Nordic Workshop for PhD students on Anadromous Salmonid Research

Agdenes, Norway
7. – 10. April 2005

Programme

Location: Slettvik field station (NTNU), Trondheim, Norway
(http://www.bio.ntnu.no/eng/field_stations.php)

Thursday 7th:
1600: Departure from Trondheim to Agdenes field station by bus
1800: Housing
1900: Welcome and opening by Morten Stickler
1930: Dinner and social gathering

Friday 8th:
0800: Breakfast
0900: Invited talk: Hans Petter Fjeldstad
1000: Session I
1100: Coffee break
1115: Invited talk: Tormod Schei
1215: Lunch
1315: Invited talk: Sigurd Einum
1415: Coffee break
1440: Session II
1540: Break
1600: Session II continues
1700: Break
1800: If good weather, social gathering and drinks by the ocean
2000: Dinner and social gathering

Saturday 9th:
0800: Breakfast
0930: Session III
1030: Break
1045: Session IV
1200: Lunch
1300: Invited talk: Eva Thorstad
1400: Coffee break
1415: Session V
1515: Break
1530: Session V continues
1655: Workshop: group work/discussions
2000: Conference dinner and social gathering
23:00: Sauna☺

Sunday 10th:
0900: Breakfast
1000: Discussion and closure
1130: Lunch

1300: Departure by bus to Trondheim

Presentations by participants:

- 1.March: Deadline for submission of abstract (maximum 350 words) and committed registration to morten.stickler@ntnu.no
- Oral presentation or poster
- Time of talks would be approximately 10 min with 5 minutes for discussion

Invited speakers:

Invited talks given by: Sigurd Einum (Norwegian Institute of Nature Research), Eva Thorstad (Norwegian Institute of Nature Research), Hans Petter Fjeldstad (Sintef Energy Research) and Tormod Schei (Statkraft).

Workshop:

- Evaluation of NoWPAS 2005
- Future work (European network?)

Organising committee:

Morten Stickler, coordinator (Norway), Anders Gravbrøt Finstad (Norway), Lasse Fast Jensen (Denmark), Olle Calles (Sweden) and Saja Koljonen (Finland).

- Friday 8th:
  - Chair: Anders Finstad
- Saturday 9th:
  - Chair: Olle Calles
- Workshop:
- Sunday 10th:
  - Discussion and closure: Lasse Fast Jensen and Morten Stickler

Costs and reimbursement:

Accommodation (included 3 meals per day) and conference fees are covered by NoWPAS. No sheets needed. You may have to share room with 1-3 other participants Travel costs will be partly covered. Participants apply for reimbursement. Maximum 350 Euros. Reimbursement form will be send out by e-mail within 5.April. Receipts and forms are to be collected during the meeting.

Travel information:

- Cheap accommodation in Trondheim city: http://www.trondheim-vandrerhjem.no/
- From airport to town → Bus from airport to city centre corresponds with flights and stops at railway station (approx.8 Euro). 30 minutes of travel.
- Trondheim-Agdenes → Chartered bus from railway station, Trondheim
- From railway station to airport → every 15 min (approx. 8 Euro)
- Contacts:
  - Morten Stickler - 99030752 (mobile), 73598388 (office)
  - Anders Gravbrøt Finstad – 90018545 (mobile), 73801446 (office)

Sessions

Session	Day	Time	Name	Title
I: Freshwater Habitat	Friday	10:00	Peter Borsanyi	Scaling for assessment of production potential and mitigation of environmental effects on River Nausta – habitat classification
		10:20	Morten Stickler	Physical winter habitat for juvenile Atlantic salmon (Salmo salar)
		10:40	Anders Gravbrøt Finstad	Winter survival in salmonids and the importance of ice cover
II: Population dynamics and genetics		14:40	Eli Kvingedal	Population regulation in Atlantic salmon: the impact of scale, environment and phenotypic variation
		15:00	Lasse Fast Jensen	Spatio-temporal genetic variation in Danish brown trout (*Salmo trutta*) populations
		15:20	Sofia Brockmark	The effect of environment on phenotypic and genetic diversity in brown trout
		16:00	Anni Tonteri	Phylogeography of Atlantic Salmon (*Salmo salar*) from Northern Europe
		16:20	Lena Neregård	Effects of growth hormone in salmonids
		16:40	Line Sundt-Hansen	Costs of enhanced growth in Atlantic salmon
III: Pollution	Saturday	09:30	Mikko Kiljunen	Accumulation of Dioxin-like Organochlorines in Baltic Salmon (*Salmo salar)* – Bioenergetics Approach
		09:50	Torstein Kristensen	The low P_aO_2 strategy in Atlantic salmon- Is it present, and what are the implications?
		10:10	Tore Christian Svendsen	Investigation of salmon and trout migration using PCB-fingerprinting.
IV: Parasites		10:45	Anja Celine Winger	*Gyrodactylus salaris* in northern Norway: Population dynamics and parasite induced effects upon host behaviour and physiology.
		11:05	Kjetil Olstad	Survival, infectivity and transmission in *Gyrodactylus salaris*
		11:25	Martin Österling	Interactions between trout and parasitic larvae of freshwater mussels.
V: Behaviour and Migration		14:15	Johan Östergen	Restored rivers, restored salmonids populations?
		14:35	Ivan Olsson	To migrate or not to migrate: that is *the* question
		14:55	Elianne Wassvik	Fish lock as an entrance to fish ladders at hydropower plants
		15:30	Olle Calles	Natural-like fishways for re-establishing connectivity

		15:50	Panu Orell	Synchrony in the downstream migration of smolts and upstream migration of adult Atlantic salmon in the subarctic River Utsjoki
		15:10	Petri Karpinen	Migration examples of Baltic salmon in Bothnian Bay – by-product observations from a river migration study

Preface

During the last decade's research on Anadromous salmonids has increased and will most likely augment in the future. In this connection, PhD and post-doctoral students with related focus will play an important and central role in gaining new knowledge and by developing new methods in order to cope with today's and the future challenges. In order to increase and further improve the profit obtained from the PhD study's a new network has been established. As an element of building a European network a Nordic workshop over three days with title NoWPAS (Nordic Workshop for PhD students on Anadromous Salmonid research) iss held at Agdenes, Mid-Norway, April 2005. About 30 participants will give oral presentations whereas 4 guest lectures is invited.

The objective with such a network is two fold: Firstly we wish to arrange an annual independent workshop where the participants can gather, exchange knowledge and ideas and to have discussions in an interdisciplinary forum. Secondly we wish to establish connections with the "outer world" by inviting key researchers to give lectures and short courses within the sphere. On the basis of this we mean that the utility value is potentially larger for both the participants and the community.

Todays and future PhD students are representing the recruitment of researchers within the science of Anadromous salmonids. Therefore it will be very important that younger scientists establish connections with thoughts of future collaboration in an international environment. The network has objective to both act as an informal basis and as a serial of annual workshops. It will emphasize both the opportunity for collaboration through existing and future projects. As an overview the network will have following main objectives:

i) Participating PhD and Post-doctoral students shall present their work and obtained results. In this way they will have the opportunity to get feedback on their own work and to be oriented of other people's work and findings within the sphere.

ii) It will aim at invitation of external scientists within the sphere to present actual problem issues in addition to take part in discussions.

iii) Presented materiel and the discussions will make basis for a report which will be published and send to all participants and members of the network.

iv) A homepage is to be established where publications and information on international conferences, workshops etc. can be presented. This web page will therefore act as an information centre.

