

European Workshop for
Doctoral Fellows on
Salmo salar
and
Salmo trutta
Research



Pitlochry, Scotland
March 11th – 14th 2010

Sessions and detailed schedule

Wednesday 10 March **Committee meeting and arrivals**

Time	Activity
17:00	Committee meeting (David, Pauliina, Kirsteen, Donald, Christian)
18:00	Dinner: key-note speakers and Committee members
19:30	Ice breaker at Waxy O'Connors (Everybody welcome!)

Thursday 11 March **NoWPaS day 1: Excursion**

Time	Activity
09:15	Coach departs from outside Eurohostel
10:00	Arrival at Howietoun Fishery, part of the University of Stirling's Institute of Aquaculture, tour of facilities
12:00	Talk by John Taylor from the Institute of Aquaculture: Triploidy salmon research
12:45	Lunch at Stirling
13:15	Coach departs Howietoun Fishery
14:00	Coach arrives at Marine Scotland's facility at Almondbank, tour of facilities, talks from Marine Scotland researchers
16:00	Coach departs Almondbank
17:30	Arrive at Kindrogan, finding rooms etc.
18:30	Dinner and ice breaker

Friday 12 March
NoWPaS day 2

Time	Activity
07:30-8:45	Breakfast
09:00	Opening – David McCormick – NoWPaS Committee Representative
09:10	Invited speaker – IAIN MALCOLM – Environmental controls on salmonid spawning success
10:00	Break
10:05	Session I – Hydraulic habitat – Chair David McCormick <ul style="list-style-type: none"> ➤ Roser Casas-Mulet – <i>Dynamics of dewatering and flooding during hydropeaking</i> ➤ Kestutis Skrupskelis – <i>Impact of small hydro-power plants on salmon and sea trout spawning migrations</i>
10:35	Break
10:55	Session II – Population dynamics – Chair David McCormick <ul style="list-style-type: none"> ➤ Johan Spens – <i>Using GIS to predict landscape-scale establishment and extinctions of brown trout: impact from keystone species, exotics, chemical & physical factors</i> ➤ Sarah-Louise Counter – <i>Salmon sustainability on the Exe</i> ➤ Grethe Robertsen – <i>Performance of Atlantic salmon juveniles resulting from multiseawinter and grilse parents at varying population densities</i>
11:40	Break
11:45	Invited speaker – ALAN YOUNGSON – Spawning as a limit on recruitment: behavioural architecture of salmonid redds
12:35-13:35	Lunch
13:35	Invited speaker – PHIL RONI – Habitat restoration science in the Pacific Northwest USA: Challenges, techniques and results of monitoring and evaluation
14:25	Coffee
14:55	Session III – Habitat – Chair Christian Imholt <ul style="list-style-type: none"> ➤ Jukka Syrjänen – <i>Success of stream restorations in Finland</i> ➤ Pauliina Louhi – <i>Effects of habitat rehabilitation on juvenile brown trout (<i>Salmo trutta</i>) in boreal forest streams</i> ➤ David McCormick – <i>Experimental removal of riparian canopy enhances local density and foraging efficiency of juvenile Atlantic salmon</i> ➤ Donald Reid – <i>Effects of food predictability and habitat complexity on the relationship between metabolic rate and performance in stream living juvenile salmon</i>
15:55	Break

- 16:00 **Session IV –Spawning and early life stages– Chair Donald Reid**
- **Maxim Teichert** – *Effects of spawning site distribution on juvenile Atlantic salmon (*Salmo salar* L.) density and growth: the mothers tailprint*
 - **Thomas Régnier** – *Influence of physiological processes on emergence of brown trout (*Salmo trutta*)*
 - **Tim Burton** – *Epi-genetic transfer of social status via maternal steroid hormones in *Salmo trutta**
 - **Markus Noack** – *An approach to simulate interstitial processes in river beds to meet biological requirements for reproduction of brown trout*
 -
- 18:00 **Predinner**
- 18:30 **Dinner and social**

Saturday 13 March
NoWPaS day 3

Time	Activity
07:30-8:45	Breakfast
09:00	Invited speaker – KEN WHELAN - SALSEA Merge project
09:50	Break
09:55	Session V – Marine life and climate – Chair Donald Reid
	<ul style="list-style-type: none"> ➤ Cyril Piou – <i>Atlantic salmon population dynamics under scenarios of climate change: an individual-based demogenetic approach</i> ➤ Nora Hanson – <i>Multi-source sampling: stable isotope variation and the “skinny” salmon story</i> ➤ Kirsteen MacKenzie – <i>Identification of marine feeding areas of Atlantic salmon: climate control of river stocks</i>
10:40	Break
10:45	Session VI – Physiology and disease– Chair Pauliina Louhi
	<ul style="list-style-type: none"> ➤ Alexandra Howe – <i>Condition, lipids and the “skinny” salmon</i> ➤ Christian Imholt – <i>Does the magnitude of diurnal temperature variability affect growth in juvenile Atlantic salmon?</i> ➤ Marleen Werkman – <i>A simple model of the spread of invasive diseases in salmon aquaculture</i>
11:30	Break
11:35	Invited speaker – TOM CROSS – The Irish Atlantic salmon Genetic Stock Identification project: Genetic Screening and Mixed Stock Fishery Analysis

- 12:30-13:30 **Lunch**
- 13:30 **Invited speaker** – KEN WHELAN – Atlantic Salmon Trust works seminar
- 14:20 Coffee
- 14:50 **Session VII – Genetics – Chair Kirsteen MacKenzie**
- **Roseanne Miller** – *The role of the major histocompatibility complex (MHC) in mate choice and survival in sea trout (Salmo trutta)*
 - **Ciar O'Toole** – *Determining the scale of biologically important local adaptation in Atlantic salmon using a common garden experimental approach*
 - **Beatrice Frank** – *Predicting the demo-genetics of brown trout populations on a regional scale*
- 15:35 Break
- 15:40 **Group discussions**
- Critique of NoWPaS-2010
 - Topics for next year's technical workshop
 - www.nowpas.eu – what do we need? Suggestions for our home page
- 16:40 Closing - The Committee of 2010-11 and presentation of group works (5 min for each group)
- 18:00 **Predinner**
- 18:30 **Dinner**

