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Nature and Culture: Comparative Biology and Interactions of Wild and Farmed Fish

Introduction

Aquaculture for food, ornament, research, fisheries enhancement and conservation is expanding throughout the world. Many fish species are being cultured and have entered a process of domestication with consequences for their morphology, physiology, ecology and evolution. Intentional domestication can yield significant benefits for all forms of aquaculture, but inadvertent or poorly managed domestication can be detrimental to aquaculture as well as wild stocks. Accidental and intentional releases of cultured fish are widespread, and interactions between cultured and wild fish pose new challenges as well as opportunities for the conservation of wild stocks. There is thus a compelling need to understand the process of domestication, the comparative biology of farmed and wild fish, and their interactions in order to maximise benefits and minimize risks associated with the "blue revolution". Recent years have witnessed rapid advances in many areas of fish biology associated with, or relevant to, these issues. At the same time, research on domestication and farmed-wild fish interactions has generated considerable spin-offs for our understanding of basic fish biology. We thus believe it is timely to convene a symposium to synthesise this dynamic area of fish biology, place it within the wider context of aquaculture development and fisheries conservation, and identify promising avenues for future research. Your enthusiastic response to the call for papers has enabled us to assemble a wide-ranging programme covering the process and status of fish domestication, physiological and behavioural consequences, life history responses to culture, genetics and evolution in widely cultured species, conservation aquaculture and fisheries enhancement, conservation risks from released and feral fish, and contributions of the field to fundamental biology. We will close with a synthesis session drawing together the diverse strands of symposium.

We welcome you to FSBI 2004, and hope that you will find the symposium both fruitful and enjoyable!

Kai Lorenzen
Malcolm Beveridge
Marc Mangel

Programme

Page numbers in brackets at the end of each presentation signify the page on which the abstract appears.

Monday 19 July 2004

14:00-18:30 **Registration** — Sir Alexander Fleming Building (SAF)

18:30-19:30 **ICEBREAKER RECEPTION** — Senior Common Room, Sherfield Building (SCR)

19:30 **DINNER** — SCR

Tuesday 20 July 2004

07:30 -09:00 **BREAKFAST** — SCR

Note: All lectures take place in Lecture Theatre 1, Sir Alexander Fleming Building

09:15 **Welcome and announcements**

Session 1: The biology of fish domestication
(Chair: Marc Mangel)

09:30 **Jack Jones Memorial Lecture**

Eugene Balon
About the oldest domesticates among fishes and the epigenetic dichotomy of fish culture (p9)

10:30 **COFFEE/TEA**

11:00 *Randall Brummett and Raul Ponzi*
Genetic quality of domesticated African tilapia populations (p10)

11:20 *M. Lenhardt, M. Prokes, I. Jaric, V. Barus, J. Kolarevic, I. Krupka, G. Cvijanovic, P. Cakic and Z. Gacic*
Comparative analysis of morphometric characters of juvenile sterlet (*Acipenser ruthenus* L.) from natural populations and aquaculture (p26)

11:40 *Guillaume Mairesse, Marielle Thomas, Jean-Noël Gardeur and Jean Brun-Bellut*
Reared perch vs. wild perch - First results about organoleptical and technological quality (p27)

12:00 *Bernard P. Walrut*
Domestication and absolute ownership of fish in the English common law (p40)

12:20 **LUNCH** — SAF

Session 2: Behavioural and physiological consequences of domestication
(Chair: John Armstrong)

14:00 **Keynote:** *Felicity Huntingford*
Implications of domestication and rearing conditions for the behaviour of cultivated fish (p21)

14:45 *M.-L. Bégout Anras, J.P. Lagardère and D. Covès*
Swimming activity of seabass: comparative patterns obtained in natural environments and in recirculating tanks under high density (p9)

15:05 *Stephen P. Cotterell and Clem S. Wardle*
An investigation into the endurance swimming of diploid and triploid Atlantic salmon (*Salmo salar* L.) (p15)

15:25 *Eva Enders, Daniel Boisclair and André G. Roy*
Differences in the energetic cost of swimming in turbulent flow between wild, farmed and domesticated juvenile Atlantic salmon (*Salmo salar* L.) (p16)

15:45 **COFFEE/TEA**

16:15 *Lorraine A. Hawkins, Anne E. Magurran and John D. Armstrong*
Rapid breathing in progress-wild and hatchery fish alert to danger! (p19)

16:35 *Stefano Malavasi, V. Georgalas, M. Lugli, P. Torricelli, and D. Mainardi,*
Differences in the pattern of antipredator behaviour between hatchery-reared and wild Sea-bass (*Dicentrarchus labrax*) juveniles (p28)

16:55 *Annamari Salonen, and Nina Peuhkuri*
A year in the hatchery – effects on aggressive behaviour in young European grayling? (p33)

17:15 *Heikki Hirvonen and Mika Laakkonen*
Why do salmonid anti-predator responses weaken in hatchery rearing? (p20)

19:00 **BARBEQUE AT LONDON ZOO - Sponsored by The Zoological Society of London (Coaches leave Imperial College at 18:15)**

Wednesday 21 July 2004

07:30-09:00 **BREAKFAST** SCR

Session 3: Life history responses to culture
(Chair: Kai Lorenzen)

09:00 **Keynote:** *John E. Thorpe* (presented by Marc Mangel)
Life history responses of fishes to culture (p37)

09:45 *Andy Ferguson, Philip McGinnity, Paulo Prodöhl, Rosallen Hynes, Niall Ó Maoiléidigh, Deirdre Cotter, Natalie Baker and Brendan O'Hea*
A comparison of survival, migration and growth of native, ranched and non-native Atlantic salmon under natural conditions (p17)

10:05 *John E Joyce, Alex C. Wertheimer, Andrew Gray and Frank Thrower*
Comparison of maturation timing, egg size and fecundity between hatchery lines of chinook salmon and their wild donor stocks (p23)

10:25 **COFFEE/TEA**

11:00 *James E. Orpwood, Siân W. Griffiths and John D. Armstrong*
Competitive asymmetries as influenced by density and rearing conditions amongst overwintering sheltering juvenile salmon (p30)

11:20 *John D. Armstrong, Keith M. Martin-Smith, Jörgen Johnsson and Björn Thrandur Björnsson*
Growth hormone increases growth and dominance of wild juvenile Atlantic salmon without affecting space use (p8)

11:40 *Miroslaw Ciesla and Ryszard Wojda* (presented by Zbigniev Kaczkowski)
Effect of domestication on ide (*Leuciscus idus* L.) reproductive parameters (p13)

12:00 *Carlos García de Leániz, S. Consuegra and A. Serdio*
Maladaptation and phenotypic mismatch in cultured Atlantic salmon used for stocking (p19)

12:20 **LUNCH** SAF

Session 4: Genetics and evolution in widely cultured species
(Chair: Robin Welcomme)

14:00 **Keynote:** *Fred M. Utter*
Population genetics, conservation and evolution in widely cultured fishes (p38)

14:45 *K.E. Jørstad, G. Nævdal, Ø. Karlsen, S. Torkildsen, O.L. Paulsen and H. Otterå*
Long-term studies on genetic interactions between wild and ranched cod (*Gadus morhua*) by use of a genetic marked strain (p23)

15:05 *Jennifer L. Lawlor and Jeffrey A. Hutchings*
Consequences to fitness-related traits of hybridisation between farmed and wild Atlantic salmon, *Salmo salar* (p25)

15:25 *William Smoker, Ivan Wang, Anthony Gharrett and Jeffrey Hard*
No effect on survival at sea in second generation after outbreeding of coho salmon (p35)

15:45 **COFFEE/TEA**

16:15 *Frank Thrower, Jeff Hard and John Joyce*
Heritability of precocious maturation, smolting and growth in anadromous and derived freshwater populations of steelhead (*Oncorhynchus mykiss*) (p38)

16:35 *Juha-Pekka K. Vähä and Craig R. Primmer*
Efficiency of allele frequency based Bayesian programs for detecting hybridization between farmed and wild salmon (p39)

16:55 **Overview of Posters**

17:15-18:15 **POSTER VIEWING WITH WINE**
Sponsored by Blackwell Publishing

Thursday 22 July 2004

07:30-09:00 **BREAKFAST** SCR

Session 5: Conservation aquaculture and fisheries enhancement (Chair: Fred M. Utter)

09:00 *Mikhail S. Chebanov, Elena V. Galich and Yuri N. Chmir*
Stock enhancement and conservation culture of sturgeons: problems and prospects (p12)

09:20 *John Selden Burke, James Morris and Judson Kenworthy*
Polyculture production of juvenile fishes for survival in nature (p11)

09:40 *Jonathan W. Carr and Fred G. Whoriskey*
Feasibility of releasing captive reared broodstock into an imperiled wild salmon river as a recovery strategy (p11)

10:00 Elizabeth A. Fairchild and W. Huntting Howell
Winter flounder stock enhancement: deficits in cultured fish (p16)

10:20 **COFFEE/TEA**

10:50 *Helge Paulsen and Josianne Støttrup*
Growth rate and nutritional status of wild and reared juvenile turbot (*Scophthalmus maximus*) in the Southern Kattegat (p31)

11: 10 *Ayesha Taylor, J. Robert Britton and Stephen A Axford*
Comparison of the growth and condition of cultured barbel *Barbus barbus* (L.) introduced into stillwater catch and release fisheries with wild barbel in riverine habitats (p37)

11:30 *Kai Lorenzen*
Population dynamics of fisheries stock enhancement (p26)

12:00 **Annual General Meeting of the Fisheries Society of the British Isles**

13:00 **LUNCH** SAF

Session 6: Conservation risks from cultured fish in the wild (Chair: Malcolm Beveridge)

14:00 **Keynote:** *Ian Fleming*
Reproductive ecology of cultured fish in the wild (p17)

14:45 *Sean A. Hayes, Morgan H. Bond, Chad V. Hanson and R. Bruce MacFarlane*
Interactions between endangered wild and hatchery salmonids; can the pitfalls of artificial propagation be avoided in small coastal streams? (p20)

15:05 *Anti Vasemägi*
Compensatory releases reduce genetic differentiation among Atlantic salmon populations in the Baltic Sea: evidence from the River Ume-Vindelävlen (p40)

15:25 *Andi Stephens and Andrew B. Cooper*
Ecological model of interactions between escaped and wild Atlantic salmon (*Salmo salar*) (p36)

15:45 **COFFEE/TEA**

16:15 *Ravi K. Chatterji, Dominic N. Stubbing, Anthony W. Bark and W. Peter Williams*
Experimental investigation of the success of stocked, domesticated brown trout and their effects on wild brown trout in upland and lowland rivers (p12)

16:35 *Jan Baer*
Stocking hatchery-reared brown trout in different densities into a wild population - a comparison of growth and movement (p8)

16:55 Edmund J. Peeler and Alexander G. Murray
Disease interaction between farmed and wild fish populations (p32)

17:15 *Ondrej Slavík, Ludek Bartoš and Pavel Horký*
What are the reasons of the Prussian carp expansion in the Upper Elbe River, Czech Republic (p34)

19:00 **CONFERENCE DINNER** SCR

Friday 23 July 2004

07:30-09:00 **BREAKFAST**

Session 7: Contributions to fundamental biology and synthesis (Chair: Ian Fleming)

09:00 *Keith H. Nislow, John D. Armstrong, Ben H. Letcher, and Sigurd Einum*
The ecology of Atlantic salmon during the transition from maternal dependence to independent feeding: experiments with stocked fish (p29)

09:20 *Marc Suquet, Marie-Joëlle Rochet and Jean Louis Gaignon*
Why do some fish do it younger than others? Learning from experiments (p36)

09:40 *M.T. Spedicato, P. Carbonara, and G. Lembo*
Life history traits of the common pandora (*Pagellus erythrinus*) interpreted using information from aquaculture experiments (p35)

10:00 *Ove T. Skilbrei and Vidar Wennevik*
A comparative study of the performance of family groups of Atlantic salmon reared in tanks and released in a river (p34)

10:20 **COFFEE/TEA**

11:00 **Synthesis**
Kai Lorenzen, Malcolm Beveridge and Marc Mangel
Wild and farmed fish: domestication, comparative biology, and interactions (p27)

11:45 **Closing remarks**

12:00 **LUNCH** SAF

Posters

Ricardo Almuly, Yael Poleg-Danin, Yechezkel Kashi, Sergei Gorshkov, Galina Gorshkova, Anna Dyman,Benzion Cavari, Boris Rapoport, Morris Soller and Bruria Funkenstein
Variable number of tandem repeats in the growth hormone gene of Sparus aurata: association with growth and effect on gene transcription (p7)

Rosa Maria Araguas Sola, N. Sanz and J.L. García-Marín
Breakdown of brown trout evolutionary history due to hybridization between wild and cultured fish (p7)

