainbow trout was shown to be lowest by several fold for fly-caught fish compared to lures (Schisler and Bergersen, 1996). Similarly, Meka (2004) showed that rainbow trout captured on spinning lures tended to be injured more frequently than fish caught by fly-fishing. Muoneke and Childress (1994) concluded that artificial lures as spoons, spinners, wobblers and flies tend to hook fish superficially thereby allowing quick hook removal and less opportunity for damage to vital organs or tissues. Pauley and Thomas (1993) revealed that cutthroat trout (*Oncorhynchus clarkii*) mortality rates were generally higher for fish captured on worm-baited hooks (40-58 %) relative to those captured on lures (11-24 %). Further, high mortalities (73 %) were recorded for landlocked Atlantic salmon allowed to swallow worm baits, while worm and fly-hooked salmon generally suffered higher mortality than salmon caught on lures (Warner, 1976, 1979). In contrast, studies of ling cod (*Ophiodon elongates*) (Albin and Karpov, 1998) and weakfish (*Cynoscion regalis*) (Malchoff and Heins, 1997) did not find differences in mortality between fish captured on natural baits and those caught on artificial lures.

Organic and live bait are typically fished more passively or with a slack line compared to artificial baits. Schill (1996) found that the frequency of deep hooking was greater in rainbow trout captured on a “slack line” than on a “tight line”. Similar observations were made by Schisler and Bergersen (1996) among rainbow trout caught with artificial fish eggs as bait.

### Barbless or barbed hooks

Traditionally, hooks have been designed to penetrate effectively through the mouth parts of the fish and then to prevent the hook from dislodging. This is, achieved through the use of barb; a sharp pointed part of the hook that points backwards.

Arlinghaus et al. (2007) reviewed the literature on barbed versus barbless hooks and found conflicting results. For example, the use of barbless hooks has been shown to reduce the amount of time required to remove the hook by increasing the ease of removal (Diggles and Ernst, 1997; Cooke et al., 2001; Schaeffer and Hoffmann, 2002; Meka, 2004). Furthermore, tissue damage on hook removal was also reduced using barbless hooks. In contrast, Schill and Scarpella (1997) synthesized the results of past studies comparing hooking mortality of resident salmonids caught and released with barbed and barbless hooks. The authors concluded that the use of single barbed or barbless flies or lures plays no role in subsequent mortality of trout caught and released by anglers. Taylor and White (1992), Schill and Scarpella (1997) and Turek and Brett (1997) have also concluded that single barbless hooks provide little benefit compared to barbed hooks. Nevertheless, in spite of these studies, based on the reduced handling times and increased sub-lethal injuries, the use of barbless hooks has been recommended for use in catch and released fisheries (Cooke et al., 2001; Cook and Suski, 2005; Arlinghaus et al., 2007; Pelletier et al., 2007). Barbless hooks are now readily available in most fishing tackle shops and mail order outlets, and barbed hooks can be easily de-barbed with the use of pliers.

### Hook removal

The purpose of most hooks is to get lodged in the jaw, where they can best be removed using long-nosed pliers or forceps. Unless the hook is set immediately after the strike, it will be more or less swallowed by the fish and may penetrate deep into the tissues of the gills, pharynx, oesophagus or stomach ("deep hooking"), and will, therefore, be more difficult to remove without causing damage to the fish (Pauley and Thomas, 1993). Deep-hooking is frequently correlated to haemorrhage after release (Alós et al., 2008). Typically the removal of such hook(s) will be more difficult, the level of damage to soft tissues more extensive, and may require more handling of the fish than is desirable. All these factors are likely to increase the risks of damage and reduced survival after release (Cooke and Wilde, 2007). Special pliers and de-hooking devices have been designed in order to facilitate the removal of hooks embedded in soft tissues.

As hook removal in deeply hooked fish may cause increased injuries, it has been recommended to cut the fishing line and leave the hook in the fish: often under the assumption that the hook will eventually be regurgitated (Bartholomew and Bohnsack, 2005; Cooke and Wilde, 2007). For example, Schill (1996) found that 60 % of rainbow trout managed to expel hooks. Some studies have presented results documenting reduced mortality if the hook was not removed in deeply hooked fish, e.g. for rainbow trout (Schill, 1996; Schisler and Bergersen, 1996). Aalbers et al. (2004) also found increased survival in white seabass (*Atractoscion nobilis*) when deep hooks were left in, but the growth rate of the affected fish was reduced. Others report similar mortality rates for fish where the hooks were left in or removed, such as red drum (*Sciaenops ocellatus*) hooked in the oesophagus (Jordan and Woodward, 1994). Wilde and Sawynok (2009) studied the catch and release recapture rates of 27 Australian species and found that recapture rates were similar for fish were hooks were left in versus those from which hooks were removed. In a study on Japanese char (*Salvelinus leucomaenis*) and masou salmon (*Oncorhynchus masou*), Doi et al. (2004) found that hooks removed from the mouth caused low mortality (0-15 %) in both small and larger fish within 21 days after catch and release. In contrast, if the hooks were not removed from the mouths of the larger char, mortality was relatively high (40 %). When hooks were removed from the oesophagus, levels of mortality were significantly higher both in small char (66.7 %) and large masou salmon (45 %).

Deep hooking may be less of a problem when circle hooks are used (Cooke and Wilde, 2007), and the use of barbless or de-barbed hooks makes the removal of the hooks from the pharynx or oesophagus region easier and faster (Cooke and Suski 2004; Meka, 2004).

*Are certain hooks more aversive to fish, and do any hooks cause more lesions? Will the additional use of live bait or other types of bait cause additional tissue damage? Does the removal of the hook cause any additional suffering? Will the removal of deeply embedded hooks or certain types of hooks imply higher risks of suffering?*

The reviewed literature suggests that the hooking location may be the single most important equipment related factor determining the outcome of a catch and release procedure. However, the probability of being injured and mortality when using one gear type for one species is not easily transferable to another species. In addition, studies exploring the number of hooks, use of live, natural or artificial bait and removal of hooks on mortality are contradictory and may depend on the species studied and angling techniques applied. Only a few studies have been performed on Atlantic salmon, while none have been conducted on sea trout and Arctic char caught during the river phase. More studies are, therefore, needed with regard to all three species before the effect of different types of hooks and bait combinations can be determined.

However, in general when fishing with live or natural bait the use of circle hooks seems to result in less harmful hooking positions than other types of hooks. In addition, if a fish is deeply hooked the removal of the hook may cause increased injuries compared to cutting the line and leaving the hook in the fish.

The number of hooks used and the use of barbless hooks may influence subsequent handling times, but whether the increased handling time caused by increased number of hooks or barbed hooks have any significant influence on levels of fish mortality is uncertain and may be dependent on associated factors such as angler competence.

Published studies generally show that there is an increased risk of deep hooking when using live bait compared to flies and spinning or wobbling lures. However, this may not only depend on the type of bait used, but also the angling techniques. There are no known studies on the effect of hooking location associated with worm fishing for salmonids in Norway. However, the general pattern gleaned from a number of studies of other species indicates that there may be a greater risk of deep hooking during worm fishing (i.e. natural baits) than when using flies and lures.

*Figure 6: Most often the hook can be easily removed with long-nosed pliers (Photo: T. Næsje).*

## 5. AFTER RELEASE

### A) RECOVERY TIME

Recovery is the process whereby an individual returns to a normal state, and in veterinary or medical terms this means the animal returns to a healthy condition. In a catch and release context, recovery can be defined as a complete return to normal behavioural and physiological functioning after being returned to the water (Anderson et al., 1998). If not seriously wounded by the fishing activity in the immediate phase (hook or handling), most fish appear to be able to recover rather soon after exposure to angling (Arlinghaus et al., 2007). Furthermore, in the majority of cases, fish seem to recover and return to the pre-fishing physiological state within 2 to 24 hrs if they are not disturbed again and the water quality is good (Wang et al., 1994; Milligan, 1996; Richards et al., 2002; Suski et al., 2006).

Insights into the subsequent post-release behaviours and fate of adult Atlantic salmon released by anglers have been provided by various tagging studies. Real-time behaviours have been recorded directly via the use of radio or acoustic tagging and rates of movement and survival have been inferred by analysis of recapture data of normal (non-transmitting) external tags or marks. Tracking studies suggest that movements immediately following release away (particularly downstream) from the release site are common. However, there is significant variation between the frequency and extent of such behaviours within and among studies.

The frequency of rapid, longer-range movements (>2 km) immediately following release (particularly downstream) is low and usually takes place over the course of 24 – 48 hrs. (Walker and Walker, 1992; Webb, 1998). However, fish exhibiting rapid and unusually extensive movements away from the release site are no more or less prone to in-river mortality or recapture than other groups. Consequently, these behaviours may therefore constitute an atypical response to a complex range of factors including aspects of capture and associated handling prior to release, individual migratory states and homing targets of different fish, and the local characteristics of the watercourse. The extent to which these kinds of immediate post-release behaviours constitute direct physiological or behavioural responses to stress or fear is therefore not known.

Several studies suggest that catch and release angling and associated handling at water temperatures at 17-18°C and above can result in elevated levels of immediate and delayed mortality (e.g. DFO, 1998) (See also chapter 5e).

*Which factors will affect the recovery rate, including those mentioned above and any additional factors, such as environmental variables (e.g. water or air temperature)?*
*How long will it take for the fish to recover and resume normal physiological body functions and behavioural patterns?*

Recovery rate will be affected by a number of factors. Fish that are caught in warm water and weather conditions, fully exhausted, handled extensively are likely to require the longest period of recovery. Elevated levels of mortality of Atlantic salmon have been associated with water temperatures higher than 17 ºC (see also chapter 5e).

### B) WOUND INFECTIONS AND INFECTIOUS DISEASES

Stress and physical injury is a major factor in the health of fish, and it is well known that stress in general (chemical, toxicological, physical, etc), increases the susceptibility of fish to infections (Wendelaar Bonga, 1997, Ingram, 1980). Fish may carry pathogens but clinical problems only occur after particularly stressful events. For example, common aquaculture practices can cause stress and injury that can strongly increase the susceptibility of farmed fish to pathogens (Ashley and Sneddon, 2007). Skin and scales are most commonly damaged by handling stress. Scale loss, skin abrasions and fin damage resulting from poor handling techniques (including contact with sediments and line) during retrieval of the fish, may lead to chronic stress and may in turn increase susceptibility to infections and parasites. Potential pathogens first of all include fungi (*Saprolegnia* spp) and opportunistic bacterial infections (e.g. *Aeromonas* spp., *Pseudomonas* spp.) (Ferguson, 2006).

Lesions associated with catch and release may occur first of all as physical damage to mouth parts, or as scale loss and epidermal damage following handling or physical contact with gravel, rocks, sand etc. The use of landing nets with a coarse knotted mesh will also have the potential to cause severe bruising to the skin and trapping and splitting of fins (particularly the tail, pectoral and pelvic fins). The use of proper landing nets and other procedures of landing (Chapter 2) will reduce the risk of damage to skin and fins.

Physical damage to mouth parts occurs regularly where catch and release is practised. For example, Meka (2004) found that 30 % of the rainbow trout in the catch and release fishery on the Alagnak river (Alaska) had at least one scar consistent with hooking. The most common type of damage was tearing, dislocation or complete loss of the maxilla, the external part of the upper jaw (Figure 7). Damage to both the jaws and the eyes occurred in 10 % of the fish sampled.

*Figure 7: Atlantic salmon with damaged maxilla (Photo T. Poppe).*

*Figure 8: Brown trout* with *undamaged maxilla (Photo J. Webb).*

Reports of secondary infections associated with hook penetration related lesions in the mouth have not been found. Furthermore, the extent to which damage to the oral region including loss of the maxilla interferes with normal feeding behaviours and intake is not documented. Damage may also occur to the gills, particularly if the fish is deeply hooked. The gills should never be touched with hands as they are fragile structures that easily break, causing haemorrhage and increased susceptibility to fungal infection (Ferguson, 2006; Pickering and Richards, 1980).

The skin of salmonid fish is covered by scales. The scales originate in pockets in the dermal layer of the skin and are covered by epidermis and a mucus layer of variable thickness (Figure 9).

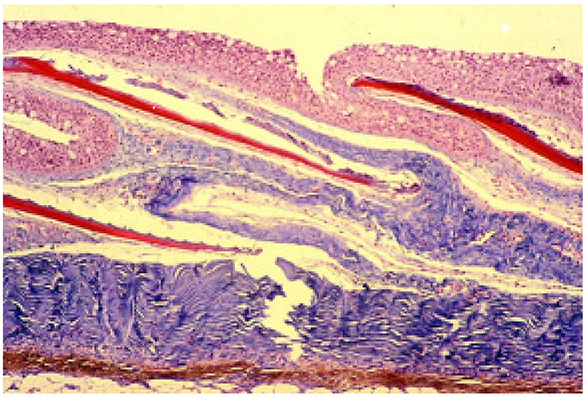

*Figure 9: Trichrome-stained section of normal salmon skin showing scales (red) covered by epidermis (pink) with numerous goblet cells producing mucus. The scales are embedded in the dermal layer of the skin (blue).*

The thickness of the skin may vary considerably, and is usually thicker in spawning fish than in sexually immature fish (Ferguson, 2006). An intact epidermis and mucus layer is important not only for the osmotic integrity of the animal, but also as a barrier against opportunistic pathogens such as fungi and bacteria (Ferguson 2006, Pickering and Richards 1980). A typical infection following both scale and epidermal loss after handling is infection with the opportunistic fungal pathogen *Saprolegnia* spp. (Hughes, 1994; Willoughby, 1978). *Saprolegnia* spp. is ubiquitous in the aquatic environment and has an important function in breakdown of dead organic material in water. However, it may also infect damaged fish tissues such as the skin and fins. Affected fish typically show cotton-like coats of fungal mycelium on the skin surface (Figure 10).

*Figure 10: Dorsal view of brook trout with severe* Saprolegnia *infection following handling with dry hands (Photo T. Poppe).*

The colour of the mycelium is typically white to off-white, but may also be brownish depending on the water colour and quality. On removal of the fish from the water, the cotton-like mycelium collapse to a slimy coat on the skin surface. Such lesions can spread readily and will often be fatal to the fish.

Superficial damage to the skin and gills may also facilitate the entry of other pathogens; first of all ubiquitous bacteria in the aquatic environment such as *Aeromonas hydrophila* and *Pseudomonas* spp. However, reports of such infections following catch and release are rare and not well documented.

*Will released fish be more prone to wound infections or infectious diseases?*

Fish caught and released are subjected to wounds during hooking, usually in the oral region but also occasionally in the gills and gullet. The skin may also be damaged due to handling procedures prior to release. However, it is has not been demonstrated that catch and released fish are more prone to secondary infections through wounds or otherwise, but it cannot be ruled out because susceptibility of fish to such infections is known to be correlated to stress (including environmental).