Sunday 14 March
NoWPaS day 4

Time	Activity
07:30 - 8:45	Breakfast
09:00	Departure for Glasgow ... Bus station

PREFACE

NoWPaS ~ European (formerly Nordic) Workshop for PhD and post-doctoral fellows on anadromous *Salmo salar* and *Salmo trutta* research

The aim of NoWPaS is to build and maintain an international network to promote collaboration and to exchange knowledge within the group, and also to maximize the research quality of PhD studies. During the last few decades research on *Salmo salar* L. and *Salmo trutta* L. has increased and will most likely intensify in the future. Research conducted by PhD and post-doctoral students will play an important and central role in the advancement of our knowledge of these ecologically and socially important species. Therefore, we look forward to welcoming new members each year.

The objectives of the network are twofold: firstly, we wish to arrange an annual independent workshop where the participants can gather, exchange knowledge and ideas, and hold discussions in an interdisciplinary forum. In this way, participating doctoral and post-doctoral students will have the opportunity to receive feedback on their own work, to be informed of the work of fellow delegates as well as developments within the field. Secondly, we wish to invite key researchers to give lectures and short courses within the field and also highlight areas where future research is required. Through this framework, we intend this workshop to be mutually beneficial to all delegates and therefore help promote research.

Since the inception of NoWPaS by Dr Morten Stickler, we have succeeded in organizing annual workshops in Norway, Sweden, Finland, Denmark and England in 2005, 2006, 2007, 2008 and 2009, respectively. In total, over 150 early-stage researchers so far have given oral presentations, combined with extended lectures by invited speakers to each workshop. The delegates of this workshop are the future experts within this field of research. Therefore it is very important that these young scientists establish connections with thoughts of future collaboration in mind within an international environment. Through the generosity of our investors, our workshops are free for our members to attend, and we hope to keep them this way.

Previous key-note speakers in our workshops have been Sigurd Einum (NTNU, Norway), Eva Thorstad (NINA, Norway), Tormod Skei (Statkraft Norge), Neil Metcalfe (Glasgow University, Scotland), Torgny Bohlin (Göteborg University), Rick Cunjak (New Brunswick University, Canada), and Ari Huusko (Finnish Game and Fisheries (Finland), Malcolm Elliott (Freshwater Biological Association, England), John Armstrong (Marine Scotland Freshwater Laboratory, Scotland), Michael M. Hansen (DTU, National Institute of Aquatic Resources, Denmark), Berton Lee Lamb (US Geological Survey, USA), Jan Heggenes (Høgskolen I Bø, Norway), Brian Shields (Environment Agency, England), David Sear (University of Southampton, England), Thom Hardy (Utah State University, USA), Ken Bovee (US Geological Survey, USA), Mike Dunbar (Centre for Ecology and Hydrology, England), and Clive Trueman (University of Southampton, England).

This year's workshop will be held in Kindrogan, near Pitlochry, Scotland, and we are delighted to have as our keynote speakers Alan Youngson and Iain Malcolm from Marine Scotland (Freshwater laboratory), Pitlochry, Phil Roni from the Northwest Fisheries Science Centre, Seattle, Ken Whelan from the Irish Marine Institute, the Atlantic Salmon Trust and University College Dublin and Tom Cross from University College Cork.

Our homepage (www.nowpas.eu) is to be continuously improved so that publications and information on international conferences, workshops etc. can be easily accessed. This homepage therefore acts as an information centre.

ACKNOWLEDGEMENTS

NoWPaS-2010 has primarily been based on voluntary work by the steering committee. It is not possible to put words on the effort they have put into this network. Their contribution and quality of work have been tremendous and of vital importance. On behalf of the committee great thanks goes first of all to the participants and their contributions, which form the basis for this network; without them this would of course not be possible. Further, thanks go to key-note speakers for their oral presentations, and for giving up their time to participate and interact with the network.

NoWPaS as an organisation recognises the importance of not only our scientific obligations to the scientific community, but also our moral obligations to society. As many of our members travel large distances to the workshops and the resources consumed during the workshops, we realise our commitment to keep our environmental impact to a minimum. This is the reason why NoWPaS supports an organisation dedicated to preserving rainforests. The organisation is called Rainforest Rescue www.rainforestrescue.org.au. To date NoWPaS has preserved 10 hectares of Ecuadorian cloud forest, a biodiversity hotspot and an important carbon sink. This allows NoWPaS to operate as a completely carbon neutral organisation and we will continue to support Rainforest rescue to remain carbon neutral.

Thank you!

The organizing committee of NoWPaS-2010 has consisted of following people:

- Dave McCormick, Ireland, Web administrator
- Pauliina Louhi, Finland
- Kirsteen MacKenzie, England
- Donald Reid, Scotland
- Christian Imholt, Scotland

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ENVIRONMENTAL CONTROLS ON SALMONID SPAWNING SUCCESS

IAIN MALCOLM

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Abstract:

Salmonid embryo survival is dependent on complex interactions between physical, chemical and biological processes. However, the vast majority of studies in this area have focussed on the role of fine sediment to the exclusion of other processes. In recent years there has been increasing interest in understanding hyporheic zone processes. This wider conceptual understanding of hydrological exchange and hydrochemical processes within the streambed offers new insights and a more complete understanding of the environmental controls on embryo survival. In this paper, the second of a pair of papers, we demonstrate the processes controlling in-river water quality at spatial scales ranging from small catchment to the micro-scales associated with individual egg pockets, and temporal scales ranging from inter-annual to individual hydrological events. The results are discussed in the context of salmonid and river management.