Kathleen Beyer
Escapees of potentially invasive fishes from an ornamental aquaculture facility: the case of topmouth gudgeon *Pseudorasbora parva* (p10)

Miroslav Ciesla, Jerzy Sliwinski, Piotr Konieczny and Robert Litynski
Changes of nase (*Chondrostoma nasus* L.) occurrence in the Wislok River, Southern Poland, after stocking with pond reared juveniles (p13)

Miroslav Ciesla Ryszard Wojda, Jerzy sliwinski and Zbigniew Kaczkowski
Influence of rearing method on ide (*Leuciscus idus* L.) juvenile survival under pike and pikeperch predation (p14)

Alexis Conides, Branko Glamuzina and Costas Papaconstantinou
Laboratory simulation of the effects of environmental salinity on wild-caught juveniles of European sea bass (*Dicentrarchus labrax*) and gilthead seabream (*Sparus aurata*) (p14)

Abstracts

VARIABLE NUMBER OF TANDEM REPEATS IN THE GROWTH HORMONE GENE OF *SPARUS AURATA*: ASSOCIATION WITH GROWTH AND EFFECT ON GENE TRANSCRIPTION

Almuly, Ricardo[1], Poleg-Danin, Yael[2], Kashi, Yechezkel[2], Gorshkov, Sergei[3], Gorshkova, Galina[3], Dyman, Anna[1], Cavari, Benzion[1] Rapoport, Boris[1], Soller, Morris[4], Funkenstein, Bruria[1]

[1]National Institute of Oceanography, Israel Oceanographic & Limnological Research, Haifa, Israel

[2]Department of Food Engineering and Biotechnology, The Technion, Haifa, Israel

[3]National Center of Mariculture, Israel Oceanographic & Limnological Research, Eilat, Israel

[4]Department of Genetics, The Alexander Silberman Life Sciences Institute, The Hebrew University of Jerusalem, Jerusalem, Israel

The GH gene of *Sparus aurata* (saGH) contains variable number of tandem repeats (VNTR). The hyper-variable minisatellites in the first and third introns segregate in a Mendelian manner and exhibit numerous alleles. Analysis by PCR and sequencing of the two introns in several wild Sparidae species revealed comparable minisatellites with some variations. "Zoo blot" with the first intron unit as a probe showed this sequence to be characteristic of several families from the Perciformes order. Unexpectedly, a similar minisatellite was found in the first intron of the GH gene in flounder, which belongs to a different order. Transfection of constructs containing a reporter gene and first intron of different length to four cell lines resulted in an inhibitory effect of the longer intron relative to the short intron. A $(CA)_n$ microsatellite (saGHpCA) is found in the GH promoter. A similar repeat at the same location is present in GH promoters of several other fish species. High variability (11 alleles) of the saGHpCA was found in a hatchery population. Full-sib family genotyping showed a Mendelian inheritance of these alleles. A significant association was found between allele distribution and body weight in large and average size fishes from a hatchery population. The intron minisatellites may serve as markers for hybrid population and parental assignment. Its presence in families and orders of the higher teleosts may help solving classification uncertainties. Their conservation and inhibitory effect suggest a biological role. The saGHpCA is correlated with growth and may be a good candidate for predicting growth performance.

BREAKDOWN OF BROWN TROUT EVOLUTIONARY HISTORY DUE TO HYBRIDIZATION BETWEEN WILD AND CULTURED FISH

Araguas, R. M., Sanz, N. and García-Marín, J. L.

Laboratori d'Ictiologia Genètica, Universitat de Girona, Avd. Montilivi sn, 17071 Girona, Spain

E-mail: rosa.araguas@udg.es

On the Iberian Peninsula, thousands of years of evolution have endowed brown trout with a large genetic differentiation between populations. However, ongoing hybridization between native and stocked fish has resulted in introgressed populations with an altered genetic structure. Based on allozyme data from four diagnostic loci (*G3PDH*50, sMDH-A2*120, sMDH-B1,2*80* and *LDH-C*90*) that clearly distinguish hatchery fish from native ones, the temporal change in introgression levels from 1993 to 1999 has been monitored in 13 local populations of *Salmo trutta* from four Mediterranean drainages. The average annual rate of introgression was 0.01, and a clear relationship exists between the estimated introgression rate and heterozygosity (r=0.861). Samples with higher introgression coefficients showed higher values of heterozygosity. This increase in heterozygosity does not imply a gain in total genetic variation but is linked to a decrease of genetic differentiation between populations. In this sense, since the replacement of the autochthonous genome by exogenous genes has been estimated as 1-5% per year, the ancestral patterns of differentiation could be erased within a few hundred years if the present stocking patterns continue.

GROWTH HORMONE INCREASES GROWTH AND DOMINANCE OF WILD JUVENILE ATLANTIC SALMON WITHOUT AFFECTING SPACE USE

Armstrong, John D.[1], Martin-Smith, Keith M.[1,2], Johnsson, Jörgen[3] and Björnsson, Björn Thrandur[4]

[1]Fisheries Research Services Freshwater Laboratory, Faskally, Pitlochry, Perth PH16 5LB, Scotland

[2]Fish Biology Group, Division of Environmental & Evolutionary Biology, Institute of Biomedical & Life Sciences, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ, Scotland

[3]Department of Zoology/Zooecology, Göteborg University, Box 463, S-40530 Göteborg, Sweden

[4]Fish Endocrinology Laboratory, Department of Zoology/Zoophysiology, Göteborg University, Box 463, S-40530 Göteborg, Sweden.

Hatchery rearing selects for fish with fast growth. As part of a programme to explore aspects of the potential effects of escaped reared fish on wild populations without risking genetic pollution, growth hormone (GH) was applied to proportions of groups of Atlantic salmon parr (the pre-migratory freshwater life stage) to manipulate growth potential experimentally. Observations were made of the effects of this manipulation on dominance status, actual growth, exploratory activity and home range. Experiments were conducted using seven groups of eight parr from May-September of two successive years. The fish were tagged with passive integrated transponders (PIT tags), tested for dominance, and then held in an enclosed section of a natural stream which was fitted with an array of PIT tag detectors to record space use at a definition of ca. 2m. Relationships between dominance rank, space use and growth were established over two weeks. The four lowest ranking fish in each group were then given a slow-release GH implant while the other fish received a placebo. GH stimulated increase in length and weight and decrease in condition factor due to the relatively greater increase in length. However, there was an interaction between GH-stimulated increase in growth and season, with the hormone having an effect only during the early part of the summer. The fish that moved most around their home range were also the fish that grew fastest. However, increased growth due to GH treatment was not associated with an increase in movement, but an increase in growth per unit movement. Overall, space use, measured in terms of home range size and time allocation throughout the range, did not vary consistently in response to application of GH. There was a strong correlation between the weighted centre of the home range (a measure of position within the enclosure) before and after treatment, irrespective of whether fish were given GH or a placebo. The study shows that when density is low relative to carrying capacity, GH stimulates increased dominance and growth in a near-natural environment without having measurable effects on space use at a definition of c. 2m. The results are interpreted as suggesting that dominance status gives no significant growth advantage in a highly competitive situation, but increases foraging rate when food is abundant. Increased foraging appears to result from local changes in time budgeting rather than variations in the extent of home range and larger-scale movements within it.

STOCKING HATCHERY-REARED BROWN TROUT IN DIFFERENT DENSITIES INTO A WILD POPULATION - A COMPARISON OF GROWTH AND MOVEMENT

Baer, Jan

Fisheries Research Station of Baden-Württemberg, Untere Seestraße 81, 88085 Langenargen, Germany

In spring 2001 and 2002 a small stream was stocked with tagged hatchery-reared yearling brown trout (*Salmo trutta*), in order to study their influence on the resident brown trout population. The stream was separated into 6 sections: two sections without stocking, two sections where stocking doubled the trout population and two sections where the fish population was quadrupled. The working hypothesis was that due to food limitation (competition) growth of the wild fish will be negatively influenced by stocking, and wild fish will be displaced by the (possibly more aggressive) hatchery fish. Surprisingly, growth rate of wild and stocked fish of the same age was similar and independent of stocking density. Two main reasons may be responsible for this finding: only a low percentage of the stocked fish remained in the stream, and food was not limited during summer. Only 12-19% of the stocked fish were recaptured after six months, in contrats to 40-70 % of one-year old and up to 100 % of older wild trout. The wild fish were not displaced by hatchery-reared fish: During summer the wild fish remained more or less stationary, whereas most of the stocked trout had left their release site. The results indicate that in a natural stream stocking of hatchery reared brown trout does not influence negatively growth and movement of the wild fish independent of stocking density.

ABOUT THE OLDEST DOMESTICATES AMONG FISHES, AND AN EPIGENETIC DICHOTOMY IN FISH ONTOGENIES AND CULTURE

Balon, Eugene K.

Department of Zoology, University of Guelph, Guelph, Ontario N1G 2W1, Canada

Domestication of mammals like cattle, dogs, swine and horses preceded that of fishes by at least ten thousand years. The first candidate for domestication among fishes was the common carp, *Cyprinus carpio*. Initially these fish were held as exploited captives and did not undergo major changes in body shape or color variations that would survive only under human protection. About 2,000 years ago, wild common carp were most abundant in the inland delta of the Danube River at the northern edge of the very important Roman province Pannonia. At that time Romans indulged in keeping fish in specially built piscinae. The common carp were the hardiest fish available to survive the primitive transport of that time and therefore proved an ideal candidate. Keeping them in ponds became more popular in medieval times when monasteries required fasting food for their monks. The culture of common carp and the building of special ponds gradually became the most profitable branch of agriculture in central Europe. From the twelfth to the mid-fourteenth century some unintentional artificial selection had already taken place. Soon carp were produced in a series of specialized ponds; from the smallest spawning pond to a sequence of growing ponds. The color aberrations called nishikigoi appeared en masse in the 1950s in Niigata Prefecture, Japan. It is a myth that the common carp was originally domesticated in China. However, a domestication that did occur in China is that of the silver-grey goldfish, *Carassius auratus*, a much smaller cyprinid called *chi* which occasionally appeared as a xanthic form. These red goldfish have been documented since 960 AD. Release of the rare xanthic form into Buddhist ponds of mercy was considered a better deed than the release of an ordinary *chi*. By the 1200s the fish had become tamed and were used as ornamental animals, first in garden pools of rich landowners but later in aquarium-like vessels when rich and poor alike became breeders of the fancy domesticated goldfish. The variously shaped monstrosities and color aberrants were freaks, but they became very fashionable at that time and still are. More recently other species became domesticated in the aquarium hobby, such as the guppy, *Poecilia reticulata*, or the neon tetra, *Paracheirodon innesi*. Many other fishes kept as ornamentals like swordtails and platies, the discus and angelfishes, as well as those cultured for food like the rainbow trout, channel catfish are merely exploited captives. The occurrence of alternative phenotypes has been documented in many species, and has implications for culture. The altricial (less specialized) or precocial (more specialized) alternative forms are caused by, among other factors, differences in endogenous food proviso (e.g., yolk) in early development as well as responses to changing environments.

SWIMMING ACTIVITY OF SEABASS: COMPARING PATTERNS OBTAINED IN NATURAL ENVIRONMENT AND IN RECIRCULATING TANKS UNDER HIGH DENSITY.

Bégout Anras, M.-L.[1], Lagardère, J.P.[1] and Covès, D.[2]

[1]Centre de Recherche sur les Ecosystèmes Marins et Aquacoles, CNRS/IFREMER, BP 5, F-17137 L'Houmeau, France
E-mail: mlbegout@ifremer.fr, jplagard@ifremer.fr

[2] Station Expérimentale d'Aquaculture, IFREMER, Chemin de Maguelone, F-34250 Palavas, France
E-mail: dcoves@ifremer.fr, gdutto@ifremer.fr

Seabass (*Dicentrarchus labrax*) swimming activity was compared between natural environments and aquaculture facilities. Behaviour under natural conditions was assessed in a saltmarsh pond (250m^2, 18x14x0.8m) using acoustic telemetry. From several surveys, we documented the diel activity rhythm and demonstrated group effects on swimming patterns and amplitudes by comparing activity of solitary fish with that of a fish living in a group of 60. Consequences of weather variability were also analysed and revealed a high sensitivity of fish to atmospheric conditions for both swimming and demand-feeding behaviour. Behaviour in fish tanks was also studied using acoustic telemetry, as part of the EUREKA EU1 960 "Aqua-Maki 2" project investigating aspects of fish culture in recirculating tanks under high density. A recirculating hexagonal tank (5.4 x 5.4 m, 1.8 depth, 48 m^3) was equipped with positioning and demand-feeding systems, oxygen and temperature probes. Initial density was 50 kg m^3 in March and rose to 90 kg m^3 at the end of the experiment in May. During this period, the movements of 9 fish were continuously recorded for 24 hrs each, reaching a total of six 24 hrs-episode at 8 days interval. Swimming activity was analysed in terms of activity rhythms and space occupation specially around feeding events. The two data set and main results will be presented and compared to assess seabass behavioural plasticity and sensitivity to husbandry conditions.