Acknowledges

NoWPAS-2005 has primary been based on voluntary work and self effort. Nevertheless, it has not been possible to establish the network and conduct the workshop without external help and finance. We want to thank following people and their companies for financial contribution: Tormod Schei, Statkraft, Hallvard Ødegaard, NTNU, Hans Otto Haaland, The Norwegian Research Council (The RENERGI programme), Knut Ivar Nyhaug, The Power companies in Orkla, Hans Petter Fjeldstad, Sintef Energy Research, Børge Hanssen, Trondheim Energy Company and Trond Rosten, The Norwegian Institute of Water Science.

We also want to thank external participants; Tormod Schei (Statkraft), Hans Petter Fjeldstad (Sintef), Eva Thorstad (NINA) and Sigurd Einum (NINA).

And, not at least, members and participants of NoWPAS who made this work possible.

The organizing committee of NoWPAS-2005 has consisted of following people:

- Morten Stickler, Norway. Coordinator
- Anders Gravbrøt Finstad, Norway
- Saja Koljonen, Finland
- Olle Calles, Sweden
- Lasse Fast Jensen, Denmark

Morten Stickler, Trondheim 3rd of April 2005.

Coordinator of NoWPAS 2005.

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Additonal abstracts by members of NoWPAS-205

Members of NoWPAS-2005

Investors

Notes

Scaling for assessment of production potential and mitigation of environmental effects on River Nausta – habitat classification phase

Péter Borsányi and Knut Alfredsen
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Abstract

An application of a mesohabitat classification method is presented. A long river reach (~15 km) is the subject of a study for mitigation and improvement of physical salmon habitat. The purpose of the study was to identify crucial factors and to suggest necessary measures which can serve as basis for sustainable river management regarding the salmon population. The study utilizes distributed sampled data over the study reach on river Nausta in Western-Norway, by means of a mesoscale habitat classification method. The method is linked to calculated fish densities, thus a link between hydro-morphology and habitat quality is provided.

Data are collected and analyzed in depth on certain parts of the reach where large fish density is combined with sensible habitat-flow connection. The fish density values are calculated from observed fish sampling, while habitat-flow sensitivity is derived from the physical features of the meso-scale classes.

Physical winter habitat for Atlantic salmon (*Salmo salar*) in lotic environments.

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Abstract

Today, there is a consensus for the importance of needed understanding about the interaction between physical and ecological conditions in order to improve and preserve the natural environment. In both national and international relation this discipline has gained increased attention especially within river management and preservation of the wild Atlantic salmon (*Salmo salar*) stock. Further, focus on the interaction between cold climate processes and winter habitat of Atlantic salmon has increased. Research indicates that winter time may be a limited factor and has identified critical habitats and different mechanisms by which winter conditions may affect changes in fish behaviour and population density. Up to this date research in water courses has mainly focused on impact assessment related to power production, e.g. minimum release, hydro peaking and intervention during summer conditions. In the future, research with an increased focus on the cold, physical environment itself is therefore needed. At the same time it is necessary to not only investigate the biological and hydraulic conditions separately, but as one integrated system. This includes and provides challenges in a new interdisciplinary manner.

In this study the main objective is to "Understand and investigate the processes behind a dynamic ice regime in water courses and link this and the surrounding physical environment to fish habitat in cold climate". The study is to emphasize theoretical understanding and development of methods and tools for assessing dynamic ice regimes in rivers in relation to physical fish habitat. The study will be based on widespread fieldwork in water courses where existing and/or future interdisciplinary projects are planned to be conducted. Within this work, field observations collected by modern sampling methods, are to be adapted to numerical hydraulic and habitat models by means of geographic information tools.

The study will not only increase the understanding of the interaction between the physical environment and the biological mechanisms behind habitat selection of Atlantic salmon,

but also provide basic knowledge on ice in rivers, e.g. flood problems, ice damming and ice growth around existing river constructions.

Winter survival in salmonids and the importance of ice cover

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Abstract

Ice cover of northern hemisphere aquatic habitats is declining due to climatic changes. Also, on a local scale, hydropower regulation may reduce ice cover in regulated rivers. My PhD aims at exploring the sensitivity of different species and populations to changes in ice cover using northern salmonid fishes as model. This is done using a combination of field data, laboratory experiments and energetic modelling.

Firstly, the effect of ice cover on energy turnover is explored using common environment experiments in laboratory environment where the energetic consequences of altered light conditions with or without ice cover are investigated, and also in semi-natural stream channels where we simulate ice-cover or absence of ice-cover. Secondly, we test for energy dependent winter mortality in a northern population of juvenile Atlantic salmon. Finally, winter mortality and changes in energy turnover are linked using energetic modelling.

Resting metabolism was on average 30% lower under simulated ice cover than under natural day length. However there were marked between population differences in growth rate and northern salmon grew equally well in dark and light conditions, whereas the southern grew significantly poorer in the dark. Fish from all populations fed more under natural day length than in the dark and the northern population had higher consumption than the southern. The experiments in semi-natural stream channels also demonstrated a clear effect of ice cover on over-winter energy loss rates. Observed overwinter changes in distribution of specific energy for juvenile Atlantic salmon in the River Alta corresponded to a removal of low energy individuals from the population. No changes in mean size of the fish, or in the shape of the size distributions, were observed between successive sampling periods, indicating that mortality was linked to levels of storage energy rather than body size *per se*. Our study indicated a critical body energy level for survival of juvenile salmon at ≈ 4400 to 4800 J g^{-1}, corresponding to a depletion of storage lipids.

Our study indicates that changes in energy turnover following loss of ice cover are of a scale that significantly may reduce over-winter survival in northern salmonids.

Population regulation in Atlantic salmon: the impact of scale, environment and phenotypic variation

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Abstract

Salmonid populations experience large spatial and temporal variability in abundance and there is a need to better understand the underlying mechanisms of this variation. Three important issues that I will look into during my PhD research are 1) how the environmental effect on population growth may depend on population density, 2) the interactive effect of phenotype and environment on density dependence, and 3) the spatiotemporal scale of density dependence. These issues will be investigated both by experimental studies and by a modelling approach. The main focus will be on the early juvenile stage when density dependence is more likely to occur due to restricted mobility. The experiments will be performed both in outdoor semi-natural channels and in experimental or natural streams. Environmental factors that will be manipulated in the semi-natural channels are water flow and food availability, while the phenotype will be given by egg size or juvenile body size. Performance, given by survival, body growth or changes in energy contents, will be evaluated for the different phenotypes at varying levels of densities. Empirical data from these studies will be utilized in a simulation model that is under development. This population model follows individuals with daily increments in a spatially structured stream with specific habitat characteristics and temperature regimes. Based on the parameterized population model predictions of abundance will be tested against empirical observations.

Spatio-temporal genetic variation in Danish brown trout (*Salmo trutta*) populations

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Abstract

A high number of population genetic studies have addressed the structuring of brown trout populations using allozymes, mitochondrial DNA and microsatellites. Often, populations have been found to be significantly differentiated, even across very short geographical distances. But what is the biological significance of these differences and is the population structure temporally stable? The development of molecular techniques permitting the extraction of DNA from old fish scales opened for the possibility to analyse genetic markers from archived scale samples from brown trout. The analysis of temporally separated samples allows us to address questions regarding temporal population structure and in addition makes joint estimation of migration rates and effective population sizes possible. These parameters are of great importance to conservation and management considerations.