SPAWNING AS A LIMIT ON RECRUITMENT: BEHAVIOURAL ARCHITECTURE OF SALMONID REDDS

ALAN YOUNGSON

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Abstract:

Juvenile recruitment is inherently density-dependent. However, density-independent effects dominate particular stages and, at times of low adult abundance, may dominate overall juvenile recruitment. Mortality of embryos is widespread, variable and often high. It may be possible to prevent or reduce these losses by practical management. This part of the two linked talks deals with the defining behavioural characteristics of the salmonid redd.

HABITAT RESTORATION SCIENCE IN THE PACIFIC NORTHWEST USA: CHALLENGES, TECHNIQUES AND RESULTS OF MONITORING AND EVALUATION

Philip Roni

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Abstract:

The listing of several stocks of Pacific salmon and trout as threatened and endangered under the United States Endangered Species Act has led to large restoration efforts to restore watersheds and increase salmon numbers. It is currently estimated that nearly 300 to 400 million US dollars is spent annually on restoration in the Pacific Northwest, though little is spent on monitoring and evaluation of project success. I provide an overview of common habitat restoration techniques, challenges facing implementation of these efforts and our research to evaluate the effectiveness of many techniques at increasing Pacific salmon abundance. Common challenges to restoration include: proper assessments to identify degraded habitat and areas in need of restoration, identification of appropriate restoration actions, prioritization of actions, and appropriate monitoring and evaluation. To help resolve many of these challenges, we have been conducting research to evaluate the effectiveness of many techniques, particularly those focusing on restoration of floodplain habitats and habitat complexity. The response of Pacific salmon and trout to different restoration techniques varies greatly depending on the species, season and life stage. The success of these projects is often determined not by the technique, but by whether other watershed scale processes have been addressed. Using data from these studies, we demonstrate that the current approach of spending hundreds of millions of dollars on small projects spread across the landscape is unlikely to lead to significant changes in salmon or trout abundance in any one watershed. Additional research evaluating restoration actions at a watershed or population scale and measuring life-stage specific survival of salmonids in response to restoration actions is sorely needed.

SALSEA MERGE PROJECT

Ken Whelan

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Abstract:

Over the past two decades, an increasing proportion of North Atlantic salmon are dying at sea during their oceanic feeding migration. The specific reasons for the decline in this important species are as yet unknown. However, climate change is likely to be an important factor. In some rivers in the southern part of the salmon's range, wild salmon now face extinction. This is in spite of unprecedented management measures to halt this decline. Arguably the greatest challenge in salmon conservation is to gain insight into the spatial and ecological use of the marine environment by different regional and river stocks, which are known to show variation in marine growth, condition, and survival. Salmon populations may migrate to different marine zones, whose environmental conditions may vary. To date it has been impossible to sample and identify the origin of sufficient numbers of wild salmon at sea to enable this vital question to be addressed. SALSEA-Merge is providing the basis for advancing our understanding of oceanic-scale, ecological and ecosystem processes. Such knowledge is fundamental to the future sustainable management of this key marine species. In addition, the use of the three-dimensional Regional Ocean Modelling System, merging hydrography, oceanographic, genetic and ecological data, will deliver novel stock specific migration and distribution models.

THE IRISH ATLANTIC SALMON GENETIC STOCK IDENTIFICATION PROJECT: GENETIC SCREENING AND MIXED STOCK FISHERY ANALYSIS

Tom Cross

ZEPS, AFDC, University College Cork

Key words: Atlantic salmon, Irish mixed stock fisheries, genetic management

Abstract: Genetic analysis of mixed stock fisheries allows proportional contribution from individual rivers to be determined with considerable accuracy and precision. This technique has been used in real time management of Pacific salmon for the last 25 years. The Irish project represents the first large-scale application of the technique to Atlantic salmon. Samples of parr were taken from rivers throughout Ireland representing 98% of the production capability of the country. These samples were typed for 15 microsatellite loci and this formed a database to assess mixed-stock fisheries. These mixed-stock samples came from drift and draft nets right along the coast of the Republic of Ireland. Drift net samples were a mixture of many riverine populations, whereas draft nets, being closer inshore, tended to take salmon from a more localised area. These results have major management implications and have been partially responsible for the closure of the Irish drift net fishery.

SEMINAR ON THE ATLANTIC SALMON TRUST

Ken Whelan

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Discussion of work with the Atlantic Salmon Trust (www.atlanticsalmontrust.org), and the new AST Fellowship scheme. Advice and opinions will be sought on what format might be best. This will not be a powerpoint presentation, but an interactive session where attendees have an opportunity to influence the AST's salmon research Fellowship.

DYNAMICS OF DEWATERING AND FLOODING DURING HYDROPEAKING

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Key words: hydropeaking, hyporheic zone, hydraulic habitat, stranding potential

Abstract:

Increasing differences in power prices on short time scales give incentives to producers to run power plants during high price periods. Hydropower systems are particularly suited for this kind of operation due to simple start and stop procedures, and reservoir storage of water. We do also see the potential for even more peaking operation in the future when the hydropower systems will be used for load balancing in a power system with increasing non-storable renewable sources.

Frequent changes in discharge in rivers downstream of power plant outlets in rivers can have large physical and ecological impacts on the river environment. Based on experiences from previous studies of hydro peaking in rivers several areas of research have been identified and are currently underway. The research within the area of physical impacts of peaking will be carried out on a several scales from micro scale to catchment scale. The major research areas can be summarized as follows:

1. Experience from cage experiments with fish during peaking operation showed survival of fish between experiments, indicating refuges with water in the substrate even when water is drawn down. Work will be undertaken to study the hyporheic exchange during peaking to investigate potential survival potential in the substrate. Similar studies will be undertaken to study egg survival in the peaking zone and hyporheic influences on survival of benthic invertebrates.
2. To estimate hydraulic habitat during peaking operation detailed 3D modeling of peaking zones will be undertaken, and results will be linked to the findings in 1). Knowledge of detailed hydraulics processes during draw down is limited and needed for understanding stranding behavior. To properly assess stranding potential in larger rivers 1D modeling of shutdown waves is needed. Currently we have little information on the necessary number of and detail in cross sections used in modeling of stranding areas, and data from the 3D modeling will also be used as a basis for studying accuracy of predictions based from 1D modeling.
3. Making management decisions in rivers with peaking operation requires the ability to combine hydropower operation, wave propagation and small-scale processes. Combining all scales are challenging and research will be done into integrated modeling systems for hydro peaking impact assessment.