ESCAPEES OF POTENTIALLY INVASIVE FISHES FROM AN ORNAMENTAL AQUACULTURE FACILITY: THE CASE OF TOPMOUTH GUDGEON *PSEUDORASBORA PARVA*

Beyer, K.[1,2,3]

[1]Centre for Ecology and Hydrology, Winfrith Technology Centre, Dorchester, Dorset DT2 8ZD, UK

[2]University of Hull, Cottingham Road, Hull, HU6 7RX, UK

[3]Centre for Environment Fisheries and Aquaculture Science, The Nothe, Barrack Road, Weymouth, Dorset DT4 8UB, UK

Accidental escapees from aquacultural facilities are an ongoing problem facing scientists, conservationists, policy makers and naturalists throughout the world. The topmouth gudgeon *Pseudorasbora parva*, a small cyprinid native to Southeast Asia, was introduced to Romanian waters in 1960 via the aquaculture trade and has since spread throughout Europe. It first appeared in England in an ornamental fish farm near Romsey in Hampshire. The aim of the present study was to quantify the dispersal of this potentially highly invasive species from an ornamental fish farm into the wild. In order to measure the dispersal of escapees, intensive electrofishing surveys were carried out between June and September 2003 in the catchment downstream of the fish farm. The distribution of topmouth gudgeon in the catchment was found to be limited and patchy. The presence of small individuals suggests that the species has successfully established itself in the wild, but this remains to be confirmed. The results were examined in light of invasion theory principles of biological resistance and ecological fitness.

GENETIC QUALITY OF DOMESTICATED AFRICAN TILAPIA POPULATIONS

Brummett, Randall E. and Ponzoni, Raul

WorldFish Centre, BP 2008, Yaoundé, Cameroon

Anecdotal and empirical evidence exists for substantial (up to 40%) declines in growth among *Oreochromis* populations domesticated in both large and small-scale fish farms in Africa. These declines are at least partly attributable to poor genetic management, including inadvertent selection, inbreeding, bottle-necks and founder effects. Due to restricted cash flow and investment capital, genetic management and selective breeding for the improvement of domesticate populations are difficult for small-scale farmers, but feasible on larger-scale farms. In managing domesticated gene pools, feral populations can serve as a broodstock reservoir, making the use of indigenous species advantageous. A development model of large-scale hatcheries producing selected lines of sex-reversed, indigenous tilapia for sale to smaller-scale farmers is proposed as a solution to the problems of poor genetic management in African aquaculture.

POLYCULTURE PRODUCTION OF JUVENILE FISHES FOR SURVIVAL IN NATURE.

Burke, John Selden, Morris, James and Kenworthy, Judson

NOAA , National Ocean Service, Center for Coastal Fisheries and Habitat Research, 101 Pivers Island Road, Beaufort, NC 28516-9722, USA

Production of seed for stock enhancement projects requires consideration of the behavioral quality of the animals to be released in the wild. Our approach to improving behavioral quality of hatchery fish is to raise them in polyculture with the plants or animals that fish normally utilize as shelter in nature. Results suggest that such “naturalized” systems provide a broad improvement in behavior as both predator avoidance and feeding skills were improved relative to control hatchery fish. In addition fish in a naturalized system grew better and were more tolerant of stress than were fish reared by traditional hatchery methods. We hypothesize that the spatial heterogeneity of our “naturalized” systems provided training in both hiding and seeking and that these activities improved feed conversion and stress tolerance.

FEASIBILITY OF RELEASING CAPTIVE REARED BROODSTOCK INTO AN IMPERILED WILD SALMON RIVER AS A RECOVERY STRATEGY

Carr, Jonathan W. and Whoriskey, Fred G.

Atlantic Salmon Federation, PO Box 5200, St. Andrews, New Brunswick, E5B 3S8, Canada

Adult Atlantic salmon were released into the Magaguadavic River, New Brunswick, Canada, to determine if broodstock releases could significantly contribute to recovery efforts for this river’s seriously depressed wild population. The fish were first generation progeny from wild Magaguadavic parents, and had spent their entire lives in captivity. Some were reared in commercial sea cages, whereas others were grown to maturity in a freshwater culture facility. Releases to the river were done either singly, or in small groups (three fish), early or late in the migration season. Movements of fish from the different treatments were compared by sonic telemetry. No differences in movement and behavior patterns were observed between freshwater and sea cage reared groups. Tagged fish released above head of tide in the lower river early (35 to 80 days prior to the natural spawning period) moved into a lake low in the system and resided near the commercial hatchery where they had been reared from egg to smolt. None moved to the upper river reaches during spawning season were most spawning habitat exists. Broodstock released in the upper river reaches near the time of spawning (the late group) stayed there during the spawning period. However, extensive electrofishing surveys conducted the following year yielded few to no salmon fry in all sites. The present results show that the spawning success of these fish was poor.

EXPERIMENTAL INVESTIGATION OF THE SUCCESS OF STOCKED, DOMESTIC BROWN TROUT AND THEIR EFFECTS ON WILD BROWN TROUT IN UPLAND AND LOWLAND RIVERS

Chatterji, Ravi K.[1], Stubbing, Dominic N. [1], Bark, Anthony W.[2] and Williams, W. Peter[2]

[1]The Game Conservancy Trust, Fordingbridge, Hampshire SP6 1EF, UK

[2]Department of Life Sciences, King’s College, Franklin-Wilkins Building, 150 Stamford Street, London SE1 9NN, UK

The stocking of adult, domestic brown trout (DBT) (*Salmo trutta* L.) to supplement angling catches is a common practice. However, there is increasing concern over the effects of such stockings on indigenous wild brown trout (WBT) populations. This paper describes an experimental field trial to explore the success of stocked DBT and their effects on WBT growth and abundance. DBT adults were stocked into upland rain-fed and lowland spring-fed streams. Three stocking treatments and a control were replicated six times for each of the two stream categories. In spring, baseline adult (defined as ≥200mm LF) WBT densities were increased by 25%, 50% and 100% using equal quantities of two different strains of DBT from two large suppliers. All DBT were measured, weighed and tagged before being stocked. The stocking procedure approximated to current stocking practice. A total of 48 500m experimental sites were used. The abundance of WBT was estimated at each survey site in the summer prior to stocking via electrofishing and the depletion method. All WBT captured were measured and weighed. In addition, all WBT ≥100mm were tagged. Habitat was assessed using the HABSCORE model. Post-treatment monitoring was undertaken in the summer following stocking. Data will be presented regarding the effects of the stocking treatments on the growth and abundance of WBT as well as the strain-dependent performance of DBT across all sites and on a river type-specific basis. The suitability of using HABSCORE to formulate appropriate stocking densities will be discussed.

STOCK ENHANCEMENT AND CONSERVATION CULTURE OF STURGEONS: PROBLEMS AND PROSPECTS

Chebanov, Mikhail.S, Galich, Elena.V. , Chmir, Yuri .N.

Federal Centre for Genetics and Selection in Aquaculture, 12 Oktyabrskaya Str, Krasnodar 350063, Russia
E-mail: Chebanov@sturg.kuban.ru

Stock enhancement is the main source of *Acipenser gueldenstaedtii* and *A. stellatus* recruitment in the Sea of Azov, where up to 30 million juveniles have been released in recent years. The hatchery production strategy aimed solely to produce and release the largest possible number of juveniles, utilizing only the most mature brood fish of the spring spawning run. Although monitoring of age, weight and physiological conditions of the broodstock during the period of hatchery breeding did not show significant changes, the spawning run was dramatically shortened from several months to just 15 days, and includes only fish with advanced gonadal maturity. Conservation of the Azov Sea species and their unique spawning ecotypes is currently supported by the Federal Living Gene Bank, which maintains over 9,000 adults of eight endangered species. This paper summarizes the results of comparative analysis of biological characteristics such as growth, age of the first sexual maturation, relative fecundity, and morphological and physiological indices in wild and cultured specimens of different species and intraspecific groups of sturgeons. We conclude that there is a need for developing better hatchery technologies to maintain diversity of the stocks, through breeding protocols that maximize the genetic diversity of offspring based on evaluation of parentage and relatedness in farmed stocks by microsatellite loci.

EFFECT OF DOMESTICATION ON IDE (*LEUCISCUS IDUS* L.) REPRODUCTIVE PARAMETERS.

Ciesla, Miroslaw and Wojda, Ryszard

Department of Ichthyobiology and Fisheries, Warsaw Agricultural University, ul. Ciszewskiego 8,
PL-02-786 Warszawa, Poland
E - mail ciesla@alpha.sggw.waw.pl

Ide (*Leuciscus idus* L.) is a riverine cyprinid commonly produced as a subsidiary species in polyculture with common carp in Poland. In many cases production of restocking material is based on farm-reared broodstock. The aim of the paper is to study possible domestication effects on female reproductive parameters in ide following long – term pond cultivation. Three groups of fish were analyzed: group (1) consisted of fish cultivated in carp ponds for three generations; group (2) consisted of fish caught as wild one-year-olds in rivers and kept in ponds until till sexual maturation (first pond-reared generation) and group (3) consisted of wild ide females caught at spawning sites just before natural spawning. All fish originated from the Vistula River in central Poland. Fish were stimulated with Hungarian synthetic hormone analogue (Ovopel). Body length and weight, individual fecundity and egg size were measured during spawning, and egg survival was assessed at the eyed ova stage.

CHANGES OF NASE (*CHONDROSTOMA NASUS* L.) OCCURRENCE IN THE WISLOK RIVER, SOUTHERN POLAND, AFTER STOCKING WITH POND REARED JUVENILES

Ciesla, Miroslaw [1], Sliwinski, Jerzy [1], Konieczny, Piotr [2] and Litynski, Robert[1]

[1]Department of Ichthyobiology and Fisheries, Warsaw Agricultural University, ul. Ciszewskiego 8,
PL-02-786 Warszawa, Poland.
E-mail: ciesla@alpha.sggw.waw.pl

[2]Polish Anglers Association in Krosno, ul. Jasna 26a, PL-38-404 Krosno, Poland
E-mail: pzwkrosno@poczta.onet.pl

Nase (*Chondrostoma nasus* L.), once one of the most common fish species in the upper reaches of central European rivers, is now considered endangered throughout its natural range. Since 2000 the Department of Ichthyobiology and Fisheries, Warsaw Agricultural University, has cooperated with the Polish Anglers Association in Krosno to study the effects of river restocking with pond-farmed nase juveniles. The experiment is carried out on Wislok River, where nase was very twenty years ago but has now completely disappeared. Selected parts of the river are stocked with tagged, one-summer and one-year-old juveniles. Changes in nase occurrence, and their growth and foraging behavior have been analysed.

INFLUENCE OF REARING METHOD ON IDE (*LEUCISCUS IDUS* L.) JUVENILE SURVIVAL UNDER PIKE AND PIKEPERCH PREDATION

Ciesla, Miroslaw[1] and Kaczkowski, Zbigniew[2]

[1]Dept. of Ichthyobiology and Fisheries, Warsaw Agricultural University, ul. Ciszewskiego 8, PL-02-786 Warszawa, Poland.
E-mail: ciesla@alpha.sggw.waw.pl

[2]Dept. of Applied Ecology, University of Lodz, ul. Banacha 12/16,PL-90-237 Lódz, Poland.
E-mail: kaczko@biol.uni.lodz.pl.

The influence of rearing methods on ide (*Leuciscus idus* L.) juvenile survival under pike and pikeperch predation was investigated. Survival of two groups of ide was compared: group (1) consisted of juveniles reared in tanks under fully controlled conditions, while group (2) consisted of pond-reared juveniles. Both groups were obtained from the same parents, separated at the larval stage in early spring and cultured in the different environments until late autumn. Juveniles from both groups were placed in tanks with pike or pikeperch, and their survival compared after one, three and six days of exposure to the predators.