Analyses of the spatio-temporal component in the structuring of Danish brown trout populations have revealed great diversity of the genetic population structure in brown trout. The results from these studies stress the importance of a temporal sampling scheme when describing population structures and in addition question the value of merely estimating F_{ST} in the deduction of population structures. Specifically, two Danish population systems will be presented. The first deals with a number of large anadromous populations living in large stable rivers running through farmland at the Danish peninsula Jutland. These populations show a temporally stable population structure, high effective population sizes and low migration rates. The second system is comprised of a number of small populations of potamodromous brown trout living in small unstable rivers emptying into Lake Hald, Central Jutland, Denmark. These populations show temporally unstable structuring, small effective population sizes and high migration rates. However, the estimated F_{ST} values for both systems are very similar.

The presentation aims at illustrating the great diversity of brown trout populations at the genetic level, supplementing the great ecological and morphological diversity of this highly polytypic species.

The effect of environment on phenotypic and genetic diversity in brown trout

S. Brockmark[1], J. Dannewitz [2], T. Bohlin[1] and J.I. Johnsson[1]

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Abstract

Genotype-environment interaction occurs when different genotypes have different phenotypic responses to environmental variation. It has been suggested that complex environments permit different genotypes to optimize their phenotypic means to a larger extent than homogenous environments. Artificial rearing environments, which lack the variation normally found in nature, should therefore constrain phenotypic adaptations and thereby genetic variation. The present study examined the influence of environmental and social conditions on genetic variation and phenotypic expression using 12 families of brown trout. We manipulated two important factors determining phenotypic response: habitat structure (plain tanks, tanks with sand, or tanks with rocks) and density (natural densities or half of natural). Trout were reared over their most critical survival period, i.e. the first 10 weeks after emergence. Growth, genetic diversity and morphology will be presented regarding the effects of structural enrichment and population density.

Phylogeography of Atlantic salmon (*Salmo salar*) from Northern Europe

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Abstract

Despite being intensively studied, the post-glacial origin of north European Atlantic salmon (*Salmo salar*) remains unclear. Refugia in glacial ice-lakes in the east as well as in the Atlantic Ocean in the west have been suggested as sources of post-glacial colonization, however, no consensus of the origin has been reached. Here, a total of 21 nuclear loci (14 microsatellite and seven allozyme loci) were used to infer the phylogeography of 15 anadromous and eight non-anadromous north European Atlantic salmon populations, including 18 populations from northwest Russia. A neighbour-joining population tree revealed three groups corresponding very well to the sampling regions. A comparison of FST and RST estimates with a novel allele size permutation method suggested that at least two of the groups had diverged from each other already prior to the ice receding after the last ice age, thus suggesting that north European Atlantic salmon are derived from at least two separate refugia. I propose that the non-anadromous salmon from lakes Ladoga and Onega (Russia) and anadromous populations from the Baltic Sea most likely originate from a southeastern ice-lake refugium. The present day White and Barents Sea basins have probably been colonized from multiple refugia.

Selective breeding of Atlantic salmon affects growth hormone action on growth and lipid metabolism

Lena Neregård[1], Line Sundt-Hansen[2], Kjetil Hindar[2], Sigurd Einum[2], Jörgen I Johnsson[3], Robert H. Devlin[4], Ian Fleming[5] and Björn Thrandur Björnsson[1]

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Abstract

Selective breeding of Atlantic salmon for aquaculture has been carried out for eight generations, resulting in domesticated AquaGen salmon strains. To elucidate the effects of breeding selection on growth, endocrine growth regulation and lipid metabolism, an AquaGen strain was compared with its principal wild progenitor strain (River Namsen strain) as well as a wild local strain (River Imsa strain).

Groups of equal-sized parr of the three strains were implanted with a slow-release growth hormone (GH) implant (or sham implant). Growth was monitored every month for three months, after which the fish were sampled for blood and tissues. Of the sham-implanted controls, the AquaGen strain had the fastest growth rate. GH increased growth rate in all three strains, with the wild strains having a significantly higher growth response than the domesticated strain. Comparisons of muscle and hepatic lipid content indicate that the AquaGen fish have elevated muscle lipid content compared with the wild strains, while the hepatic lipid content is similar among all strains. GH decreases the hepatic lipid content of the Namsen fish, but not of the two other strains. In contrast, GH decreases the muscle lipid content of the AquaGen strain, but not of the two other strains. Apart from faster growth, domesticated salmon typically have higher muscle fat content, as confirmed by the present study. GH is the main endocrine regulator of growth rate. The fact that the wild strains have a stronger growth response to GH-treatment than the domesticated strain indicates that the breeding selection process has already utilized some of the GH-inducible growth potential of the species. GH has previously been indicated to be lipolytic in salmonids, but it is notable that the three strains show a differentiated GH-response in terms of lipid metabolism. Thus, the AquaGen fish mobilize muscle lipids down to the levels seen in wild fish. The wild fish, on the other hand, do not mobilize muscle lipids, and only the Namsen fish mobilize hepatic lipids. It is concluded that wild

salmon have a great physiological scope for growth, and that this can be linked to the role of GH in regulating lipid mobilization from tissues.

Financed by the Norwegian Research Council and the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning

Cost of growth enhancement in Salmonids

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Abstract

This PhD aims to study the ecological effects of rapid growth using GH transgenic salmon and salmonids with bovine growth hormone (GH) implants as model animals. The thesis is part of an international project titled "Quantifying biological risks of growth enhanced transgenic salmon" and is founded by the Norwegian Research Council. The background for the thesis is the increasing worldwide interest in applying gene technology to aquaculture and the importance of assessing the environmental effects that growth enhanced transgenic fish can have on wild populations of salmonids. In addition to considering the ecological effects of growth enhancement on survival, foraging and spawning behaviour of salmonids.

The experiments will consider different life stages of salmonids, from the juvenile stage, to smolts and spawning adults. Most of the work will be performed on salmonids injected with bovine growth hormone to mimic important biological changes in GH-transgenic fish. Currently two experiments have been conducted, both during the fall of 2004. First, a field experiment in Sweden looking at movements of GH-implanted brown trout and, second, a spawning experiment at NINA Research Station Ims in Norway estimating spawning success of competing GH implanted Atlantic salmon males and controls.

In the field experiment GH implanted brown trout and controls were equipped with radio transmitters and tracked for 3 months to study the effect of enhanced growth on movement before and during the spawning season. Preliminary results suggest that growth enhanced brown trout males have a significantly larger range of movement than control males before the spawning season (August-September). The spawning experiments were performed in semi natural spawning arenas. Wild and GH-implanted Atlantic salmon males were paired and introduced to one wild female, in addition to a group of 10 wild and 10 GH-implanted parr. Spawning success was assessed by video and direct visual recording of spawning behaviour. The offspring has been sampled for microsatellite profiling to measure spawning success of the adult males and the parr in cases where success could not be unequivocally established based on male presence and redd identity.

Accumulation of Dioxin-like Organochlorines in Baltic Salmon (*Salmo salar)* – Bioenergetics Approach

Mikko Kiljunen[1], Heikki Peltonen[2], Hannu Kiviranta[3], Pekka Vuorinen[4], Matti Verta[2] & Juha Karjalainen[1]

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Oral presentation, NowPAS meeting, April 2005
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Abstract

An individual-based bioenergetics accumulation model was developed to simulate accumulation of dioxin-like substances in Baltic salmon (*Salmo salar*). The work is a part of the BIREME project "*DIOXMODE: Bioaccumulation of Dioxin-Like Organochlorines in Baltic Fish – Experimental and Modelling Approach*".With bioenergetics modelling, food consumption of fish can be estimated from the growth and metabolic rates of individuals. Due to the hierarchic structure of energy budgets, it also describes efficiently trophic transfers and thus links different levels of biological communities. This enables studies on the transfer of harmful substances in food webs.