This presentation summarizes the current knowledge of hydro peaking operations and outlines ongoing and planned research to improve knowledge and develop assessment tools and mitigation measures.

IMPACT OF SMALL HYDRO-POWER PLANTS ON SALMON AND SEA TROUT SPAWNING MIGRATIONS

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Key words: spawning migration, redds distribution and abundance, fish ladder

Abstract:

Impact of small hydropower plants on salmon and sea trout spawning migrations has been well assessed in Western and Northern Europe, but there's no data from Eastern Baltic sea basin. Moreover - no data from long distance (more than 500km) lowland spawning migrations routes.

Salmonids migration studies in those natural Lithuanian rivers fulfils various salmonids migration data in west part of Baltic sea basin and highlights new patterns in recent findings. Studies were performed in Vilnia and Siesartis rivers, where fish ladders were built during last decade (in 2000 and 2005). The analysis of redds distribution and abundance in both rivers revealed that the construction of fish ladders significantly increased the abundance and distribution of redds in those rivers, however, a significant increase in redds above the dam occurred 2-4 years after fish ladders construction supporting homing behaviour as one of the most important factors for the recolonization of the newly accessible habitats.

Data of radio tagged salmon and sea trout spawners revealed that passage of fish ladders mostly depends on fish ladder construction and water level during upstream migration. Poaching also remains one of the main adverse factors reducing fish ladders effectiveness.

USING GIS TO PREDICT LANDSCAPE-SCALE ESTABLISHMENT AND EXTINCTIONS OF BROWN TROUT: IMPACT FROM KEYSTONE SPECIES, EXOTICS, CHEMICAL & PHYSICAL FACTORS

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Key words: fish passage, introduced species, isolation, natural barriers, baselines.

Abstract:

This study reveals fundamental factors that determine the distribution of self-sustaining lake-living brown trout. Large-scale temporal and spatial data provided estimates and validations of pre-industrial baseline distributions and extinction rates. Non-native species impact on the survival of brown trout (*Salmo trutta*) populations greatly exceeded any impact from natural causes or water chemistry. Novel Geographic Information System (GIS) tools were the best predictors of landscape-scale distributions of the keystone species pike (*Esox lucius*), which in turn largely governed brown trout distribution among lakes.

SALMON SUSTAINABILITY ON THE EXE

Counter, S.⁽¹⁾, Stevens, J.R.⁽¹⁾, Bright, D.⁽²⁾, Ilbery, B.⁽³⁾.

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Key words: Atlantic Salmon, population genetics, sustainability

Abstract:

The decline in number of Atlantic salmon (*Salmo salar* L.) throughout their range has been well documented. Following the outbreak of Ulcerated Dermal Necrosis in the 1960's salmon numbers on the Exe have not fully recovered. Concern for the catchment's salmon has been well publicised with articles in the BBC news as well as local papers. The River Exe and Tributaries Association initiated a 10 year project on the catchment involving habitat management, counts and genetics. Of the two main tributaries one is more productive and is currently used as a source of broodstock for the catchment. While many studies to date have considered the genetics alone in these situations, it is essential to establish the importance of the results to the region in a broader context; this is where sustainability becomes a multidisciplinary approach encompassing economics, sociology and biology. I will be using this idea as a basis for my case study on the catchment, exploring the more traditional biological questions, as well as establishing the socio-economic context for the results.

PERFORMANCE OF ATLANTIC SALMON JUVENILES RESULTING FROM MULTI-SEAWINTER AND GRILSE PARENTS AT VARYING POPULATION DENSITIES

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Abstract:

When natural selection depends on population density, spatial heterogeneity in density may contribute to maintenance of genetic variation. Furthermore, under such situations, temporal changes in density may be accompanied by evolutionary changes. In a field experiment we investigated whether population density can influence selective regimes in Atlantic salmon by comparing the relative performance of juveniles from different family-groups across densities. Eggs from 10 family groups, 5 from multi-seawinter parents and 5 from grilse parents, were planted out at high or low densities in ten small tributaries of the River Conon, Scotland. Natural salmon spawning is absent in these streams, but most had natural brown trout populations. Five months after outplanting we electrofished the streams and recorded body size and the location of the fish caught (both salmon and trout) along the lengths of the streams. Salmon juveniles were assigned to different family-groups using microsatellite analyses. Results from this study in terms of growth, survival and dispersal will be presented.

SUCCESS OF STREAM RESTORATIONS IN FINLAND

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Key words: stream restoration, habitat improvement, gravel bed, brown trout

Abstract:

In Finland, almost all stream channels was dredged for sawmills, lake regulation, forest dehydration and especially for timber transport. At its maximum, the total length of dredged channels in Finland amounted to 20 000 - 40 000 km in 1900 - 1950. Then, restoration of channels began and spread through the country in 1980's. In the process, part of removed stones is replaced into channels, using excavators to construct enhancement structures such as deflectors, boulder dams or cobble ridges. Furthermore, channels are widened, side channels are opened, and gravel beds are created to enhance spawning grounds for salmonid fishes. However, installation of large woody debris is rarely used. Monitoring for stream restorations began slowly, and now after 30 years of the start of restoration realizations, results are still sparse. As results, channel morphology changes to more rough and salmonid parr habitat is improved, but only a little. However, habitat simulations have been done only for parr stage of salmonids, not to spawning/egg stage or adult stage of salmonids or to other common species, like bullhead or burbot. Success of artificial gravel beds as spawning sites is almost never monitored, but a small material is available in Central Finland. If the origin of gravel in real redds is divided in three categories - natural, authority & excavator and volunteers & bucket - natural gravel is mostly used. Real fish data of 13-26 years in Central Finland shows no change in abundance of wild brown trout or burbot, but bullhead density has began to rise years after restoration in two streams that have almost lacked the species. Clearly, as restoration process continues in Finland and focuses in smaller streams in coming years, more intensive monitoring for habitat change and fish community is needed. In management level, monitoring should be integrated in restoration projects as rigorous and natural part of it.