LABORATORY SIMULATION OF THE EFFECTS OF ENVIRONMENTAL SALINITY ON WILD-CAUGHT JUVENILES OF EUROPEAN SEA BASS *DICENTRARCHUS LABRAX* AND GILTHEAD SEABREAM, *SPARUS AURATA*

Conides, Alexis J.[1], Glamuzina, Branko[2] and Papaconstantinou, Costas[1]

[1]Hellenic Centre for Marine Research, Agios Kosmas, Hellinikon, 16610 Athens, Greece
E-mail: akoni@tee.gr

[2]Aquaculture Department, University of Dubrovnik, Cira Carica 4, 20000 Dubrovnik, Croatia
E-mail: glamuzina@yahoo.com

Gilthead seabream, *Sparus aurata*, and European sea bass, *Dicentrarchus labrax*, are two important species in Mediterranean aquaculture. In the wild, their juveniles occur in brackish areas such as lagoons and river deltas. Even though the juveniles seem to favour brackish environments, low salinity incurs an energy cost for osmoregulation. This paper presents the results of a series of laboratory experiments exploring the effects of salinity on growth, feeding, food conversion, survival and maintenance energy requirements of wild-caught juveniles. The fish were kept in the laboratory, divided in groups of 20 in small tanks of 50 L each, and supplied with biologically filtered seawater of four salinity levels (8, 18, 28 ‰ and natural seawater) and fixed temperature (20±1.4°C). The fish were fed pelleted feed throughout the experiment. Both species showed great similarity in their responses to lower salinities. Satiation time for both species increased with decreasing salinity, while maintenance requirements (required daily ration and energy) increased as with increasing salinity. Growth and feed conversion is highest for salinities around 28‰ and lower for salinities above and below. Both species share common physiological features, and intermediate salinities are optimal for their performance in nature and in captivity.

AN INVESTIGATION INTO THE ENDURANCE SWIMMING OF DIPLOID AND TRIPLOID ATLANTIC SALMON, (*SALMO SALAR* L.).

Cotterell, Stephen P.[1] and Wardle, Clem S.

FRS Marine Laboratory, PO Box 101, 375 Victoria Road, Aberdeen, AB11 9DB

[1]Corresponding author’s current address: School of Earth, Ocean and Environmental Science, University of Plymouth, Drake Circus, PLYMOUTH, PL4 8AA.
Tel: +44 (0) 1752 232411; Fax: +44 (0) 1752 232406; E-mail: scotterell@plymouth.ac.uk

The intermediate swimming endurance (*E*) of diploid and triploid Atlantic salmon was examined when the fish (0.33 and 0.35 m means respectively) were forced to swim at controlled speeds in a carefully monitored 10 m diameter annular tank. The selection of the fish for the trials was based upon their ability to swim with a moving pattern projected from a gantry rotating at the radius of the tank. The selection procedure did not prove to be significantly influenced by ploidy, though diploids tended to respond better. No significant difference was found between the maximum sustained endurance speeds (U_{ms}, maintainable for 200 minutes) where the fish swim at the limit of their aerobic capability. Diploids achieved 2.99 body lengths per second, (bls^{-1}) (0.96 ms^{-1}) and triploids sustained 2.91 bls^{-1} (1.02 ms^{-1}). A significant difference was found between the anaerobic capabilities of the fishes as measures by their prolonged swimming speed. *E* decreased as speed increased according to $log\ E$ = -3.25 U +12.837 (r = 0.961) for diploids and $log\ E$ = -4.420 U + 15.259 (r = 0.983) for triploids. During the course of the experimentation the voluntary swimming speed increased and the schooling behaviour improved. The data are compared to literature values of U_{ms} for mackerel, herring and saithe. Findings are discussed with reference to preceding work on the influence of triploidy on swimming behaviour. The effect of the curvature of the tank on the fish is calculated, and suggestions for the development of future techniques are put forward.

PHOTOPERIOD AND TEMPERATURE EFFECTS ON GAMETOGENESIS IN WINTER FLOUNDER, *PSEUDOPLEURONECTES AMERICANUS*

Duchemin M. B.[1,2], Audet C.[1], Lambert Y.[3]

[1]ISMER, Université du Québec à Rimouski, 310 allée des Ursulines, Rimouski, Québec G5L 3A1, Canada

[2]Present address: LEMAR, Institut Universitaire Européen de la Mer, Place Nicolas Copernic, Technopôle Brest-Iroise, 29280 Plouzané, France

[3]Ministère des Pêches et des Océans, Institut Maurice-Lamontagne, C.P. 1000, Mont-Joli, Québec G5H 3Z4, Canada

The winter flounder is an in-shore flatfish living in shallow waters on the east coast of North America from Labrador to Georgia. In the St. Lawrence estuary, the reproductive season is May and June. Our objective was to test the effects of winter-spring photoperiod and temperature conditions on the timing of sexual maturation in both males and females. Groups (16 animals each) of winter flounder breeders were maintained from mid-January to mid-May under five different experimental conditions (L: light and D: dark period): (1) natural photoperiod and temperature conditions; (2) natural photoperiod, 6ºC; (3) 15L:9D, natural temperature conditions; (4) 15L:9D, 6ºC; (5) accelerated photoperiod increase from winter to spring conditions, 6ºC. Natural photoperiod and temperature conditions correspond to a gradual increase in light period from 8L:16D (January) to 15L:9D (May) and in temperature from –1ºC (January to April) to 6ºC (May). GSI and condition factor did not differ among the treatments ($p > 0.05$). In males, milt production occurred simultaneously in the different treatments and histological examination did not indicate any significant effect of either photoperiod or temperature on testes development. In females, seven stages of oocyte development were observed. Both the number of oocytes at the cortical alveoli stage and number of atretic oocytes increased at 6ºC (warm temperature conditions). Overall, neither photoperiod nor temperature modified the reproductive period. However, warm winter-spring temperature conditions may decrease egg numbers and egg quality.

DIFFERENCES IN THE ENERGETIC COST OF SWIMMING IN TURBULENT FLOW BETWEEN WILD, FARMED AND DOMESTICATED JUVENILE ATLANTIC SALMON (*SALMO SALAR* L.)

Enders, Eva C.[1], Boisclair, Daniel [1], and. Roy, André G [2]

[1]Département de sciences biologiques, Université de Montréal, C.P. 6128 Succursale Centre ville, Montréal, Québec, H3C 3J7, Canada

[2]Département de géographie, Université de Montréal, C.P. 6128 Succursale Centre ville, Montréal, Québec, H3C 3J7, Canada

Domestication has been shown to have an effect on morphology and behaviour of Atlantic salmon (*Salmo salar*). We compared swimming costs of three groups of juvenile Atlantic salmon subject to different levels of domestication: (1) wild fish; (2) first generation farmed fish origination from wild genitors; and (2) seventh generation farmed fish originating from Norwegian aquaculture stocks. We assessed swimming costs under two types of turbulent flow (one mean flow velocity of 23 $cm{\cdot}s^{-1}$ and two standard deviations of flow velocity of 5 $cm{\cdot}s^{-1}$ and 8 $cm{\cdot}s^{-1}$). Respirometry experiments were conducted with fish in a mass range of 5-15 g wet at a water temperature of 15°C. Our results confirm (1) that net swimming costs are affected by different levels of turbulence such that, for a given mean flow velocity, fish spent 1.5-times more energy as turbulence increased, (2) that domesticated fish differed in their morphology (having deeper bodies and smaller fins) and in their net swimming costs (being up to 30.3% higher than for wild fish), and (3) that swimming cost models developed for farmed fish may be also be applied to wild fish in turbulent environments.

WINTER FLOUNDER STOCK ENHANCEMENT:DEFICITS IN CULTURED FISH

Fairchild, Elizabeth A. and W. Huntting Howell

Department of Zoology, University of New Hampshire, Spaulding Hall, 46 College Road, Durham, New Hampshire 03824 USA

The survival of hatchery-reared juveniles in a stock enhancement program is of paramount importance, however, post-release survival of cultured fish may be impaired by behavioral, morphological, and physiological differences to their wild counterparts. For flatfish, high mortality is directly related to their conspicuousness to predators. Abnormal coloration, lack of burying abilities, and behavioral anomalies increase their visibility, and thus their vulnerability to predators. The cryptic abilities of cultured juvenile winter flounder, *Pseudopleuronectes americanus*, were examined in the laboratory by investigating the rate of burial and color change. Both abilities increased with time. The majority of cultured fish completely buried in sediment after 48 hours, and flounder color-adapted from the light, rearing tank color to the dark, release site sediment color over 3 months. Cultured juvenile winter flounder were compared to wild conspecifics in a series of laboratory and field experiments. Non-cryptic, cultured flounder were more vulnerable to piscivorous and avian predation than cryptic, cultured flounder indicating that appropriate coloration is paramount in predator avoidance. Additionally, cryptic, cultured fish were more vulnerable to avian predation than cryptic, wild fish suggesting that behavioral differences exist between cultured and wild flounder. When behavioral comparisons were made between cultured and wild flounder in the presence of cues from potential predators, differences were observed between fish types (cultured, wild) and their reactions to cues (activity level, degree of burying). Augmenting the cryptic abilities of cultured flounder prior to stocking may be an effective way to increase post-release survival by reducing the mortality due to predation.

A COMPARISON OF SURVIVAL, MIGRATION AND GROWTH OF NATIVE, RANCHED AND NON-NATIVE ATLANTIC SALMON UNDER NATURAL CONDITIONS

Ferguson, Andy[1], McGinnity, Philip[2], Prodöhl, Paulo[1], Hynes, Rosallen1, Ó Maoiléidigh, Niall[2], Cotter, Deirdre[2], Baker, Natalie[1] and O'Hea, Brendan[2]

[1]School of Biology and Biochemistry, Queen's University, Belfast BT9 7BL, N. Ireland
E-mail: a.ferguson@qub.ac.uk; Tel. 02890942024

[2]Marine Institute, Newport, Co Mayo, Ireland.

The genetic and ecological impacts of escaped farm Atlantic salmon on wild populations have been studied in detail in recent years. However, in such studies it is not possible to differentiate between the effects of non-native origin and domestication on the reduced survival of farm and farm x wild hybrids. Here we report on an experiment to examine the impact, on a wild population, of multi-generation ranching of native fish and non-native stocking. The experiment was undertaken in the Burrishoole system in western Ireland and involved multiple families of native wild; native ranched, and non-native salmon from an adjacent river. Fertilised eggs were incubated to the eyed stage in the hatchery before being counted accurately and planted out in a river from which natural spawning had been excluded. Samples of parr were electrofished from the river and all emigrant parr and smolts were captured in a downstream trap. Aliquots of each group were maintained in the hatchery, smolts released to sea, and subsequent returning adults sampled. Offspring were assigned to family and group parentage by minisatellite or microsatellite DNA profiling. Survival, growth, migration and maturity characteristics were examined at each stage and overall lifetime success was estimated. The results will be discussed in relation to the potential genetic and ecological impacts of deliberate and accidental introductions of non-native and farm Atlantic salmon and other salmonids on the fitness and performance of native populations.

REPRODUCTIVE ECOLOGY OF CULTURED FISH IN THE WILD.

Fleming, Ian A.

Ocean Sciences Centre, Memorial University of Newfoundland, St. John's, NL A1C 5S7, Canada

Fish show a tremendous diversity in patterns of reproductive investment and in associated breeding systems (i.e. parental care and sexual selection, including the number of mates obtained by both sexes and the manner in which they are obtained through competition for mates and resources, courtship, and mate choice). These patterns play an integral role in shaping the evolution of populations and their dynamics, and thus changes in these patterns necessarily affect population viability. Artificial culture of fish in hatcheries, net-pens and gene banks almost invariably disrupts the natural breeding system and alters fitness-related traits. The implications, both genetic and ecological, of the intentional and unintentional release of these fish for wild populations are largely dependent on what occurs during breeding and its subsequent effects on offspring performance. Our findings and those of others have indicated that gene flow from cultured to wild populations is frequently impeded by altered breeding behaviour and biased by sex and life history strategy. Moreover, breeding affects subsequent offspring performance through not only genetic (e.g., disruption of co-adapted gene complexes, MHC non-assortative mating), but also non-genetic maternal effects (e.g., breeding time and location, egg size). While significant advances have been made in the last decade, our understanding of the reproductive ecology of cultured fish in the wild remains somewhat in its infancy. Such study continues to be integral in enlightening our management of cultured fishes in the wild, and more broadly for increasing our understanding of fish breeding systems and thus population dynamics.

PHYSIOLOGICAL AND BEHAVIORAL DIFFERENCES OF HATCHERY AND WILD-REARED STEELHEAD (*ONCORHYNCHUS MYKISS*) SMOLTS OF THE SAME GENETIC ORIGIN

Gale, W.L., Hill, M.S., and Zydlewski, G.B.