The bioenergetics part of the model is based on the "Wisconsin model". However, in our approach, the model has been modified to include individual variation in salmon growth and prey selection. The physiological parameters of pink salmon (*Onchorhynchus gorbuscha*) have been used (Fig. 1).

Salmon (individuals) and prey species-specific (pooled age groups) PCBs and PCDD/F's were analysed in the 2003-2005 (see poster by Vuorinen et al.). Accumulation efficiencies of each congener were derived from published studies. Salmon growth rates, sea water temperatures, prey growth and prey selection data were extracted from databases available for the researchers of the project and from unpublished data sets.

PCB and PCDD/F concentrations of Baltic salmon were simulated under different conditions. In the simulations, prey species consumed by salmon were herring (*Clupea harengus*), sprat (*Sprattus sprattus*) and three-spined stickleback (*Gasterosteus aculeatus*). Baseline simulations were carried out for three different locations using site-specific input data. Subsequently, the baseline models were modified to predict salmon organoclorine (OC) concentrations under different feeding conditions. The simulation alternatives included changes in OC concentrations of prey due to changes in growth rates and changes in the supply of different prey species. Later, the model will allow

evaluation of the effect of different fisheries management actions on salmon OC-concentrations.

The low P_aO_2 strategy in Atlantic salmon- Is it present, and what are the implications?

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Abstract

Respiratory strategies witch aim to minimize oxygen partial pressures in cells and tissues are applied by a number of aquatic animal groups to avoid toxic effects of oxygen through ROS (Reactive Oxygen Species) formation. The strategy applied by fish and aquatic invertebrates has been termed the low P_aO_2 strategy. As the name implies, the strategy is based on maintaining arterial partial pressures as low as possible during resting conditions without compromising oxidative metabolism. The low P_aO_2 is hypothetized to apply to all water breathers, and the strategy has been documented on fish species with "sluggish" life history strategies. Atlantic salmon, as an active pelagic predator with high growth rate and metabolism residing in well oxygenated waters, represents an "ultimate" test of the hypothesis, and a confirmation of the hypothesis on Atlantic salmon will strengthen the universality of this respiratory strategy.

Experiments with sampling of cannulated fish in experimental facilities constructed to minimize stress effects on the fish are conducted throughout 2005. The ability to regulate P_aO_2 will be tested at different P_wO_2 levels to determine the regulatory capacity of Atlantic salmon, and possible trade-offs between food conversion/growth and P_aO_2 regulation will be investigated.

Investigation of salmon and trout migration using PCB-fingerprinting.

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Abstract

During the last centuries the environment has been polluted by non-biodegradable compounds like dioxins, PCBs and heavy metals. These are now present all over the world and are found in high concentrations in biota from the oceans especially in the higher trophic levels due to bioaccumulation. Measurements of these compounds are usually performed to ensure that they do not posses a health risk to humans but different sources of pollutants leads to different concentrations or patterns of the pollutants in different areas of the sea. Knowledge about how the composition is in a specific area of the sea can therefore be used to predict the feeding area of the fish.

The main object is to investigate if it is possible to fingerprint salmon and sea trout and thereby find out where they migrate after leaving the rivers. During the migration and especially during the stay in the river the fish only consume a very limited amount of food. Since the intake of pollutants primarily comes from food the pattern of pollutants should be representative of the eating area.

21 different PCB congeners, 3 HCH-isomers, o,p'-DDT, o,p'-DDE, p,p'-DDT, p,p'-DDE and p,p'-DDD are tested in this study. These are analysed using twin column GC-ECD and the data analysis is carried out using principal component analysis (PCA). In order to build up a fingerprinting model salmon and sea trout from 4 different localities will be used. The salmon comes from Vättern (S), Vänern (S), The Baltic Sea (DK) and The Atlantic Ocean and the trouts come from: The Baltic Sea, two different streams from Limfjorden (DK) and Øresund (DK).

Gyrodactylus salaris in northern Norway: Population dynamics and parasite induced effects upon host behaviour and physiology.

Anja C. Winger, Pål Adolfsen, Roar Kristoffersen & Rune Knudsen

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Abstract

Species of the genus *Gyrodactylus* Normann are, like monogeneans in general, little harmful to their host. One exception is *Gyrodactylus salaris* Malmberg with its devastating effect on the Norwegian stock of wild Atlantic salmon parr (*Salmo salar*). Over time, a total of 45 Norwegian watercourses have been infected by *G. salaris* and the two currently infected rivers, Signaldalselva and Skibotnelva in northern-Norway, are the subject of this thesis. The rivers are inhabited by several fish species, and most of them are infected with different gyrodactylids. The focus here will be on the salmonids infected with *G. salaris*, particularly the riverine populations of anadromous Arctic charr (*Salvelinus alpinus*) that inhabit both rivers. Arctic charr is susceptible to *G. salaris* (Bakke et al. 2002) and an examination of the two rivers has revealed that 60-70 % of the population is infected (Knudsen, et al, 2004.; Kristoffersen, et al, 2005. in prep). A genetic study has confirmed that the species infecting Arctic charr in the river Signaldalselva actually is *G. salaris* (pers.com H. Hansen).

An ongoing study of the seasonal dynamics in the *G. salaris* populations has revealed ample fluctuations within the population infecting Arctic charr. These results, along with future plans regarding parasite constraint upon physiology and behaviour in the two rivers will be presented.

Work supported by the NRC Wild Salmon Program, co-funded by NFH, University of Tromsø, Norway (project NFR 159386/S40)

Survival, infectivity and transmission in *Gyrodactylus salaris*

Kjetil Olstad, Jo Cable, Grethe Robertsen, Lutz Bachmann and Tor A. Bakke

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Abstract

Economically, one of the most important platyhelminths to have successfully invaded novel fish populations is *Gyrodactylus salaris*. This ectoparasitic monogenean has devastated stocks of wild Atlantic salmon in Norway since its introduction from the Baltic during the 1970s. The parasite with its high fecundity and transmission potential can rapidly colonize an entire river system. Having no specific transmission stage, *G. salaris* utilizes four different routes of transfer to new hosts: via contact with live hosts, via dead hosts, by detached parasites drifting in the water column, and by parasites attached to the substrate. However, the relative importance of these different routes is largely unknown. In the current study, we evaluate the transmission strategies of *G. salaris* focusing on the importance of dead hosts, by assessing the survival and infectivity of detached worms and those removed from dead hosts. At 18^{o}C, survival off the host is 1d, but at 3^{o}C parasites survive for 4d. Surprisingly, however, most parasites remain with their host following its death. Such worms survive despite being wrapped in decaying host tissue, their life span being doubled compared with individuals maintained *in vitro,* probably sustained by feeding on the dead host. *G. salaris* can actually survive for up to 6d at 12^{o}C on a dead host and, importantly, are still infectious, at least up until 72h post-host death. For *G. salaris,* dead hosts may thus serve as an important infection source. When ageing transmitting worms, it appears that those having given birth are more likely to transfer to a new host than those that have not. Thus, although having no specific transmission stage, gyrodactylids apparently do display a non-random timing of transmission. The present results highlight the importance of dead hosts as a significant reservoir of infection. Taken the significant threat that *G. salaris* constitutes to populations of Atlantic salmon, this is an aspect which should be incorporated into future management polices and risk assessments. This work was supported by the National Centre for Biosystematics (Project no. 146515/420), co-funded by the NRC and the NHM, University of Oslo and the NRC Wild Salmon Program (Project no. 145861/720).

The freshwater pearl mussel – status and recruitment patterns

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Abstract

The freshwater pearl mussel has disappeared from more than 35% of the Swedish rivers inhabited 100 years ago, and in many of the remaining populations juvenile mussels are missing. The mussel is dependent on trout and salmon since their glochidia larvae are obligate parasites on these fish species. To study recruitment patterns and processes, three stages in the life cycle are investigated: larvae, parasite and juvenile stages. Ten streams were electro-fished in the autumn of 2004, and there was a large variation in the number of glochidia that infected an individual trout, raising questions about infection: is there an immune response that hinders infection in some individuals or do glochidia not encounter all fish? The results indicate that glochidia infect each gill encountered in a stream, and that number of spawning mussels is important. Analyses also indicate that mussel population size and density of trout are important for recruitment probability. Production of glochidia larvae, i.e. the proportion and number of mussels that are spawning will be investigated and coupled to infected trout and the status of mussel population. Abundance of juvenile mussels in the sediment was higher in places where fine sediment load and fine particulate material in the water were low.

Restored rivers restore salmonid populations?

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Abstract

Human activities have strongly affected wild salmonid populations in Sweden. Streams were cleared of large boulders and channelized to facilitate log transport during 1850 – 1970. Building of waterpower stations in the 1900'es gave large fish-passage problems. Simplified channel morphology, altered flood- and sediment regimes, migratory barriers and a severe loss of aquatic habitats for spawning and juvenile growth are together with overfishing and environmental problems in the Baltic Sea threats to wild stocks of anadromous salmonids. Knowledge of all life history stages is of great importance in order to evaluate the effect of habitat restoration, stocking and harvesting for migrating salmonids.

Telemetry studies in 2002-2004 showed that 74% out of 31 radio-tagged sea trout in river Piteälven, used tributaries for spawning. In the river Vindelälven only 2 %, one out of 56 radio-tagged sea trout, used minor tributaries for spawning. In this river a majority of upstream migrating sea trout were, at time for spawning, positioned in areas in the main stem where previous releases of one-summer old juveniles had been done. Our telemetry studies are combined with genetic analyzes and we hope to determine the genetic status in sea trout in the two rivers. We also aim at finding the relatedness between sea trout and stationary brown trout. Telemetry studies in four years reveal that only 32 % of upstream migrating salmon pass the fish ladder at the power station in Ume- Vindelälven. It takes on average 47 days the 32 km from the estuary to the fish ladder. After passing they use only 15 to 20 days to reach the main spawning area 230 km upstream Vindelälven. Salmon exclusively selected spawning sites in the main stem in both river systems. Further studies entail that smolt and kelts entering the turbine water intake face high mortality risk. We aim at evaluating the conditions for fish-passage vs. flow-regulation and will help to find long-term solutions for natural stocks.

Restoration of Brown trout nursery and rearing areas show encouraging results. Due to significant increase of wetted area restored stream reaches had higher biomass of juvenile Brown trout biomass (176-480%) per unit of stream length.

Our long term goal is to establish a sustainable management strategy for salmon and anadromous brown trout that will permit both a biologically sound exploitation and conservation of these resources.

To migrate or not to migrate: that is *the* question

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Abstract

The decision to migrate or remain resident is regarded as genetically controlled for many invertebrate and vertebrate populations. Here we show that the environment influences this decision. By reciprocally transplanting brown trout (*Salmo trutta* L.) between two sections in a stream, we show that both migratory and resident behaviour can be environmentally induced; migratory behaviour developed in a section with high trout densities and low individual growth rates, whereas residency developed in a section with low trout densities and high individual growth rates. In a laboratory experiment, we tested the effect of food availability on the development of migratory and resident morphologies and found that most trout became migrants when food levels were low but fewer did so at high food levels. Thus, the decision to migrate seems to be a plastic response, influenced by growth opportunities.

Fish lock as an entrance to fish ladders at hydropower plants

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Abstract

Migrating fish that swim upstream in rivers for reproduction need to overcome obstructions, such as power plants or similar. If a fish ladder is used to help the fish pass such an obstacle, water needs to be taken from the dam without first passing through the turbines. Also, the fish may have difficulties finding the fish ladder, due to the dominating flow from the turbine tailrace.

A fish lock, that uses turbine tail water to entice the fish into the lock and further on to a fish ladder, is studied. The fish lock is a shallow open channel that uses a small fraction of the tail water. A local acceleration of the flow is created by changing the cross sectional area of the lock channel. This velocity increase has been investigated in a lab-scale model and an increase of 38 % was reached.

In the summer of 2004 a full-scale prototype of the fish lock was tested at the Sikfors hydropower plant (40 MW) in the Pite river in Sweden. The lock was equipped with underwater cameras to monitor and record the fish swimming through the lock. About 50 fishes swam through the fish lock during the test period of three weeks.

In the presentation, the setup of the test and results will be discussed.

Natural-like fishways for re-establishing connectivity

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Abstract

We evaluated the function of two natural-like fishways for re-establishing connectivity for anadromous salmonids in the regulated River Emån. Between 90-100% of the salmonids that entered the fishways actually passed through them, with median speeds of 180-190 m h-1. Only 50% of the anadromous brown trout that passed the first fishway also passed the second one, indicating that the fish might have had problems locating the upstream fishway. The fishways were also observed to function as a passage for downstream post-spawning migrants. The densities of brown trout yearlings upstream of the fishways were higher in 2002, after the fishways were built, than during prefishwayyears. In control sites in other parts of the river as well as in a nearby river, no changes in yearling densities were observed. Thus, the fishways are working for upstream spawners, albeit at a recolonisation rate that is slower than expected.

Synchrony in the downstream migration of smolts and upstream migration of adult Atlantic salmon in the subarctic River Utsjoki

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Abstract

The migration of smolts and adult Atlantic salmon (*Salmo salar* L.) were studied between years 2001 and 2004 in the subarctic River Utsjoki, a tributary river of the River Teno, using underwater video monitoring. The objective was to analyse the diel and seasonal migration patterns of smolts and adults in natural conditions without disturbing manmade constructions. Both smolts and adults migrated actively throughout the day, although differences occurred between these two-way migrations. Smolts migrated most intensively during hours of rising (03-09) and high (09-15) sun, while adults favoured the period of low sun (21-03). Seasonal synchrony between smolt and adult migrations were observed in years of slowly warming water, whereas in year of exceptionally warm early summer, smolts migrated earlier than adults. Thus, water temperature seems to be important environmental factor triggering the smolt migration, while the migration of adults is probably more fixed to certain period. Underwater video monitoring was found to be useful and effective method for observing smolt and adult migrations simultaneously without disturbing the behaviour of fish.

Migration examples of Baltic salmon in Bothnian Bay – by-product observations from a river migration study

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Abstract

In order to study upstream migration of Baltic salmon in River Simojoki, Finland, 89 salmon were tagged with radiotransmitters at sea, ca 5 km from the river mouth. Based on the results from earlier studies, the majority of salmon caught by trap net and released at this location were expected to ascend River Simojoki. The aim of the study was to model migration patterns, examine possible effects of environmental factors on migration, and to compare migration behaviour of wild and stocked fish within the river. In addition to radiotracking, upstream migration of salmon was monitored by fixed split-beam echosounders. Here, observations on the tagged salmon that did not enter River Simojoki are presented. The results of the actual river migration study will be published subsequently elsewhere.