EFFECTS OF STREAM REHABILITATION ON JUVENILE BROWN TROUT (*SALMO TRUTTA*) IN BOREAL FOREST STREAMS

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Keywords: BACI-design; electrofishing; salmonid densities; stream restoration

Abstract:

Degradation of stream habitats due to anthropogenic activities (e.g. channelization) has had a dramatic impact on fluvial environments and their biota. We used a spatially and temporally replicated, balanced Before-After-Control-Impact (BACI) design to assess the impact of stream habitat rehabilitation on the densities of juvenile brown trout of three age-classes in North Finnish forest streams.

Three separate sections in each of six streams were selected for the study. After three years of pre-rehabilitation monitoring, two randomly selected sections in each stream were restored, one using both large woody debris and boulders, one using only boulders, while the third section remained as an unmodified control. Monitoring of fish densities then continued for another three years after rehabilitation.

Rehabilitation clearly increased streambed complexity, but did not have detectable effects on brown trout stocks in either of the rehabilitation schemes (LWD or stones), except for age-2+ and older fish which decreased in abundance less in the rehabilitated than control reaches. A severe drought in late summer 2002 after rehabilitation reduced densities of trout to a low level in all study streams, overriding any local effects that rehabilitation. Rehabilitation structures seemed to provide some safeguard against drought for age-2 and older, but not for the younger age-classes.

Our results add to the growing body of literature suggesting that large-scale regional factors may overwhelm local management efforts. To be successful in the future, stream rehabilitation schemes must include drought refuge areas for fish and other stream biota.

EXPERIMENTAL REMOVAL OF RIPARIAN CANOPY ENHANCES LOCAL DENSITY AND FORAGING EFFICIENCY OF JUVENILE ATLANTIC SALMON

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Key words: Atlantic salmon, habitat, stream management

Abstract:

Riverine salmonid populations are affected by a number of different factors, including instream physical and chemical habitat, inter- and intra- specific competition and the nature of riparian vegetation. While it is known that dense riparian canopy can reduce the growth and abundance of epilithic algae, higher plants and their invertebrate consumers in a stream, little is known about the complex interactions between riparian shade, instream plants such as *Ranunculus*, and salmonid ecology. In 2008 a manipulation experiment investigating the effect of the addition of an artificial macrophyte analogue on the local density and foraging success of young-of-year salmon was carried out using a modified BACI design. A large increase in density and food consumption was observed in the treatment stretch compared to controls. In January 2009, all but a few trees were removed from 100m of previously heavily shaded riverbank, resulting in a great increase in instream macrophyte growth, which had reached nearly 40% of wetted surface area by midsummer, from less than 2% the year before. This stretch was electrofished in July and again in September, as was a similar 100m control stretch, to establish population density and foraging success. These data were compared with data gained during the 2008 experiment on these stretches in a BACI design. Our results show a significant increase in the density of young-of-year salmon in the experimental stretch in comparison with the control, with this density being concentrated in the macrophyte patches. Additionally, despite no difference in either benthic macroinvertebrate density or invertebrate drift between the two stretches, young-of-year salmon were found to be feeding more successfully in the experimental stretch than in the control. The management of riparian canopy along nursery streams therefore has the potential to highly impact the survival of Atlantic salmon juveniles during their first summer.

EFFECTS OF FOOD PREDICTABILITY AND HABITAT COMPLEXITY ON THE RELATIONSHIP BETWEEN METABOLIC RATE AND PERFORMANCE IN STREAM-LIVING JUVENILE SALMON

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Key words: Atlantic salmon, SMR, food predictability, habitat, dominance

Abstract:

Physiological traits can vary greatly within a species and may have profound effects on aspects of performance. Atlantic salmon (*Salmo salar*) exhibit striking variation in standard metabolic rate (SMR) which affects energy budgets and may influence life-histories and success in the wild. However, it is not clear how variation in the structure of the environment determines the consequences of individual SMR. The relationship between SMR and growth rates of 1+ Atlantic salmon was examined in relation to predictability in food supply and habitat complexity using replicate sections of a large scale controlled indoor stream. SMR was strongly correlated with dominance. Under predictable feeding conditions, dominance rank influenced the quality of feeding territory acquired, which in turn was significantly correlated with growth. In a simple habitat, individuals exhibited an ability to track changes in food availability over time, and dominant (high SMR) fish were able to spend more time in profitable feeding territories and exhibit highest growth. However, in complex habitats individuals seemed unable to track changes in food availability and grew more slowly possibly due to increased shelter use, and there was no relationship between social status and growth. The relative benefit of a high SMR thus depends on habitat complexity and food predictability.

EFFECTS OF SPAWNING SITE DISTRIBUTION ON JUVENILE ATLANTIC SALMON (*SALMO SALAR* L.) DENSITY AND GROWTH: THE MOTHER'S TAILPRINT

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Key words: density dependence, habitat, spatial variation, dispersal, population dynamics

Abstract:

Here we test whether the spatial distribution of spawning sites in a natural population may cause variation in juvenile stream-dwelling salmonid density and thus potentially influence juvenile growth via density dependence. Combining fine-scale data of the spatial distribution of Atlantic salmon nest sites, juvenile densities and body size and habitat characteristics, we examined the relative importance of spawning site distribution and juvenile habitat selection on the resulting young-of-the-year (YOY) growth. The summed area of nests was positively correlated with local YOY densities and was the strongest predictor of local densities. In turn, increased YOY densities resulted in negative density-dependent growth and YOY density was the strongest predictor of YOY size. Habitat variables had little effect on YOY density, which suggests that redistribution of YOY salmon according to habitat preferences was limited. Maternal spawning site selection was therefore the main determinant of local densities and subsequently YOY growth. Thus, during the YOY stage when dispersal is limited, local density-dependence may be the dominant factor responsible for spatial variation in growth.

INFLUENCE OF PHYSIOLOGICAL PROCESSES ON EMERGENCE OF BROWN TROUT (*SALMO TRUTTA*)

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Key words: Metabolic rate, energetic status, *Salmo trutta*, emergence from gravel

Abstract:

Energy stores and metabolism, representing the Energetic status of an individual, condition a number of traits linked to growth or reproduction, such as maternal investment and migration decision at the individual level. In salmonids, ontogeny of early behaviours is poorly understood. Emergence from gravel is thought to be one of the most critical phases for young salmonids due to high selective pressures combined with the acquisition of swimming behaviours. Yet, this critical period is characterized by behavioural variability on emergence dynamic.

Until yolk depletion, energetic status of an individual is only conditioned by maternal provisioning and the yolk absorption rate (metabolic rate) but their respective role in behavioural strategies at this period remain unknown. The aim of this study is to investigate the role of metabolic rate on the date of emergence of brown trout (*Salmo trutta*) fry by measuring Routine Metabolic Rate (RMR) on emerging individuals. First emergents were smaller in both size and weight but had higher RMR (higher energetic needs). These first results are discussed with implications for further research.

EPI-GENETIC TRANSFER OF SOCIAL STATUS VIA MATERNAL STEROID HORMONES IN *SALMO TRUTTA*

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Key words: maternal effects, offspring development, stress

Abstract:

Inter-individual variation in social status of juvenile salmonids is well documented and driven by differences in standard metabolic rate, but the role of additional causal agents has not been investigated. For a range of vertebrate species, mothers affect offspring phenotypes through variation in the levels of hormones that are transferred to eggs. Salmonid mothers encounter variation in environmental conditions, such as habitat quality and social stress that contribute to variation in maternal hormone levels that is pronounced prior to spawning. We investigated whether exposure to elevated levels of maternal steroid hormones during late egg development influenced the social status of juvenile brown trout (*Salmo trutta*). Egg levels of testosterone (T) and cortisol (C) were manipulated immediately post-fertilisation in baths containing mild concentrations of C and T. Fry from elevated T and C eggs were smaller at first feeding. After correcting for body size effects, fry from elevated C eggs were less aggressive than those from controls and fry from T eggs were less competitive and occupied poorer quality territories than controls. This study quantifies a mechanistic link between maternal hormone levels and the social status of juvenile salmonids.

AN APPROACH TO SIMULATE INTERSTITIAL PROCESSES IN RIVER BEDS TO MEET BIOLOGICAL REQUIREMENTS FOR REPRODUCTION OF BROWN TROUT

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Key words: hyporheic interstitial, reproduction, fuzzy-logic, habitat, modelling

Abstract:

The quality of the hyporheic interstitial is described by multifaceted interstitial processes ranging from biological and chemical to physical and morphological processes. From the biological point of view, the interstitial zone between ground water and surface water is a significant section of riverine ecosystems as many aquatic organisms have life-cycle stages related with the hyporheic zone. From a morphological point of view, the hyporheic interstitial is characterized by complex sediment processes like interactions between river bed grain size composition and sediment-transport. The intrusion of fine sediments in the coarser river bed impacts both roughness characteristics and can also alter porosity and permeability. This may lead to a reduction of the intragravel flow which in turn has ecological effects. E.g. the incubation period of salmonids requires sufficient intragravel flow in terms of the supply of dissolved oxygen and the rate of removal of carbon dioxide and metabolic waste. The challenge is to use output data of high sophisticated morphodynamic models (3D) to meet biological knowledge about habitat preferences in the hyporheic interstitial. Existing approaches and parameters (Fredle-Index, Sorting Coefficient, Porosity Models etc.) have to be tested and combined with additional relevant parameters like the vertical hydraulic gradient, the organic matter, the consolidation or the permeability. To combine relevant parameters a multivariate fuzzy-logical approach will be applied giving an imprecise range of dissolved oxygen as response for a certain combination of interstitial describing parameters. As not all occurring interstitial processes can be considered due to their complexity and more than one parameter is decisive in determining the ecological quality of the interstitial, warranting the application of the fuzzy-logical approach. Thus the consideration of both biological and morphological factors can be considered in the approach.

A SIMPLE MODEL OF THE SPREAD OF INVASIVE DISEASES IN SALMON AQUACULTURE

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Key words: *Salmo salar*, fallowing strategies, management area, long-distance movements, disease transmission

Abstract:

Scotland is the second-largest salmon producer worldwide but salmon production is threatened by emerging diseases. Outbreak of diseases can have an enormous economical impact and can cause disease outbreaks in wild fish populations. Pathogens can spread between farms by local processes such as water movement or by long-distance processes such as live fish movements. Here, network modelling was used to investigate the significance of transmission routes at these two scales and the effect of different fallowing strategies (synchronised, partial synchronised and unsynchronised fallowing). Interacting farms were modelled in such a way that neighbours within a management area could infect each other and non-local transmission occurred at random. Synchronised fallowing was highly effective when long-distance movements were <1.5 movements per farm per month and for $\beta=0.10$. Partial and unsynchronised fallowing strategies were unable to eradicate an epidemic for $\beta=0.10$ when long distance movements were >0.73 and >0.15 per farm per month, respectively for partial synchronised and unsynchronised fallowing. These results show the benefits of having epidemiologically-isolated management areas and applying synchronised fallowing.