It is well known and accepted that stress in general (yet there is little or no documentation of increased occurrence of either bacterial or viral infections in areas where catch and release is currently practised. Skin and gill lesions may, however, often be invaded by opportunistic aquatic fungi - particularly *Saprolegnia* spp. that may cause severe wounding or lesions and as a result increased levels of mortality. The significance of careful handling with wet hands and avoidance of exposing the fish skin to sand, gravel and coarse twine or knotted mesh landing nets should, therefore, be emphasised along with hook types that cause the least damage. Minimising damage should reduce the risk of secondary infections.

### C) REPRODUCTION

When evaluating potential effects of catch and release on spawning and reproduction it should be noted that angling for anadromous salmonids in Norway usually ends several weeks before the fish commence spawning. For example in Atlantic salmon, the peak spawning period for 16 populations varied between 20 October and 10 January (Heggberget, 1988), while the associated river fisheries end on the 31 August at the latest. Potential long term or delayed effects of catch and release are therefore more likely to affect reproduction than shorter term or initial effects.

Documentation of the correspondence between physiological and behavioural effects and the effects on reproductive fitness and production is lacking in most studies of effects of catch and release on Atlantic salmon (Thorstad et al., 2008a). In the few studies that exist, there is no indication that there are any significant negative effects by catch and release on gamete viability, survival of eggs, survival to hatching or fry first feeding (Davidson et al., 1994; Booth et al., 1995). However, there is some evidence that acute stress may affect reproduction of salmonids through several mechanisms including alterations in the levels of reproductive hormones, suppressed ovulation and egg production, and reductions in gamete quality (conf. Booth et al., 1995). However, Boot et al. (1995) did not find any difference in the hatching success of eggs from late angled and non-angled Atlantic salmon. Reproductive activity can also be suppressed directly during periods of stress, via an effect on reproductive hormones (Pickering et al., 1987; Pankhurst and Van der Kraak, 1997, Wendelaar Bonga, 1997). However, it is unknown whether the stress imposed by catch and release may be large enough to cause long term effects with consequences for reproduction.

In the River Alta, Atlantic salmon caught, radio tagged and released both early and late in the fishing season, at different phases of their upstream migration, were all recorded on known spawning sites during the spawning period (Thorstad et al., 2003a, 2007). Therefore, hooking, retrieval and associated handling (in excess of what might be expected for normal catch and release fishing), did not influence the Atlantic salmon’s ability to find suitable spawning grounds. In addition, visual observations of caught and released Atlantic salmon have recorded spawning (Berg et al., 1986; Thorstad et al., 2003a) and spent fish (Whoriskey et al., 2000; Thorstad et al., 2003a).

Concerns have been expressed in both North America and the UK that late season catch and release angling may have the potential to negatively impact the reproductive competence of the released fish (see Booth et al., 1995, Tufts et al., 2000). Nevertheless, the physiological response of Atlantic salmon to angling late in the season has been shown to be similar to other forms of exhaustive exercise, while the physiological recovery may be more rapid than in other salmonid species (Wood, 1991; Booth et al., 1995; Tufts et al., 2000). Moreover, levels of spawner mortality and egg survival are similar in angled and non-angled Atlantic salmon, suggesting that the likelihood of delayed mortality is minimal with no significant consequences for gamete viability (Tufts et al., 2000).

The relatively long period between the catch and release event and the spawning season for the Norwegian salmonids, may suggest that these concerns are unlikely to be relevant under the present management regime in Norway.

Positive population effects of catch and release angling have been documented in the River Alta Atlantic salmon population (Thorstad et al., 2003a; Ugedal et al., 2007). The number of spawning redds more than doubled after introduction of compulsory catch and release in a section of the river that had both reduced levels of recruitment and juvenile population size after being affected by hydropower development (Thorstad et al., 2003a). Also in the River Ponoi, Russia, densities of Atlantic salmon juveniles increased after the introduction of catch and release angling (Whoriskey et al., 2000).

*Is the fish' reproduction affected? If so, in what way?*

It is not known if and to what extent the stress imposed by catch and release on maturing anadromous salmonids will have long term effects that are likely to affect gamete production, spawning and the resulting offspring negatively. Few studies have focused on this with regard to Atlantic salmon and non are known on sea trout and Arctic char. So far, no negative effects on reproduction have been documented. In studies of caught and released Atlantic salmon, more than 90 % of the fish were documented to be alive and present on known spawning grounds during the spawning period, and spawning has been observed. More studies, however, are needed to conclude on this question.

### D) PREDATION

Mortality due to predation of individual fish is generally difficult to study in nature. Only a few investigations have quantified predation mortality after catch and release. However, the studies were done on others species, such as marine bonefish (*Albula* spp.) (e.g. Cooke and Philipp, 2004; Danylchuk et al., 2007), and the high predation rate reported (due to shark predation), may not be relevant to the present assessment. Therefore, little relevant data exist for the anadromous salmonids and no detailed studies of predation after catch and release has been published for the species that are the focus for this report. However, in a study conducted in Western Scotland, Cunningham et al. (2002) reported that both salmon unaffected by catch and release and salmon returned by anglers (bearing tags) were predated by otters (*Lutra lutra*) during the subsequent spawning period. Jensen and Rikardsen (2008) anecdotally referred to an observation of an otter predating a large sea trout (3-4 kg). This episode was linked to reduced ice cover and increased fish exposure below a hydropower plant. As direct evidence is lacking, the assessment below is therefore based on parameters that may influence fish predation after catch and release in general.

### Stress and predation

Catch and release may cause fish to behave aberrantly making them more vulnerable to predators, for example via changes in behaviour (Schreck et al., 1997). After catch and release, individuals may experience a period of set-back due to sublethal factors (e.g. stress and minor injuries), which may in turn cause aberrant behaviours which act to increase predation risks (Arlinghaus et al., 2007). In addition, the risk of predation may also be increased when fish are released into habitats where they normally do not normally reside, such as in shallow or calm waters and away from shelter.

### Predators and fish size

Over much of Norway the minimum size limit at which anglers are permitted to kill anadromous salmonids is 35 cm. The exceptions include Nordland, Troms and Finnmark Counties which have a smaller minimum size limit of 30 cm for sea trout and Arctic char (Kgl. res. 20 juni 2003). In rivers, the potential predators on salmonids larger than the statutory size limit include mammals (e.g. seals, otters, and mink), large piscivorous birds (e.g. sea eagle, osprey and sea gulls) and large piscivorous fish (e.g. pike). As predation risk may be size dependent, smaller sea trout and Arctic char returned by anglers might theoretically be more susceptible to predation than Atlantic salmon.

*Will the fish be more susceptible to increased predation? If yes, how great a percentage of the fish might be expected to die due to predation?*

Fish may be more susceptible to predation in the recovery period immediately after catch and release. The likelihood of predation is probably inversely related to size with small fish being most prone. However, any extension of existing requirements to release fish (i.e. above the existing size limit of 30-35 cm for retention) will necessarily involve larger fish, which by virtue of their size may be less susceptible to predation. In most rivers, potential predators as seals, otters and eagles are relatively rare, and in watercourses where large pike are present, the highest predation risk is likely to be associated with lakes and slow flowing parts of the river. However, if predators are present, then particular care should be taken to refine handling procedures and make sure that fish are released in good condition and in suitable habitat.

If fish are released in good condition and the presence of potential predators is low, as in most rivers, the rate of loss via predation of fish that otherwise would be killed in retention fishing, is expected to be low in catch and release fisheries involving anadromous salmonids.

### E) MORTALITY RATE

Mortality may be divided into immediate or initial mortality defined as capture related death that occurs during and following capture up to the time when the fish is released, and delayed mortality defined as mortality that occurs after the fish is released.

The mortality rate after catch and release varies significantly (0 – 89 %) among different species (Muoneke and Childress, 1994). The most important factors affecting rates of post-release (delayed) mortality are stress (e.g. water temperature and air exposure) and physical injuries caused by retrieval, hook and handling related wounds. Most mortality usually occurs within 24 h of release (e.g. Warner 1976, Muoneke and Childress, 1994; Brobbel et al., 1996; Carbines 1999, Tufts et al., 2000), but longer-term effects caused by for example, injuries and a generally reduced condition after hook and release may also occur. Circumstances and actions that risk causing severe sub-lethal injuries to fish should therefore be avoided to minimize the risks of suffering and loss of reproductive fitness and production.

Levels of mortality after release might depend upon local environmental conditions. Water temperatures appear to be a very important factor influencing fish survival after catch and release (Gustavson et al., 1991; Wilkie et al., 1997; Wilde, 1998; Wilde et al., 2000; Dempson et al., 2002; Thorstad et al., 2003a). Fish are poikilothermic, with body temperatures similar to the external environment. Changes in water temperature may have significant impacts on a fish's metabolism (Fry, 1971). The level of dissolved oxygen in water decreases with increasing water temperature. The availability of oxygen is an important factor for fish recovering from stress, and reduced oxygen levels may be the reason for reduced recovery for fish released at higher water temperatures (Arlinghaus et al., 2007). However, different species, populations and individuals might have different adaptations and tolerance to water temperature (Beitinger et al., 2000; Arlinghaus et al., 2007). Atlantic salmon from different Norwegian rivers have been shown to have different thermal performance (growth and food consumption) at the same temperatures (Finstad et al., 2004).

Different species of fish vary significantly in their sensitivity to handling and air exposure (Arlinghaus et al., 2007). For some species, air exposure for less than a minute may cause increased mortality in exercised fish (rainbow trout mortality: air 0 sec, 12 %; air 30 sec, 38 %; air 60 sec, 78 %; Ferguson and Tufts, 1992), while other species may survive for long periods in air (for example the European eel *Anguilla anguilla*). The handling technique during and after landing the fish, may also play an important role for the survival. Diodati and Richards (1996) and Meka (2004) reported higher levels of mortality among fish released by inexperienced anglers than experienced anglers. The tolerance to handling may, however, vary among species.

Catch and release has been studied in both laboratories and *in situ* (i.e. under natural conditions), but the methods to assess mortality after catch and release may affect the results (Table 4 and 5). Typically, in laboratory studies experimental fish have been chased to exhaustion, sometimes after being hooked or angled, to simulate angling impacts, and most studies have focussed on immediate or initial levels of mortality (up to 72 hrs after simulated release). In some of the *in situ* studies, previously caught fish have been hooked and played, but in the majority, the fish have been angled in a normal way. Under experimental conditions, it is very difficult to treat fish as it would be in a normal catch and release fishery. For example, catch and release under normal conditions might involve a wider spectrum of handling competency ranging from optimal to poor. Consequently, the scientific results of some studies that have been conducted in the laboratory might therefore be atypical than would be experienced under more “normal” conditions.

Although the fish may be forced to experience a longer handling time as part of telemetry studies than under normal catch and release conditions, the approach does allow researchers to follow the fate and behaviour of individual fish in their natural environment for weeks and months, and often until spawning. In contrast, *in situ* studies, may involve fish being released into pens or other types of enclosures. However, such approaches to post-release monitoring might serve to increase levels of mortality, especially over longer periods, as being held in captivity may generate stress as well. It should also be noted that in some of the cited studies the primary objectives and design were not to study catch and release mortality, and that the mortality rate was presented as supplementary information to the main findings.

### Atlantic salmon

Mortality rate due to catch and the release and effects of water temperature

The catch and release related mortality reported in published studies of Atlantic salmon has been highly variable, ranging from 0 to 40 % (Table 4, 5 and Figure 11). The highest mortality recorded in an *in situ* study was 40 % (Wilkie et al., 1996). However, the number of fish in this study was relatively low (10 fish) and the fish were held in an enclosure post-treatment to study mortality. However, there was no control group to establish mortality due to catch and release and the effects of being held in the enclosure. The study period was only 12 hrs and, hence, the fish died soon after handling. With the exception of this study, all other *in situ* studies report a range of mortalities lower than 22 % (Table 4). Generally, the mortality rates were low (0 – 6 %) when the water temperature was below 17-18 $^{o}$C. From 17-18 $^{o}$C upwards the rates of mortality increase (Thorstad et al., 2003a, 2007), and are predicted to be higher than 20 % from 20 $^{o}$C upwards (Dempson et al., 2002). In the study by Wilkie et al.

(1996), hooking mortalities were 0 % at 6 °C and 40 % at 22 °C. However, it should be noted that for all *in situ* studies documenting mortality rates of 9 % or above, the fish were held in enclosures in the river, which might have served to increase the rate of mortality (Table 4).

The numbers of reliable studies conducted under natural conditions at high water temperatures are few, and to determine reliable mortality levels for catch and release at water temperatures above 17-18 °C more studies should be performed.

Not included in our overview is the work of Anderson et al. (1998) who reported 80 % mortality after 72 hrs in a study of only five catch and release simulated fish in the laboratory. We have excluded this study because the number of fish was low and the fish had been surgically equipped with heart rate transmitters, which may have considerably added to the stress level.

**Table 4.** Mortality rates (%) and water temperature ($^{o}$C) in wild Atlantic salmon catch and release experiments conducted in rivers and lakes.

| Mortality % | Water temp. | Study period | No of fish | Fish size | Location | Method | Reference |
|---|---|---|---|---|---|---|---|
| 0 | 6 ± 1 | 24 hrs | 20 | Large | Miramichi R. | In-river, H | Booth et al., 1995 |
| 0 | 4 ± 1 | 12 hrs | 24 | Small | Miramichi R. | In-river, H | Brobbel et al., 1996 |
| 0 | 12 ± 2 | 14-40 days | 8 | Small | Conne R. | In-river, A | Dempson et al., 2002 |
| 0 | 9 ± 1 | ? | 5 | Small | Teno R. | Natural, A, T | Mäkinen et al., 2000 |
| 0 | 12 | Until spawning | 37 | Small, large | Målselva R. | Natural, A, T | Svenning, 2007 |
| 0 | 11 – 15 | Until spawning | 34 | Small, large | Orkla R. | Natural, A, T | Thorstad et al., 2003b |
| 2 | ? | 24 hrs | 62 | Small, large | Ponoi R. | Natural, A, T | Whoriskey et al., 2000 |
| 3 | 12 ± 2 | Until spawning | 30 | Small, large | Alta R. | Natural, A, T | Thorstad et al., 2003a |
| 3 | 12-14 | Until spawning | 62 | Small, Large | Alta R. | Natural, A, T | Thorstad et al., 2007 |
| 4 | 2-22 | Until spawning | 24 | Small, large | Dee R. | Natural, A, T | Webb, 1998 |
| 9 | 19 ± 2 | 14-40 days | 21 | Small | Conne R. | In-river, A | Dempson et al., 2002 |
| 10 | 16 ± 1 | 14-40 days | 20 | Small | Conne R. | In-river, A | Dempson et al., 2002 |
| 12 | 16 ± 1 | 12 hours | 25 | Small | Miramichi R. | In-river, H | Brobbel et al., 1996 |
| 15 | ? | Until spawning | 208 | Small, large | River Eden | Natural, A, T | Gowans, 2004 |
| 22 | 17 | > 2 days | 175 | Small | Moosehead L. | In-lake, A | Warner and Johnson, 1978 |
| 40 | 18-22 | 12 hrs | 40 | Small | Miramichi R. | In-river, H | Wilkie et al., 1996 |

In all experiments, the fish were hooked/angled and then released. Small = mostly 1-sea-winter fish, Large = mostly multi-sea-winter fish, Until spawning = the fish were followed until the presumed spawning period, In-river or In-lake = the fish were held in enclosures in the river/lake after release, Natural = the fish were released in the river. All studies where fish were released in the river (Method: Natural) were telemetry studies. Method A = angled, i.e. the fish were captured by hook and line, Method H = hooked i.e. the fish were manually hooked and played in a manner similar to ordinary fishing. Method T = telemetry studies.