US Fish and Wildlife Service, Abernathy Fish Technology Center, 1440 Abernathy Creek Rd., Longview, WA 98632, USA.
E-mail: gale@fws.gov

In many parts of the world release of hatchery-reared smolts has long been used to mitigate for the deleterious effects of habitat loss and overfishing on salmonid populations. Of increasing concern is whether this may cause harm by spreading non-native stocks and potentially releasing incompetent smolts. The objective of this study was to determine if smolt physiology and behavior of juveniles produced from a recently founded native broodstock differ from their wild (naturally-reared) counterparts. In the fall of 2002 and 2003 juvenile wild steelhead were captured, PIT tagged, and returned (n=1,360 in 2002 and n=2,708 in 2003) to Abernathy Creek. In winter of 2003 and 2004 hatchery-reared fish were PIT tagged and later released (n=1,100 in 2003 and n=1,400 in 2004) into Abernathy Creek. Gill biopsies were collected from wild and hatchery fish throughout the rearing and out-migration season. The timing and speed of outmigration was assessed using two stationary PIT tag antennas (92-97% efficient). Hatchery migrants in 2003 were larger, had significantly lower gill Na^+,K^+-ATPase activities, and migrated slower than wild fish. Results from the 2004 migratory season will also be presented. This study shows that hatchery rearing can result in smolts which are physiologically and behaviorally different from genetically similar wild fish. Whether these differences are critical enough to affect the rate of adult returns will be determined in future years.

COMPARATIVE EVALUATION OF STURGEON LARVAE AND JUVENILES REARED UNDER CONTROL OF SEASONAL PROPOGATION OF THE WILD AND DOMESTIC BREEDERS

Galich, Elena V. and Chebanov, Mikhail S.

Federal Centre for Genetics and Selection in Aquaculture, 12 Oktyabrskaya Str., Krasnodar 350063, Russia
Email: Chebanov@sturg.kuban.ru

Sturgeon populations (*Acipenser gueldenstaedtii* and *A. stellatus*) in the Sea of Azov basin are maintained largely through stock enhancement. A monitoring is in operation for biological characteristics of juveniles, including body length and weight, physiological-biochemical indices, teratology, thermal stability, salt resistance, oxygen deficiency resistance and melanophore adaptive response as indicators of physiological fitness, and neuro-pharmacological testing with a sedative (MS-222). Behavioural experiments include the assessment of background movement and reactivity to the effect of low/high frequency sounds and light of long/short duration. Juveniles obtained from breeders in which the reproductive cycle had been delayed for up to 90 days did not show significantly different levels of morphological anomalies compared to juveniles obtained with conventional reproductive techniques. The most frequent defects are observed in pectoral fins (up to 20 percent) and olfactory organs (up to 10 percent). Fingerlings showed and adequate and timely adaptive reaction of melanophores towards dark and light background. The experiment demonstrated that sturgeon fingerlings produced under controlled conditions are euryhaline and robust to thermal and oxygen stress. Some differences in biological attributes were noted between juveniles obtained from wild and domesticated breeders of *A. gueldenstaedtii* and *A. stellatus*.

MALADAPTATION AND PHENOTYPIC MISMATCH IN CULTURED ATLANTIC SALMON USED FOR STOCKING

García de Leániz, C.[1], Consuegra, S.[2] and Serdio, A.[1]

[1]Centro Ictiológico de Arredondo, 39813 Arredondo, Cantabria, Spain

[2]Zoological Society of London, Institute of Zoology, Regent's Park, London, UK

Compared to wild populations, cultured Atlantic salmon often sustain higher mortality rates and lower adult return rates when stocked as juveniles into natural streams. However,the ultimate causes for such differences in fitness are not clear. Here we tested if relaxed levels of natural selection and improved survival in the hatchery environment could account for the observed degree of maladaptation among stocked fish. To do this, we assessed the degree of phenotypic mismatch between wild and cultured fish in three populations over five consecutive years. Significant differences were found in several phenotypic traits that are likely to have fitness implications. Thus, if the objective is to mimic wild individuals for restoration purposes, current hatchery practices aimed at maximising juvenile survival and enhancing growth may need to be revised.

RAPID BREATHING IN PROGRESS – WILD AND HATCHERY FISH ALERT TO DANGER!

Hawkins, L.A.[1], Magurran, A.E.[1] and Armstrong, J.D.[2]

[1]Division of Environmental and Evolutionary Biology, Gatty Marine Laboratory, University of St Andrews, St Andrews, Fife, KY16 8LB, Scotland, UK.

[2]Fisheries Research Services Freshwater Laboratory, Faskally, Pitlochry, Perthshire, PH16 5LB, Scotland, UK.

A number of studies have documented reduced-predator evasion skills in hatchery-reared salmonids. However, it is unclear whether these fish are naïve to the danger posed by predators or whether they recognise the risk but lack the experience to be able to respond appropriately. An increase in opercular rate may indicate stress, and so could provide a measure to gain an insight into perception of risk in hatchery and wild fish. Here we report an experiment in which wild and hatchery Atlantic salmon (*Salmo salar*) fry were exposed to a predator model (a dead trout). Opercular rate was found to be a good measure of stress response to the model. Wild fish had a much lower resting opercular rate. Nonetheless, both wild and hatchery fry showed a strong and significant increase in opercular rate after encountering the predator. This outcome suggests that hatchery fish are indeed capable of recognizing danger. The duration for which opercular rate remained elevated was also very similar in wild and hatchery fry. Our results are consistent with the hypothesis that it is the absence of learning opportunities, rather than an inherent inability to recognise danger, than accounts for the poorer anti-predator skills of hatchery-reared salmonids.

INTERACTIONS BETWEEN ENDANGERED WILD AND HATCHERY SALMONIDS; CAN THE PITFALLS OF ARTIFICIAL PROPAGATION BE AVOIDED IN SMALL COASTAL STREAMS?

Hayes, Sean A., Bond, Morgan H., Hanson, Chad V. and MacFarlane, R. Bruce

Salmon Ecology Group, NOAA Fisheries, 110 Shaffer Road, Santa Cruz, CA 95060, USA

Scott Creek is a small coastal watershed in central California, inhabited by wild and hatchery populations of steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*). Both species are listed by the U.S. Endangered Species Act. We examined local artificial propagation practices for impacts on wild stocks by monitoring comparative development, predation, and competition. We also compared hatchery and wild adult salmonid spawning behavior and morphology. Juveniles were sampled throughout the year in the stream and at the hatchery. Both species grew faster in captivity than in the wild. Based upon gill Na^+, K^+ -ATPase activities, hatchery fish of both species were ready to enter seawater when planted during the wild fish migration. Downstream migrant trapping and stream surveys indicated hatchery smolts went to sea soon after planting. No negative impacts associated with artificial propagation were observed at the juvenile life stage. Adult steelhead were sampled throughout the watershed during two spawning seasons. The return of hatchery steelhead was highly synchronized with wild steelhead. A disproportionate number of hatchery steelhead returned to the tributary where the hatchery is located, despite being planted throughout the watershed. Hatchery steelhead did not differ in mean age or size from wild steelhead. Spawning observations indicated that hatchery and wild steelhead interbreed. No competition for mates or spawning substrate was observed between hatchery and wild steelhead. We conclude that many of the problems commonly associated with artificial propagation can be avoided when wild broodstock are used, fish are released as smolts and migration distances are short.

WHY DO SALMONID ANTI-PREDATOR RESPONSES WEAKEN IN HATCHERY REARING?

Hirvonen, Heikki and Laakkonen, Mika V. M.

Integrative Ecology Unit, Department of Biological and Environmental Sciences, University of Helsinki, PO Box 65, FIN-00014 Helsinki, Finland
Email: heikki.hirvonen@helsinki.fi

The Arctic charr of Lake Saimaa are the most endangered fish population in Finland, and reintroduction programs have been unsuccessful. Low success of reintroduction programs has drawn attention to behavioural properties of hatchery-reared fish. Mortality due to predation often is a principal cause of failure. Anti-predator behaviour may degenerate rapidly under hatchery conditions due to (i) reduced genetic variation in antipredator behaviour and/or (ii) selection that would favour bold and fast growing individuals and disfavour predator awareness supposedly associated with slow growth. To test the relative importance of these two factors we first analysed the amount of variation in innate anti-predator responses between and within families of hatchery-bred Arctic charr of the Lake Saimaa stock. We then tested whether fast growing individuals would show reduced responses to chemical cues from their natural predators compared to their slow growing counterparts. Based on the results we propose procedures for maintaining and improving anti-predator skills of hatchery-reared salmonids.

GENE EXPRESSION PATTERNS IN ATLANTIC SALMON (*SALMO SALAR*): GENE EXPRESSION DURING OSMOREGULATION IN INTESTINE TISSUE

Hubert, Sophie[1], O'Keeffe, A.M.[1], Cotter, D.[2], Wilkins, N.P. [3] and Cairns,M.T.[1]

[1]National Diagnostics Centre, NUI, Galway, Ireland

[2]Marine Institute, Furnace, Newport, Ireland

[3]Department of Zoology, NUI, Galway, Ireland

Ireland has the world's largest stocks of wild Atlantic salmon. A better understanding of gene expression will benefit conservation of wild stock as well as salmon aquaculture. We describe the PRTLI project designed to advance the fundamental understanding of the genome of Atlantic Salmon (*Salmo salar*). The major objective is to create the first comprehensive database of gene expression and functional information using cDNA libraries and Microarray technology. One key area of interest to salmon biology is osmoregulation, which is critical to the ability of salmon to adapt in seawater. Tissues implicated in this process are the gills, intestine and skin. To initiate studies, SSH (Suppression Subtractive Hybridization) libraries were constructed from intestine RNA extracted from smolts sampled in January and May. A number of potentially interesting clones have been identified, among those a heat shock protein, hsp90 in the reverse library. Others SSH libraries from various tissues (pituitary, hypothalamus, brain, gill, intestine, head kidney and spleen) have also been constructed and will be used to construct a 5000 clone microarray slide. This slide will then be used to elucidate gene expression profiles in various tissues. Further sample collection has been carried out to answer questions regarding biological differences between one- year and two-year old parr and wild and hatchery smolt.

IMPLICATIONS OF DOMESTICATION AND REARING CONDITIONS FOR THE BEHAVIOUR OF CULTIVATED FISH

Huntingford, Felicity Ann

Fish Biology Group, Institute of Biomedical and Life Sciences, University of Glasgow, Glasgow G12 8QQ, UK.
Tel: +44 (0) 141 330 6643; Fax: +44 (0) 141 330 6643;
E-mail: F.Huntingford@bio.gla.ac.uk.

The striking differences in the environment experienced by wild and cultured fish offers considerable scope both for unplanned, natural selection for different inherited behavioural phenotypes and for behavioural differences arising from differential experience. In this paper, the evidence that such processes have produced behavioural differences between wild and cultured fish is reviewed in relation to feeding, anti-predator responses, aggression and reproductive behaviour. The reported findings are discussed in relation to the concept of "behavioural syndromes", or suites of co-varying behavioural traits that adapt individuals of the same population to spatial and/or temporal variation in selection regimes. The implications of the behaviour of cultured fish for production and welfare in production cages, for the environmental impact of escapees on wild stocks and for the success of hatchery-based restocking programmes will be considered. The review inevitably concentrates on salmonid fish, in which such phenomena have been intensively researched.

FEASIBILITY OF A PROJECT FOR ACTIVE RESTOCKING OF THE SEA ADJACENT THE SALT PANS OF TARQUINIA (ITALY)

Ingle, Enrico and Venzi, Lorenzo

Dipartimento di Ecologia e Sviluppo Economico Sostenibile (DECOS), Universita' della Tuscia, Via S. Giovanni de Lellis #1, 01100 Viterbo, Italy

The depletion of fish stocks in the Mediterranean suggests that restocking may be a useful approach for restoring fisheries. In this paper we consider the potential for using derelict salt pans at Tarquinia (50 miles north of Rome) to rear fish for restocking in adjacent coastal areas. We discuss candidate species for stock enhancement, ways of minimizing stress in the capture of broodstock, genetic monitoring of wild catches, various aspects of operational restocking (release stage of larvae or juveniles, etc.) and suggest approaches for evaluating results. Finally, we provide an economic and financial analysis of investment costs and likely benefits for different scenarios, and guidelines for a restocking policy that may be implemented by public authorities.

DNA POLYMORPHISM OF PERCIDAE POPULATION STRUCTURE IN THE KUIBYSHEV WATER RESERVOIR OF RUSSIA

Islam, Asiful[1,2], Gorshkov, O. V.[1], Chernov, V. M.[1] and Kuznetsov, V. A.[2]

[1]Kazan Institute of Biophysics and Biochemistry, Russian Academy of Science, 420111 Kazan, Russia

[2]Kazan State University, 420008 Kazan, Russia
Tel: +7-8432-315146, Fax: +7-8432-387418, Email: asifuli@yahoo.com

The pike perches (*Stizostedion lucioperca* and *S. volgense*), river perch (*Perca fluviatilis*) and ruffe (*Gymnocephalus cernuus*) are important components of the fish fauna of the Kuibyshev reservoir in Russia. We analyzed genetic variation within and among populations of these species. Two microsatellite DNA from walleye (*S. vitreum*) were used as primers of this study. Each of the DNA markers resolved 6-10 alleles with locus Svi4 and Svi6 and size range of 102-169 base pairs (bp). PCR was performed with the selected primers, with temperature cycles followed a denaturing profile for 30 s at 94°C. A final 10 min elongation step was resumed at 72°C after 35 cycles. *S. volgense* showed the highest bp of 100 to 3000, differing by sex, age and maturity level. The populations of *P. fluviatilis* have variable DNA polymorphism within the range 90-1000 base pairs. We also detected a new band in the fingerprints. The degree of neutral genetic variation detected indicates that effective population sizes of the study species are large.