Contrary to expectations, only twenty-five (28 %) of the radiotagged salmon entered River Simojoki. Seventeen tags (19 %) were recovered by fishermen in the sea, and six salmon (7 %) were observed to enter other rivers. The proportion of salmon ascending River Simojoki was affected by the date of tagging and the origin of the fish (as determined by fin clippings and scale analysis).

The results suggest coastline following migration routes and large-scale straying behaviour of river seeking salmon in Bothnian Bay area.

Additional abstracts by members of NoWPAS-2005:

Effects of winter conditions, particularly ice, on the biology and habitat of juvenile Atlantic salmon (*Salmo salar* L.) in small rivers

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Abstract

The main objective of this research project is to understand the movement, survival and habitat use of juvenile Atlantic salmon (*Salmo salar* L.) related to the prevailing physical conditions in small rivers during the winter. A special interest is the effect of different ice forms on salmon parr movements and ice-induced changes to habitat availability and suitability during winter. Thus, there is a biotic (behavioural) component as well as an abiotic (physical habitat) component in this work.

Data from both these components are central to the development of a numerical habitat model describing the distribution of fish and their preferred (and avoided) habitats for any given water discharge. This work requires 1) a working hydrodynamic model for habitat availability data and 2) an adequate but parsimonious biological model including the key variables defining winter habitat preferences. The winter habitat model can be further used to help in habitat construction in river enhancement projects and evaluate the success of such projects. This will be done to see the model's ability to predict fish locations in areas outside the study sites.

Much of the data will be collected by using Passive Integrated Transponder (PIT) – tagged fish. Individually tagged fish will be followed throughout the winter to determine their movement patterns and habitat use. Also, the activity changes are monitored on a diel basis whenever tracking is done, but changes in activity within the winter season are studied as well. These will reveal behavioural changes and life-strategy choices of the individuals and can be linked to their further fate (e.g. dead/alive, migrant/resident, precocious/immature).

As winter has been suggested to be a bottleneck phase of juvenile salmonid survival, the survival and migration will be measured during the study. This will be based on the use of data logging antennae at each end of study areas, and the multiple active tracking of fish with a portable antenna. Migrating fish will be recognized from the stationary antenna-loggers and the fate of fish residing in the study site can be monitored and linked to either abiotic physical features prevailing in the site or to biotic factors such as predation. The survival and emigration rates will be estimated using suitable software for analysing mark-recapture data (e.g., MARK, multi-strata model).

Furthermore, winter stream conditions affect not only the fish in the parr life-stage but also the incubating eggs in the substrate. Ice formations such as frazil- and anchor ice may have a strong influence on the number of eggs that survive to emergence. The effects of different ice formations will therefore be studied to see how winter hydrological conditions change due to localized ice conditions and what are the consequences for egg survival when compared to no-ice conditions in different river reaches.

Ecological responses to stream habitat and catchment rehabilitation in salmonid rivers

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Abstract

The deterioration of water and streambed quality has reduced the reproductive success of naturally-spawning stream salmonids. Agriculture, forestry activities and peat mining have caused increased mobilisation and transport of land-derived particulate matter, which is one of the most intensive disturbances on the intragravel stages of salmonids. Here we monitor the rehabilitation effects of catchment area on spawning areas of riverine salmonids and benthic macroinvertebrates by using BACI (Before-After-Control-Impact) –design. We focus on two commonly used methods in forest drainage to reduce particle sedimentation in streams. Parallel to our field study, we used the laboratory experiment to study the influence of fine organic material on salmonid egg-to-fry-survival. Preliminary results from both studies indicate that the survival of salmonid eggs is inversely related to particulate matter loading. Therefore, increased sedimentation through ditching in the catchment area may be crucial factor for salmonid reproduction downstream of forest drainage areas.

Responses of stream biota to habitat restoration in salmonid rivers

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Abstract

The aim of this study is to evaluate the ecological effects of in-stream restorations. The main objective is to monitor the effects in the River Kiiminkijoki which has been recently restored after dredging for log transportation and is included in the Salmon Action Plan program. The research is carried out using a before-after study frame (BACI, Before-After-Control-Impact). In addition, the physical and biological impacts are evaluated by using hydraulic and habitat modelling. Comparing these two methods, BACI (fish and invertebrate population research) and modelling (change in the suitable habitats), allows an assessment of the accuracy of the habitat models. Furthermore it will be helpful in defining the possibilities of the method in planning stream restoration and management, as well as assessment of the results.

The research focuses on juvenile salmonids (Atlantic salmon, *Salmo salar* and brown trout, *Salmo trutta*), but it also includes other fish species, benthic invertebrates and ecological processes. In addition to field studies and habitat modelling the effects of restorations are evaluated by examination of over wintering condition of juvenile brown trout in restored and dredged artificial streams. The effect of differently restored streams on leaf retention is as well assessed by experimental studies.

Cortisol action and corticosteroid receptors in teleost fish osmoregulatory tissue

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Abstract

Cortisol is the major corticosteroid in teleost fish and apart from its catabolic role; cortisol has been proven to be important in acquiring SW tolerance in several euryhaline fish. This is somewhat peculiar given that the hormone mainly responsible for salt and water homeostasis in mammals is the mineralocorticoid, aldosterone. Aldosterone is not present in teleost fish and cortisol has therefore been hypothesized to manage both the glucocorticoid and the mineralocorticoid signalling, since cortisol bind well to both the glucocorticoid receptor (GR) and the mineralocorticoid receptor (MR). Both a GR and MR have recently been cloned in rainbow trout, which indicate that the sometimes opposite glucocorticosteroid effect is mediated through both GR and MR, and that this effect can be differentiated on the receptor level.

Cloning of the rainbow trout 11β hydroxysteroid dehydrogenase type 2 (11βHSD2), the enzyme that protects the MR from cortisol binding by converting cortisol to the inactive corticosterone, supports this model. However, very recently 11-deoxycorticosterone a precursor in the synthesis of cortisol from cholesterol was identified as a potential agonist for the MR in rainbow trout. Taken together this opens up a whole lot of exiting schemes about the glucocorticoid role in osmoregulation.

In this work the presence of GR, MR and 11βHSD2 and the consequence of this will be investigated in osmoregulatory tissue in Atlantic salmon. Overall, the role of cortisol in development of salt water tolerance, regulation of ion transporters and gill chloride cell differentiation will be examined with the use of specific agonists for GR and MR (cortisol and 11-DOC, respectively) and antagonists (RU486 and spironolactone, respectively). Studies will be conducted on intact fish during smoltification using hormone injections and salt water transfers. Physiological parameters as the level of Na^+K^+ATPase activity, the fraction of chloride cells in the gill, muscle water content and sodium and chloride concentration in blood plasma after SW transfer will be investigated along with investigations on the gene regulatory level. These include immunohistochemical investigations on gill epithelia and QPCR investigation of any transcriptional regulation of GR, MR, 11βHSD2 and different important ion pumps and transporters.

Danish trout farms and the downstream migration of salmonids; effects of weirs and water intakes

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Abstract

In Denmark, the majority of trout farms are situated in close proximity to rivers which provide a ready source of water controlled by a weir. However in recent years, mark and recapture studies have documented extensive loss (an average of 40%) and delays of downstream migrating salmonids as they pass Danish trout farms. Therefore, a study was commissioned to provide recommendations to decrease the effect of trout farms on wild fish. The present case study investigated the spatial behaviour of tagged juvenile Atlantic salmon (*Salmo salar* L.) and brown trout (*Salmo trutta*) migrating past a fish farm water intake towards a weir on the River Kongåen, Denmark. In the spring 2004, 123 fish were tagged with acoustic positioning tags and held for 8 hours before release in darkness. An array of four hydrophones collected 2-dimensional position data in the shallow river (average depth ~ 0.9 m) as the fish passed the fish farm water intake. To facilitate comparison of fish that migrated successfully through the study area, a smolt trap captured fish as they passed through the weir 100 m. down stream of the array. Differences in the behavioural patterns of successful versus non-successful migrating fish is described together with the preliminary implications of these results.

Feeding of Atlantic salmon (*Salmo salar* L.*)* post smolts in the North-east Atlantic

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Abstract

The marine phase of the salmon is essential because most of the growth of the species occurs during this lifestage. The postsmolt stage is of vital importance as it has been suggested that the major marine mortality of salmon at sea occurs during this period. Nonetheless few investigations have been made on the diet of salmon in the oceanic areas of the Northeast Atlantic and even fewer exist for postsmolt feeding.

The present study covers the period between the investigations of postsmolt diet in some fjords and costal areas of the Northeast Atlantic and the diet of preadult and adult salmon in some areas in the Norwegian Sea. The postsmolts were sampled in 1991 and 1995 - 2003 from early June to mid August during northward migration and on the feeding areas (55º-75ºN and 10ºW-20ºE). The main focus was on the Atlantic waters of the Norwegian Sea. In the Slope Current west of the British Isles in early summer the postsmolts fed on 0-group of blue whiting and sandeel which together with other fish constituted 80-90% of the prey in weight. One of two postsmolts had also fed on crustaceans in this area although they accounted for less than 10% by weight. 0-group of sandeel was the main prey in the northern part of the North Sea at this time of the year. In the Norwegian Sea fish constituted two-thirds of the prey by weight with 0-group herring as the most important species. Other fish found in the stomachs were sandeel, gadoids, pearlside, lanternfish and rockfish, most of them 0-group. Crustaceans constituted about one-third of the total prey by weight and amphipods of the species *Themisto abyssorum* (TL 2-8 mm) dominated this group. Copepods and young stages of krill were recorded in very limited amounts by weight in the stomachs, indicating that they are insignificant as prey for the postsmolts. Annual differences in diet were observed, probably reflecting both variations in abundance of the prey species and a patchy distribution of prey and catches of postsmolt. In one of three occasions we found an indication of a size selective feeding of the postsmolts on *T. abyssorum,* none were found for 0-group herring.

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Information about investors of NoWPAS-2005.

Statkraft

Environment and hydropower
- focus on the environment at hydropower plants and regulated river systems

Our vision is to be a European leader in environment-friendly energy. While all energy production affects the environment in one way or another, Statkraft strives to reduce any negative environmental consequences to a minimum. We work to understand the environmental impact of our hydropower operations and how to use this knowledge to implement cost-effective environmental protection measures.

We are convinced that environmently friendly solutions will be preferred in the future. As we see it, taking care of the environment is a must if Statkraft is to be a leading player in the energy projects of tomorrow.

Which is why we …

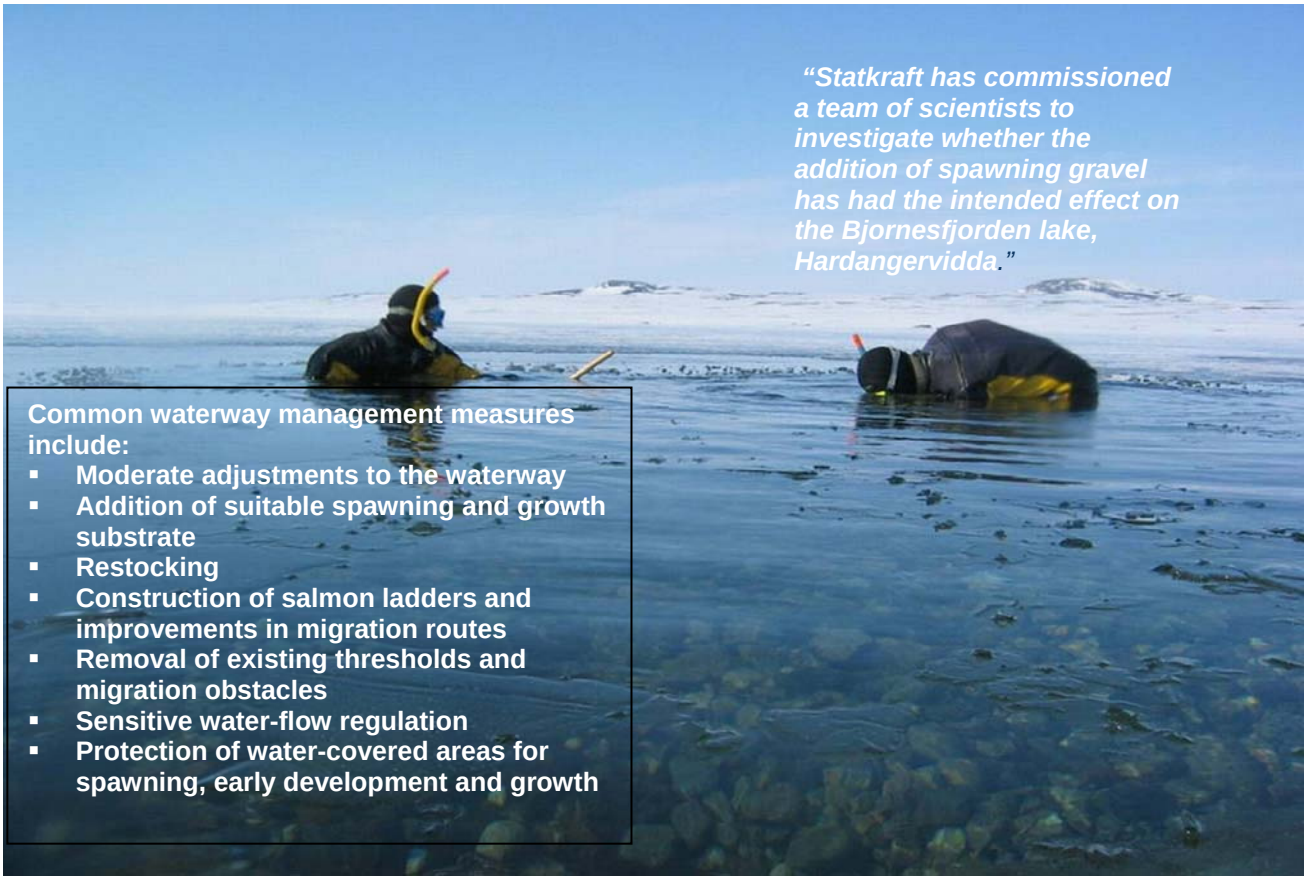
… constantly monitor the river systems we regulate and take part in analysis and research projects to find modern solutions to the problems that arise.

… look for solutions that are acceptable to all parties through close contact and collaboration with the regulatory authorities, local government administrations and other parties with a legitimate interest in the various river systems.

… have implemented an environmental management system (ISO 14001) which helps us to keep a check on the potential environmental consequences of our operations and constantly improve our environmental performance.

Fish conservation

An important objective of our fishery strategy is to have self-recruiting fish populations in our regulated waterways. Measures to protect fish populations and fishing in general are among the most important environmental measures associated with the operation of hydropower plants. Measures are implemented as a result either of directives from the authorities or of Statkraft's own efforts to identify needs and opportunities for improvement. In either case, measures are implemented in cooperation with the relevant authorities.



Example of fish-related measures in Jostedøla
In Jostedøla, which is located in Luster, Sogn og Fjordane, measures have been implemented to increase the natural recruitment of sea trout and salmon. Two obstacles to migration up the river have been removed such that the fish now have access to 7 km of new spawning grounds. Eggs have also been planted in the areas above the former migration obstacles to achieve a more rapid establishment of fish populations there. During the autumn of 2004 a number of spawners were recorded in the newly available areas.

Restocking

Statkraft is both a major producer and purchaser of juvenile fish for restocking. Each year we plant around 600,000 juvenile salmon, sea and inland trout. We operate two of Norway's three gene banks to conserve the unique genetic material of the country's salmon populations.

Monitoring fish populations

Test fishing is normally undertaken in hydropower reservoirs every eight to ten years. In rivers with salmon and sea trout populations it may be necessary to conduct surveys of fish biology more often and over several years. The findings of such surveys are available to all, and the results are presented and discussed in meetings with the scientists, relevant authorities and other directly affected parties.

Compensation and fishing funds

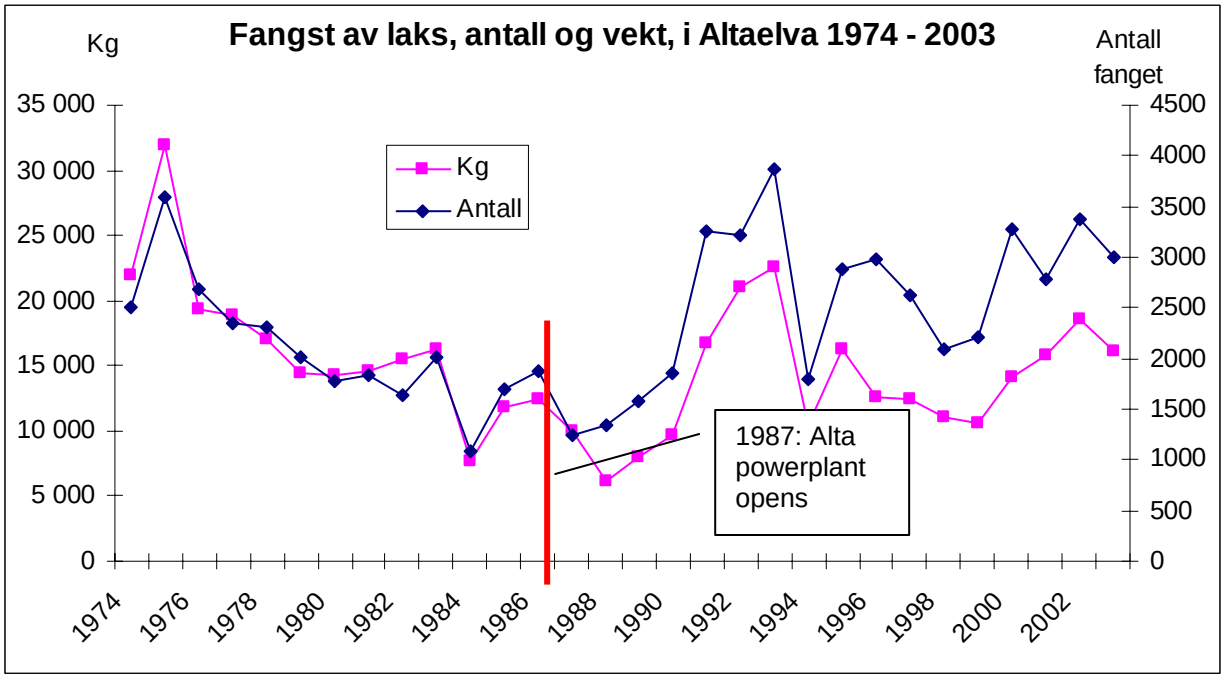
The value of private fishing rights was estimated at the time the rivers were initially regulated. As a result of these estimates, several million Norwegian krones (NOK) is paid out each year to trust funds, or in direct compensation to individuals, landowner associations and local authorities.

Salmon fishing in regulated river systems

As a result of favourable water-flow conditions and effective conservation measures, several regulated waterways are counted among the country's best fishing rivers. Of the ten river systems that produced the largest catches of salmon and sea trout in 2003, eight were regulated for hydropower purposes. Among these eight were the Numedalslågen and Alta rivers.

Catches of salmon (number and weight) in the Alta river 1974 – 2003

———	No. caught
———	Weight in kg



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Environmental contact person : Vilde Eriksen (vilde.eriksen@statkraft.com)

SINTEF Energy Research

-Division of Water resources

SINTEF Energy Research, division of water resources, focus primary on environmental issues related to hydropower in a physical aspect. Our division aim at following two main directions:
Research within Environmental aspects of water resources
Research within Hydrology

During recent decades developments of computerized one- and multi dimensional modeling tools of physical environments have increased. Our division has been a leading part of development and use of such tools. Therefore, one main part of our research is hydraulic and hydrological modeling. We use and develop new techniques in order to cope with today's and future challenges in our work. An example of hydraulic modeling followed by habitat modeling of anadromous salmonids rivers is given below. Here, modeling of a Norwegian river reach was conducted in order to reveal knowledge of how physical alterations of the site resulted in habitat changes for juvenile Atlantic salmon (*Salmo salar*).

Figure 1: Research on winter habitat for Atlantic salmon has gained focus the recent

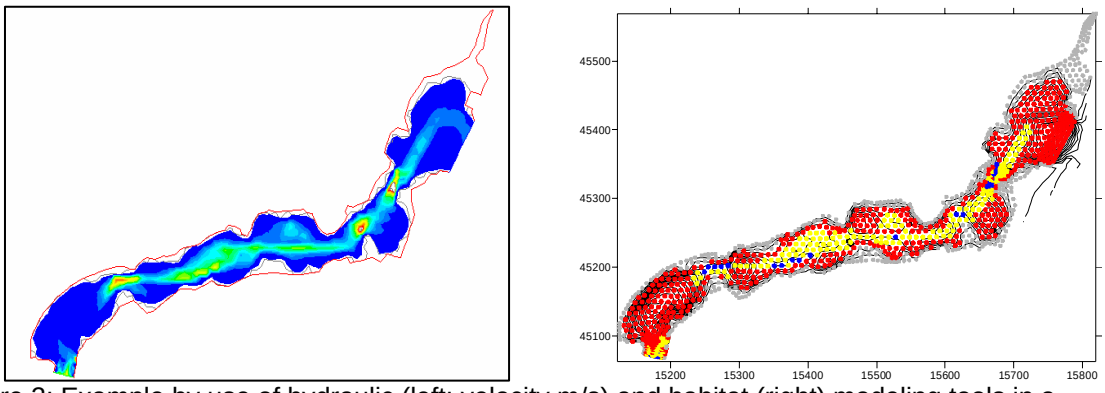

Figure 2: Example by use of hydraulic (left; velocity m/s) and habitat (right) modeling tools in a Norwegian river.

Other examples of conducted and ongoing projects are given below.

- Environmental water resource planning and operation
- Fish habitat and hydropower production
- New environmentally friendly overhead lines
- Rapid changes in flow

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Notes