ATLANTIC SALMON POPULATION DYNAMICS UNDER SCENARIOS OF CLIMATE CHANGE: AN INDIVIDUAL-BASED DEMOGENETIC APPROACH

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Key words: Climate change, *Salmo salar*, individual-based modelling

Abstract:

Atlantic salmon, *Salmo salar*, populations are prone to the influence of climate change both in their river and oceanic phases. Increase in river temperature and flow variability could modify growth conditions and secondarily marine survival. Marine growth and survival conditions have been hypothesized as affected by past climate changes. The current balances between alternatives life histories could be altered. We integrated a cohesive amount of knowledge on *S. salar* biology representing the processes of growth, survival, life history decisions and reproduction in an individual-based demogenetic model to simulate small Western European populations. Migration and maturation processes are represented as genetically heritable probabilistic reaction norms in order to incorporate the influence of life histories evolution on population dynamics. We used this model to assess the changes in life history balances (e.g. river residence vs. anadromy; one winter vs. multiple winters at sea) in relation to three synergetic influences: 1) differential exploitation rates of the different age class; 2) river climate change; 3) marine environmental change. We find that as long as the stressors are not lethal for the population, the evolutions of marine life history traits are mainly driven by selective pressures from exploitation rates. However, marine conditions and flow regimes are also of upmost importance in controlling stocks abundances and in shaping river residence proportions and evolution toward shorter life cycles. We discuss these findings in the light of recent field observations of modifications of European populations and the future of Southern vs. Northern Europe populations.

MULTI-SOURCE SAMPLING: STABLE ISOTOPE VARIATION AND THE 'SKINNY' SALMON STORY

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Key words: stable isotope, $\delta^{15}\text{N}$, $\delta^{13}\text{C}$, condition

Abstract:

Growth condition of returning one-seawinter Atlantic salmon populations has been linked to temperature anomalies in the eastern North Atlantic. The indirect effects of temperature anomalies on the distribution and abundance of prey is likely to influence both growth condition and marine survivorship, but direct observation of marine migration and feeding is difficult and costly. Growth indices and $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ variation in various tissues of 26 mixed-stock 1SW Atlantic salmon from the north coast of Scotland were used as proxies for dietary history to examine its effect on growth condition factor. Liver, red muscle, white muscle and scales were included in the analysis to provide insight into dietary history integrated over different timescales. $\delta^{13}\text{C}_{\text{liver}}$ values account for 59% of the variation in whole fish lipid content, reflecting the fractionation of ^{13}C and ^{12}C during lipidogenesis but this relationship disappears once lipids have been extracted. There were no linear patterns of lipid-extracted $\delta^{13}\text{C}$ variation associated with condition factor but fish returning in poor condition had significantly higher $\delta^{15}\text{N}_{\text{liver}}$: $\delta^{15}\text{N}_{\text{red muscle}}$ values, suggesting that catabolism in liver tissue may be initiated prior to freshwater spawning migration. This could also contribute to the lower estimated post winter growth rates of poor condition fish. The results suggest that 'skinny' returning 1SW salmon, with depleted lipid reserves, are experiencing difficulties provisioning their tissues towards the latter end of their marine migration.

IDENTIFICATION OF MARINE FEEDING AREAS OF ATLANTIC SALMON: CLIMATE CONTROL OF RIVER STOCKS

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Key words: isotopes, marine, location, climate, plankton

Abstract:

Diadromous fish are influenced by climate change both at sea and in freshwater habitats. Monitoring freshwater responses is facilitated by the relative accessibility of habitats, and constrained location of fish and prey. In the open ocean, assessing population response to climate change is particularly challenging.

Climate change may influence the distribution of oceanic fish through the distribution of water masses with suitable temperature ranges, the distribution and abundance of prey items, and changes in ocean currents. Assessing population response to climate change therefore requires a cost-effective method of identifying location at sea.

We analysed the stable isotope composition of collagen in scales of Atlantic salmon, *Salmo salar* (L.), and developed a novel data analysis method to predict the location of marine feeding areas using sea surface temperature. We demonstrate separation in marine feeding areas (and therefore migration routes) between UK populations throughout the 18 years covered by the study. Sustained separation in marine feeding area leads to a divergence in the vulnerability of each population to climate drivers such as the NAO, and this is reflected in the relationship between marine mortality and climate indices for these stocks.

Our technique is applicable to any fish species where long-term tissue archives are available, potentially providing a novel method to study the response of marine fish populations to climate change.

CONDITION, LIPIDS AND THE ‘SKINNY’ SALMON

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Key words: lipid storage, condition, *Salmo salar L.*

Abstract:

It is commonly acknowledged that populations of wild Atlantic salmon (*Salmo salar L.*) are declining. The majority of these declines are due to overfishing, however, recent years have seen drops in population condition that cannot be described by this alone. Increasing sea surface temperature (SST) has been shown to compromise both salmon prey items and the predicted weight (and condition factor) of salmon returning from sea to spawn. One-sea-winter (1SW) Atlantic salmon returning to the North of Scotland were monitored to estimate the condition of the returning population. The total body fat content of returning fish was estimated, along with the lipid content of selected fish being examined more specifically. The condition of returning salmon showed a positive non-linear relationship with fish lipid content and the selected study fish showed variations of lipid storage among different tissue types. These results indicate a ‘bottoming-out’ of salmon condition with no apparent recovery of populations.

DOES THE MAGNITUDE OF DIURNAL TEMPERATURE VARIABILITY AFFECT GROWTH IN JUVENILE ATLANTIC SALMON?