LONG TERM STUDIES ON GENETIC INTERACTION BETWEEN WILD AND RANCHED COD (*GADUS MORHUA*) BY USE OF A GENETIC MARKED STRAIN

Jørstad, K.E.[1*], Nævdal, G.[2], Karlsen, Ø.[1], Torkildsen, S.[2], Paulsen, O.I.[1], and Otterå, H.[1]

[1]Institute of Marine Research, Department of Aquaculture, Bergen, Norway

[2]University of Bergen, Department of Fishery and Marine Biology, Bergen, Norway
*Corresponding author K.E. Jørstad, POB 1870 Nordnes, 5817 Bergen, Norway
E-mail: knut.joerstad@imr.no

Releases of farmed fish, whether accidental from commercial aquaculture facilities or intentional as part of stock enhancement / ranching activities, are considered to pose a risk to native gene pools. Stock enhancement studies of Atlantic cod, *Gadus morhua*, based on artificially produced juveniles, were initiated in 1984 in western Norway, and genetic aspects were incorporated. In order to investigate potential interbreeding between released and wild cod, a genetically marked cod strain was developed, being homozygotic for a rare allele (*GPI-1*30*) expressed in white muscle tissue. In the period from 1990-1994, juveniles from the genetic marked strain were released in large quantities in three locations (Masfjord, Øygarden, Heimarkspollen), giving a significant increase of the marker allele in the local wild cod populations. Recently, studies have been conducted in the same areas to estimate the extent of interbreeding between the wild and released cod. The results, however, revealed no permanent increase of the frequency of the marker allele and/or *GPI-1*30* heterozygotes as would be expected from interbreeding. The recent data are compared with comprehensive genetic data of the cod populations in the areas before the actual releases, covering the full period from 1994 to 2003. The present results are also discussed in relation to fishing pressure on coastal cod, migration information and reproductive success of released, genetically marked cod.

COMPARISON OF MATURATION TIMING, EGG SIZE AND FECUNDITY BETWEEN HATCHERY LINES OF CHINOOK SALMON AND THEIR WILD DONOR STOCKS

Joyce, John E., Wertheimer, Alex C., Gray, Andrew and Thrower, Frank

National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Highway Juneau, Alaska 99801, USA
Email: John.Joyce@noaa.gov

Increasing concern has been expressed about the genetic effects of cultured salmonid fishes on natural populations. Avoidance of extreme negative outcomes was one reason for the establishment of a genetic management policy for the State of Alaska. However, domestication within the hatchery may still cause divergence from the wild donor population. This divergence could potentially lead to adverse impacts on wild stocks through straying and introgression. This study examines potential domestication in two Alaskan chinook salmon stocks. The Little Port Walter (LPW) Hatchery Chickamin River stock resulted from a small collection of wild broodstock in 1976. The LPW Unuk stock was founded with a larger number of individuals in 1976 and has had subsequent infusion of wild gametes. These lines have been maintained at LPW through ocean ranching of tagged smolts. Comparisons are made between the hatchery lines, progeny of wild chinook collected from the Chickamin and Unuk Rivers, and hybrids between the hatchery and wild groups. Mature ocean-ranched female chinook salmon returning to the facility were periodically graded for ripeness and spawned. Body size and meristic measurements were collected from these mature spawners. Maturation timing, fecundity, and individual egg size of these fourth generation hatchery fish are compared with that of offspring of wild fish from the same donor stock. Stock of origin is confirmed for all spawners and offspring using microsatellite DNA analysis.

THE IMPORTANCE OF AQUACULTURE TO NASE (*CHONDROSTOMA NASUS*) CONSERVATION IN POLAND

Kaczkowski, Zbigniew[1], Ciesla, Miroslaw[2] and Zalewski, M[3]

[1]Department of Applied Ecology, University of Lodz, ul. Banacha 12/16, 90-237 Lódz, Poland
Fax +48 42 665 58 19; E-mail: kaczko@biol.uni.lodz.pl

[2]Institute of Ichtiobiology and Fisheries Warsaw Agricultural University, ul. Ciszewskiego 8, 02-786 Warszawa, Poland

[3]International Centre of Ecology Polish Academy of Science, ul. M. Konopnickiej 1, Dziekanów Lesny, 05-092 Lomianki, Poland

Nase (*Chondrostoma nasus* L.) is one of the most threatened reophilic fish species in Poland. At present it has almost disappeared from the northern and central parts of its range while in the south its abundance has decreased. Protection of the species through closed seasons, catch and size limits has not been sufficient, and active enhancement through stocking is now applied. Developing the technology of hormonally induced spawning and adapting carp pond culture techniques for the rearing of nase enabled substantial enhancement efforts. According to Polish Anglers Association, stocking has in creased from 50 000 of hatchlings in 1994 to 840 000 of hatchlings, 568 000 summer and 900 000 autumn juveniles, and 1720 two year old fish in 2002. At present the problems to be solved urgently are preserving the genetic diversity of cultured and wild populations, and evaluating stocking effectiveness.

STATE AND ROLE OF ACTIVE CONSERVATION OF BARBEL (*BARBUS BARBUS*) IN POLAND

Kaczkowski, Zbigniew[1] and Miroslaw, Ciesla[2]

[1]Department of Applied Ecology, University of Lodz, ul. Banacha 12/16, 90-237 Lódz, Poland
Tel: (42) 635 44 38; E-mail: kaczko@biol.uni.lodz.pl

[2]Institute of Ichtiobiology and Fisheries, Warsaw Agricultural University, ul. Ciszewskiego 8, 02-786 Warszawa, Poland
Tel: (22) 853 09 38; E-mail ciesla@alpha.sggw.waw.pl

Barbel *(Barbus barbus*) is a highly valued target of recreational fisheries. Due to environmental degradation and growing angler pressure, its abundance has decreased in many rivers. In response to this, active protection strategies are being developed by scientists and the Polish Anglers Association. Methods of breeding in captivity have been developed for restocking purposes. Production and release have increased from 19,600 summer fry and 692 adult fish in 1998 to 7,000 summer and 32,000 autumn juveniles, and 3,150 two-year-old fish in 2002. The preservation of genetic diversity is a major challenge in these enhancement programmes.

DISRUPTION OF THE MELATONIN RHYTHM IN WILD AND FARMED FISH: A CONSEQUENCE OF PROLONGED THYROXINE ADMINISTRATION AND CALCIUM DEPLETION

Kulczykowska, Ewa, Sokolowska, Ewa, Gozdowska, Magdalena and Kalamarz, Hanna

Institute of Oceanology PAS, Powstanców Warszawy 55 Str., 81-712 Sopot, Poland

Recent studies suggest that the pineal gland and its major product melatonin (N-acetyl-5-methoxytryptamine: Mel) play a role in integration of various neural and endocrine functions. Observations indicate that Mel as a signal of photoperiod regulates a number of biological phenomena, including reproduction, day/night activity and many other physiological events associated with daily or seasonal rhythms in vertebrates, including fish. Mel has also been found to be a highly effective preventive antioxidant and free radical scavenger, protecting organism from oxidative damage. In all species examined, plasma melatonin concentration shows a diurnal rhythm, with the highest levels during the night. Our studies are focused on the cues affecting Mel synthesis capacity in wild and farmed fish. The Mel rhythm in fish can be disrupted by fluctuations in surrounding calcium concentration or by prolonged thyroxine (T4) exposure. Physiological depletion of plasma ionized calcium may limit the capacity of Mel night production in two fish species, farmed rainbow trout and wild flounder. Prolonged (2-week) exposure to high level of exogenous thyroxine (T4) results in reduced night-time plasma Mel levels, and may thus inhibit the melatonin-related time-keeping system in juvenile salmon. Disruption of the daily Mel rhythm implies a reduced ability of organisms to respond properly to environmental signals, and may be a useful indicator of disturbance in physiological functions.

CONSEQUENCES TO FITNESS-RELATED TRAITS OF HYBRIDISATION BETWEEN FARMED AND WILD ATLANTIC SALMON, *SALMO SALAR*

Lawlor, Jennifer L. and Hutchings, Jeffrey A.

Department of Biology, Dalhousie University, Halifax, Nova Scotia B3H 4J1 Canada

Introgression between wild and farmed Atlantic salmon, *Salmo salar*, has been hypothesised to influence the persistence of wild populations, particularly those at heightened risk of extinction. Based on pure and hybrid crosses involving one farmed and two wild populations (Tusket River and Stewiacke River, an endangered population) in a common-garden environment, we examined the consequences of introgression to survival, growth, and disease resistance in the first year of life. Introgression with farmed salmon had either no effect (Stewiacke) or a negative effect (Tusket) on survival. Importantly, the among-family variance in survival (a negative correlate of population persistence) was higher for the hybrids than it was among the pure crosses. There was also evidence of genetic differences in growth rate and disease susceptibility. Introgression with their farmed counterparts is unlikely to have a positive effect on the fitness of wild Atlantic salmon. The degree to which genetic interactions between farmed and wild salmon threaten the latter's persistence almost certainly depends on the degree to which individuals are adapted to their local environment, on the genetic differentiation between farmed and wild individuals, and on the relative proportions of farmed and wild salmon during spawning.

COMPARATIVE ANALYSIS OF MORPHOMETRIC CHARACTERS OF JUVENILE STERLET (*ACIPENSER RUTHENUS* L.) FROM NATURAL POPULATION AND AQUACULTURE

Lenhardt, M.[1], Prokes, M.[2], Jaric, I. Z.[3], Barus ,V.[2], Kolarevic, J.[3], Krupka, I.[4], Cvijanovic, G.[3], Cakic, P.[1] and Gacic, Z.[3]

[1]Institute for Biological Research, 29 Novembra 142, 11000 Belgrade, Serbia and Montenegro

[2]Insitute of Vertebrate Biology, Academy of Sciences of the Czech Republic, Kvetna 8, 603 65 Brno, Czech Republic

[3]Centre for Multidisciplinary Studies, Kneza Viseslava 1, 11000 Belgrade, Serbia and Montenegro

[4]Majerníkova 10, 841 05 Bratislava, Slovak Republic

A comparative analysis was performed on sixteen morphometric characters, in three different juvenile sterlet (*Acipenser ruthenus* L.) populations. Specimens were collected from a wild population in the Serbian part of the Danube River (n=46), from aquaculture stocks in the Czech Republic originating from Russia (n=40), and aquaculture stocks in the Slovak Republic originating from Slovakian part of the Danube River (n=28). Average values for total length were 29.9 ± 3.9 cm, 29.1 ± 3.7 cm and 27.3 ± 7.7 cm for Serbia, Czech Republic and Slovak Republic, respectively. Populations were compared using t-test and sequential Bonferroni correction for multiple comparisons was applied in order to determine significant differences between them. Results of analysis showed that all three populations differed in prebarbel length, interocular distance and maximum head width. Although all these characters are head-related, head length itself was very uniform among all populations. The natural population from the Serbian part of the Danube River differed from the populations reared in aquaculture in seven morphometric characters. The tow populations reared in aquaculture consistently showed lower morphological variability than the wild population, even though they had different genetic backgrounds (Russia and Slovakia). Future genetic studies will show if this tendency is caused by a reduction in genetic variability.

POPULATION DYNAMICS OF FISHERIES STOCK ENHANCEMENT

Lorenzen, Kai

Department of Environmental Science and Technology, Imperial College, Prince Consort Road, London SW7 2BP, UK. (k.lorenzen@imperial.ac.uk)

The population dynamics of fisheries stock enhancement, and its potential for generating benefits over and above those obtainable from optimal exploitation of wild stocks alone are poorly understood and highly controversial. I extend the dynamic pool theory of fishing to stock enhancement by unpacking recruitment, incorporating regulation in the recruited stock, and accounting for biological differences between wild and hatchery fish. I then analyse the dynamics of stock enhancement and its potential role in fisheries management, using the candidate stock of North Sea sole as an example. Enhancement through release of recruits or advanced juveniles is predicted to increase total yield and stock abundance, but reduce abundance of the naturally recruited stock component through compensatory responses or overfishing. Release of genetically maladapted fish reduces the effectiveness of enhancement, and is most detrimental overall if fitness of hatchery fish is only moderately compromised. As a temporary measure for rebuilding of depleted stocks, enhancement can not substitute for effort limitation, and is advantageous as an auxiliary measure only if the population has been reduced to a very low proportion of its unexploited biomass. Quantitative analysis of population dynamics is central to the responsible use of stock enhancement in fisheries management, and the necessary tools are available.