**Table 5.** Mortality rates (%) and water temperature (°C) in Atlantic salmon catch and release experiments under laboratory conditions.

| Mortality % | Water temp. | Study period | No of fish | Fish size | Origin | Method | Reference |
|---|---|---|---|---|---|---|---|
| 0 | 18 | 24 hrs | 6 | Small | Wild | Chased | Tufts et al. 1991 |
| 0 | 16.5 ± 1 | 72 hrs | 5 | Small | Wild | Hooked | Anderson et al. 1998 |
| 0 | 8 ± 1 | 72 hrs | 6 | Small | Hatchery | Hooked | Anderson et al. 1998 |
| 0 | 12 | 72 hrs | 10 | Small | Hatchery | Chased | Wilkie et al. 1997 |
| 0 | 18 | 72 hrs | 10 | Small | Hatchery | Chased | Wilkie et al. 1997 |
| 0 | 5-6 | Until spawning | 26 | Small, large | Wild | Hooked | Davidson et al. 1994 |
| 3 | 13 | > 9 days | 1200 | Small | Wild | Angled | Warner 1976 |
| 4 | ? | Until spawning | 30 | Large | Wild | Angled | Grant 1980 |
| 5 | 13-15 | 3-5 days | 1221 | Small | Wild | Angled | Warner 1979 |
| 30 | 23 | 72 hrs | 10 | Small | Hatchery | Chased | Wilkie et al. 1997 |

Small = mostly 1-sea-winter fish, Large = mostly multi-sea-winter fish, Until spawning = the fish were followed until presumed spawning period, Chased = The fish were not hooked but chased until exhaustion, Angled = The fish biting the hook, Hooked = The fish was manually hooked and then played similar to ordinary fishing.

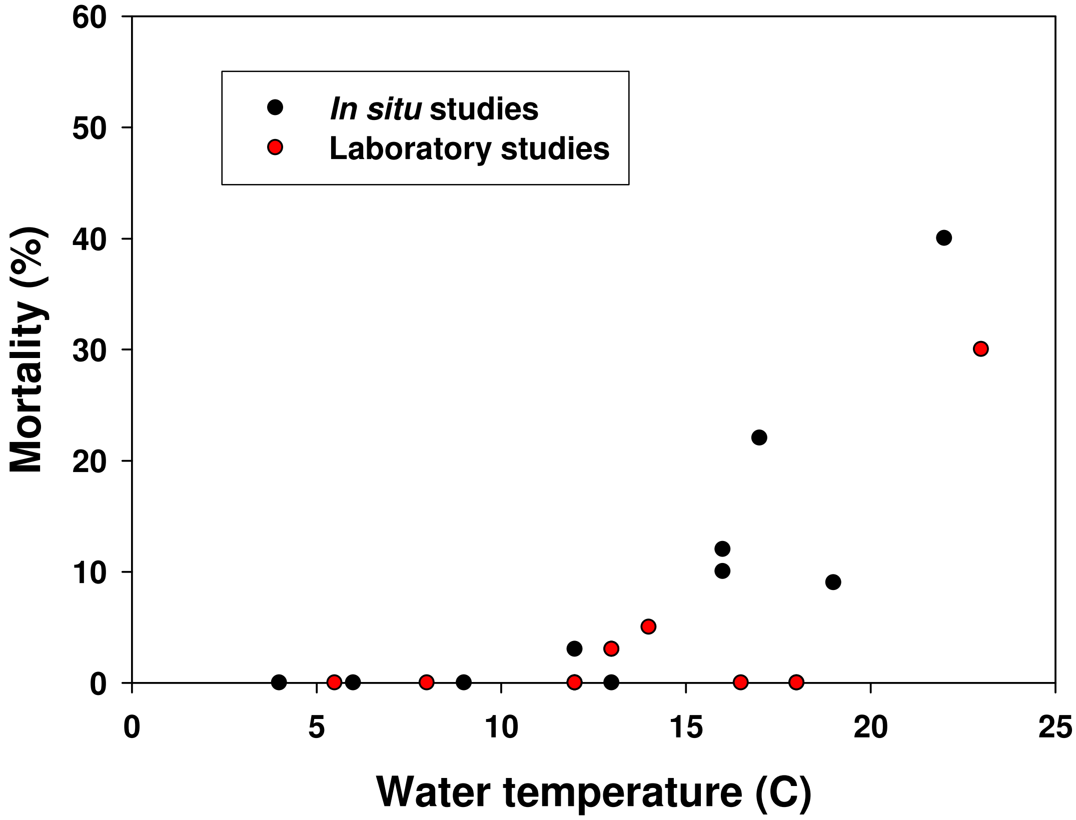

*Figure 11: The documented mortality rates at various water temperatures from the studies summarized in Table 4 and 5. It should be noted that not all studies were designed to report mortality rates and most in situ studies lacked suitable control groups. In the in situ studies reporting the high mortality rates (9 % or above) were associated with fish held in enclosures in the river.*

## Other factors:

**Hooking:** Severe deep hooking (e.g. in stomach) and hooking in gill arches may cause severe bleeding and increased mortalities (Chapter 4). For example, in landlocked Atlantic salmon, 73 % mortalities were observed when fish were allowed to swallow worm baits (Warner, 1976, 1979). High mortalities were also observed among worm and fly-hooked salmon compared to those caught with some lures. In addition, the fish might be hooked in other places that could cause lethal injuries, but little information exists for Atlantic salmon (Chapter 4).

**Air exposure:** In general, air exposure is harmful and potentially lethal to all salmonid fish (Thorstad et al., 2003a, 2003b, and 2008a). The effects of air exposure is dependent upon numerous factors including water temperature, water quality, retrieval (‘playing’) time, human handling, retention time, weather conditions and fish size (Chapter 2).

**Life history state:** Higher levels of mortality have been recorded for salmon that had recently entered freshwater from the sea, compared with kelts returning to the sea after spawning and a prolonged period of starvation (Brobbel et al., 1996). This indicates that the vulnerability to catch and release and the associated handling might vary with the stage of migration and state of the fish while in the estuary or river.

**Water flow:** We know of no studies that focus on the impact of water flow. However, summer flows are usually associated with higher water temperatures, and higher water temperatures appear to act to exacerbate the occurrence of delayed mortality in exercised Atlantic salmon (Wilkie et al., 1996; Casselman, 2005). In some circumstances, high water levels may also act to preclude safe entry by the angler or guide into the water – necessitating fish being removed from the water (i.e. increased air exposure) for unhooking and release.

**Time of day:** The affects of the time of day has not been reported. It has been suggested that any impacts are most likely to be the result of differences in water temperatures rather than time of day (DFO, 1998).

**Sex of fish:** We know of no studies that have examined the effects of the sex of fish subjected to catch and release. Anecdotal observations suggest that male salmonids in an advanced state of sexual maturity may require additional handling because of the tendency of the kype (i.e. the hook at the tip of the lower jaw) and pronounced teeth to get entangled in landing net meshes (Webb, personal observation).

Note: Sea trout and Arctic char: No data on mortality rate due to catch and release and effects of other factors is available.

*What is the mortality rate of released fish caused by the catch and release procedure, and how long will it take before they die? Are there types of injuries or physiological or behavioural reactions that will always be lethal to the fish?*

Published studies suggest that mortality rates among adult Atlantic salmon following catch and release procedures varies between 0 % and approximately 40 %. Generally, the mortality rates were low (0 – 6 %) when the water temperatures were low (below 17-18 °C). Studies conducted on the River Alta, in Norway, showed losses of 0-3 % among fish caught and released between July and September and subsequently monitored until spawning in October.

The numbers of reliable *in situ* studies on the impact of catch and release at high water temperatures are few, and to determine reliable estimates of mortality levels at water temperatures above 17 – 18 °C, more studies should be performed.

There is little or no data on the mortality of sea trout and Arctic char following catch and release. However, practical experience with large individuals (> 30 cm) conducted at low water temperatures do not indicate higher mortality rate caused by handling than for Atlantic salmon (Norwegian Institute for Nature Research). Due to poor levels of knowledge, more studies of the mortality of sea trout and Arctic char after catch and release should be performed.

The consequences of injuries to fish, and the associated physiological or behavioural responses, depend on dose (degree of exposure) and tissue response, such as wounds and bleeding in relation to various environmental factors as water temperature, water chemistry and the presence of predators. Secondary infections may also be an important factor determining the final outcome of injuries. It is therefore very difficult to determine the minimum level of injuries or physiological or behavioural responses that will always be lethal to the fish as they will depend on other biotic and abiotic factors. However, serious and sustained bleeding from the gills or gill arches is an injury that in most cases will be fatal.

*Figure 12: When the water temperature is below 17-18 °C and the fish is properly handled, the mortality of caught and released Atlantic salmon is low (0-6 %) (Photo: T. Næsje).*

## 6. POSSIBILITY OF RECAPTURE

The recapture of previously released individuals in catch and release fisheries may act to further increase the chance of injury, and hence the mortality, of the fish involved. Furthermore, under some circumstances fish caught and released in one part of a watercourse or time of the year may be subsequently re-captured and killed elsewhere later in the season. The vulnerability of fish to multiple recapture impacts is therefore an important aspect of catch and release fisheries.

The probability of recapture may be species specific and vary with factors linked to their life history phase and sex (Arlinghaus et al., 2007). In a review of catch and release in fishing tournaments, Wilde (2003) found that 15 % of smallmouth bass and 22 % of largemouth bass were subsequently recaptured, but there was a large variation in the recapture rates quoted in different studies. Hence, the probability of being recaptured seemed to vary with species and location. Burkett et al. (1986) have suggested that the vulnerability of recapture is a heritable trait in largemouth bass. Recapture rates have also been studied in common carp (*Cyprinus carpio*), and the probability of being captured was reduced after the fish had been fished once, but the vulnerability to angling seemed to increase after one year (Beukema, 1970a; Raat, 1985). In a study of catch and release of cutthroat trout in Yellowstone National Park, fish were on average recaptured 9.7 times per season (Schill et al., 1986).

Availability in the fishery will be an important factor for the probability of recapture. For example, in a river fishery for anadromous species the fish will only be vulnerable after river ascent from the sea. In the same way, factors such as the distribution of fisheries in relation to the fish's preferred spawning area and the length of the fishing season may be important in determining the probability of recapture.

The vulnerability to recapture may also be dependent on the energy status (body condition score) and size of the fish. Under experimental conditions, common carp that were more vulnerable to angling had better growth (Raat, 1985); while Tsuboi and Morita (2004) found that larger white-spotted char were more likely to be recaptured than small ones.

### Atlantic salmon

Within season recapture rates after catch and release were in all Atlantic salmon studies less than 25 %, and few fish were recaptured twice (< 2.3 %) (Table 6). When the general catch rate in the river was low, the rate of recapture may be of a similar magnitude (Whoriskey et al., 2000). However, when the catch rate was higher, the recapture rates seemed to be substantially lower than the capture rates (Thorstad et al., 2003b; Gudbergsson and Einarsson, 2009). For example in the Alta River, recapture rates were typically 4 %, while the initial capture rates were approximately 20 % and 50 %, between years (Thorstad et al., 2003b; T. Næsje, NINA, unpublished).

The probability of recapture of caught and released Atlantic salmon may depend on the time of the year the fish enter the river. In a study of 786 tagged fish in the River Spey (Scotland), recapture rates during the first two months in the river decreased from more than 25 % for fish initially caught and released in February to 2 % among fish caught in June/July. However, in marked contrast to the UK and Ireland, salmon fishing in Norwegian rivers usually begins in June; fisheries on earlier ascending salmon (February - May) being illegal. The recapture rates measured in the River Spey in June/July are consistent with the 4 % recapture rates reported from the River Alta, Norway (Thorstad et al., 2003b).

The probability of Atlantic salmon being initially hooked decreases with time after river ascent. In a telemetry study of ascending adult salmon in Alta River, approximately 50 % of the fish caught in the sport fishery were caught within the first 10 % of the time the fish were available in the fishery, and most of the fish were caught within the three first weeks in the river (fishing season 1 June – 31 August, Jensen et al. in prep.). This was confirmed by Thorstad et al. (2003b), who, using external characteristics, classified 60 % of 188 Atlantic salmon captured by anglers in the River Alta to have entered the river recently. Similarly, in a large tagging study in the Namsen Fjord, half of the salmon ever recaptured were recaptured by anglers in the River Namsen within 15 days after tagging (Thorstad et al., 2006). The length of time the salmon has been in the river may therefore influence the vulnerability to both initial capture and subsequent recapture; the longer the salmon has been in the river the less susceptible it may be to fisheries by rod and line.

**Table 6.** Rates of recapture among tagged fish released in various rivers.

| Recaptured once % | Recaptured twice % | Location | No fish tagged | Catch rate % | Author |
|---|---|---|---|---|---|
| 0 | 0 | River Ewe | 25 | | Cunningham et al. 2002 |
| 2 | ? | River Spey[1] | Ca 55 | | Thorley et al. 2007 |
| 4 | 0.3 | Alta River | 353 | 20 – 50 | Thorstad et al. 2003b, Næsje unpubl. |
| 5 | 0 | Aberdeeshire Dee | 210 | | Report cited in Webb 1998 |
| 8 | 0 | Aberdeeshire Dee | 24 | | Webb 1998 |
| 11 | 0.5 | Ponoi River | 2520 | 10 – 19 | Whoriskey et al. 2000 |
| 15 | 0.3 | Haffjardara River | 379 | ? | Gudbergsson & Einarsson 2009 |
| 18 | 0 | Grimsa River | 234 | ? | Gudbergsson & Einarsson 2009 |
| 24 | 1.7 | Hofsa River | 592 | ? | Gudbergsson & Einarsson 2009 |
| 25 | 2.3 | Sela River | 605 | 75 – 80 | Gudbergsson & Einarsson 2009 |
| 25 | ? | River Spey[2] | Ca 140 | | Thorley et al. 2007 |

[1] Tagged (C&R) in early June
[2] Tagged (C&R) in early March

It should be noted that some salmonids species may be able to learn predator cues and to associate neutral stimuli with a reward (Clarke and Sutterlin, 1985; Hawkins et al. 2008). Rainbow trout for example can learn to avoid a negative stimulus by associating escape behaviour with a light cue (Yue et al. 2004; Dunlop et al. 2006). However, there is no indication that anadromous salmonids can learn to avoid being hooked.

There is no data or information on the risk of repeated recaptures of sea trout and Arctic char after river ascent in a European context. Recent research on the Rio Grande, Tierra Del Fuego, in Argentina suggested that rates of recapture among sea-trout tagged and returned by anglers was as low as 0,02 % (O'Neal and Standford, 2006). This result, however, may depend on various factors as fishing pressure, life history stage, fishing regulations and other abiotic and biotic factors.

*What is the risk that released fish will be repeatedly captured? Will any learned avoidance behaviour depend on certain factors, such as type of fish hook used and/or the use of different types of bait?*

The recapture rates of catch and released Atlantic salmon, sea trout and Arctic char may vary between species and populations. In addition, factors such as management regulations, population size and environmental factors may affect the recapture rate.

The risk of released Atlantic salmon being recaptured is variable, but relatively low. Rates of recapture may vary between rivers and within and between years, and higher rates have been associated with earliest returning migratory groups. In the only available Norwegian study, the recapture rate of Atlantic salmon was low (4 %, River Alta). Some other studies indicate that a small proportion of Atlantic salmon may be recaptured for a second time, - but at a rate considerably less than that of first time recapture.

The reduced recapture rates compared to first time capture rates may not be due to a learnt behaviour response, but could possibly be explained by a reduced likelihood of being caught with increased time spent in the river.

The factors that influence the frequency and distribution of recaptures are not fully understood. Nevertheless, studies suggest that the probability of recapture reflects local levels of exploitation, the timing of river entry by target species and the temporal and geographical extent of associated fisheries. For Atlantic salmon, the timing of return, rather than sea-age and body weight, has been shown to be a reliable predictor of recapture probability.

Since the rates of mortality among fish caught and released for the first time are typically low (particularly at low water temperatures i.e. < 17-18 $^{o}$C), and subsequent rates of recapture may also be low in river fisheries that commence in June, the recapture of Atlantic salmon in Norwegian catch and release fisheries may not be a significant problem as long as the fish are properly handled on both occasions.

Little information exists on the effects and probability of recapture of sea trout and Arctic char. More studies are, therefore, recommended.

## 7. POSSIBLE PROCEDURES TO AMELIORATE EFFECTS ON WELFARE

Fishing with a hook(s) and line will always probably pose potential welfare risks to both target and non-target fish irrespective of whether a fish is hooked and lost, landed and humanely killed, or landed and then released.

Catch and release is not a new concept in fisheries management and among most fishery managers, guides and anglers there is a presumption that the fish returned to the water will be unharmed and survive. Nevertheless, variable numbers of fish that are captured or released by anglers may be subject to mortality for number reasons; the two primary causes being stress and wounding. Both factors may vary extensively with a range of factors (for reviews, see DFO, 1998; Tufts et al., 1991; Casselman, 2005; Cooke and Sneddon, 2007, Pelletier et al., 2007).

Given that the catch and release procedures involve subjecting fish to significant stress and other disturbances, it is likely that the fish's welfare is impaired. Tissue damage, via hooking and through net abrasion when landed (Butcher et al., 2008), could give rise to the sensation of pain. Placing fish in abnormal circumstances that give rise to the stress "fight or flight" response may also result in fear and/or negative states associated with stress. One could infer if these animals experience pain or discomfort, fear or distress and physiological stress, then their welfare, health and wellbeing are compromised (see pages 19-22 for discussion on pain, fear and stress).

During the process of conducting this review a number of general trends have emerged suggesting that many catch and release related impacts are likely to be broadly applicable to many species of salmonid – including the three species that provide the focus of this report. Nevertheless, provided that angling is performed with the intent to release fish, there are several ways to reduce the impacts on the fish that are involved. Some of the approaches have been detailed in the previous chapters are summarised below.

**Table 7.** Catch and release: summary of potential impacts, strategic responses and practical management options to ameliorate effects on fish welfare. Note: a section of humane killing is also included for comparative purposes.

| **Challenges** | **Challenges** | **Strategic response(s)** | **Practical management options for a catch and release fishery** | **Ref** |
|---|---|---|---|---|
| **Retrieval ('playing') of fish (hooking to capture)** | Stress, fear and physical exhaustion<br>Physical trauma (e.g. scale loss), pain<br>Delayed recovery<br>Post release impacts | Reduce retrieval time | Impose minimum tackle specifications (e.g. line breaking strength)<br>Encourage use of suitable landing net<br>Limit C&R angling during high water temperatures | **Ch 1** |
| **Handling** | Stress/fear<br>Physical trauma<br>Air exposure<br>Excess/inappropriate handling<br>Delayed recovery | Minimise handling<br>Minimise risk of air exposure (keep fish in the water) | Prohibit the use of certain equipment for catch and release (e.g. gaffs and tailers)<br>Encourage use of suitable un-hooking equipment<br>Encourage the use of suitable landing nets | **Ch 2** |
| **Humane killing:** | Stress/fear<br>Physical trauma<br>Air exposure<br>Inappropriate handling | Compliance with Animal Welfare Legislation | Ensure anglers and their guides comply with the requirements of Animal Welfare Legislation | **Ch 3** |
| **Hook types** | Physical trauma<br>(i.e. hook penetration and retention)<br>Risks of hook penetration in non-target areas<br>Post-unhooking impacts | Design of hook | Restrict the use of natural baits<br>Discourage the use of barbed hooks<br>Encourage the use of flattened barbs | **Ch 4** |
| **After release** | | | | **Ch 5** |
| **A. Recovery time** | Physical exhaustion/delayed recovery | As detailed above | As detailed above | |
| **B. Wound infections and secondary infections** | Physical trauma and stress | As detailed above | As detailed above | |
| **C. Predation** | Wounding and mortality | As detailed above | As detailed above | |
| **D. Reproduction** | Risks of predation | As detailed above | As detailed above | |
| **E. Mortality Rate** | | As detailed above | As detailed above | |
| **Possibility of recapture** | Cumulative impacts of repeated exposure to associated risks | Reduce risks of recapture<br>Maintain C&R policies throughout fishing season | Resist attempts to extend angling seasons towards the spawning season | **Ch 6** |

The summary of possible management responses detailed above in Table 6 constitutes a set of different but related actions and considerations, with related and often overlapping goals. Each has a role to play in reducing the risks of stress, injury and mortality – but may have their own strengths, limitations and risks.

Much of the literature reviewed recommends that retrieval, air emersion, and time spent handling should be kept to a minimum to reduce the amount of stress imposed on the fish Cooke and Sneddon, 2007; Thorstad et al., 2003a; Arlinghaus et al., 2007, 2008; Thompson et al., 2008). This is likely to be beneficial to the individual fish's wellbeing but also for the conservation of stocks. In addition, for the purposes of attempting to limit the impact of catch and release on the fish involved it would seem vital that all factors which may increase injury (hook and bait type and net type), stress and fear (duration of catch and release) should be avoided or minimised when possible.

Many previous reviews of catch and release practices include references to published recommendations on aspects of angling equipment, retrieval, handling and air exposure and release methods etc. (e.g. Thorstad et al., 2003a; Meka, 2004; Davie and Kopf, 2006; Arlinghaus et al., 2007; Cooke and Sneddon, 2007; Thompson et al., 2008).

**Possible additional measures to improve fish welfare**
It has been noted that sub-lethal stressors are rarely considered by many fishery managers who tend to focus mainly on population level processes (e.g. mortality) and the maintenance of attractive and economically sustainable angling opportunities (Wydoski, 1977; Cooke et al., 2002; Cooke and Schramm, 2007). Nevertheless, it may be increasingly desirable that fish that are subject to catch-and-release survive and experience negligible sub-lethal effects (Pelletier et al., 2007). Consequently, there is increasing interest in the incorporation of animal welfare considerations into angling practices via the continued development and promotion of approaches that serve to minimise stress and the risk of injury (Cooke and Schramm, 2007).

Though some aspects of catch-and-release (e.g. hooking and retrieving fish) cannot be substantially altered (Cooke and Sneddon, 2007), there is now compelling scientific evidence that the behaviour and equipment used by anglers can affect the survival and wellbeing of fish. These factors may also have the potential to affect the success of a management and conservation strategy (Pelletier et al., 2007) through significant reductions in injury and post-release mortality (Cooke and Suski, 2005; Cooke and Sneddon, 2007).

Pelletier et al., (2007) suggest that it is important that fishery managers, anglers and guides obtain clear, consistent, practical and scientifically backed information on catch and release methods from credible sources - and not from their peers or by a process of trial and error. Furthermore, it has been noted that the impact of catch-and-release can only be fairly evaluated on the basis of good science, and that a key issue in measuring the effects of catch-and-release should be concerned about the utility of the information available and the levels of management effort and resources required to influence and maintain acceptable practices (Cooke and Schramm, 2007).

However, it is probable that few guides, anglers and fishery managers have easy access to the relevant scientific data and information via either peer-reviewed science journals or the so-called 'grey' unpublished literature. Consequently, most have to rely heavily on government agencies or local fisheries management interests to provide credible advice based on the latest scientific information. Efforts to maintain the welfare of fish by minimising the impacts of catch and release fishing may therefore rely upon the development and targeted dissemination of appropriate information and practical advice (Malchoff et al., 1992; Cooke and Sneddon, 2007; Pelletier et al., 2007).

**Examples of published catch and release guidelines**

Guidelines on catch- and- release for Atlantic salmon have already been developed by a number of national and international organisations including NASCO, the Atlantic Salmon Federation (ASF), the Environment Agency (EA), The Scottish Government and the Scottish Anglers National Association (SANA). A number of other UK based 'umbrella' organisations including the Atlantic Salmon Trust, Association of District Fishery Boards (ASFB) and the Trout and Salmon Association have also produced advice on catch- and -release fishing for salmonids as part of the Game Angling Code. Norwegian recommendation brochures made by Norske Lakseelver and Norges Jeger- og fiskerforbund and an instruction video has also been produced (www.lakseelver.no; www.njff.no)

**Video and internet-based downloads**

Following the introduction of catch and release on one of Scotland's major salmon rivers in 1995, a video on how to catch and release salmon was produced in Scotland by the Fisheries Research Services (FRS). The project was jointly funded by FRS, the Environment Agency (EA), The Salmon and Trout Association (S&TA), Association of District Fishery Boards (ASFB -Scotland) and the Atlantic Salmon Trust (AST). In an effort to get the message across a well-known television actor and keen angler was chosen to be the main presenter. The main aim of the video was to demonstrate basic handling techniques and the equipment that should be used to ensure minimum standards of animal welfare and maximise the chances of survival among fish returned. The video was subsequently distributed to all anglers who had previously purchased a state migratory fish angling license (England and Wales) by the licence issuer - free of charge. Similar types of instructive videos are now also available for downloading via various websites.

**Local management advice**

In the UK and elsewhere, local fisheries management interests a number of individual rivers and lakes have produced advisory literature aimed at angling guides ('ghillies') and anglers which are distributed via leaflets or via downloads on angling related websites. Most of these initiatives in the UK have focused on wild Atlantic salmon and migratory and non-migratory forms of wild brown trout.

**Training**

Catch and release involves more than just releasing fish. Proper handling of any fish that are involved is an imperative; otherwise factors such as water temperature etc. may become irrelevant and poorer standards of welfare and associated higher levels of mortality may result regardless (Dempson et al., 1988).

Whilst general and simplistic guidelines do provide some level of protection they do have limitations. In the practical field training and advice on basic live salmon handing and catch and release methods has been provided by experts. The main purpose of this activity is to increase awareness and live fish-handling skills among fishery managers, guides and anglers. Typically, courses are run over half or full days and cover a wide range of aspects of catch and release – including in-river training. Follow-up 'refresher' training sessions are also undertaken; providing a useful opportunity to train new fishery staff and to consider any local problems or queries that may arise. In future, such training could become part of a more formal professional development programme for angling guides.

**Other possible 'outreach' approaches: conferences**
In both North America (Barnhart and Roelofs, 1977, 1987; Barnhart, 1989) and Europe (Aas, 2008) catch and release angling has been the focus of major conferences in Europe.  In 2001 the Institute of Fishery Management (Scottish branch) held a conference on catch- and -release of Atlantic salmon. The agenda was carefully designed to attract fishery scientists, fishery managers and anglers from all over the UK, and the resulting proceedings were subsequently published (Lyndon, 2002) and distributed to all the attendees.

**Emerging challenges**
Anglers and their guides who practice catch and release fishing for salmonids are increasingly using photography to record the results of their sport. In the UK, many fishery proprietors actively encourage the use of photography in an effort to enhance the experience of their clients and as a means of gaining publicity (Webb, 2009).  Photography can result in significant increase in the amount of handling and associated air-exposure – particularly when a fish is photographed with its captor by another person.

*Is it possible to reduce or eliminate any suffering or avoid further impairment of fish welfare after release, by using certain hooks, types of equipment or certain practices for angling and handling of the fish?*

The issues surrounding catch and release are complex and involve much more than just 'returning live fish' that have been captured by angling. Current knowledge indicates that it is unlikely to be possible to eliminate all of the potential welfare impacts of catch and release fishing. This is because all angling is based upon the principle of a fish being hooked in the mouth and retrieved.

Improvements to angling equipment and handling practices are likely to reduce many of the potential negative welfare consequences (immediate and post-release) for the individual fish. Management efforts focused solely upon minimising the impact of angling equipment on released fish, although desirable, may prove ineffective if not combined with addressing other factors. The attitude, knowledge and skill-base of anglers, guides and fishery managers is also very important and should be influenced via readily available up-to-date information and guidance.

Catch and release guidelines should be consistent with the latest scientific information and updated as new information becomes available. Significant modifications to procedures should be monitored to ensure they do indeed improve fish wellbeing.

Future research should help to refine catch and release practices and allow for more informed decision making on important issues such as angling season extensions and closures related to stock status and environmental conditions.

## FUTURE RESEARCH NEEDS

The summary of the effects of catch and release detailed in this report shows that whilst a number of scientific studies have been performed on Atlantic salmon, comparatively little (if any) research has been conducted on either Arctic char or sea trout. Hence, it is difficult to arrive at any firm and substantial conclusions regarding these two important species.

The *ad hoc*-group strongly suggests that there should be an increased research emphasis on several aspects of catch and release for all three species that are the focus of this report, and with particular emphasis on Arctic char and sea trout. The main areas of interest are clearly stated in this report.

Against the background of declining or threatened fish stocks, the *ad hoc*-group is of the opinion that an increased knowledge base will provide a firmer scientific basis for future decisions made by the different governmental, nongovernmental and local management bodies with regard to the methods, impact and sustainable management utility of catch and release (angling) fisheries.

Some areas of further research needs on the effects of catch and release of Atlantic salmon are outlined below. The list is the contribution of individual members of the *ad hoc*-group, and does not necessarily represent the opinion of the panel as such. In depth specification into these areas is, however, beyond the mandate of this report.

*Some areas where information is lacking for Atlantic salmon:*

- Economic and cultural benefits of catch and release angling versus fishery closure
- Equipment, bait and angler behaviour related issues
- Impact of environmental conditions, especially mortality and other effects at water temperatures above 17-18 °C
- Rates and impacts of recapture
- Lifetime fitness issues (including spawning and juvenile recruitment)
- Refinement of catch and release handling methods for very large fish (larger than 15 kg)
- Fish health status of populations subject to significant catch and release fisheries
- Impact of catch and release on the reliability of National catch statistics
- Skin/tissue responses to hand-tailing, netting and beaching of fish by anglers

# REFERENCES

http://www.fsbi.org.uk/docs/brief-welfare-refs.pdf

http://www.freshwatersanglers.com.au

www.lakseelver.no

www.njff.no

Forskrift 2003-02-25 nr 256. Forskrift om oppgaveplikt og om redskaper som er tillatt benyttet ved fiske etter anadrome laksefisk

LOV-2009-06-19-97 Norwegian Animal Welfare Act of 1974/2009

Ot.prp. 15 (2008-2009) 2.2.19.4

Aalbers, S.A., Stutzer, G.M., Drawbridge, M.A. 2004. The effect of catch-and-release angling on the growth and survival of juvenile white seabass captured on offset circle hooks and J-type hooks. N. Am. J. Fish Manage. 24, 793-800.

Aas, Ø. 2002. The next chapter: multicultural and cross-disciplinary progress in evaluating recreational fisheries, in: Pitcher, T.J., Hollingworth, C.E. (Eds.), Recreational Fisheries: Ecological, Economic and Social Evaluation. Oxford Blackwell Science, 252–263.

Aas, Ø. (red) 2008. Global challenges in recreational fisheries. Blackwell Publishing Ltd.

Aas, Ø., Kaltenborn, B.P. 1995. Consumptive orientation of anglers in Engerdal, Norway. Environ. Manage. 19, 751–761.

Albin, D., Karpov, K. 1998. Mortality of lingcod, *Ophiedon elongatus*, related to capture by hook and line. Mar. Fish. Rev. 60, 29-34.

Alós, J., Palmer, M., Grau, A.M., Deudero, S. 2008. Effects of hook size and barbless hooks on hooking injury, catch per unit effort, and fish size in a mixed-species recreational fishery in the western Mediterranean Sea. ICES J. Mar. Sci. 65, 899-905.

Anderson, W.G., Booth, R., Beddow, T.A., McKinley, R.S., Finstad, B., Økland, F., Scruton, D. 1998. Remote monitoring of heart rate as a measure of recovery in angled Atlantic salmon, *Salmo salar* (L.). Hydrobiol. 371/372, 233-240.

Anon. 1999b. Til laks åt alle kan ingen gjera? Om årsaker til nedgangen i de norske villaksbestandene og forslag til strategier og tiltak for å bedre situasjonen. NOU 1999: 9 (In Norwegian with English abstract).

Anon. 2009. Status for norske laksebestander i 2009 og råd om beskatning. Rapport fra Vitenskapelig råd for lakseforvaltning nr 1. 230 s. Vitenskapelig råd for lakseforvaltning, Trondheim. (In Norwegian).

Arlinghaus, R., Mehner, T. 2003. Socio-economic characterisation of specialised common carp (*Cyprinus carpio* L.) anglers in Germany, and implications for inland fisheries management and eutrophication control. Fish. Res. 61, 19–33.

Arlinghaus, R., Cooke, S.J., Lyman, J. Policansky, D., Schwab, A., Suski, C., Sutton, S. G., Thorstad, E.B. 2007. Understanding the Complexity of Catch-and-Release in Recreational Fishing: An Integrative Synthesis of Global Knowledge from Historical, Ethical, Social, and Biological Perspectives. Rev. Fish. Sci. 15, 75-167.

Arlinghaus, R., Klefoth, T., Kobler, A., Cooke, S.J. 2008. Size selectivity, injury, handling time and determinants of original hooking mortality in recreational angling for northern pike: the influence of type and size of bait. N. Am. J. Fisher. Manage. 28, 123-134.

Ashley, P.J., Sneddon L.U. 2007. Pain and fear in fish. In Fish Welfare. Branson E, ed. Wiley UK: Blackwell Publishing.

Ashley, P.J., Ringrose, S., Edwards, K.L., Wallington, E., McCrohan, C.R., Sneddon, L.U. 2009. Which is more important in fish: pain, anti-predator responses or dominance status? Anim. Behav. In press. doi:10.1016/J. Anim. Behav. 2008.10.015.

AVMA (American Veterinary Medical Association), 2001. Report of the AVMA panel on euthanasia. J. Am. Vet. Med. Assoc. 218, 670-696.

Banks J.W. 1969. A review of the literature on the upstream migration of adult salmonids. J. Fish. Biol. 1, 85–136.

Barnhart, R. A. 1989. Symposium Review: Catch and Release Fishing, a Decade of Experience. N. Am. J. Fish. Manage. 9, 74-80.

Barnhart, R. A., Roelofs, T. D. 1977. Catch-and-release fishing as a management tool. Humbolt State University, Arcata, California.

Barnhart, R. A., Roelofs, T. D. 1987. Catch and release fishing – a decade of experience. Calif. Coop. Fish. Res. Unit, Arcata.

Barthel, B.L., Cooke, S.J., Suski, C.D., Philipp, D. P. 2003. Effects of landing net mesh type on injury and mortality in a freshwater recreational fishery. Fish. Res. 63, 275-282.

Bartholomew, A., Bohnsack, J.A. 2005. A review of catch-and-release angling mortality with implications for no-take reserves. Rev. Fish Biol. 15, 129-154.

Bateson, P. 1991. Assessment of pain in animals. Anim. Behav. 42, 827–839.

Beitinger, T.L., Bennett, W.A., McCauley, R.W. 2000. Temperature tolerances of North American freshwater fishes exposed to dynamic changes in temperature. Env. Biol. Fishes. 58, 237–275.

Bekoff, M., Sherman, P.W. 2004. Reflections on animal selves. Trends Ecol. Evol. 19, 176-180.

Berejikian, B.A., Smith, R.J.F., Tezak, E.P., Schroder, S.L., Knudsen, C.M. 1999. Chemical alarm signals and complex hatchery rearing habitats affect antipredator behavior and survival of chinook salmon (*Oncorhynchus tshawytscha*) juveniles. Can. J. Fish. Aquat. Sci. 56**,** 830-838.

Berejikian, B.A., Tezak, E. P., LaRae, A. L. 2003. Innate and enhanced predator recognition in hatchery-reared chinook salmon. Env. Biol. Fishes. 67**,** 241-251.

Berg, M., Abrahamsen, B., Berg, O.K., 1986. Spawning of injured compared to uninjured female Atlantic salmon, *Salmo salar* L. Aquacult. Fish. Manage. 17, 195–199.

Berg, O.K., Berg, M. 1988. Sea growth and time of migration of anadromous Arctic char (*Salvelinus alpinus*) from the Vardnes River, in northern Norway. Can. J. Fish. Aquat. Sci. 46, 955–960.

Berg, O.K., Berg, M. 1989. The duration of the sea and freshwater residence of the sea trout, *Salmo trutta*, from the Vardnes River in northern Norway. Env. Biol. Fishes. 24, 23–32.

Berg, O.K., Berg, M. 1993. Duration of sea and freshwater residence of Arctic char (*Salvelinus alpinus*), from the Vardnes River in northern Norway. Aquaculture 110, 129–140.

Beukema, J.J. 1970a. Angling experiments with carp (*Cyprinus carpio L.*) II. Decreased catchability through one trial learning A. Netherland J. Zool. 19**,** 81-92.

Beukema, J.J. 1970b. Acquired hook avoidance in the pike *Esox lucius L.* fished with artificial and natural baits. J. Fish Biol. 2, 155-160.

Bielak, A. T. 1996. A discussion document on the implications of catch-and-release angling for Atlantic salmon, with particular reference to water temperature-related closures. DFO Atl. Fish. Res. Doc. 96/117. pp17.

Bisazza, A., Rogers, L. J., Vallortigara, G. 1998. The origins of cerebral asymmetry: A review of evidence of behavioural and brain lateralization in fishes, reptiles and amphibians. Neurosci. Biobehav. Rev. 22**,** 411-426.

Black, A. H., deToledo, L. 1972. The relationship among classically conditioned responses: heart rate and skeletal behaviour, in: Black, A. H. & Prokasy, W. F. (Eds.), Classical conditioning. II. Current theory and research. Appleton, New York, 290-311.

Bolles, R.C., Fanselow, M.S. 1980. A perceptual-defensive-recuperative model of fear and pain. Behav. Brain Sci. 3**,** 291-301.

Booth, R.K., Kieffer, J.D., Davidson, K., Bielak, A.T., Tufts, B.L. 1995. Effects of late-season catch and release angling on anaerobic metabolism, acid-base status, survival and gamete viability in wild Atlantic salmon (*Salmo salar*). Can. J. Fish Aquat. Sci. 52, 283-290.

Bradford, M.R. 1995. Comparative aspects of forebrain organization in the ray-finned fishes - touchstones or not. Brain Behav. Evol. 46**,** 259-274.

Bradley, M.M., Lang, P.J., Cuthbert, B.N. 1993. Emotion, novelty, and the startle reflex - habituation in humans. Behav. Neurosci. 107**,** 970-980.

Brobbel, M.A., Wilkie, M.P., Davidson, K., Kieffer, J.D., Bielak, A.T., Tufts, B.L. 1996. Physiological effects of catch and release angling in Atlantic salmon (*Salmo salar*) at different stages of freshwater migration. Can. J. Fish. Aquat. Sci. 53, 2036-2043.

Brown, G.E., Smith R. J. F. 1997. Conspecific skin extracts elicit antipredator responses in juvenile rainbow trout (*Oncorhynchus mykiss*). Can. J. Zool. 75, 1916-1922.

Burkett, D.P., Mankin, P.C., Lewis, G.W., Childers, W.F., Philipp, D.P. 1986. Hook-and-line vulnerability and multiple recapture of largemouth bass under a minimum length-limit of 457 mm. N. Am. J. Fish. Manage. 6, 109–112.

Butcher, P.A., Broadhurst, M.K., Cairns, S.C. 2008 Mortality and physical damage of angled- and released dusky flathead, Platycephalus fuscus. Dis. Aquat. Org. 81, 127-134.

Butler, A.B. 2000. Topography and topology of the teleost telencephalon: a paradox resolved. Neurosci. Lett. 293**,** 95-98.

Cantalupo, C., Bisazza, A., Vallortigara, G. 1995. Lateralization of predator-evasion response in a teleost fish (*Girardinus falcatus*). Neuropsychologia 33**,** 1637-1646.

Carter, R. 1996. Mapping the mind. London: Phoenix Press.

Carbines, G.D. 1999. Large hooks reduce catch-and-release mortality of blue cod *Parapercis colias* in the Marlborough Sounds of New Zealand. N. Am. J. Fish. Manage. 19, 992–998.

Casselman, S.J. 2005. Catch and release angling: A review with guidelines for proper fish handling practices. Fish and Wildlife Branch. Ontario Ministry of Natural Resources. Peterborough, Ontario. pp26.

Chandroo, K.P., Duncan, I.J.H., Moccia, R.D. 2004. Can fish suffer?: perspectives on sentience, pain, fear and stress. Appl. Anim. Behav. Sci. 86, 225-250.

Clarke, L.A., Sutterlin, A.M. 1985. Associative learning, short-term-memory, and color preference during 1st feeding by juvenile Atlantic salmon. Can. J. Zool./Rev. Can. Zool. 63, 9-14.

Committee on Atlantic salmon in Maine. 2004. Atlantic salmon in Maine. National Academy of Sciences. The National Academies Press, Washington, D.C. pp276.

Cooke, S.J., Philipp, D.P., Dunmall, K.M., Schreer, J.F., 2001. The influence of terminal tackle on injury, handling time, and cardiac disturbance of rock bass. N. Am. J. Fish. Manage. 21, 333–342.

Cooke, S.J., Schreer, J.F., Dunmall, K.M., Philipp, D.P. 2002. Strategies for quantifying sublethal effects of marine catch-and-release angling—insights from novel freshwater applications. Am. Fish. Soc. Symp. 30, 121–134.

Cooke, S.J., Barthel, B.L., Suski, C.D. 2003a. Effects of hook type on injury and capture efficiency of rock bass, *Ambloplites rupestris*, angled in southeastern Ontario. Fish Manage. Ecol. 10, 269-271.

Cooke, S.J., Ostrand, K.G., Bunt C.M., Schreer J.F., Wahl D.H., Philipp, D.P., 2003b. Cardiovascular responses of largemouth bass to exhaustive exercise and brief air exposure over a range if water temperatures. Trans. Amer. Fish. Soc. 132, 1154-1165.

Cooke, S.J., Suski, C.D., Barthel, B.L., Ostrand, K.G., Tufts, B.L., Philipp, D.P. 2003c. Injury and mortality induced by four hook types on bluegill and pumpkinseed. N. Am. J. Fish. Manage. 23, 883-893.

Cooke, S.J., Cowx, I.G. 2004. The role of recreational fisheries in global fish crises. BioScience, 54, 857–859.

Cooke, S.J., Philipp, D.P. 2004. Behavior and mortality of caught-and-released bonefish (*Albula* spp.) in Bahamian waters with implications for a sustainable recreational fishery. Biol. Cons. 118, 599–607.

Cooke, S.J., Suski, C.D. 2004. Are circle hooks effective tools for conserving freshwater and marine recreational catch and release fisheries? Aquat. Conserv. Mar. Freshwat. Ecosys. 14, 299-326.

Cooke, S. J., Suski, C. D. 2005. Do we need species-specific guidelines for catch and release recreational angling to conserve diverse fishery resources? Biodiv. Cons. 14, 1195-1209.

Cooke, S.J., Schramm, H.L. 2007. Catch-and-release science and its application to conservation and management of recreational fisheries. Fish. Manage. Ecol. 14, 73-79.

Cooke, S.J., Sneddon, L.U. 2007. Animal welfare perspectives on catch and release recreational angling. Appl. Anim. Behav. Sci. 104, 176-198.

Cooke, S.J., Wilde, R.W. 2007. The fate of fish released by recreational anglers, In: Kenelly, S.J. (Ed.), By-catch reduction in the world’s fisheries. Springer, The Netherlands, 181-234.

Cunningham, P., Starr, K., Butler, J. 2002. The River Ewe salmon radio-tracking project 2001-2002. Research report produced by the Wester Ross Fisheries Trust. pp27.

Dalley, E.L., Andrews, C.W., Green, J.M. 1983. Precocious male Atlantic salmon parr (*Salmo salar*) in insular Newfoundland. Can. J. Fish. Aquat. Sci. 40, 647–652.

Danylchuk, S.E., Danylchuk A.J., Cooke S.J., Goldberg T.L., Koppelman J., Phillip D.P. 2007. Effects of recreational angling on the post-release behaviour and predation of bonefish (*Albula vulpes*): The role of equilibrium status at the time of release. J. Exp. Mar. Biol. Ecol. 346, 127-133.

Davidson, K., Hayward, J., Hambrook, M., Bielak, A. T., Sheasgreen, J. 1994. The effects of late season angling on gamete viability and early fry survival in Atlantic salmon. Can. Tech. Rep. Fish. Aquat. Sci. No 1982, 1-12.

Davie, P.S., Kopf, R.K. 2006. Physiology, behaviour and welfare of fish during recreational fishing and after release. NZ Vet. J. 54, 161-172.

Dempson, J.B., Reddin, D.G., O'Connell, M.F. 1998. To what extent does catch and release contribute to mortality in Atlantic salmon? Canadian Stock Assessment Secretariat Research Document 98/99. pp14.

Dempson, J.B., Furey, G., Bloom, M. 2002. Effects of catch and release angling on Atlantic salmon, *Salmo salar* L., of the Conne River, Newfoundland. Fisher. Manage. Ecol. 9, 139-147.

DFO 1998. Historical research into the effects of hook-and-release angling on Atlantic salmon. DFO Stock Status Report DO-03. pp10.

Diggles, B.K., Ernst, I. 1997. Hooking mortality of two species of shallow water reef fish caught by recreational angling methods. Mar. Freshwat. Res. 48, 479-483.

Diodati, P.J., Richards, R.A. 1996. Mortality of striped bass hooked and released in salt water. Trans. Am. Fish. Soc. 125, 300-307.

Doi, T., Nakamura, T., Yokota, M., Maruyama, T., Watanabe, S., Noguchi, H., Sano, Y., Fujita, T. 2004. Hooking mortality and growth of caught and released Japanese char *Salvelinus leucomaenis* and masou salmon *Oncorhynchus masou masou* in experiment ponds. Nippon Suisan Gakk. 70: 706-713.

Domenici, P.D., Blake, R. W. 1997. The kinematics and performance of fish fast-start swimming. J. Exp. Biol. 200, 1165-1178.

DuBois, R.B., Dubielzig, R.R. 2004. Effect of hook type an mortality, trauma, and capture efficiency of wild stream trout caught by angling with spinners. N. Am. J. Fish. Manage. 24, 609-616.

DuBois, R.B., Kuklinski, K.E. 2004. Effect of hook type on mortality, trauma and capture efficiency of wild stream-resident trout caught by active baitfishing. N. Am. J. Fish Manage. 24, 617-623.

Dunlop, R., Millsopp, S., Laming, P. 2006. Avoidance learning in goldfish (Carassius auratus) and trout (Oncorhynchus mykiss) and implications for Pain perception. Appl. Anim. Behav. Sci. 97 (2-4): 255-271.

Elliott, J.M. 1989. Wild brown trout *Salmo trutta*: an important national and international resource. Freshwat. Biol. 21, 1-5.

Environment Agency. 2006. Salmonid and freshwater fisheries statistics for England and Wales, 2006. Environment Agency, Bristol.

European Commission DGXI: 1996: Recommendations for euthanasia of experimental animals: Part 1. Close, B., Banister, K., Baumans, V., Bernoth, E.M., Bromage, N., Bunyan, J., Erhardt,W., Flecknell, P., Gregory, N., Hackbarth, H., Morton, D., Warwick, C. 1996. Lab Anim. 4, 293-316.

Fagerlund, U.H.M. 1970. Response to mammalian ACTH of the interrenal tissue of sockeye salmon (*Oncorhynchus nerka*) at various stages of sexual maturation. J. Fish. Res. Bd. Can. 27, 1169–1172.

Fendt, M., Fanselow, M.S. 1999. The neuroanatomical and neurochemical basis of conditioned fear. Neurosci. Biobehav. Rev. 23**,** 743-760.

Ferguson, R.A., Tufts, B.L. 1992. Physiological effects of brief air exposure in exhaustively exercised rainbow trout (*Oncorhynchus mykiss*): Implications for ‘‘catch and release’’ fisheries. Can. J. Fish. Aquat. Sci. 49, 1157–1162.

Ferguson, H.W. 2006. Systemic Pathology of Fish. Scotian Press, London.

Figler, M.H., Klein, R.M., Thompson, C.S. 1975. Chlordiazepoxide (librium)-induced changes in intraspecific attack and selected non-agonistic behaviors in male siamese fighting fish. Psychopharmacologia 42, 139-145.

Finstad, B., Heggberget, T.G. 1993. Migration, growth and survival of wild and hatchery-reared anadromous Arctic char (*Salvelinus alpinus*) in Finnmark, northern Norway. J. Fish Biol. 43, 303–312.

Finstad, A.G., Næsje, T.F., Forseth, T. 2004. Seasonal variation in the thermalperformance of juvenile Atlantic salmon (*Salmo salar*). Freshwat. Biol. 49, 1459-1467.

Fisheries Research Services. 2004. Statistical Bulletin – Scottish salmon and trout catches, 2003. Fisheries Series No. Fis./2004/1. Scottish Executive, Edinburgh. pp29.

Fiske, P., Aas, Ø. 2001. Laksefiskeboka. Om sammenhenger mellom beskatning, fiske og verdiskaping ved elvefiske etter laks sjøaure og sjørøye. NINA Temahefte 20. pp100.

Fleming, I.A., Jonsson, B., Gross, M.R., Lamberg, A. 1996. An experimental study of the reproductive behaviour and success of farmed and wild salmon (*Salmo salar*). J. Appl. Ecol. 33, 893–905.

Frost, W.E., Brown, M.E. 1967. The Trout. London: Collins. pp316.

Fry, F.E.J. 1971. Effects of environmental factors on the physiology of fish, in: Hoar, W. S., Randall, D.J. (Eds.), Fish Physiology, Vol. VI. New York, Academic Press, 1–98.

Gowans, A. 2004. Radio-tracking of Atlantic salmon (*Salmo salar* L.) on the River Eden, Cumbria: spawning distribution and survival to spawning. Environment Agency Report, UK. pp30.

Grant, G.L. 1980. Catching, releasing and tagging Atlantic salmon in Iceland's River Grimsa. Proceedings of the Annual Meeting of the Colorado-Wyoming Chapter, American Fisheries Society 15: 64-99 (Colorado State University, Fort Collins). Proceedings of the Annual Meeting of the Colorado-Wyoming Chapter, Am. Fish. Soc. (Colorado State University, Fort Collins). 15, 64-99.

Grover, A.M., Palmer-Zwahlen, M.L., Mohr, M.S. 2002. Hook-and -release mortality of Chinook salmon from drift mooching with circle hooks: Management implications for California's ocean sport fishery. Am. Fish. Soc. Symp. 30, 36-56.

Gudbergsson, G., Einarsson, S.M. 2009. Study on the frequency of multiple recapture and the effects of catch and release on rod catch statistics and estimated spawning stock size. ICES Working Paper, 2009/WP24, 1-12.

Gustavsson, A.W., Wydoski, R.S. Wedemeyer, G.A. 1991. Physiological response of largemouth bass to angling stress. Trans. Am. Fish. Soc. 120, 629–636.

Halttunen, E., Rikardsen, A.H., Davidsen J.G., Thorstad E.B., Dempson, J.B. 2009. Survival, migration speed and swimming depth of Atlantic salmon kelts during sea entry and fjord migration, in: Nielsen, J. L., Arrizabalaga, H., Fragoso, N., Hobday, A., Lutcavage, M. and Sibert, J. (Eds.), Tagging and tracking of Marine Animals with Electronic Devices II. Volume 8 Reviews: Methods and Technologies in Fish Biology and Fisheries. Springer, The Netherlands.

Hamdani, E.H., Stabell, O.B., Alexander, G., Doving, K.B. 2000. Alarm reaction in the crucian carp is mediated by the medial bundle of the medial olfactory tract. Chem. Senses, 25**,** 103-109.

Hansen, L.P., Quinn, T.P. 1998. The marine phase of the Atlantic salmon (*Salmo salar*) life cycle, with comparisons to Pacific salmon. Can. J. Fish. Aquat. Sci. 55, 104–118.

Harden Jones, F.R. 1968. Fish migration. Edward Arnold Ltd, London.

Hasler, A.D. 1966. Underwater guideposts; homing of salmon. University of Wisconsin Press, Madison, WI.

Hawkins, L.A., Magurran, A.E., Armstrong, J.D. 2008. Ontogenetic learning of predator recognition in hatchery-reared Atlantic salmon, *Salmo salar*. Anim. Behav. 75, 1663-1671.

Hebebrand, J., Friedl, W., Reichelt, R., Schmitz, E., Moller, P., Propping, P. 1988. The shark GABA-Benzodiazepine receptor - further evidence for a not so late phylogenetic appearance of the benzodiazepine receptor. Brain Res. 446**,** 251-261.

Heggberget T.G., Lund, R.A., Ryman, N., Ståhl, G. 1986. Growth and genetic variation of Atlantic salmon (*Salmo salar*) from different sections of the River Alta, North Norway. Can. J. Fish. Aquat. Sci. 43, 1828–1835.

Heggberget, T.G. 1988. Timing of spawning in Norwegian Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 45, 845-849.

Hindar, K., Ryman, N., Utter, F. 1991. Genetic effects of cultured fish on natural fish populations. Can. J. Fish. Aquat. Sci. 48, 945 – 957.

Hindar, K., Diserud, O., Fiske, P., Forseth, T., Jensen, A.J., Ugedal, O., Jonsson, N., Sloreid, S.-E., Arnekleiv, J.V., Saltveit, S.J., Særov, H., Sættem, L.M. 2007. Spawning targets for Norwegian Atlantic salmon populations. NINA Report 226. pp78.

Hughes, G.C. 1994. Saprolegniasis, then and now: a retrospective, in: Mueller, G.J. (Ed.), Salmon Saprolegniasis. Report to Bonneville Power Administration, Portland, 3-32.

Høgåsen, H.R. 1998. Physiological changes associated with the diadromous migration of salmonids. Can. Spec. Publ. Fish. Aquat. Sci. 127. viii 128.

IASP (International Association for the Study of Pain). 1979. Pain terms: a list with definitions and notes on usage. Pain 6, 249–252.

ICES 2004. Report of the Working Group on North Atlantic Salmon. Halifax, Canada 29 March–8 April. ICES CM 2004/ACFM: 20. pp286.

ICES. 2009. Report of the Working Group on North Atlantic Salmon (WGNAS), 30 March–8 April, Copenhagen, Denmark. ICES CM 2009/ACOM:06. pp282.

Ingram, G.A. 1980. Substances involved in the natural resistance of fish to infection – a review. J. Fish Biol. 16, 23-60.

Jenkins, T.M. 2003 Evaluating recent innovations in bait fishing tackle and technique for catch and release of rainbow trout. N. Am. J. Fisher. Manage. 23, 1098-1107.

Jensen, K.W. 1968. Sea trout (*Salmo trutta* L.) of the River Istra, western Norway. Rep. Inst. Freshwat. Res. Drottningholm 48, 187–213.

Jensen, K.W., Berg, M. 1977. Growth, mortality and migrations of the anadromous char, *Salvelinus alpinus* L., in the Vardnes River, Troms, northern Norway. Rep. Inst. Freshwat. Res. Drottningholm 56, 70–80.

Jensen, A.J., Rikardsen, A.H. 2008. Do northern riverine anadromous Arctic char *Salvelinus alpinus* and sea trout *Salmo trutta* overvinter in estuarine and marine waters? J. Fish Biol. 73, 1810-1818.

Johnsen, B.O., Jensen, A.J. 1991. The *Gyrodactylus* story in Norway. Aquaculture 98, 289 - 302.

Johnson, L. 1989. The anadromous Arctic char, *Salvelinus alpinus* of Nauyuk Lake, N.W.T., Canada. Physiol. Ecol. Jpn. 1, 201–228.

Jones, R.B. 1997. Fear and distress, in: Appleby, M.C., Hughes, B.O. (Eds.) Animal Welfare. CAB International, Cambridge. University Press, 75-87.

Jordan, S.R., Woodward, A.G. 1994. Survival of hook-caught red rum. Proc. of the Annual Conf. Southeastern Assoc. Fish. Wildl. Agencies 46, 337-344.

Jonsson, B. 1985. Life history patterns of freshwater resident and sea-run migrant brown trout in Norway. Trans.Am. Fish. Soc. 114, 182–194.

Jonsson, B. 1989. Life history and habitat use of Norwegian brown trout (*Salmo trutta*) Freshwat. Biol. 21, 71–86.

Jonsson, N. 1991. Influence of water flow, water temperature and light on fish migration in rivers. Nordic J. Freshwat. Res. 66, 20–35.

Jonsson, B, Jonsson, N, Hansen, L.P. 1990. Does juvenile experience affect migration and spawning of adult Atlantic salmon? Behav. Ecol. Sociobiol. 26, 225–230.

Jonsson, N., Hansen, L.P., Jonsson, B. 1991a. Variation in age, size and repeat spawning of adult Atlantic salmon in relation to river discharge. J. Anim. Ecol. 60, 937–947.

Jonsson, B., L'Abèe-Lund, J.H., Heggberget, T.G., Jensen, A.J., Johnsen, B.O., Næsje, T.F., Sættem, L.M. 1991b. Longevity, body size and growth in anadromous brown trout. Can. J. Fish. Aquat. Sci. 48, 1838–1845.

Jonsson, B., Jonsson, N. 1993. Partial migration: niche shift versus sexual maturation in fishes. Rev. Fish Biol. Fish. 3, 348–365.

Jonsson, B., L'Abèe-Lund, J.H. 1993. Latitudinal clines in life-history variables of anadromous brown trout in Europe. J. Fish Biol. 43, 1–16.

Jonsson, N., Jonsson, B., Hansen, L.P. 1997. Changes in proximate composition and estimates of energetic costs during upstream migration and spawning in Atlantic salmon *Salmo salar.* J. Anim. Ecol. 66, 425–436.

Jonsson, B., Jonsson, N., Brodtkorb, E., Ingebrigtsen, P.-J. 2001. Life-history traits of brown trout vary with the size of small streams. Funct. Ecol. 15, 310–31.

Jonsson, N., Jonsson, B. 2002. Migration of anadromous brown trout *Salmo trutta* in a Norwegian river. Freshwat. Biol. 47, 1391–1401.

Kieffer J.D. 2000. Limits to exhaustive exercise in fish. Comp. Biochem. Physiol. 126A, 161-179.

Klemetsen, A., Elliott, J.M., Knudsen, R., Sørensen, P. 2002. Evidence for genetic differences in the offspring of two sympatric morphs of Arctic char. J. Fish Biol. 60, 933–950.

Klemetsen, A., Amundsen, P.-A., Dempson, J.B., Jonsson, B., Jonsson, N., O'Connell, M.F., Mortensen, E. 2003 Atlantic salmon *Salmo salar* L., brown trout *Salmo trutta* L. and Arctic char *Salvelinus alpinus* (L.): a review of aspects of their life histories. Ecol. Freshwat. Fish. 12, 1–59.

Knutsen, J. A., Knutsen, H., Olsen, E. M., Jonsson, B. 2004. Marine feeding of anadromous *Salmo trutta* during winter. J. Fish Biol. 64, 89–99.

Kristoffersen, K., Halvorsen, M., Jørgensen, L. 1994. Influence of parr growth, lake morphology and freshwater parasites on the degree of anadromy in different populations of Arctic char (*Salvelinus alpinus*) in northern Norway. Can. J. Fish. Aquat. Sci. 51, 1229–1246.

L'Abèe-Lund, J.H., Jonsson, B., Jensen, A.J., Sættem, L.M., Heggberget, T.G., Johnsen, B.O., Næsje, T.F. 1989. Latitudinal variation in life-history characteristics of sea-run migrant brown trout *Salmo trutta*. J. Anim. Ecol. 58, 525–542.

Lebedeva, N.Y., Vosilene, M.A.Y., Golovkina, R.V. 1994. Aspects of stress in rainbow trout, *Salmo gairdneri*, release of chemical alarm signals. J. Ichthyol. 33**,** 66-74.

LeDoux, J.E. 2000. Emotion circuits in the brain. Ann. Rev. Neurosci. 23**,** 155-184.

Lyndon, A.R. 2002. (Ed.) Catch and Release: Atlantic Salmon in the UK. Proceedings of a conference held at the Atholl Palace Hotel Pitlochry, 1st November 2001. Published by the Institute of Fisheries Management (Scottish Branch). pp80.

MacCrimmon, H.R., Marshall, T.L., Gotos, B.L. 1970. World distribution of brown trout, *Salmo trutta*: further observations. J. Fish. Res. Bd. Can. 27, 811–818.

MacCrimmon, H.R., Gots, B.L. 1979. World distribution of Atlantic salmon, *Salmo salar*. J. Fish. Res. Bd. Can. 36, 422–457.

Maitland, P. 1995. World status and conservation of the Arctic char *Salvelinus alpinus* (L.). Nordic J. Freshwat. Res. 71, 113–127.

Malchoff, M.H., Voiland, M.P., MacNeill, D.B. 1992. Guidelines to increase survival of released sport fish. Cornell Cooperative Extension Sport Fish Fact Sheet. Sea Grant.

Malchoff, M., Heins, S. 1997. Short-term hooking mortality of weakfish caught on single-barb hooks. N. Am. J. Fish. Manage. 17, 477-481.

Maren, S. 2001. Neurobiology of pavlovian fear conditioning. Ann. Rev. Neurosci. 24**,** 897-931.

Mason, J.W., Hunt, R.L. 1967. Mortality rates of deeply hooked rainbow trout. Prog. Fish Cult. 29, 87-91.

McNair, D. 1997. Effect of gear and methods on marine sports salmon hooking mortality rates. NEAP Final Research Report 68.2. Pacific Fisheries Management Council.

Meka, J.M., 2004. The influence of hook type, angler experience, and fish size on injury rates and the duration of capture in an Alaskan catch-and-release rainbow trout fishery. N. Am. J. Fish. Manage. 24, 1309–1321.

Meka, J.M., McCormick, S.D. 2005. Physiological response of wild rainbow trout to angling: Impact of angling duration, fish size, body condition, and temperature. Fish. Res. 72, 311–322.

Millard, M.J., Mohler, J.W., Kahnle, A., Cosman, A. 2005 Mortality associated with catch and release angling of striped bass in the Hudson river. N. Amer. J. Fisher. Manage. 25, 1533-1541.

Milligan, C.L. 1996. Metabolic recovery from exhaustive exercise in rainbow trout. Com. Biochem. Phys. 113A, 51–60.

Molony, V. 1997. Comments on Anand and Craig (Letters to the Editor). Pain 70, 293-293.

Muoneke, M.I., Childress, W.M. 1994. Hooking mortality: a review for recreational fisheries. Rev. Fish Sci. 2, 123-156.

Myers, R.A., Hutchings, J.A. 1987. Mating of anadromous Atlantic salmon parr, *Salmo salar* L., with mature male parr. J. Fish Biol. 31, 143–146.

Mäkinen, T.S., Niemelä, E., Moen, K., Lindström, R. 2000. Behaviour of gill-net and rod-captured Atlantic salmon (*Salmo salar* L.) during upstream migration and following radio tagging. Fish. Res. 45, 117-127.

Nielsen, M., Braestrup, C., Squires, R.F. 1978. Evidence for a late evolutionary appearance of brain specific benzodiazepine receptors: an investigation of 18 vertebrate and 5 invertebrate species. Brain Res. 141, 342–346.

Nilsson, S. 1984. Adrenergic control systems in fish. Mar. Biol. Lett. 5, 127-146.

Nordeng, H. 1977. A pheromone hypothesis for homeward migration in anadromous salmonids. Oikos 28, 155–159.

Nordeng, H. 1983. Solution to the ‘char problem’ based on Arctic char (*Salvelinus alpinus*) in Norway. Can. J. Fish. Aquat. Sci. 40, 372–1387.

North, R. 2002. Factors affecting the performance of stillwater coarse fisheries in England and Wales, in: Cowx, I.G. (Ed.), Management and Ecology of Lake and Reservoir Fisheries. Blackwell Science, Oxford, 284–298.

NRC (National Research Council). 2005. Developing a research and restoration plan for Arctic- Yukon-Kuskokwim (Western Alaska) salmon. National Academies Press, Washington, DC.

O’Neal, S., J.A. Stanford. 2006. Population status and ecology of brown trout Rio Grande, Tierra del Fuego, Argentina. FLBS Report 193-06. Prepared for Nervous Waters of Argentina and Estancia Maria Behety, by Flathead Lake Biological Station, The University of Montana, Polson, Montana. pp18.

Pankhurst, N.W. Van der Kraak, G. 1997. Fish stress and health in aquaculture. Soc. Exp. Biol. Sem. Ser. 62, 73-93.

Pauley, G.B., Thomas, G.L. 1993. Mortality of anadromous coastal cutthroat trout caught with artificial lures and natural bait. N. Am. J. Fish. Manage. 13, 337-345.

Pelletier, C., Hanson, K.C., Cookes, S.J. 2007. Do catch-and-release guidelines from state and provincial fisheries agencies in North America conform to scientifically based best practices? Env. Manage. 39, 760-773.

Pelzman, R.J. 1978. Hooking mortality of juvenile largemouth bass, *Micropterus salmoides*. Calif. Fish Game, 64, 185-188.

Pickering, A.D., Richards, R.H. 1980. Factors influencing the structure, function and biota of the salmonid epidermis. Proc. Royal Soc. Edinburgh 79. 93-104.

Pickering, A.D., Pottinger, T.G., Carragher, J, Sumpter, J.P. 1987. The effects of acute and chronic stress on the levels of reproductive hormones in the plasma of mature male brown trout, *Salmo trutta* L. Gen. Comp. Endocrinol. 68, 249-259.

Pitcher, T.J., Hollingworth. C.E. 2002. Fishing for fun: Where's the catch? in: Pitcher, T. J., Hollingworth, C.E. (Eds.), Recreational fisheries: Ecological, economic and social evaluation. Blackwell Science, Oxford, 1–16.

Policansky, D. 2002. Catch-and-release recreational fishing: A historical perspective. in: Pitcher, T. J., Hollingworth, C.E. (Eds.), Recreational fisheries: Ecological, economic and social evaluation. Blackwell Science, Oxford, 74–93.

Portavella, M., Vargas, J.B., Torres, B., Salas, C. 2002 The effects of telencephalic pallial lesions on spatial, temporal and emotional learning in goldfish. Brain Res. Bull. 57, 397–399.

Portavella, M., Torres, B., Salas, C. 2004 Avoidance response in goldfish: emotional and temporal involvement of medial and lateral telencephalic pallium. J. Neurosci. 24, 2335–2342.

Power, G. 1981. Stock characteristics and catches of Atlantic salmon (*Salmo salar*) in Quebec, and Newfoundland and Labrador in relation to environmental variables. Can. J. Fish. Aquat. Sci. 38, 1601–1611.

Precourt, D. R. 1999. The American fly fisher. J. Am. Mus. Fly Fish. 25, 14–21.

Primmer, C.R., Veselov, A.J., Zubchenko, A., Poututkin, A., Bakhmet, I., Koskinen, M.T. 2006. Isolation by distance within a river system: genetic population structuring of Atlantic salmon, *Salmo salar*, in tributaries of the Varzuga River in northwest Russia. Mol. Ecol. 15, 653–666.

Raat, A.J.P. 1985. Analysis of angling vulnerability of common carp, *Cyprinus carpio* L., in catch-andrelease angling in ponds. Aquac. Fish. Manage. 16, 171–187.

Rehnberg, B.G., Smith, R.J.F., Sloley, B.D. 1987. The reaction of pearl dace (Pisces, Cyprinidae) to alarm substance – time course of behavior, brain amines, and stress physiology. Can. J. Zool. 65**,** 2916-2921.

Rehnberg, B.G., Bates, E.H., Smith, R.J.F., Sloley, B.D., Richardson, J.S. 1989. Brain benzodiazepine receptors in fathead minnows and the behavioral-response to alarm pheromone. Pharmacol. Biochem. Behav. 33, 435-442.

Richards, J.G., Heigenhauser, G.J.F., Wood, C.M. 2002. Lipid oxidation fuels recovery from exhaustive exercise in white muscle of rainbow trout. Am. J. Physiol. 282, 89–99.

Rikardsen, A.H., Svenning, M.A., Klemetsen, A. 1997. The relationships between anadromy, sex ratio and parr growth of Arctic char in a lake in North Norway. J. Fish Biol. 51, 447–461.

Rikardsen, A.H., Amundsen, P.A., Bjørn, P.A., Johansen, M. 2000. Comparison of growth, diet and food consumption of sea run and lake dwelling Arctic char. J. Fish Biol. 57, 1172–1188.

Rikardsen, A.H., Thorpe, J.E., Dempson, B. 2004. Modelling the life-history variation of Arctic char. Ecol. Freshwat. Fish 13, 305–311.

Rikardsen, A.H., Amundsen, P.A., Knudsen, R., Sandring, S. 2006. Seasonal marine feeding and body condition of sea trout *Salmo trutta* (L.) at its northern distribution area. ICES J. Mar. Sci. 63, 466–475.

Robb, D.F.H., Kestin, S.C. 2002. Methods used to kill fish: field observations and literature reviewed. Anim. Welf. 11, 269–282.

Rose J.D. 2002. The neurobehavioral nature of fishes and the question of awareness and pain. Rev. Fish Sci. 10, 1-38.

Rossiter, A., Kieffer, J.D., Kieffer, T., Davidson, K., Forsyth, L., Tufts, B.L. 1996. Physiology and survival of Atlantic salmon following exhaustive exercise in acidic and soft water: implications for the ‘catch and release’ sportfishery. Abstract of poster, Can. Conf. Fish. Res. Montreal, Quebec, pp52.

Sahrange, D., Lundbeck, J. 1992. A History of Fishing. Berlin: Springer.

Schaeffer, J.S., Hoffmann, E.M. 2002. Performance of barbed and barbless hooks in a marine recreational fishery. N. Am. J. Fish. Manage. 22, 229-235.

Schill, D.J. 1996. Hooking mortality of bait-caught rainbow trout in an Idaho trout stream and a hatchery: Implications for special-regulation management. N. Am. J. Fish. Manage. 16, 348-356.

Schill, D.J., Scarpella, R.L. 1997. Barbed hook restrictions in catch-and-release trout fisheries: A social issue. N. Am. J. Fish. Manage. 17, 873-881.

Schill, D.J., Griffith, J.S., Gresswell, V. 1986. Hooking mortality of cutthroat trout in a catch-andrelease segment of the Yellowstone River, Yellowstone National Park. N. Am. J. Fish. Manage. 6, 226–232.

Schisler, G.J., Bergersen, E.P. 1996. Postrelease hooking mortality of rainbow trout caught on scented artificial baits. N. Am. J. Fish. Manage. 16, 570-578.

Schreck, C.B., Olla, B.L., Davis, V. 1997. Behavioural responses to stress, In: Iwama, G.K., Pickering, A.D., Sumpter, J.P., Schreck, C.B. (Eds.). Fish stress and health in aquaculture. Cambridge University Press, Cambridge, 145–170.

Schupplid, C.A. 1999. Report and recommended actions for humane angling in Canada. Prepared for the Animal Welfare Foundation of Canada, Vancouver, BC. pp23.

Smith, R.J.F. 1992. Alarm signals in fishes. Rev. Fish Biol. 2**,** 33–63.

Sneddon L.U. 2004. Evolution of nociception in vertebrates: comparative analysis of lower vertebrates. Brain Res. Rev. 46, 123-130.

Sneddon L.U. 2006. Ethics and welfare: Pain perception in fish. Bull. Eur. Assoc. Fish Path. 26, 6-10.

Summers, D.W. 1996. Differences in the time of river entry of Atlantic salmon, Salmo salar L., spawning in different parts of the River North Esk. Fish. Manage. Ecol. 3, 209–218.

Sumpter, J.P. 1997. Environmental Control of Fish Reproduction: a different perspective. Fish Physiol. Biochem. 17, 25-31.

Suski, C.D., Killen, S.S., Cooke, S.J., Kieffer, J.D., Philipp, D.P., Tufts, B.L. 2004. Physiological significance of the weigh-in during live-release angling tournaments for largemouth bass. Trans. Am. Fish. Soc. 133, 1291–1303.

Suski, C.D., Killen, S.S., Kieffer, J.D., Tufts, B.L. 2006. The influence of environmental temperature and oxygen concentration on the recovery of largemouth bass from exercise: Implications for live-release angling tournaments. J. Fish. Biol. 68, 120–136.

Suski, C.D., Cooke, S.J., Danylchuk, A.J., O'Connor, C.M., Gravel, M.A., Redpath, T., Hanson, K.C., Gingerich, A.J., Murchie, K.J., Danylchuk, S.E., Koppelman, J.B., Goldberg, T.L. 2007 Physiological disturbance and recovery dynamics of bonefish (*Albula vulpes*), a tropical marine fish, in response to variable exercise and exposure to air. Comp. Biochem. Physiol. 148A, 664-673.

Svenning, M.A. 2007. Målselva som storlakselv. Radiomerking av laks i Målselvvassdraget. Rapport til: RDA-sekretariatet, Troms Fylkeskommune: 1-20. (Radio-tagging of Atlantic salmon in the river Målselv (in Norwegian)).

Svenning, M.-A., Smith-Nilsen, A., Jobling, M. 1992. Sea water migration of Arctic char (*Salvelinus alpinus* L.): correlation between freshwater growth and seaward migration, based on back-calculation from otoliths. Nordic J. Freshwat. Res. 67, 18–26.

Taylor, M.J., White, K.R. 1992. A meta-analysis of hooking mortality of non-anadromous trout. N. Am. J. Fish. Manage. 12, 760-767.

Thompson, L.A., Cooke, S.J., Danalson, M.R., Hanson, K.C., Gingerich, A., Klefoth, T., Arlinghaus, R. 2008, Physiology, behaviour and survival of angled and air exposed largemouth bass. N. Am. J. Fish. Manage. 28, 1059-1068.

Thorley, J.L., Youngson, A.F., Laughton, R. 2007**.** Seasonal variation in rod recapture rates indicates differential exploitation of Atlantic salmon, *Salmo salar*, stock components. Fish. Manage. Ecol. 14, 191-198.

Thorstad, E.B., Næsje, T.F., Finstad, B., Breistein, J.B. 2000. Effects of catch and release of Atlantic salmon in the River Alta. Studies in 1998 and 1999. NINA Oppdragsmelding 656. pp26 (In Norwegian).

Thorstad, E.B., Næsje, T.F., Fiske, P., Finstad, B. 2003a. Effects of hook and release on Atlantic salmon in the River Alta, northern Norway. Fish. Res. 60, 293–307.

Thorstad, E. B., Økland, F., Hvidsten, N. A., Fiske, P., Aarestrup, K. 2003b. Oppvandring av laks i forhold til redusert vannføring og lokkeflommer i regulerte vassdrag. Rapport Miljøbasert Vannføring, Norges vassdrags- og energidirektorat, 1-2003. pp53. (In Norwegian).

Thorstad, E.B., Rikstad, A., Sandlund, O.T. 2006. Kunnskapsstatus for laks og vannmiljø i Namsenvassdraget. Kunnskapssenter for Laks og Vannmiljø, Namsos. (In Norwegian).

Thorstad, E.B., Næsje, T.F., Leinan, I. 2007. Long-term effects of catch-and-release angling on ascending Atlantic salmon during different stages of spawning migration. Fish. Res. 85, 316-320.

Thorstad, E.B., Næsje, T.F., Mawle, G.W., Policansky, D. 2008a. The Atlantic salmon C&R story. In: Aas, Ø. (Ed.), Global challenges in recreational fisheries. Blackwell Publishing, 219-222.

Thorstad, E.B., Okland, F., Aarestrup, K., Heggberget, T.G. 2008b. Factors affecting the within-river spawning migration of Atlantic salmon, with emphasis on human impacts. Rev. Fish Biol. Fisher. 18, 345-371.

Tomie, A., Silberman, Y., Williams, K., Pohorecky, L.A. 2002. Pavlovian autoshaping procedures increase plasma corticosterone levels in rats. Pharmacol. Biochem. Behav. 72**,** 507-513.

Tsuboi, J., Morita, K. 2004. Selectivity effects on wild white-spotted char (*Salvelinus leucomaenis*) during a catch-and-release fishery. Fish. Res. 69, 229–238.

Tufts, B.L., Tang, Y., Boutilier, R.G. 1991. Tufts, B.L., Tang, Y., Boutilier, R.G. 1991. Exhaustive exercise in wild Atlantic salmon: acid-base regualtion and blood transport. Can. J. Fish. Aquat. Sci. 48, 868-874.

Tufts, B.L., Davidson, K., Bielak, A.T. 2000. Biological implications of ”catch-and-release” angling of Atlantic salmon, in: Whoriskey, F.G., Whelan, K.E. (Eds.), Managing Wild Atlantic Salmon. Atlantic Salmon Federation, St. Andrews, New Brunswick, 195–225.

Turek, S.M., Brett, M.T. 1997. Comment: Trout mortality from baited barbed and barbless hooks (and reply). N. Am. J. Fish. Manage. 17, 807-807.

Ugedal, O., Thorstad, E.B., Finstad, A.G., Fiske, P., Forseth, T., Hvidsten, N.A., Jensen, A.J., Koksvik, J.I., Reinertsen, H., Saksgård, L., Næsje, T.F. 2007. Biological studies in the River Altaelva 1981-2006. Consequences of the hydro power development for the Atlantic salmon population. NINA Rapport 281. pp106. (In Norwegian).

Van de Vis, H., Kestin, S., Robb, D., Oehlenschläger, J., Lambooij, B., Münker, W., Kuhlmann, H., Kloosterboer, K., Tejada, M., Huidobro, A., Ottera, H., Roth, B., Sørensen, N.K., Akse, L., Byrne, H., Nesvadba, P. 2003. Is humane slaughter of fish possible for industry? Aquacult. Res. 34, 211–220.

Verspoor, E., Beardmore, J.A., Consuegra, S., Garcìa de Leàniz, C., Hindar, K., Jordan, W.C., Koljonen, M.-L., Mahkrov, A.A., Paaver, T., Sànchez, J.A., Skaala, Ø., Titov, S., Cross, T.F. 2005. Population structure in the Atlantic salmon: insights from 40 years of research into genetic protein variation. J. Fish Biol. 67 (Suppl. A), 3–54.

Walker, A. F., Walker, A. M. 1992. The Little Grunard Atlantic salmon (*Salmo salar* L.,) catch and release study, in: Priede, I.G., Swift, S.M. (Eds.), Wildlife Telemetry: remote monitoring and tracking of animals. Ellis Horwood, 434-440.

Wall, A.J. 2001. Ethical considerations in the handling and slaughter of farmed fish, in: Kestin, S.C., Warriss, P.D. (Eds.), Farmed Fish Quality. Blackwell Science, Oxford, 108–115.

Wang, Y., Heigenhauser, G.J.F., Wood, C.M. 1994. Integrated responses to exhaustive exercise and recovery in rainbow trout white muscle: Acid-base, phospogen, carbohydrate, lipid, ammonia, fluid volume and electrolyte metabolism. J. Exp. Biol. 195: 227–258.

Warner, K. 1976. Hooking mortality of landlocked Atlantic salmon *Salmo salar*, in a hatchery environment. Trans. Am. Fish. Soc. 3, 365-369.

Warner, K. 1979. Mortality of landlocked Atlantic salmon hooked on four types fishing gear at the hatchery. Prog. Fish Cult. 41, 99-102.

Warner, K., Johnson, P.R. 1978. Mortality of landlocked Atlantic salmon hooked on flies and worms in a river nursery area. Trans. Am. Fish. Soc. 107, 772-775.

Webb, J.H. 1998. Catch and release: the survival and behaviour of Atlantic salmon angled and returned to the Aberdeenshire Dee, in spring and early Summer. Fisheries Research Services in Association with the Atlantic Salmon Trust, Scottish Fish. Res. Rep. Number 62/1998, 1-16.

Webb, J. 2009. Catch and release: some refinements of advice on live fish handling. Atlantic Salmon Trust Winter J. 2009, 28-29.

Wedemeyer, G.A., Saunders, R.L., Clarke, W.C. 1980. Environmental factors affecting smoltification and early marine survival of anadromous salmonids. Mar. Fish. Rev. 42, 1–14.

Wendelaar Bonga, S.E. 1997. The stress response in fish. Physiol. Rev. 77, 591-625.

Whiles, M.R., Huryn, A.D., Taylor, B.W., Reeve, J.D. 2009. Influence of handling stress and fasting estimates of ammonium excretion by tadpoles and fish: recommendations for designing excretion experiments. Limnol. Oceanog. Methods 7, 1-7.

Whoriskey, F.G., Prusov, S., Crabbe, S. 2000. Evaluation of the effects of catch-and-releaseangling on the Atlantic salmon (*Salmo salar*) of the Ponoi River, Kola Peninsula, Russian Federation. Ecol. Fresh. Fish 9, 118-125.

Wilde, G.R. 1998. Tournament-associated mortality in black bass. Fisheries 23, 12–22.

Wilde, G.R. 2003. Dispersal of tournament-caught black bass. Fisheries 28, 10–17.

Wilde, G.R., Sawynok, W. 2009. Effect of hook removal on recapture rates of 27 species of angler-caught fish in Australia. Trans. Am. Fish. Soc. 138, 692-697.

Wilde, G.R., M.I. Muoneke, P.W. Bettoli, K.L. Nelson, Hysmith, B. T. 2000. Striped bass hooking mortality in freshwater. N. Am. J. Fish. Manage. 20, 809–814.

Wilkie, M.P., Davidson, K., Brobbel, M.A., Kieffer, J.D., Booth, R.K., Bielak, A.T., Tuftes, B.L. 1996. Physiology and survival of wild Atlantic salmon following angling in warm summer waters. Trans. Am. Fish. Soc. 125, 572-580.

Wilkie, M.P., Brobbel, M.A., Davidson, K., Forsyth, L., Tufts, B.L. 1997. Influences of temperature upon the postexercise physiology of Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 54, 503-511.

Willoughby, L.G. 1978. Saprolegniasis of salmonid fish in Windermere: a critical analysis. J. Fish Dis. 1, 51 -67.

Wood, C.M. 1991. Acid-base and ion balance, metabolism and their interactions after exhaustive exercise in fish. J. Exp. Biol. 160, 285-308.

Wood, C.M., Turner, J.D., Graham, M.S. 1983. Why do fish die after severe exercise? J. Fish. Biol. 22, 189-201.

Wydoski, R.S. 1977. Relation of hooking mortality and sublethal hooking stress to qualify fishery management, in: Barnhart, R.A., Roelofs, T.D. (Eds), Catch-and-release fishing as a management tool. Humbolt State University, Arcata, California, 43-87.

Yue, S., Moccia, R.D., Duncan, I.J.H. 2004. Investigating fear in domestic rainbow trout, *Oncorhynchus mykiss*, using an avoidance learning task. Appl. Anim. Behav. Sci. 87**,** 343-354.

Zimmerman, M. 1986. Physiological mechanisms of pain and its treatment. Klin. Anaesthesiol. Intensivtherap. 32, 1–19.

# APPENDIX

**Table 8.** Categorisation of Atlantic salmon rivers (June 2007). The table shows the number of watercourses that have or have had self-reproducing salmon stocks by county and category, and the number of watercourses affected by various factors (only the impact-factor(s) which is decisive for assigned category is/are shown). One watercourse might be affected by several impact factors. *Overexploitation* is temporarily excluded from the table, because stock assessments in relation to spawning targets are not integrated in the categorisation from 2007.

| County | Number of watercourses with self-reproducing salmon stock | Category* | | | | | | | | | Factor decisive for assigned category | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3a | 3b | 4a | 4b | 5a | 5b | X | Hydro-Power development | Other habitat deterioration | Acidification | Pollution by agriculture | Other water pollution | *Gyrodactylus salaries* | Sea-Lice | Other Fish Diseases | Unknown factor | Other factors |
| Østfold | 2 | | | | | | | 2 | | | 1 | 1 | 1 | 2 | 2 | | | | | |
| Oslo og Akershus | 10 | | | 8 | | 2 | | | | | 3 | 7 | | 4 | 6 | | | | | |
| Buskerud | 3 | | | | 2 | | | 1 | | | | | | | | 2 | | | | |
| Vestfold | 3 | | 2 | | | | | 1 | | | 1 | 1 | | 1 | 1 | 1 | | | | |
| Telemark | 3 | 1 | | | | 1 | | 1 | | | 3 | | | | | | | | | |
| Aust-Agder | 1 | | 1 | | | | | | | | 1 | | | | | | | | | |
| Vest-Agder | 9 | 3 | | | 6 | | | | | | | | 8 | | 1 | | | | | |
| Rogaland | 32 | 2 | | 3 | 6 | 6 | | 11 | | 4 | 8 | 1 | 13 | 3 | 2 | | | | 1 | |
| Hordaland | 25 | 6 | 8 | 2 | 4 | 1 | | 3 | | 1 | 7 | | 10 | | 2 | | 12 | | 1 | |
| Sogn og Fjordane | 32 | 5 | 1 | 2 | 1 | 5 | | 18 | | | 7 | 1 | 9 | | | 1 | 16 | | | |
| Møre og Romsdal | 62 | | 9 | | | 7 | | 38 | 8 | | 8 | 5 | | | | 8 | | | | |
| Sør-Trøndelag | 59 | 4 | | 2 | | 23 | 1 | 23 | 6 | | 18 | 13 | | 6 | 1 | | | | | 1 |
| Nord-Trøndelag | 31 | 4 | 4 | 4 | | 2 | | 16 | 1 | | 9 | 1 | | | | 2 | | 1 | | 4 |
| Nordland | 99 | 16 | 4 | 4 | | 14 | 1 | 50 | 10 | | 15 | 5 | 1 | 4 | 2 | 12 | 2 | 1 | | 5 |
| Troms | 37 | 1 | 2 | 5 | | 1 | | 25 | 2 | | | 1 | | | | 2 | | | | 6 |
| Finnmark | 42 | 3 | 1 | | | 1 | | 19 | 12 | 6 | 5 | 2 | | | | | | | | 3 |
| **The whole country** | **450** | **45** | **32** | **30** | **19** | **63** | **2** | **208** | **38** | **13** | **83** | **37** | **41** | **20** | **17** | **28** | **22** | **2** | **2** | **19** |