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Key words: Temperature, growth, condition

Abstract:

Growth and performance of juvenile Atlantic salmon have been shown to be sensitive to changes in water temperature; most dramatically this is evident in lethal and sub-lethal effects of extremely high temperatures. Most studies of the thermal performance of juvenile salmonids have typically assessed the effects of thermal regime using constant temperatures, whereas in reality stream temperatures can vary over much of the reported performance range (>7°C) over short (i.e. diurnal) temporal scales. This study focused on quantifying the effects of variation in thermal regimes on the performance of 1+ salmon. Experimental manipulation of water temperature was used to simulate (a) constant and (b) naturally varying thermal regimes with similar mean values. Data from 2 replicates of 4 treatments (2 thermal and 2 feeding regimes) with 125 fish per tank were collected over a 6 month period corresponding to the main spring and summer growth period. Fish growth and performance was assessed at fortnightly intervals. Small but significant differences in length were found, with the constant regime having larger fish under both feeding regimes. The research showed that more variable thermal regimes can cause a reduction in growth rates and ultimately fish performance.

A SIMPLE MODEL OF THE SPREAD OF INVASIVE DISEASES IN SALMON AQUACULTURE

Werkman, M.⁽¹⁾, Green, D.M.⁽¹⁾, Murray, A.G.⁽²⁾, Turnbull, J.F.⁽¹⁾

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Key words: *Salmo salar*, fallowing strategies, management area, long-distance movements, disease transmission

Abstract:

Scotland is the second-largest salmon producer worldwide but salmon production is threatened by emerging diseases. Outbreak of diseases can have an enormous economical impact and can cause disease outbreaks in wild fish populations. Pathogens can spread between farms by local processes such as water movement or by long-distance processes such as live fish movements. Here, network modelling was used to investigate the significance of transmission routes at these two scales and the effect of different fallowing strategies (synchronised, partial synchronised and unsynchronised fallowing). Interacting farms were modelled in such a way that neighbours within a management area could infect each other and non-local transmission occurred at random. Synchronised fallowing was highly effective when long-distance movements were <1.5 movements per farm per month and for $\beta=0.10$. Partial and unsynchronised fallowing strategies were unable to eradicate an epidemic for $\beta=0.10$ when long distance movements were >0.73 and >0.15 per farm per month, respectively for partial synchronised and unsynchronised fallowing. These results show the benefits of having epidemiologically-isolated management areas and applying synchronised fallowing.

THE ROLE OF THE MAJOR HISTOCOMPATIBILITY COMPLEX (MHC) IN MATE CHOICE AND SURVIVAL IN SEA TROUT (*SALMO TRUTTA*)

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Key words: Major Histocompatibility Complex, balancing selection, mate choice

Abstract:

Understanding the factors that affect spatial and temporal levels and distribution of genetic diversity is essential for the management of genetic resources in natural populations. Salmonids generally either remain in their natal habitat throughout their life cycle or they return to their natal habitat to spawn. This predicts reduced gene flow between populations and the potential for genetic drift to erode genetic variation. However, both sexual selection and natural selection can abrogate the effects of drift, though this has been poorly examined in natural populations. The genes of the Major Histocompatibility Complex (MHC) represent the most diverse genomic region in vertebrates, and have become a paradigm both for adaptively important genetic variation and how balancing selection can act to retain diversity in the face of gene flow. However, there is still debate about the mechanisms which drive balancing selection. In this study I shall be investigating whether mate choice of adult sea trout (*Salmo trutta* L.) and the survival of offspring according to their MHC genotype can act to retain higher levels of genetic variation than predicted under neutral theory. Preliminary results suggest that females exercise mate choice and often allow extra pair copulations which could, theoretically, be a mechanism to maximise diversity. Here we characterise MHC among mated pairs of sea trout from 118 nests in NE Scotland and examine 1) the extent to which MHC diversity between individuals is greater than expected by chance; 2) the genetic contribution of extra pair males to brood MHC diversity; 3) the amount of variance in survival of offspring explained by MHC genotype. This study will allow for a unique overview of mate choice and survival in a wild population and will contribute to the understanding of the relationship between mate choice, survival and the MHC.

DETERMINING THE SCALE OF BIOLOGICALLY IMPORTANT LOCAL ADAPTATION IN ATLANTIC SALMON USING A COMMON GARDEN EXPERIMENTAL APPROACH

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Key words: Atlantic salmon, *Salmo salar*, common-garden experiment, local adaptation.

Abstract:

A series of common-garden experiments have been carried out in the Srahrevagh River, NW Ireland, over the last two decades. In these experiments, the relative fitness of different groups of Atlantic salmon (*Salmo salar*) has been compared using a genotype approach. A previous study suggested that large fitness differences can exist between populations at small local spatial scales (50km). No provision was made in this study, such as the establishment of inter-population hybrids, which could have allowed for a more definitive conclusion about the genetic basis of the result. Intermediate fitness values for the hybrids would provide convincing evidence that there was additive genetic explanation for the results. Here we report on the setting up and running of a follow up experiment which seeks to explore local adaptation using inter-specific hybrids as a genetic control.

PREDICTING THE DEMO-GENETICS OF BROWN TROUT POPULATIONS ON A REGIONAL SCALE

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Key words: brown trout, demography, model, population genetics

Abstract:

The aim of my thesis is to develop a model predicting the changes over time in density and genetic structure of several brown trout (*Salmo trutta fario* L.) populations, taking into account its life cycle and habitat quality. The first step of the strategy is to develop a single-population individual-based model limited to a system comprising a river and its tributary. Individual-based (or agent-based) modelling techniques will be used to integrate both demographic and genetic data. In a further step, the demo-genetic model will be extended to the regional scale and will consider several brown trout populations. On this larger scale, data on spatial heterogeneity and movement of trout will be added.

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Panu Orell	Finland	panu.orell@rktl.fi	Atlantic salmon, migrations (both adult and smolts), stock evaluation (underwater video surveillance, surface diving), conservation spawning limits, etc.
Patricia Johnston,	Canada	Patricia_Johnston@ete	the influence of habitat structure on Atlantic salmon parr (<i>Salmo salar</i>) movements, growth and survival.

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