DOMESTICATION, COMPARATIVE BIOLOGY AND INTERACTIONS OF WILD AND CULTURED FISH: CONVENOR'S SYNTHESIS

Lorenzen, Kai[1], Beveridge, Malcolm[2] and Mangel, Marc [3]

[1]Environmental Science & Technology, Imperial College, London SW7 2BP, UK

[2]FRS Freshwater Laboratory, Pitlochry, Perth PH16 5LB, UK

[3]Applied Mathematics and Statistics, University of California, Santa Cruz 95060, USA

Aquaculture is expanding rapidly and many fish species are brought into cultivation, entering a process of domestication with consequences for their morphology, physiology, ecology and evolution. In some species the abundance of cultured populations matches or exceeds that of wild stocks, and interactions between cultured and wild fish can pose significant conservation challenges. At the same time, captive breeding and re-introduction play an important role in the conservation of some of the world's most endangered fishes. Drawing on contributions from the FSBI Symposium and the wider literature, we synthesize current knowledge of the process and extend of fish domestication, interactions between cultured and wild fish, and the use of cultured fish in fisheries enhancement and restoration. We provide a perspective on the role of biological issues within the wider context of aquaculture development and aquatic conservation biology, and conclude with a discussion of promising avenues for further research.

REARED PERCH VS. WILD PERCH - FIRST RESULTS ABOUT ORGANOLEPTICAL AND TECHNOLOGICAL QUALITY

Mairesse, Guillaume, Thomas, Marielle, Gardeur, Jean-Noël and Brun-Bellut, Jean

Laboratoire de Sciences Animales, INPL-INRA-UHP Nancy 1, 34, rue Sainte Catherine, F-54000 Nancy, France
E-Mail: Guillaume.Mairesse@lsa-man.uhp-nancy.fr

The Eurasian perch, *Perca fluviatilis* L., has good potential as a candidate for inland aquaculture diversification in Europe. To aid the development of this new product, we define a quality reference based on attributes of wild perch, and compare the quality of perch reared in 3 different culture systems: (1) extensive [pond], (2) semi-extensive [tank] and (3) intensive [recirculation system]. In order to define a precise quality reference, it is necessary to characterize the spatial and seasonal variability in quality attributes of wild fish. To do so, wild perch were harvested every three month for a full biological cycle from two different natural systems (Lake Geneva in France and the River Rhine in the Netherlands). Two components of quality were taken into account: organoleptical (colour of skin and fillets (L*C*H° system; 12 variables), 7 morphological measurements) and 6 technological components (viscero, hepato and gonadosomatic index, perivisceral fat index, fillet yield and condition factor K_2). Using Principal Component Analysis, we show that within-season variability is high, particularly for Rhine perch. Perch from the Rhine have a compact body and caudal fin, and possess a longer mouth and head than perch from Lake Genva. Reared fish possess wild-like characteristics except for technological variables. Fish from extensive and semi-extensive system show similar attributes, while fish from intensive rearing systems show a higher viscerosomatic and perivisceral fat index.

DIFFERENCES IN THE PATTERN OF ANTIPREDATOR BEHAVIOUR BETWEEN HATCHERY-REARED AND WILD SEA-BASS (*DICENTRARCHUS LABRAX*) JUVENILES

Malavasi, S.[1], Georgalas, V.[1], Lugli, M.[2], Torricelli, P.[1] and Mainardi, D.[1]

[1]Dipartimento di Scienze Ambientali, Università Ca' Foscari di Venezia, Castello 2747/b, Campo della Celestia, 30122 Venezia, Italy

[2]Dipartimento di Biologia Evolutiva e Funzionale, Università di Parma, Viale della Scienza, 1-43100 Parma, Italy

The antipredator response of hatchery-reared and wild shoals of sea-bass juveniles were analysed and compared. Shoals of wild and hatchery-reared juveniles, each composed of 15 individuals placed into a suitable tank, were exposed to a live Eel (*Anguilla anguilla*) placed into a separate compartment of the tank. Video-recording of fish behaviour consisted of 10-min pre-stimulus and 10 min post- stimulus observations periods. Eight replicates were obtained for each group of juveniles (wild vs hatchery). Data were analysed by splitting the behavioural sequences into subsequent temporal frames. The behavioural responses of wild and hatchery-reared groups of juveniles were compared both within and between the pre-stimulus and the post-stimulus phase of each test. In both groups of shoals, the sight of the predator caused a significant increase in the index of shoaling, and a shift of the shoal towards the bottom and away from the predator. Wild fish aggregated faster and moved away from the predator farther than hatchery-reared fish. Conversely, hatchery-reared juveniles tended to stay closer to the bottom. The presence of inspection behaviour by juveniles toward the predator was observed in both wild and hatchery shoals. Observed differences in antipredator behaviour are likely to be the result of differences in selection regimes between the hatchery and natural environments. Results are discussed with reference to restocking programmes.

GONADAL MATURATION IN THE BLACKSPOT SEA BREAM *PAGELLUS BOGARAVEO*: A COMPARISON BETWEEN A FARMED AND A WILD BROODSTOCK

Micale, Valeria, Maricchiolo, Giulia and Genovese, Lucrezia

Consiglio Nazionale delle Ricerche – Istituto per l'Ambiente Marino Costiero, sezione di Messina
Spianata S.Raineri 86, 98122 Messina, Italy

The blackspot sea bream *Pagellus bogaraveo* (Brünnich, 1768) has been regarded as a possible alternative to traditionally cultured Mediterranean species such as seabream and seabass, due to its high market value and good adaptation to captivity. Broodstock establishment and management represent the first step towards reliable production of eggs and fry, which is required to develop aquaculture of this new species. Two different broodstocks were tested for gonadal maturation and spawning, one constituting of wild fish caught as juveniles and reared in tanks until sexual maturity (4 years), and one assembled from wild adult fish caught during or just before the reproductive season. All fish were maintained under the same rearing conditions and fed the same diet. Gonadal stripping and biopsies were performed weekly to monitor maturation in both males and females. Ovarian samples were staged for maturity on the basis of follicular diameter and migration of germinal vesicle. Sperm samples were tested for density (no. of spermatozoa ml-1) and motility. The fish reared in captivity reached ovarian maturity during the breeding season of the wild stock. Eggs were obtained by stripping from both farmed and wild specimens, but appeared degenerated as a result of being retained too long in the ovarian cavity due to the absence of spontaneous spawning. Spermiation was prolonged in the farmed fish, but appeared to be blocked in the wild breeders after first sampling. However, the sperm was very viscous and the motile spermatozoa did not exceed 10%.

THE ONTOGENY OF THE ALIMENTARY TRACT OF LARVAL PANDORA, *PAGELLUS ERYTHRINUS* L.

Micale, Valeria[1], Garaffo, Manuela[2], Genovese, Lucrezia[1], Spedicato, Maria Teresa[3] and Muglia, Ugo[4]

[1]Consiglio Nazionale delle Ricerche, Istituto per l'Ambiente Marino Costiero, sezione di Messina spianata S.Raineri 86, 98122 Messina, Italy

[2]Dipartimento di Sanità Pubblica Veterinaria, Facoltà di Medicina Veterinaria, Università di Messina – Polo Universitario Annunziata, 98168 Messina, Italy

[3]COISPA Tecnologia & Ricerca, Via dei Trulli 18, 70045 Bari -Torre a mare, Italy

[4]Dipartimento di Morfologia, Biochimica, Fisiologia e Produzioni Animali – Facoltà di Medicina Veterinaria, Università di Messina – Polo Universitario Annunziata, 98168 Messina, Italy

The ontogenesis of the alimentary tract and its associated structures (liver, pancreas, gall bladder) was studied in common pandora *Pagellus eythrinus* L., a promising species for diversification in Mediterranean aquaculture. Mass production of pandora has been limited so far by high larval and juvenile mortalities, which appear to be related to nutritional deficiencies. The development of the larval digestive system was studied histologically from hatching (0 DAH) until day 50 (50 DAH) in reared specimens, obtained by natural spawning from a broodstock adapted to captivity. At first feeding (3-4 DAH) both the mouth and anus had opened and the digestive tract was differentiated in four portions: buccopharynx, oesophagus, incipient stomach and intestine. The pancreas, liver and gall bladder were also differentiated at this stage. Soon after the commencement of exogenous feeding (5-6 DAH), the anterior intestinal epithelium showed large vacuoles indicating the capacity for absorption of lipids, whereas acidophilic supranuclear inclusions indicating protein absorption were observed in the posterior intestinal epithelium. Both the bile and main pancreatic ducts had opened in the anterior intestine, just after the pyloric sphincter, at this stage. Intestinal coiling was apparent since 4 DAH, while mucosal folding began at 10 DAH. Scattered mucous cells occurred in the oral cavity and the intestine, while they were largely diffused in the oesophagus. Gastric glands and pyloric caeca were firstly observed at 28 DAH and appeared well developed by 41 DAH, indicating the transition from larval to juvenile stage and the acquisition of an adult mode of digestion.

THE ECOLOGY OF ATLANTIC SALMON DURING THE TRANSITION FROM MATERNAL DEPENDENCE TO INDEPENDENT FEEDING: EXPERIMENTS WITH STOCKED FISH

Nislow, Keith H.[1], Armstrong, John D.[2], Letcher, Ben H.[3], and Einum, Sigurd.[4]

[1]U.S. Forest Service, Res. Unit NE-4251, University of Massachusetts, 201 Holdsworth NRC, 160 Holdsworth Way, Amherst, MA 01003, USA

[2]Fisheries Research Services Freshwater Laboratory, Faskally, Pitlochry, Perthshire PH16 5LB, UK

[3]S.O. Conte Anadromous Fish Research Center, USGS/Leetown Science Center, Turners Falls, MA 01376, USA

[4]Norwegian Institute for Nature Research, Tungasletta 2, N-7485 Trondheim, Norway

As salmon fry transition from dependence on maternally-derived yolk reserves to independent feeding they experience a highly dynamic biotic and abiotic environment, which often results in high mortality rates. As restoration and supplementation efforts often involve stocking individuals at or near this stage, understanding the determinants of performance during this transition may be key to the success of programs. In addition, controls on the parentage, density, timing and manner of stocking enable detailed experimental approaches that are impractical with wild populations. We present the results of field experiments in North America and Europe that investigate the importance of fine scale spatial (scale of meters) and temporal (scale of weeks) variation in environmental (stream discharge, temperature) and biotic (population density, prior residence) factors for juvenile survival, growth, and life-history. Results of these studies indicate that survival and growth during this period result from a complex interaction between abiotic and biotic factors in combination with maternal effects (egg size) and have longer-term and larger-scale population and life-history consequences. We discuss the implications of these results for management, specifically in the context of restoration efforts involving stocking programs.

INFLUENCE OF DRY DIETS ON REPRODUCTIVE PERFORMANCE AND EGG LIPID COMPOSITION DURING THE FIRST SPAWNING SEASON OF CAPTIVE POLLACK

Omnes, M. H., Recek, S., Barone, H., Le Delliou, H., Schmitz, A., Mutelet, A., Suquet, M. and Robin, J. H.

IFREMER, Laboratoire Adaptation, Reproduction et Nutrition des poissons marins, BP. 70, 29280, Plouzané, France

Four-year-old pollack (*Pollachius pollachius* L.), previously fed on dry pellets since their juvenile stage, were divided into three experimental groups two months prior their first spawning season. They were fed a commercial broodstock pellet enriched with 6% added oils, either: (1) capelin oil (control), (2) capelin oil plus arachidonic acid, or (3) DHA rich tuna oil. Spawning performance was determined in each group and egg lipids were analysed. During the vitellogenic period, the estradiol levels in plasma increased with oocyte enlargement, indicating that captivity and pelleted feed did not affect reproductive capacity. Females from each group spawned spontaneously between February and May. Egg production per kg of female was highest in the control group. Fertilization rate was highest (39%) in the group fed on diet enhanced in DHA. Lipid content in eggs reached 16% of dry weight, containing mainly phospholipids (75%). Egg fatty acid profiles showed few differences between dietary treatments. There was no significant difference in the concentration of Docosahexaenoic acid (22:6n-3) between groups. Arachidonic acid (20:4n-6) was lower in neutral and polar lipids of eggs from the control group than in the other groups. Tuna oil diet induced the highest DHA/EPA ratio in eggs and seemed to provide sufficient arachidonic acid for pollack broodstock. Egg fatty acid profiles are compared with six-year-old pollack broodstock fed on fish, and with other cultured and wild fish species.

COMPETITIVE ASYMMETRIES AS INFLUENCED BY DENSITY AND REARING CONDITION AMONGST OVERWINTERING SHELTERING JUVENILE SALMON

Orpwood, James E.[1,2], Griffiths, Siân W,[1]and Armstrong, John D.[2]

[1]Cardiff School of Biosciences, Main Building, Cardiff University, PO Box 915, Cardiff, Wales, CF10 3TL, UK

[2]Fisheries Research Services, Freshwater Laboratory, Faskally, Pitlochry, Perthshire, Scotland. PH16 5LB, UK

The use of hatchery-reared fish to boost declining populations of stream-dwelling juvenile Atlantic salmon *Salmo salar* (L.) is widespread. Juvenile Atlantic salmon reared in the wild vigorously defend sub-gravel refuges and the availability of such refuges may strictly limit population size. However, hatchery-reared salmon are less aggressive and willingly share shelters. This shelter-sharing behaviour could potentially be used to advantage in restoring depleted populations of Atlantic salmon parr. However, if wild-reared fish are intolerant of hatchery-reared shelter-sharers, they may be out-competed and streams will become depleted of naturally-reared stocks. As yet, little is know about how introduced hatchery-reared fish interact with wild-reared resident fish when in competition for winter refuges. This paper describes an experiment that uses a glass-sided indoor stream to test the hypothesis that competitive asymmetry for shelter between wild- and hatchery-reared Atlantic salmon is density dependent. Specifically, the sheltering behaviour of a single wild-reared 0 + salmon parr was compared with treatment groups where a single wild-reared fish was in competition with one, two or four hatchery-reared individuals. The implications of the findings are discussed in relation to stock enhancement.

GROWTH RATE AND NUTRITIONAL STATUS OF WILD AND REARED JUVENILE TURBOT (*SCOPHTHALMUS MAXIMUS*) IN THE SOUTHERN KATTEGAT

Paulsen, Helge and Støttrup, Josianne

Danish Institute for Fisheries Research, P O Box 101, K-9850 Hirtshals, Denmark
E-mail: hep@dfu.min.dk

More than 800.000 reared juvenile turbot were released in Danish waters during the period 1990 to 1997, as part of a stock enhancement programme. Performance of the released fish has been investigated using a combination of surveys and experimental studies. A total of 1311 wild fish and 448 alizarine marked, released fish were caught in 16 surveys from 1993 to 1997. Released fish were caught over a period of around two years after release. Growth rates were calculated using length frequency analysis. The results of growth analysis and measurements of nutritional status (condition factor, liver index, liver dry matter and otolith residual weight) showed only minor differences between wild and released fish. Growth rates of wild and released fish were comparable to fish kept in the laboratory at the same temperature (specific length growth rate ca. 0.5%*d^{-1} at 75-185mm total length and 12.5°C). The results indicate sufficient food in the release area, but also a significant difference in growth between years. Nutritional status of both wild and released fish was comparable to fed fish in the experiments and significantly higher than in fish starved for more than one week. The effects of transport and release procedures were examined by simulated releases in laboratory tanks. The fish were observed to feed and grow at normal rates one week after simulated release, suggesting that they are relatively robust to handling and release procedures.

DISTRIBUTION OF GENETIC VARIATION IN FARMED AND NATURAL STOCKS OF EUROPEAN EEL

Pujolar, J. M., Maes, G. E. and Volckaert, F. A. M.

Laboratory of Aquatic Ecology, Katholieke Universiteit Leuven, B3000 Leuven, Belgium

European eel (*Anguilla anguilla*; Teleostei) is a valuable commercial species. However, over the past 25 years, the population of European eel has been declining to such a degree that major concerns have been raised for its long-term conservation. Since little information is available on the life-cycle and genetic structure of European eel, it has been difficult to evaluate the existence of any population substructuring. Molecular genetic methods contribute to a better knowledge of the demography and population structure in marine fish. In addition, management strategies and conservation goals must consider information on genetic substructuring as well as on life history patterns.
The aim of the study is to provide more detailed knowledge on the genetic variability, demography and population substructuring of European eel by analysing and comparing natural and farmed individuals. Natural eel samples have been obtained in two geographical sites (Netherlands, France) including temporal samples in a short-scale (within years) and a long-scale (between years). Simultaneously, farmed glass eels have been grown in two separate batches during one year. Batches have been monitored and genetic samples have been obtained during the year.
A combination of selection-sensitive (allozymes) and selection-neutral markers (microsatellites) has been used in the study since selection seems to play an important role in the determination of the quality of future eel spawners. Results suggest a positive correlation between growth and genetic variability since individuals attaining a large length and weight present significant higher heterozygosities.

DISEASE INTERACTION BETWEEN FARMED AND WILD FISH POPULATIONS

Peeler, Edmund J.[1] and Murray, Alexander G.[2]

[1]Centre for Environment, Fisheries and Aquaculture Science, Barrack Rd., The Nothe, Weymouth, DT4 7QN, UK

[2]Fisheries Research Services, PO BOX 101, 357 Victoria Rd., Aberdeen, AB11 9DB, UK

This paper reviews the literature on disease interaction between wild and farmed fish and recommends strategies to reduce the disease risks to both populations. Most, if not all, diseases of farmed fish originate in wild populations. The close contact between farmed and wild fish readily leads to pathogens exchange. Aquaculture creates conditions (e.g. high stocking levels) conducive to pathogen transmission and disease; hence pathogens can overspill back, resulting in high levels of challenge to wild populations. This is exemplified by sea lice infections in farmed Atlantic salmon. Stocking with hatchery reared fish or aquaculture escapees can affect disease dynamics in wild populations. Whirling disease has been spread to many wild rainbow trout populations in the US with the release of hatchery reared stock. The greatest impact of aquaculture on disease in wild populations has resulted from the movement of fish for cultivation. Examples of exotic disease introduction following movement of live fish for aquaculture with serious consequences for wild populations are reviewed. The salmon parasite, *Gyrodactylus salaris*, has destroyed wild salmon populations in 44 Norwegian rivers. Crayfish plague has wiped out European crayfish over much of Europe. Eels numbers have declined in Europe and infection with the swimbladder nematode *Anguillicola crassus* has in part been blamed. The impact of disease in farmed fish on wild populations can mitigated. Risk analysis methods need to be refined and applied to live fish movement and new aquacultural developments. Appropriate biosecurity strategies, based on risk assessments, should be developed to reduce pathogen exchange and mitigate the consequences.

MUSCLE DEVELOPMENT IN CULTURED BLACKSPOT SEABREAM *PAGELLUS BOGARAVEO*: PRELIMINARY HISTOCHEMICAL AND IMMUNOHISTOCHEMICAL DATA ON THE FIBRE TYPES

Rowlerson, Anthea M.[1], Silva, Paula[2], Rocha, Eduardo[2,3], Olmedo, Mercedes [4] and Valente, Luisa M.P.[2,3]

[1]School of Biomedical Sciences, King’s College, University of London, Guy’s Campus, London SE1 1UL, UK

[2]ICBAS – Institute of Biomedical Sciences Abel Salazar, University of Porto, Largo Prof Abel Salazar, No. 2, 4099-003 Porto, Portugal

[3]CIIMAR – Center for Marine and Environmental Research, R. dos Bragas, 289 Porto, Portugal

[4]Instituto Español de Oceanografia, Cabo Estay, Vigo, Spain

We studied muscle ontogeny and fibre type characteristics in the blackspot seabream, a new species for commercial aquaculture. Myosin ATPase and SDH histochemistry and immunohistochemistry were tested at different ontogenetic stages, using a panel of antibodies to myosin isoforms and parvalbumin. In general, deep white muscle was parvalbumin-positive, and superficial ‘red’ muscle was parvalbumin-negative at all ages examined. At 6 days of age (transition from endogenous to exogenous feeding) three layers of muscle fibres were observed with different antimyosin reactivities: superficial monolayer, presumptive slow red (present only as a small group of fibres adjacent to the lateral line nerve), and presumptive fast-white (forming the bulk of the muscle). The superficial monolayer and presumptive slow fibres were positive for SDH. At 60 days of age (transition from live to artificial feeding) an additional fibre type was identified: a typical ‘pink’ or intermediate layer. In juveniles, the axial muscle consisted mainly of fast white fibres covered by a slow-red layer and between them a pink layer. Surprisingly, the red layer could be resolved into 2 distinct types by myosin immunostaining. Red fibres were also present along the horizontal septum, near the notochord. Both red and white muscle layers showed a mosaic appearance, which was confirmed by ATPase reaction. The work was financed by British Council, CRUP, and FCT (PhD Grant SFRH-BD-14068-2003).

A YEAR IN THE HATCHERY– EFFECTS ON AGGRESSIVE BEHAVIOUR IN YOUNG EUROPEAN GRAYLING?

Salonen, Annamari[1] and Peuhkuri, Nina[2]

[1]Department of Ecology and Systematics, Division of Population Biology, Po. box 65, University of Helsinki, FIN-00014 Helsinki, Finland

[2]Finnish Game and Fisheries Research Institute, Kotka unit, Sapokankatu 2, FIN-48100 Kotka, Finland

Captive rearing can lead to both genetic and phenotypic differences between the original population and the population in the culture. The longer the captive history, the more the hatchery and wild populations are likely to differ genetically. Phenotypic changes may occur even during short periods of captive rearing. Due to its flexible nature, behaviour is among the traits likely to change quickly in captivity. Aggressive behaviour is important for the young salmonids to obtain feeding and shelter positions. We studied whether a one-year rearing period in common culture conditions leads to convergence of aggressive behaviour in hatchery and wild strains of European grayling. We used individuals from three populations in the experiment. The hatchery fish were initially less aggressive than the wild fish, and this difference was still evident after one year of rearing under common conditions. This implies that a relatively short period of captive rearing does not affect the aggressive behaviour of the wild fish to the extent that their behaviour matches that of hatchery fish. Consequently, when the aim is to release captive-bred individuals into the wild in order to support or re-establish the original population, it may be worthwhile to release the fish after only a short hatchery rearing period. This might maintain their behavioural characteristics and thus give the best possible basis for survival in the natural environment.

INFLUENCE OF DIETARY PROTEIN LEVEL ON GROWTH PERFORMANCE AND BODY COMPOSITION OF JUVENILE BLACKSPOT SEABREAM, *PAGELLUS BOGARAVEO* (BRUNNICH, 1768).

Silva, Paula[1], Andrade, Carlos A.P.[2], Timóteo Viriato M.F.A.[2], Rocha, Eduardo[3] and Valente Luisa M.P.[1,3]

[1]ICBAS - Institute of Biomedical Sciences Abel Salazar, University of Porto, Portugal

[2]Direcção Regional de Pescas, Centro de Maricultura da Calheta, Madeira, Portugal

[3]CIIMAR – Centre for Marine and Environmental Research, R. dos Bragas, 289 Porto, Portugal

Blackspot seabream (*Pagellus bogaraveo*) is a potential candidate species for southern European aquaculture. A 12-week feeding trial was then conducted to evaluate the effect of dietary protein level on growth performance, body composition and feed use efficiency of blackspot seabream juveniles (22.7 g each). Five isolipidic diets (12.5%) with graded levels of protein (20, 30, 40, 50 and 60%) were hand-distributed, twice a day, to duplicate groups of fish (120 fish per tank), until satiation. Growth (DGC), survival and feed utilization (FCR) were recorded through monthly sampling. Growth performance was significantly affected by dietary protein level ($P<0,05$), and fish fed at the 50% protein level exhibited the highest final body weight. Feed conversion ratio decreased with increasing levels of dietary protein, fish fed 60% protein being the most efficient. No significant differences were found in whole body composition among treatments ($P>0,05$). Financed by FCT (Project POCTI/CVT/39239/2001, PhD Grant SFRH-BD-14068-2003)

A COMPARATIVE STUDY OF THE PERFORMANCE OF FAMILY GROUPS OF ATLANTIC SALMON REARED IN TANKS AND RELEASED IN A RIVER

Skilbrei, Ove T. and Wennevik, Vidar

Institute of Marine Research, POB 1870, N-5024 Bergen-Nordnes, Norway

A study was conducted in in the Dale River as a part of a stock enhancement programme. The aim was to compare growth and the incidence of precocious maturation between offspring from precocious and large maturing males, and to study genotype-environment interactions. River and hatchery performance was compared for 5 x 2 maternal half-sib family groups, which were stocked as 0+ juveniles or maintained in the hatchery throughout. To identify the offspring, the brood fish were characterized by DNA-fingerprinting (8 microsatellite markers). