

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



Gotein-Libarrenx, France  
March 17<sup>th</sup> – 20<sup>th</sup> 2011

## **Sessions and detailed schedule**

### **Wednesday 16 March** Committee meeting and arrivals

<b>Time</b>	<b>Activity</b>
17:30-19:00	Committee meeting (David, Pauliina, Kirsteen, Donald, Guillaume, Thomas, Mélanie, Mathieu)
19:30	Dinner: keynote speakers and Committee members
21:00	Ice breaker at the Katy Daly's (Everybody welcome!)

### **Thursday 17 March** NoWPaS day 1; Excursion

<b>Time</b>	<b>Activity</b>
08:30	Coach departs at airport
09:00	Arrival at INRA research station in St Pée sur Nivelles, tour of facilities
09:10	Morning coffee and presentation of research programs at the research station
10:00	Coach departs INRA research station
10:15	Visit to Atlantic salmon fish pass and presentation of radio tracking work in progress
10:50	Coach departs fish pass
11:00	Visit to technical installations in the INRA research station + videos
12:30	Lunch, coach departs INRA research station
14:00	Presentation and visit to the INRA field installation
15:00	Coach departs field installation – passports required for border stop
16:00	Vulture birdwatching (weather permitting)
17:00	Coach departs birdwatching for Château de Libarrenx
18:30	Arrive at Château de Libarrenx, finding rooms etc.
19:00	Dinner and ice breaker

**Friday 18 March**  
**NoWPaS day 2**

<b>Time</b>	<b>Activity</b>
8:30	<b>Breakfast</b>
08:55	<b>Opening</b> – David McCormick – NoWPaS Committee representative
9:05	<b>Invited speaker</b> – JACQUES LABONNE – Evolution ecology of salmonids in the Kerguelen Islands
9:55	Break
10:00	<b>Session I – Genetics and evolution – Chair Thomas Régnier</b> <ul style="list-style-type: none"><li>➤ <b>Ciar O’Toole</b> – <i>Determining the scale of biologically important local adaptation in Atlantic salmon using a common garden experimental approach</i></li><li>➤ <b>Adam Fryer</b> – <i>Effects of MHC compatibility process on fitness and survival of Atlantic salmon and application to Atlantic salmon</i></li></ul>
10:40	Coffee
10:55	<b>Session II – Genetics and population – Chair Thomas Régnier</b> <ul style="list-style-type: none"><li>➤ <b>Monica Solberg</b> – <i>Farmed escapees and interactions with wild conspecifics: quantification of genetic differences between wild and farmed salmon</i></li><li>➤ <b>Natacha Nikolic</b> – <i>Presentation and application of a new model to estimate the evolution of effective size from the last common ancestor and application to Atlantic salmon</i></li><li>➤ <b>Béatrice Frank</b> – <i>An individual-based model to simulate the demogenetic dynamics of a brown trout population</i></li></ul>
11:55	Break
12:00	<b>Session III – Hydropower – Chair Pauliina Louhi</b> <ul style="list-style-type: none"><li>➤ <b>Stina Gustafsson</b> – <i>Technical fishways, nature-like fishways or biocanals ?</i></li><li>➤ <b>Michael Puffer</b> – <i>Long-term consequences of stranding on Atlantic salmon parr during winter</i></li><li>➤ <b>Roser Casas-Mulet</b> – <i>Physical processes, hydropower operation and scale integration for the prediction of stranding potential in rivers</i></li></ul>
13:00	<b>Lunch</b>
14:00	<b>Invited speaker</b> – JAAKKO ERKINARO – Habitat shifts of juvenile Atlantic salmon in fresh water – life histories and individual-based ecology
14:50	Break

- 14:55 **Session IV – Environment and habitat – Chair Kirsteen MacKenzie**
- **David McCormick** – *Direct and indirect effects of riparian canopy on the biology of stream-dwelling salmonids in south-west Ireland*
  - **Paolo Veza** – *Meso-scale habitat modelling in high gradient streams*
  - **Pauliina Louhi** – *Habitat use by juvenile brown trout (*Salmo trutta*) and Arctic bullhead (*Cottus poecilopus*) - influence of interspecific vs. intraspecific competition*
- 15:55 Coffee
- 16:10 **Session V –Environment and habitat – Chair Kirsteen MacKenzie**
- **Stephen Dugdale** – *Detection of salmonid thermal refugia from airborne thermal infrared (TIR) imagery*
  - **Maare Marttila** – *Fish populations, heterogeneity of river channels, and socio-economic impacts – towards a multidisciplinary analysis of river restoration programs*
- 16:50 Break
- 16:55 **Session VI – Density dependence – Chair Guillaume Dauphin**
- **Grethe Robertsen** – *Competitive regimes shape the spatio-temporal pattern of offspring size effects in Atlantic salmon*
  - **Daniel Ayllón** – *Assessing the conservation status of brown trout populations through the analysis of density-carrying capacity relationships*
  - **Alexandre Richard** – *Evidence for density-dependent and density-independent regulation in a resident brown trout population*
  - **Maxim Teichert** – *Interactions between local population density and limited habitat resources determine movements of juvenile Atlantic salmon*
- 18:15 **Predinner**
- 19:30 **Dinner and social**

**Saturday 18 March**  
**NoWPaS day 3**

<b>Time</b>	<b>Activity</b>
8:30	<b>Breakfast</b>
09:00	<b>Invited speaker</b> – RICK CUNJAK – <i>Biological significance of thermal refugia for juvenile Atlantic salmon during extreme heat events in rivers</i>
09:50	Break

- 09:55 **Session VII – Behaviour – Chair Donald Reid**
- **Carole-Anne Gillis** – *The presence of the mat-forming diatom *Didymosphenia geminata* alters foraging behaviour of young-of-the year *Salmo salar**
  - **Petra Rodewald** – *Migration and exploratory behaviour of Atlantic salmon smolts: Soft vs. hard release*
  - **Dan-Erik Lindberg** – *Selecting a path*
- 10:55 Coffee
- 11:10 **Session VIII – Metabolism and energy – Chair Mathieu Buoro**
- **Alexandra Howe** – *Partitioning of total lipid among tissues of pre-spawning and post-spawning Atlantic salmon (*Salmo salar*)*
  - **Tim Burton** – *Does maternal somatic condition, reproductive investment and smolt age influence fry performance in the wild ?*
  - **Donald Reid** – *Metabolic strategies in juvenile Atlantic salmon: the consequence of brown trout presence*
  - **Thomas Régnier** – *Parental influences on offspring energetic status in brown trout (*Salmo trutta*): consequences on early behaviour and fitness*
- 12:30 **Lunch**
- 13:30 **Invited speaker** – JOHN REYNOLDS – *Impacts of nutrients derived from salmon on biodiversity*
- 14:20 Break
- 14:25 **Session IX – Population dynamics and management – Chair David McCormick**
- **Mélanie Brun** – *Estimating the geographical repartition of the breeders by coupling capture-mark-recapture data with nest counting: a Bayesian approach*
  - **Sarah-Louise Counter** – *The population structure of Atlantic salmon (*Salmo salar* L.) in a southern English catchment, the River Exe*
  - **Guillaume Dauphin** – *Viability study of the natural population of Atlantic salmon (*Salmo salar* L.) in the Allier catchment*
- 15:25 Coffee
- 15:40 **Session X – Population dynamics and management – Chair Mélanie Brun**
- **Jukka Syrjänen** – *Does egg stocking increase the abundance of brown trout parr ?*
  - **Charles Ikediashi** – *Assessing the sustainability of Atlantic salmon across the southern part of their European range in the light of climate change and human exploitation*
  - **Kirsteen MacKenzie** – *Stable isotope evidence for the rate at which climate-driven variations in phytoplankton growth influence higher trophic levels*
- 16:40 **Group discussions**
- Discussion of NoWPaS 2011
  - [www.nowpas.eu](http://www.nowpas.eu) – what do we need ? Suggestions for the home page
- 19:30 **Dinner**

**Sunday 20 March**  
NoWPaS day 4

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<b>Time</b>	<b>Activity</b>
8:30	<b>Breakfast</b>
9:00	<b>Departure</b> for Biarritz

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## Preface

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

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. In order to maximize the research quality of PhD studies, NoWPaS (Nordic Workshop for PhD students on *Salmo salar* and *Salmo trutta* research) was established in 2005 with the aim of building an international network to promote collaboration and the exchange of knowledge. The previous workshops have been held in Norway, Sweden, Finland, Denmark, England, and Scotland in 2005-2010. In total, more than 200 young researchers have given oral presentations combined with extended lectures by invited speakers on each workshop. Previous key-note speakers have been Sigurd Einum (NTNU, Norway), Eva Thorstad (NINA, Norway), Tormod Skei (Statkraft Norge), Neil Metcalfe (Glasgow University, Scotland), Torgny Bohlin (Gøteborg University), Rick Cunjak (New Brunswick University, Canada), Ari Huusko (Finnish Game and Fisheries Research Institute, Finland), Malcolm Elliott (Freshwater Biological Association, England), John Armstrong (Fisheries Research Services 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 Water Research Laboratory, USA), Ken Bovee (US Geological Survey, USA), Mike Dunbar (Centre for Ecology and Hydrology, England), Clive Trueman (University of Southampton, England), Alan Youngson and Iain Malcolm (Marine Scotland, Freshwater Laboratory, Scotland), Phil Roni (Northwest Fisheries Science Centre, Seattle), Ken Whelan (Irish Marine Institute, The Atlantic salmon trust and University College Dublin, Ireland) and Tom Cross (University College Cork, Scotland). This year's workshop will be held in Gotein-Libarrenx, France, and we are delighted to have as our keynote speakers Rick Cunjak from the University of New Brunswick, Canada, Jaakko Erkinaro from the Finnish Game and Fisheries Research Institute, Finland, Jacques Labonne from the UMR ECOBIOP INRA (Institut National de la Recherche Agronomique) / UPPA (Université de Pau et des Pays de l'Adour), France, and John Reynolds from Simon Fraser University, Canada.

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. Secondly, we wish to invite key researchers to give lectures and short courses within the field. Through this framework, we intend this workshop to be mutually beneficial to all delegates and therefore help promote research. 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. As an overview, the workshops will have the following main objectives: *i*) Participating doctoral and post-doctoral students shall present the results of their research. In this way, they will have the opportunity to receive feedback on their own work and to be informed of the work of fellow delegates

as well as developments within the field. *ii*) Senior scientists within the field will be invited to present talks on their work and highlight areas where future research is required. *iii*) Presented material and the discussions will form the basis for a report which will be published and sent to all participants and members of the network. *iv*) The homepage ([www.nowpas.eu](http://www.nowpas.eu)) is to be improved so that publications and information on international conferences, workshops etc. can be easily accessed. This homepage will therefore act as an information centre.



## Acknowledgements

NoWPaS-2011 has primarily been based on voluntary work by the steering committee. It is not possible to put into words 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 to first of all the participants and their contributions which make 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.

One of the main principles of this workshop is that it is free to attend for all participants presenting their results (keynote speakers included). Transport costs are covered for the invited scientists and subsidized for the majority of participants (depending on the final budget). This principle would not be possible without the generous support of all our investors., shown below



The organizing committee of NoWPaS-2011 has consisted of following people:

- Mélanie Brun, France
- Mathieu Buoro, France
- Guillaume Dauphin, France
- Pauliina Louhi, Finland
- Kirsteen MacKenzie, England
- Dave McCormick, Ireland, Web administrator
- Thomas Régnier, France
- Donald Reid, Scotland

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# EVOLUTIONARY ECOLOGY OF THE KERGUELEN IS. COLONIZATION BY SALMONIDS

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**Key words:** Kerguelen islands, invasion biology, migration, adaptation, phenotypic plasticity

## **Abstract:**

The freshwater ecosystem of sub-Antarctic Kerguelen Islands has remained virgin of fish species until 1956, when the first man made introductions were realised. Eight salmonid species were released at various dates and in various conditions: numbers, genetic diversity, life stages, single or repeated releases, habitats. The monitoring of the consequences of these introductions represents a unique long term databank for the evolutionary ecology of salmonids. We first present here a brief summary of the outcome of these introductions over the years. Based on this historical report, we built a new research programme (SALMEVOL), whose purpose is both to exploit ancient tissues, samples and data, and to propose new experiments and protocols to understand the dynamics of extinction and colonization in the archipelago.

We mainly address the following questions: Did initial genetic and phenotypic diversity have an influence on the outcome of introductions? Have life history traits evolved since the various introductions? If they have, is it caused by Darwinian adaptation? Has the introduction of such species modified ecosystem structure? And finally, can we predict the progression of the colonization front in this environment submitted to global warming effects (new rivers, new colonization routes)?

# 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*, local adaptation, common-garden experiment, parentage assignment

## **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*) have 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. Preliminary results from a follow up experiment seem to indicate intermediate fitness values for the hybrids. This could indicate that there was an additive genetic explanation for the original results. We report on the setting up and running of the follow up experiment along with initial results and future plans.

# EFFECTS OF MHC COMPATIBILITY ON FITNESS AND SURVIVAL OF ATLANTIC SALMON

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**Key words:** Fitness; MHC (major histocompatibility complex); mate choice; sexual selection; *Salmo salar*

## Abstract:

Originally coined by Charles Darwin, ‘sexual selection’ has always been an untractable, slippery concept for behavioural ecologists and evolutionary biologists alike. When parents provide care, the mechanisms of mate choice are generally well understood, but in species that offer little parental investment the mechanisms of sexual selection and mate choice remain controversial. The ‘good genes hypothesis’ suggests that elaborate-traits and displays are a sign of genetic quality to potential mates, but genetic compatibility (‘compatible genes’ hypothesis) can also play a role. In Atlantic salmon it has been suggested that females can passively choose mates based on MHC (major histocompatibility complex) dissimilarity, but the optimal level of dissimilarity, or the associated fitness benefits, are subject to debate. We artificially crossed 8 female Atlantic salmon with males of varying MHC dissimilarity to generate half-sib families of different expected fitness and incubated the eggs until the eyed stage. We then planted the eggs in the wild, and assessed alevin survival, emergence patterns, and pathogen resistance patterns in the laboratory. Our study can help elucidate the significance of MHC-mediated mate choice in Atlantic salmon and other promiscuous species with little or no parental care, and provides opportunities for incorporating sexual selection into captive breeding programmes.

# FARMED ESCAPEES AND INTERACTIONS WITH WILD CONSPECIFICS: QUANTIFICATION OF GENETIC DIFFERENCES BETWEEN WILD AND FARMED SALMON

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**Key words:** genetic, farm salmon, wild salmon, hybrid, growth reaction norm

## **Abstract:**

The commercial production of Atlantic salmon (*Salmo salar* L.) was established in Norway in the 1970's, and today Norway is Europe's largest producer, followed by Scotland and Ireland. ~0.5 – 1.6% of all farmed salmon escape into the wild, and the number of farmed escaped salmon exceeds the total number of wild salmon. Of the escaped individuals ~10% return to rivers upon reaching sexual maturation, and in some rivers represent more than 80% of the total number of spawners. Traits favorable for the domesticated environment have been artificially selected for, leading to reduced genetic variation within farmed populations. Both intended and unintended selective breeding causes the farmed salmon, to deviate from the wild populations and the reduced genotypic variation may cause direct detrimental effects upon the wild populations due to interbreeding. Interbreeding may cause genetic changes as wild genotypes are being replaced by farmed genotypes, and drive already depressed populations to extinction. Hence, farmed escaped Atlantic salmon represent one of the largest threats to the genetic integrity of wild salmonid populations.

In this study we investigated the stress-responsiveness in wild, farmed and hybrid Atlantic salmon, subjected to a chronic stressor. Salmon subjected to stress display reduced feed intake, and as a consequence, reduced growth. With a negative correlation between a comprehensive stress response and fitness, e.g. growth rate, a lower stress response in farmed salmon may have been selected for inadvertently as part of the process of domestication. In this study the stress levels were manipulated by a lowering of water level, twice a day, to detect any differences in the growth reaction norm between 29 families of wild, farmed and hybrid origin. The average body weight of farmed individuals was 1.66 times the average body weight of hybrids and 3.41 times that of wild families. In the control tanks the corresponding numbers were 1.57 and 2.91. Stress-responsiveness in farmed, hybrid and wild families were detected as an average decrease in growth rate between the two treatments of 21 %, 25 % and 32%, respectively. There was however detected large differences between the families used in this study, as all three groups displayed a range of 19 % or more between the minimum and the maximum growth reduction.

# PRESENTATION AND APPLICATION OF A NEW MODEL TO ESTIMATE THE EVOLUTION OF EFFECTIVE SIZE FROM THE MOST RECENT COMMON ANCESTOR

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**Key words:** effective size, evolution, Atlantic salmon

## **Abstract:**

To overcome the difficulties of estimating the abundance and viability of aquatic populations, a new model was developed under an R package. It uses genetic data, which is less expensive and easier than demographic data, to access a parameter reflecting the abundance and the viability of a population over the long term: the effective size. This model, which is adaptable to every diploid species, provides the variation in time (evolution) of effective size from the common ancestor until event sampling.

This model has emerged after preliminary works on the genetic diversity and effective population size of wild Atlantic salmon (*Salmo salar*). Results obtained from 'classic' coalescent methods do not allow a conclusion about the future of the populations. Hence, there was much interest in developing a new model to improve the estimation of conservation status. This new model, called *VarEff*, identifies past changes of effective size with the coalescent theory and Markov chains to get every successive event. One of its strengths is to offer short computing time as a result of direct analytical resolutions without going through the coalescent trees. These resolutions have been published in *Theoretical Population Biology* (Chevalet and Nikolic 2010).

The presentation of this model and its application to an endangered species, such as the Atlantic salmon, is the current subject of a final paper (Nikolic and Chevalet 2011). The analysis was applied to wild Atlantic salmon populations in France and Scotland and has raised substantial issues in regards to the use of methods in genetics of populations and their application in conservation.



# AN INDIVIDUAL-BASED MODEL TO SIMULATE THE DEMOGENETIC DYNAMICS OF A BROWN TROUT POPULATION

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**Key words:** brown trout, demography, individual-based model, population genetics

## **Abstract:**

There is a need for ecological models combining demographic and genetic data. This was demonstrated by a literature analysis of models applied on *Salmo trutta*. This network-based analysis focused on 68 publications published between 2003 and 2008, and their 2,964 references (from 1980 to 2009). In this context, we developed a demogenetic model, using individual-based (or agent-based) modelling techniques, for predicting the evolution of the density of a brown trout population over time and the concomitant evolution of its genetic structure. The demographic and genetic data come from a study conducted since 1998 on a river and its spawning tributary in southern Belgium. Mark-recapture observations of 14,332 trout individuals (measured parameters were: location and date of capture, fish length and for some individuals, weight and sex) and the genotype of 122 of them (determined on the basis of seven microsatellite markers) were available. Mark-recapture data was obtained in two different ways: (i) electrofishing once a year in the main river and twice a year in the brook, (ii) a trapping facility located 20 metres upstream from the confluence with the river. Here, we present an overview of the ongoing development of the individual-based demogenetic model which aims at studying the role of first-order streams for spawning and recruitment in juvenile brown trout in the main river, and more particularly to find out the factors determining the downstream migration of juvenile trout to the river, and to analyse the subsequent changes in the demogenetic structure of the population.

# TECHNICAL FISHWAYS, NATURE-LIKE FISHWAYS OR BIOCANALS ?

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**Key words:** nature-like fishway, nature-like bypass channel, biocanal, passage, habitat

## **Abstract:**

The construction of fishways or fish bypasses is the most widespread action taken to restore connectivity and re-establish migration routes in streams exploited by hydropower. Most technical fish passages are made of wood or concrete and have to a large extent been adapted to facilitate the migration of adult individuals of the commercially important salmonids, which unlike many other fish species are able to ascend steep areas with fast flowing water. However, during the last decades the importance of designing passages ascendable for other fish species and aquatic organisms of different life stages has been recognized. Examples of such passages are the nature-like fishways, which has the potential not only to facilitate passage, but also to provide habitats for the organisms that live in the system. There are still some aspects in nature-like design that is yet to be taken into consideration and which may enhance the usefulness of these constructions even more. To learn more about, and to develop the concept of nature-like design, a more diverse version of a nature-like bypass channel has been constructed in Eldforsen, Sweden. The idea was to make the structure even more nature-like in regards of morphology, substrate, hydraulics, gradient, flow regime etc. The colonization and the species composition in the biocanal and in adjacent areas are being studied and compared with natural streams in the area.

# LONG-TERM CONSEQUENCES OF STRANDING ON ATLANTIC SALMON PARR DURING WINTER

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**Key words:** hydropeaking, winter habitat use, energetic consequences

## **Abstract:**

Riverine fish are suffering in different ways from hydropower operations, e.g. higher water temperatures during winter time, unnatural shifts in the macroinvertebrate community or rapid and frequent water level changes. It has been shown that stranded fish can survive such events, but little is known what the long time effects of such physiological stresses are. We therefore conducted stranding experiments with juvenile Atlantic salmon in artificial outdoor channels during winter and were interested in changes of body mass, fin damages and change in body composition. Fish were experimentally stranded twice a week for 3 hours over an 8 weeks period. The results were compared with channels, which were run at the same time at a stable water level.

Preliminary results show an overall decrease in body mass for both the experimental and the control group. Fish experiencing non-lethal stranding events show a higher decrease in body mass in comparison to the control group. Fin damages occur in both groups and both suffer from the harsh winter conditions in the channels. Until now no results are available for the body composition analyses, but will be discussed if available.

The results confirm our expectations and therefore the same experimental setup will be repeated in summertime to see if fish performance is different to the winter conditions.

# PHYSICAL PROCESSES, HYDROPOWER OPERATION AND SCALE INTEGRATION FOR THE PREDICTION OF STRANDING POTENTIAL IN RIVERS

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**Key words:** hydropeaking, physical processes, scale, stranding potential

## **Abstract:**

Frequent changes in discharge in rivers downstream of power plant outlets in rivers can have large physical and ecological impacts on the aquatic environment. Research on environmental impacts of hydropower production has traditionally focused on long-term effects, but frequent hydropeaking impacts have only been studied in a limited number of cases.

A well-documented impact of these sudden changes in discharge is the stranding of fish (Saltveit *et al.* 2001, Halleraker *et al.* 2003). However, a great degree of uncertainty on quantifying stranded fish and understanding on the physical processes driving stranding potential at several scales still remains. Moreover, integration of such processes with hydropower operations is needed in order to establish potential mitigation measures for the stranding of fish.

This paper presents the works undertaken river Lundesokna, a highly hydropeaked river in Central Norway. A methodology for analysing relevant physical processes for fish at several scales was applied. Physical processes included hydraulics, geometry, temperature, conductivity and oxygen were analysed and those were then integrated with the existing hydropower operation regime in order to predict stranding potential.

# HABITAT SHIFTS OF JUVENILE ATLANTIC SALMON IN FRESH WATER – LIFE HISTORIES AND INDIVIDUAL-BASED ECOLOGY

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**Key words:** *Salmo salar*, migration, movements, growth, individual choice

## **Abstract:**

In addition to the traditionally assumed localised behaviour of stream-resident Atlantic salmon parr, there is an increasing amount of evidence pointing to active exploratory behaviour and substantial rates of movement between freshwater habitats. These migrations of juvenile salmon are partial in a population, and in some river systems, considerable proportion of parr migrate to secondary (in time) habitats, especially upstream into small brooks that adult salmon do not use for spawning, but the juveniles enter them from their natal rivers. In some systems, salmon parr also enter the lacustrine areas of the river.

Salmon parr from the small brooks typically form the older component of the population and show better growth than their counterparts in the main stem. The migrant individuals that find a stable territory in their new habitat show the highest growth, whereas transient fish that move between the main stem and the streams do not grow better than the resident fish that stayed in their natal habitat. The brooks provide benefits such as better food resources, favourable habitat characteristics and less predation. The lacustrine parr also grow better than fluvial parr in the main stem, and adopt new diet and feeding strategy in connection with the habitat shift. The partial migration of parr may represent a conditional strategy, although quantification of the fitness payoffs is still to be done. Early choice of nursery habitat may be related to later differences in life history.

Given the widespread distribution of the habitat shifts to streams and lakes in many species-poor rivers, smolt production in secondary habitats is evidently important for salmon stocks in these river systems. Habitat restoration efforts, e.g. improving habitat connectivity at road culverts, can markedly enhance the use of secondary habitats by juvenile salmon.

# DIRECT AND INDIRECT EFFECTS OF RIPARIAN CANOPY ON THE BIOLOGY OF STREAM-DWELLING SALMONIDS IN SOUTH-WEST IRELAND

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**Key words:** Atlantic salmon, riparian canopy, aquatic macrophytes, population ecology, habitat restoration

## **Abstract:**

Previous studies have shown variable effects of riparian shade on juvenile salmonids, but little is known about the complex interactions between riparian shade, instream macrophytes and salmonid ecology. The aim of this body of research was to investigate, both through field surveys and experimentally, the relative roles of riparian canopy and aquatic macrophytes on the ecology of juvenile Atlantic salmon *Salmo salar* L. and brown trout *Salmo trutta* L. in south-west Ireland. A paired multi-stream study demonstrated a positive effect of open canopy on population densities of 0+ salmon and trout, but positive effects on size and feeding were found to be more related to macrophyte density than the extent of shading. Experimental manipulation of instream macrophytes showed that they can enhance local salmon density and play a dual role in providing both cover and an important source of preferred prey taxa to juveniles. By sampling fish at small patch scales, a considerable preference by 0+ salmon for macrophyte patches was observed. Additionally, a positive effect on the size and feeding of this group of occupying such patches was demonstrated. The final part of the research tested the potential of riparian canopy removal as a management tool for enhancing salmon production. Selective riparian canopy removal resulted in a significant increase in instream macrophyte density with significant positive effects on the density of young-of-year salmon at a local scale. These findings suggest that in systems where the prevailing conditions favour the growth of instream macrophytes, considered management of riparian vegetation could significantly increase instream habitat complexity and provide a significant source of macroinvertebrate prey for salmonids without the need for costly, disruptive instream habitat restoration measures.

# MESO-SCALE HABITAT MODELING IN HIGH GRADIENT STREAMS

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**Key words:** mesohabitat, high gradient streams, *salmo*

## **Abstract:**

The study aims to evaluate a possible methodology for habitat modelling in high gradient streams located within Apennine and Alps mountain range in North-Western Italy. The methodology is based on the meso-scale habitat modelling approach of the MesoHABSIM simulation system, and can support the environmental flows assessment and the definition of habitat restoration measures in such watercourses. Data coming from 34 study sites located within the mountainous areas of Valle d'Aosta, Piemonte and Liguria regions are used in the analysis. The use of the meso-scale approach shows several advantages in modelling habitat for fish in high gradient streams, encompassing a range of scales. Firstly, the applied meso-scale modelling uses GIS and mobile mapping techniques as a quick data collection strategy to describe and determine the spatial proportions of mesohabitats units in stream reaches. Considering biological models, the meso-scale approach employs the logistic regression, involving a large range of habitat variables (e.g. physical and chemical habitat attributes) and enabling understanding of the fish community behaviour at large spatial scale with a multivariate approach. From an hydraulic point of view, the meso-scale habitat models adapt particularly well to the high gradient watercourses not requiring hydraulic discharge simulation, being able to model the hydrodynamic and habitat variations over a range of discharges. Finally, as an example of results extrapolation, the study reports the upscaling of the environmental requirements for fish using a catchment grouping technique, splitting the study domain in homogeneous sub-regions distinct on both minimum environmental flows requirements and catchment/stream characteristics. Evaluating its application in several study sites, the proposed methodology seems to have some interesting potentials for further applications in defining environmental flows and habitat restoration measures for many mountainous rivers simultaneously.

# HABITAT USE BY JUVENILE BROWN TROUT (*SALMO TRUTTA*) AND ARCTIC BULLHEAD (*COTTUS POECILOPUS*) – INFLUENCE OF INTERSPECIFIC VERSUS INTRASPECIFIC COMPETITION

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**Key words:** competition, habitat, brown trout, Arctic bullhead

## **Abstract:**

Stream-dwelling salmonids and bullheads occupy closely similar resource niches in northern rivers with respect to habitat and food. It should therefore be of interest to examine whether they are involved in a competitive interaction, with potential implications for habitat use and growth of brown trout, or do they simply have similar habitat requirements without any direct competition.

We conducted artificial-stream experiments to test whether the interspecific competitor, Arctic bullhead, had an effect on the under-yearling (0+) and yearling (1+) trout habitat use. We hypothesized that (i) 1+ trout would be competitively superior to 0+ trout, forcing the younger fish to suboptimal habitats; and that (ii) bullhead might affect the habitat and food selection of 0+ trout but less so that of 1+ trout.

Against our predictions, no effect of bullhead was found on the habitat use of either age class of brown trout. By contrast, yearling trout forced the under-yearlings into shallower habitats and closer to the shore. We also found a shift in the diet composition of under-yearling trout, as they switched from non-biting midge (Chironomidae) larvae in the presence of large trout to blackflies (Simuliidae) in their absence. Presence of yearlings also decreased the growth of under-yearling fish (mean growth  $\pm$  1 SE in the absence of yearlings:  $0.80 \pm 0.01$  mm/day vs.  $0.53 \pm 0.03$  mm/day in their presence).

These findings suggest that, unless severely food-limited, brown trout and bullheads may coexist in most boreal rivers without any strong interspecific interactions. Intraspecific interactions between trout age classes may be much more important, with potentially detrimental effects on the growth and overwintering success of 0+ trout.



# DETECTION OF SALMONID THERMAL REFUGIA FROM AIRBORNE THERMAL INFRARED (TIR) IMAGERY

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**Key words:** thermal refugia, salmonids, remote sensing, river ecology

## **Abstract:**

During summer high temperature events, salmonid species seek out areas of cool, well-oxygenated river water to alleviate thermal stress. Collectively known as ‘thermal refugia’, these are of great significance to the ability of salmonids to survive increased water temperatures, and a better understanding of their spatial and temporal characteristics may aid mitigation strategies against the possible effects of climate change on rivers. However, thermal refugia are traditionally hard to detect, and their in-river abundance and spatial patterns are largely unknown. Although previous research has examined TIR imaging as a means to sense river temperatures, few have achieved a resolution amenable to the detection of small thermal anomalies typically used by salmonids, with the majority of literature focusing on the general application of thermal imaging to river temperature detection and analysis.

From preliminary research, we note that riverine thermal anomalies (as viewed from TIR imagery) can comprise a number of different forms resulting from a diverse range of sources. Given that the structural, spatial and temporal dynamics of thermal refugia in gravel bed rivers are a function of the complex geomorphological processes within the catchment, the ability to discriminate multi-scale thermal refugia may aid our comprehension not only of the behaviour of salmonids during high temperature events, but also of the geomorphological phenomena that are fundamental in governing river temperature heterogeneity.

In order to acquire data suitable for resolving riverine thermal anomalies, we developed a custom-designed system capable of simultaneously acquiring high resolution thermal (c. 20cm GSD) and optical (c. 3cm GSD) imagery with a view towards automatically detecting and classifying refugia. This paper presents results from several thermal image acquisition flights undertaken in Quebec, Canada, with the intention of exploring the various types of different refugia visible to thermal images. Thermal infrared imagery shows that thermal anomalies are present at a number of scales, ranging from localised ‘coldspots’ of cool water on the scale of 1s to 10s of meters up to larger ‘reach-scale’ thermal anomalies that persist both spatially, over several hundreds of meters, and temporally, over several surveys. Local-scale thermal anomalies appear to be primarily tributary driven and highly discharge-dependent, with summer low flows resulting in the virtual cessation of several refugia plumes visible during the majority of surveys, whereas larger ‘reach-scale’ thermal anomalies appear to be more complex, and are presumably the result of the intricate relationship between geomorphological and hydrological phenomena working on different scales to those of the localised refugia. We therefore hypothesise that the localised and reach-scale anomalies are used preferentially by salmonids at different stages of heat stress events, and the interplay between the two may be of critical importance to a salmonid’s ability to survive such events.

# FISH POPULATIONS, HETEROGENEITY OF THE RIVER CHANNELS, AND SOCIOECONOMIC IMPACTS – TOWARDS A MULTIDISCIPLINARY ANALYSIS OF RIVER RESTORATION PROGRAMS

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**Key words:** Restoration success, salmonids, biodiversity, ecosystem functions, socioeconomy

## **Abstract:**

The degradation of rivers and streams has led to worldwide efforts to rehabilitate freshwater habitats for fisheries and aquatic resources. Ecological restoration, societal well-being, and policy are interlinked in multiple ways, but to date the links have been highly ignored in implementation and evaluation of restorations. In this study, we are studying both ecological and socio-economic impacts of restorations in the streams that were once channelized for timber floating. Focus of these restorations has been to repair habitat heterogeneity into the channels. Study will provide new knowledge on channel heterogeneity and its significance for the ecological success of restorations. We will 1) carry out a meta-analysis of restoration impacts on riverine fish species, and particularly on the success of salmonids; 2) study salmon reproductive success on restored sites by using radio telemetry techniques, 3) investigate responses of other stream biota (macroinvertebrates and bryophytes) and ecosystem functions, and 4) examine long term persistence of habitat heterogeneity. Furthermore, we will 5) evaluate socio-economic success of restorations. Finally, by using a multicriteria decision analysis method we will integrate knowledge obtained from different disciplines and subprojects to quantify overall restoration outcomes. The designed model can be used in restoration related evaluation work, decision-making processes, and prioritizing potential restoration sites and activities.

# COMPETITIVE REGIMES SHAPE THE SPATIO-TEMPORAL PATTERN OF OFFSPRING SIZE EFFECTS IN ATLANTIC SALMON

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**Key words:** density-dependence, egg distribution, emergence timing, maternal effects, survival

## **Abstract:**

Classic life history theory predicts a single optimal offspring size to evolve within a given environment. However, because offspring size is a trait which is commonly strongly linked to competitive ability, variation in the competitive environment may contribute to maintain within-population variation. Early juvenile competition regimes may possibly be shaped both by spatial heterogeneity in local densities and temporal fluctuations in densities due to variable seasonal timing of reproduction. Here we simultaneously manipulate the spatial distribution and the timing of emergence of Atlantic salmon (*Salmo salar* L.) juveniles. To test for influences of egg size on offspring performance we used recapture data and family assignments. An overall positive correlation between egg size and final body mass was revealed. We did, however, not find any effect on growth rates. More importantly, the relationship between egg size and juvenile survival depended on both density and emergence timing. Specifically, large egg size was an advantage only at high density and under competition among juveniles with similar emergence timing. Hence, the optimal solution to the trade-off between egg size and number may vary spatially over small scales as well as temporally within one season.

# ASSESSING THE CONSERVATION STATUS OF BROWN TROUT POPULATIONS THROUGH THE ANALYSIS OF DENSITY-CARRYING CAPACITY RELATIONSHIPS

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**Key words:** habitat modelling, conservation biology, ecological indicators

## **Abstract:**

The stream carrying capacity sets the potential maximum fish abundance a given freshwater system can support. Therefore, it provides a basis to evaluate the conservation status of populations and to assess the changes in their dynamics resulting from habitat alteration or other anthropogenic impacts. On those grounds, we estimated brown trout carrying capacity (K) in 51 study-sites of 34 Mediterranean and Atlantic streams located in four major basins. In the proposed model, physical habitat quality and quantity as well as competition of individuals for its use were considered the main environmental and biological factors limiting population size. Available suitable habitat was quantified through physical habitat simulations, while a specific allometric territory size relationship was developed to define spatial requirements of individuals. Finally, K was estimated at study-sites for a 12-year period linking habitat and territory modelling and compared with population densities (D) to assess conservation status, measured through the D/K ratio. Carrying capacity and conservation status differed within and among basins. Likewise, determinants of D/K ratio differed among basins. Within Mediterranean drainages, in the river basin exhibiting the best conservation status, environmental factors such as extreme water temperatures and flooding episodes during emergence were the main drivers of the spatio-temporal variations of D/K ratio. Meanwhile, most sites in the rest of Mediterranean basins displayed a low to very low D/K ratio. Agricultural land use and water pollution were the major determinants of density decline. Finally, the Atlantic drainages presented an intermediate conservation status with most sites showing medium D/K ratios, being urban land use and number of upstream dams the main degradation sources.

# EVIDENCE FOR DENSITY-DEPENDENT AND DENSITY-INDEPENDENT REGULATION IN A RESIDENT BROWN TROUT POPULATION

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**Key words:** density-dependence, annual recruitment, habitat modelling, *Salmo trutta*

## **Abstract:**

The regulation processes of a resident Brown trout population were addressed in the Boiron-de-Morges, a small tributary of Lake Geneva. Summer and autumn electrofishing campaigns were carried out on 11 sampling sites during 10 years. Brown trout was the predominant species in this river. Variations in annual recruitment, survival and growth rates were investigated with regards to biotic factors (0+, 1+, and >1+ cohort densities) and abiotic parameters (discharge, water temperature and available habitat). Habitat modelling provided an assessment of the potential carrying capacity (WUA) for any discharge level for two life stages, i.e. juveniles and adults (>1+).

Annual survival rates showed evidence for density dependence regulation, between 0+ and 1+ stages, and between 1+ and adults (>1+). Age-0 mean length in autumn was strongly density-dependent, with mean length showing a negative power curve with increasing densities of young-of-the-year in July. The variance (as measured by S.D.) in 0+ fish size distribution positively correlated with density, indicating a significant trend for a disproportional effect of density on individual growth. On-going analyses aim at quantifying the respective influence of abiotic factors on 0+ recruitment during the study period.

# INTERACTIONS BETWEEN LOCAL POPULATION DENSITY AND LIMITED HABITAT RESOURCES DETERMINE MOVEMENTS OF JUVENILE ATLANTIC SALMON

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**Key words:** shelter, spatial distribution, competition, carrying capacity, electrofishing

## **Abstract:**

Competition for limited resources and the resulting density-dependent processes are key factors in driving stream salmonid population dynamics. Recent studies have indicated shelter availability to be a limiting factor for juvenile salmonids, such that the ratio of fish density to the available shelter may affect fish performance. Here we test for the combined effects of density and shelter availability on the movement of juvenile Atlantic salmon in a Norwegian river. Individually marked, hatchery reared salmon juveniles were released at 26 sites along a 2.5 km long stretch and recaptured after 12 months. The spatial variation in shelter availability and density of resident salmonids was quantified prior to the release. We found no effect of released fish number on the number of marked salmon moving more than 25 – 100 m away from their release site. However, the ratio of resident fish density per shelter was positively related to the number of movers. Thus, fish that were released at sites where the available shelter was already saturated by the resident population were more likely to move. These results support the prediction from smaller scale experimental studies that shelter availability acts to determine local carrying capacity in stream living salmonid populations.

# BIOLOGICAL SIGNIFICANCE OF THERMAL REFUGIA FOR JUVENILE ATLANTIC SALMON DURING EXTREME HEAT EVENTS IN RIVERS

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## **Abstract:**

Atlantic salmon (*Salmo salar* L.) parr show a behavioural and physiological stress response when water temperature exceeds 23 °C. Various climate change scenarios predict that such water temperature thresholds will be exceeded more often. In the current study, we examined *i)* the threshold conditions for initiating behavioural thermoregulation of salmon parr *in situ*, *ii)* how the incidence of temperature stress events and proximity to thermal refugia affect the distribution and abundance of wild, juvenile salmon in a large (>60m wide) river. To answer these questions, the movements and behaviour of 635 individually Passive Integrated Transponder (PIT) tagged 1+ and 2+ Atlantic salmon parr were monitored during the summers of 2009 and 2010 in the Miramichi River, NB, Canada. The monitoring of movements was carried out in a 11 km river segment where various cold water refugia (seeps, tributary plumes) were identified (from airborne thermal remote sensing) and in relation to a river reach with no available cold water refugia present. In 2009, no salmon parr aggregations were observed in cold water refugia despite maximum daytime water temperatures exceeding 24 °C for seven consecutive days in mid-August (max. 26.1 °C). In 2010, large aggregations of parr were observed (involving 46 % of the PIT tagged fish) in early July when water temperature exceeded 27 °C in daytime (max. 31 °C) and remained >23 °C at night. Concurrently, large scale mortality was apparent in all salmon age classes. Salmon parr aggregations remained in place for three consecutive days when water temperature consistently exceeded ~23 °C, with the highest numbers of parr observed in mid- to late afternoon. Most PIT tagged parr found in refugia were marked within the same river reach (within 1 km); the longest movements in response to high water temperatures were in excess of 10 km. Temperature differences in refugia ranged from ~ 4 °C to 18 °C compared with ambient water temperature. River reaches with no cold water refugia were void of tagged parr during the high temperature events and tagged fish from these areas were observed ~ 5 km up- and downstream. The number of salmon parr in aggregations was dependent on the size of the cold water refugia and ranged from 10-15 fish in small “pocket refugia” along river banks (100 cm<sup>2</sup>) to > 10 000 parr in tributary plumes (450 m<sup>2</sup>). Dissolved oxygen (DO) concentration remained >7.4 mg/L during high temperature events, suggesting that DO was not a factor for salmon parr to aggregate in cold water refugia.

# THE PRESENCE OF THE MAT-FORMING DIATOM DIDYMOSPHENIA GEMINATA ALTERS FORAGING BEHAVIOUR OF YOUNG-OF-THE-YEAR *SALMO SALAR*

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**Key words:** *Didymosphenia geminata*, foraging behaviour, periphyton, *Salmo salar*, benthic foray

## **Abstract:**

In 2006, blooms of *Didymosphenia geminata* Schmidt (didymo) were for the first time, officially identified in the Matapedia River, an Atlantic salmon (*Salmo salar*) river of the Gaspé Peninsula (Quebec, Canada). This invasive alga can form thick and extensive benthic layers in stable flow oligotrophic rivers (Spaulding & Elwell, 2007). Recreational fishing of Atlantic salmon is the main economic activity of the Matapedia river valley and there are concerns that didymo may constitute an additional stressor for this salmon population. In a previous study, Gillis and Chalifour (2010) showed that the presence of didymo caused significant changes in macroinvertebrate abundance and benthic community structure between pre- (2006) and post-incursion (2007) sites for this river. Therefore, its presence is suspected to alter diet and foraging behavior of juvenile Atlantic salmon through food web interactions. This study aimed at evaluating the effects of didymo on juvenile salmon by assessing their foraging behaviour in didymo-affected and didymo-free sites. Observational data was collected in the Patapedia River by focal-animal sampling of young-of-the-year salmon conducted by one person while snorkelling. Results show that juveniles make a higher proportion of benthic forays than drift forays with increasing didymo cover ( $R^2 = 0,87$ ). Benthic forays are known to be more energetically consuming than drift forays (Shearer *et al.*, 2007). Preliminary observations indicate that the shift in foraging behaviour may be triggered by a modification of food availability and abundance induced by the didymo mats. Further results, currently under analysis, will be presented and implications of didymo invasions for Atlantic salmon populations will be discussed.



# MIGRATION AND EXPLORATORY BEHAVIOUR OF ATLANTIC SALMON SMOLTS: SOFT- VS. HARD RELEASE

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**Key words:** acclimatization, release, stocking stress, telemetry, salmon behaviour

## Abstract:

Stress affects the behaviour of fish and impairs their cognitive abilities. Transportation is a strong stressor for fish. However, little is known of how transportation affects behaviour and survival of released fish and how release methods can be improved. In this study we tested the effect of stocking stress on hatchery reared age two year Atlantic salmon smolt in either nature or a controlled semi-natural environment. First, radio-tagged smolts were transported for three hours and released with either a soft-release method, providing them an acclimatization period of 24 hours at the release site or with a hard-release method, where fish was readily released into the wild immediately after transport. Migration and mortality were monitored for 50 days pre-release. Second, pit-tagged fish were transported for 30 minutes and released into a novel semi-natural stream where boldness to leave a shelter and time of downstream exploration in a maze was measured. Stress response (plasma cortisol concentration) of transport and control fish from both experiments were assessed to test for recovery time after transport. We found that smolts transported for 3 hours and released with the soft-release method started downstream migration earlier. After three hours transport smolt had significantly higher cortisol levels than control fish and fish that were allowed to acclimatize in a novel environment for 24 hours. Exploratory behaviour of smolt transported for 30 minutes was significantly impaired and cortisol levels raised significantly compared with their control groups. The results together suggest that a soft-release method can give advantage to fish released with quicker start of migration and lowered starting stress levels.

# SELECTING A PATH

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**Key words:** Path selection, migration, fishway, fluid dynamics.

## **Abstract:**

Economic gain is a fundamental factor for human decision makers. For centuries, fishways have been built because of economy rather than on the grounds of conservation or ecology. Fish also make decisions when they select a path of movement. But are those decisions based on economy? Salmon often seem to take an energetically expensive path on their upstream migration, swimming through fast flowing water. My project is aiming at understanding how salmon select their path of migration, and what type of hydrodynamics they prefer. The result may be used to improve fish migration paths, such as fishways, with a higher economic gain as well as being more preferential for fish.

# PARTITIONING OF TOTAL LIPID AMONGST TISSUES OF PRE- SPAWNING AND POST-SPAWNING ATLANTIC SALMON (*SALMO SALAR* L.)

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**Key words:** Atlantic salmon, lipid, condition, spawning, partitioning

## **Abstract:**

Recent declines in Atlantic salmon populations have widely noted. Considerations of the lipid content of those fish that return from sea offer a unique indication of the environment encountered by these fish and give an idea of their quality. Tissue samples from pre-spawning fish have been collected from the Melvich and Armadale fisheries, Scotland, in 2008, 2009 and 2010 and samples from spawned female fish have been collected from the River Conon, Scotland, in 2009. Total lipids for the Adipose Tissue, Red Muscle, White Muscle and standard Norwegian Cut have been estimated for these fish. This study indicates that tissue lipid content varies with condition and overall lipid content of fish and that spawned females follow the same pattern.

# DO MATERNAL SOMATIC CONDITION, REPRODUCTIVE INVESTMENT AND SMOLT AGE INFLUENCE FRY PERFORMANCE IN THE WILD?

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**Key words:** maternal effects, field experiment

## **Abstract:**

We report results from a field experiment investigating the effects of maternal somatic condition, reproductive investment and smolt age on offspring performance in Atlantic salmon (*Salmo salar*). Atlantic salmon undertaking their spawning migration were captured at a fish trap on the River Blackwater, Ross Shire North Scotland. We selected four distinct groups of 1 sea winter females ( $n = 9$  fish per group) that differed in relative somatic condition, reproductive investment and smolt age: (1) fish in relatively good somatic condition with high reproductive investment, (2) fish in relatively poor somatic condition with low reproductive investment, (3) fish in good somatic condition with low reproductive investment and (4) fish in poor somatic condition with high reproductive investment. Scale readings indicated that these females had smolted at either 2 or 3 years of age. The eggs from each female were fertilised with sperm from a single male to create 36 full sibling families. Equal numbers of eyed staged eggs from each female were stocked into a section of mid-altitude stream. Approximately 2 months after the estimated date of fry emergence, 400 metres of the stream was electrofished in a single pass to obtain data on the numbers and sizes of surviving fry. Microsatellite analysis of parentage enabled family-specific measures of fry body size, survival and biomass production. Data will be presented in relation to maternal body condition, reproductive investment and smolt age.

# METABOLIC STRATEGIES IN JUVENILE ATLANTIC SALMON: THE CONSEQUENCE OF BROWN TROUT PRESENCE

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**Key words:** Atlantic salmon, SMR, brown trout, habitat, dominance

## **Abstract:**

Individual differences in physiology should have a profound effect on fitness, yet are seldom studied in an ecological context. Standard metabolic rate (SMR) has been found to vary greatly between juvenile Atlantic salmon and is positively related to dominance status and ability to obtain a territory but at higher energy upkeep. In classic aquaria experiments SMR has seen to correlate with growth, yet similar experiments in the wild have produced divergent SMR-growth trends. It is clear that greater knowledge of interactions salmon experience in the wild may clarify these contradictory results, one being the presence of heterospecifics. Brown trout are a frequent co-occurring species with Atlantic salmon and are usually the more dominant of the two species and competition is known to occur. However it is unknown if all salmon respond similarly to trout, or if performance is dependent on metabolic strategy.

The relationship between SMR and growth was examined in juvenile Atlantic salmon in the presence and absence of juvenile brown trout. Experimental work was carried out in a 60m long artificial stream where behavioural observations of fish could be made. Results will discuss the performance of different metabolic strategies due to heterospecific competition, and the benefits of combining near natural experiments with behavioural observations.

# PARENTAL INFLUENCES ON OFFSPRING ENERGETIC STATUS IN BROWN TROUT (*SALMO TRUTTA*): CONSEQUENCES ON EARLY BEHAVIOUR AND FITNESS

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**Key words:** Brown trout, emergence from gravel, energetic status, maternal effects.

## **Abstract:**

In this study, we considered parental influences on offspring energetic status in brown trout (*Salmo trutta*) and their consequences on offspring emergence and fitness. We adapted recent micro respirometry techniques and elemental CHNS-O analysis to measure individual energetic status of offspring from fertilisation to emergence. By combining these individual measurements to hierarchical modelling, we estimated parental influences on offspring energetic status throughout ontogeny and at the onset of emergence. We then evaluated consequences of these parental influences on the timing of this first ontogenetic niche shift and on offspring growth and survival. Our results show that parents control offspring emergence dynamics and offspring fitness through their effects on offspring energetic status mean expectancy and variance.

# IMPACTS OF NUTRIENTS DERIVED FROM SALMON ON BIODIVERSITY

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**Key words:** Salmon-derived nutrients, food webs, ecosystems, community structure

**Abstract:**

When Pacific salmon die after spawning, their carcasses provide nitrogen and phosphorus to rivers, riparian zones, and estuaries. While many studies have used stable isotopes to indicate uptake of salmon-derived nutrients in plants and animals, there is controversy about potential impacts of such nutrients on biodiversity. We have tested for such impacts of salmon-derived nutrients in 50 watersheds in the Great Bear Rainforest, a remote region on the central coast of British Columbia, Canada. Our studies include a wide range of species in aquatic and terrestrial food webs, ranging from stream algae to aquatic invertebrates, riparian plants, resident fishes, and breeding birds. We have found strong impacts on several components of diversity in a variety of taxa. Furthermore, uptake of salmon-derived nutrients and their impacts on community structure are mediated by forest canopy composition and physical features of watersheds. These results can be incorporated into management of salmon to achieve objectives that are focused on wider ecosystems.

# ESTIMATING THE GEOGRAPHICAL REPARTITION OF BREEDERS BY COUPLING CAPTURE-MARK-RECAPTURE DATA WITH NEST COUNTING: A BAYESIAN APPROACH

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**Key words:** Bayesian hierarchical model, breeder geographical repartition, CMR, nest count, *Salmo salar* L.

## Abstract:

Breeders abundance and their geographical repartition both affect population dynamics as they condition reproductive success and subsequent juvenile recruitment. From a management point of view, identifying the main areas of reproduction and tracking the evolution of their utilization over time is most useful as well. A Hierarchical Bayesian Modelling approach is proposed for combining Capture-Mark-Recapture (CMR) data and spatially distributed nest count data. The coupling of these two data sources in an unique, geographically explicit and consistent framework allows simultaneously the estimation of breeders abundance and of their geographical repartition.

The approach is illustrated with data coming from the Atlantic salmon (*Salmo salar* L.) population of the River Nivelle (Southwest of France). A monitoring program for this population provides CMR and redd (i.e. nest) count data over twenty four years. The spatial and temporal evolution of the spawner (i.e. Breeder) abundance shows major changes mostly due to management action (opening access to new reproduction areas). Spawner composition, by age class and sex, was also considered. Sex ratios and age composition of the breeding population varied between reproduction areas due to different behaviours in front of the fish passage facilities allowing spawners to access the most upstream areas of reproduction.



# THE POPULATION STRUCTURE OF ATLANTIC SALMON (*SALMO SALAR* L.) IN A SOUTHERN ENGLISH CATCHMENT, THE RIVER EXE

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**Key words:** Atlantic salmon, population structure, microsatellite, supportive breeding, management

## **Abstract:**

Atlantic Salmon have been in decline for decades across their range. There are many potential reasons for this decline, some of which have already been identified. Despite management efforts, in some catchments the decline has not ceased. To try to satisfy the local pressure from anglers, managers often turn to stocking to improve numbers of salmon in their catchments. In order to correctly manage a catchment, however, it is necessary to characterise the fish within it and to understand the natural stock composition. Genetic studies have shown that genetic stocks can differ not only between catchments, but also within catchment. Each catchment therefore needs to be addressed on an individual basis. Weak stocks need to be identified, as do similar but more robust stocks which could be used as genetically compatible broodstock. This study aims to assess the salmon population(s) within the River Exe with a view to informing a functioning supportive breeding programme. This study is focused on a single catchment in South West England; however, the approach is transferrable to other catchments and species.

# VIABILITY STUDY OF THE NATURAL POPULATION OF ATLANTIC SALMON (*SALMO SALAR* L.) IN THE ALLIER CATCHMENT

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**Key words:** Bayesian hierarchical model, viability analysis, stocking, *Salmo salar* L.

## **Abstract:**

In this study, we try to synthesize all the information and knowledge that has been gathered since 1970 on the Atlantic salmon population (*Salmo salar* L.) of the Allier catchment (France). Numerous sources of information regarding to this population however, these datasets are heterogeneous in regards to the biological life stage considered, the observation techniques used but also the different temporal and spatial scales considered. Once the diversity of the datasets evaluated, a population dynamic model taking in account the various sources of uncertainty will be developed. This model will allow providing estimates of the A. salmon Allier population during the last 40 years. This model will also allow a better understanding of the population's replacement mechanisms, evaluating the population's ability to maintain itself in autonomy and also identifying the conditions required to ensure its viability.

One of the difficulties of this work will raise from trying to dissociate the part of the population dynamics related to the important stocking effort which has been occurring on this catchment and the part related to the natural population. Recent progress in the hierarchical Bayesian modelling field (and the associated numerical calculation methods) make possible the synthesis of the information and knowledge available in a formal and rigorous framework to reach the objectives described above. This approach will allow measuring the uncertainty associated to the results. Such evaluation of uncertainty is essential for the population managers who have to deal with the evaluation of a risk. A risk which is defined by the conjunction of uncertainty and an undesirable event in this case the extinction of the natural population of A. salmon.

# DOES EGG STOCKING INCREASE THE ABUNDANCE OF BROWN TROUT PARR ?

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**Key words:** brown trout, egg stocking, survival, parr abundance, alizarin

## Abstract:

Egg stocking is a common tool in management of brown trout stocks in Finland. The method has been used for a century, but there is almost a total lack of scientific reports documenting the impact of stocking on parr abundance. Trout eggs are normally stocked in the eyed phase either with small plastic boxes, like Whitlock-Vibert, or with pipes designed to tree sprout planting. The most important hatchery stock in the Finnish Lake District, the Rautalampi stock, maintained by the Finnish Game and Fisheries Research Institute (FGFRI), produces roughly a hundred liters of eggs to be introduced yearly in streams of Kymijoki watercourse. Abundance of brown trout parr is low to moderate in the Lake District streams, and egg stocking aims to improve the parr stocks and even the future spawning stocks. Now, all eggs in FGFRI hatcheries are marked with alizarin color, which can be detected later in parr otoliths, but the fish must be killed.

In this work, the autumnal abundance of brown trout parr estimated by electrofishing in six Lake District streams in years of egg stocking and years of non-stocking was compared to six control streams in years 2000-2010. The data consists of 19 egg stocking and 29 non-stocking observation pairs. Ten to thirty thousand eggs were introduced per stream and per year to streams with approximated total areas of 1000-7000 m<sup>2</sup> suitable for summerlings. The difference in the abundance between the means of the impact and control sites was on average 5 individuals (range -3 to 12 between stream pairs) per 100 m<sup>2</sup> higher in years of egg stocking indicating a small average increase in parr abundance as the impact of stocking. Otoliths were sampled in five cases, and the average proportion of parr originating from introduced eggs was 28 % (range 5-80). Both results point out a remarkable spatial and temporal variation in the increase of parr resulting probably from varying survival of stocked and/or wild parr in and after emergence. The small average increase may be due to failure in stocking methods and/or to restricted amount of introduced eggs, 200-1200 eggs per 100 m<sup>2</sup>. However in stream Simunankoski alone, the yearly abundance of parr correlated positively with the amount of stocked eggs.

# ASSESSING THE SUSTAINABILITY OF ATLANTIC SALMON ACROSS THE SOUTHERNPART OF THEIR EUROPEAN RANGE IN THE LIGHT OF CLIMATE CHANGE AND HUMAN EXPLOITATION

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**Key words:** Atlantic salmon, microsatellites, population structure, effective population size

## **Abstract:**

Atlantic salmon (*Salmo salar* L.), as a species, is known to be sensitive to climate change, habitat disruption and human exploitation. Habitat degradation has occurred across the species' range and has been particularly marked in mid-Europe. In contrast, southerly European populations still inhabit relatively undisturbed habitat, yet populations here also appear to be declining. Angling rod-catch data has previously been used to estimate the actual population size contributing to these aforementioned findings, however recent evidence suggests these estimates are not representative of the true numbers of salmon present. Microsatellites, which have been used to identify the structure of populations across Europe, are increasingly being used as an alternative to rod-catch data as they can more accurately estimate effective population size. This study aims to assess the state of populations across Europe, using microsatellite loci, and using data on past and present environmental conditions, identify specific factors causing declines.

# STABLE ISOTOPE EVIDENCE FOR THE RATE AT WHICH CLIMATE-DRIVEN VARIATIONS IN PHYTOPLANKTON GROWTH INFLUENCE HIGHER TROPHIC LEVELS

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**Key words:** Ecosystem, biogeochemistry, salmon, NE Atlantic

## **Abstract:**

Using a 20 year record of stable isotopes from Atlantic salmon migrating to different regions of the North Atlantic, we show climate-driven influences on phytoplankton growth rates with a periodicity of 11-15 years in one stock and 8-10 years in another. Trophic level indicators vary with changes in plankton growth with a 2-3 year lag. This suggests that causes of variations in carbon isotope values (likely temperature) result in either greater availability of high trophic level prey (bottom-up control) or a reduction in availability of low trophic level prey (top-down control). Coincidence of periods of high nitrogen isotope values in salmon tissues with herring biomass implies bottom-up control. Time series analysis of stable isotopes in consumer tissues provides new information on the interaction between climate and ecosystem dynamics. These time series are also used in concert with sea surface temperature records to map the likely distribution of salmon at sea, a technique which has potential for application to many marine species.

<b>Name</b>	<b>Country</b>	<b>E-mail</b>	<b>Presentation</b>
Ayllón Daniel	Spain	daniel.ayllon@bio.ucm.es	<i>Assessing the conservation status of brown trout populations through the analysis of density-carrying capacity relationships</i>
Brun Mélanie	France	mbrun@st-pee.inra.fr	<i>Estimating the geographical repartition of breeders by coupling Capture-Mark-Recapture data with nest counting: a Bayesian approach</i>
Buoro Mathieu	France	Mathieu.BUORO@cefe.cnrs.fr	Research area: My main research interests involve the study of evolutionary processes and life history evolution in a wild population of Atlantic salmon ( <i>Salmo salar</i> ).
Burton Tim	Scotland	t.burton.1@research.gla.ac.uk	<i>Do maternal somatic condition, reproductive investment and smolt age influence fry performance in the wild ?</i>
Casas-Mulet Roser	Norway	roser.casas-mulet@ntnu.no	<i>Physical processes, hydropower operation and scale integration for the prediction of stranding potential in rivers</i>
Counter Sarah-Louise	England	sc386@exeter.ac.uk	<i>The population structure of Atlantic salmon (<i>Salmo salar</i> L.) in a southern English catchment, the River Exe</i>
Cunjak Rick	Canada	cunjak@unb.ca	<i>Biological significance of thermal refugia for juvenile Atlantic salmon during extreme heat events in rivers</i>
Dauphin Guillaume	France	guillaume.dauphin@st-pee.inra.fr	<i>Viability study of the natural population of Atlantic salmon (<i>Salmo salar</i> L.) in the Allier catchment</i>
Dugdale Steve	Canada	stephen.dugdale@ete.inrs.ca	<i>Detection of salmonid thermal refugia from airborne thermal infrared (TIR) imagery</i>
Erkinaro Jaakko	Finland	jaakko.erkinaro@rktl.fi	<i>Habitat shifts of juvenile Atlantic salmon in fresh water – life histories and individual-based ecology</i>
Frank Béatrice	Belgium	beatrice.Frank@uclouvain.be	<i>An individual-based model to simulate the demogenetic dynamics of a brown trout population</i>
Fryer Adam	England	594583@swansea.ac.uk	<i>Effects of MHC compatibility on fitness and survival of Atlantic salmon</i>

Gillis Carole-Anne	Canada	gilliscaroleann@hotmail.com	<i>The presence of the mat-forming diatom <i>Didymosphenia geminata</i> alters foraging behaviour of young-of-the year <i>Salmo salar</i></i>
Gustafsson Stina	Sueden	stina.gustafsson@kau.se	<i>Technical fishways, nature-like fishways or biocanals ?</i>
Howe Alexandra	Scotland	ah677@st-andrews.ac.uk	<i>Partitioning of total lipid among tissues of pre-spawning and post-spawning Atlantic salmon (<i>Salmo salar</i>)</i>
Ikediashi Charles	England	c.ikediashi@exeter.ac.uk	<i>Assessing the sustainability of Atlantic salmon across the southern part of their European range in the light of climate change and human exploitation</i>
Labonne Jacques	France	labonne@st-pee.inra.fr	<i>Evolutionary ecology of the Kerguelen Is. colonization by salmonids</i>
Lindberg Dan-Erik	Sueden		<i>Selecting a path</i>
Louhi Pauliina	Finland	pauliina.louhi@oulu.fi	<i>Habitat use by juvenile brown trout (<i>Salmo trutta</i>) and Arctic bullhead (<i>Cottus poecilopus</i>) – influence of interspecific versus intraspecific competition</i>
MacKenzie Kirsteen	England	kirsteen.mackenzie@noc.soton.ac.uk	<i>Stable isotope evidence for the rate at which climate-driven variations in phytoplankton growth influence higher trophic levels</i>
Marttila Maare	Finland	maare.marttila@rktl.fi	<i>Fish populations, heterogeneity of the river channels, and socio economic impacts -towards a multidisciplinary analysis of river restoration programs</i>
McCormick David	Ireland	mccormick.dave@gmail.com	<i>Direct and indirect effects of riparian canopy on the biology of stream-dwelling salmonids in south-west Ireland</i>
Nikolic Natacha	France	Natacha.Nikolic@ifremer.fr	<i>Presentation and application of a new model to estimate the evolution of effective size from the most recent common ancestor</i>
O'Toole Ciar	Ireland	ciar.otoole@student.ucc.ie	<i>Determining the scale of biologically important local adaptation in Atlantic salmon using a common garden experimental approach</i>
Puffer Michael	Norway	michael.puffer@bio.ntnu.no	<i>Long-term consequences of stranding on Atlantic salmon parr during winter</i>
Régnier Thomas	France	thomas.regnier@st-pee.inra.fr	<i>Parental influences on offspring energetic status in brown trout (<i>Salmo trutta</i>): consequences on early behaviour and fitness</i>

Reid Donald	England	d.reid.2@research.gla.ac.uk	<i>Metabolic strategies in juvenile Atlantic salmon: the consequence of brown trout presence</i>
Reynolds John	Canada	Reynolds@sfu.ca	<i>Impacts of nutrients derived from salmon on biodiversity</i>
Richard Alexandre	Swiss	alexandre.richard@hesge.ch	<i>Evidence for density-dependent and density-independent regulation in a resident brown trout population</i>
Robertsen Grethe	Norway	grethe.robertsen@bio.ntnu.no	<i>Competitive regimes shape the spatio-temporal pattern of offspring size effects in Atlantic salmon</i>
Rodewald Petra	Finland	petra.rodewald@yahoo.com	<i>Migration and exploratory behaviour of Atlantic salmon smolts: Soft vs. hard release</i>
Solberg Monica	Norway	monica.solberg@imr.no	<i>Farmed escapees and interactions with wild conspecifics: quantification of genetic differences between wild and farmed salmon</i>
Stickler Morten	Norway	Morten.stickler@statkraft.com	Research area: Physical winter habitat for Atlantic salmon ( <i>Salmo salar</i> )
Syrjänen Jukka	Finland	jukka.t.syrjanen@jyu.fi	<i>Does egg stocking increase the abundance of brown trout parr ?</i>
Teichert Maxim	Norway	Maxim.Teichert@nina.no	<i>Interactions between local population density and limited habitat resources determine movements of juvenile Atlantic salmon</i>
Veza Paolo	Italie	paolo.veza@polito.it	<i>Meso-scale habitat modelling in high gradient streams</i>



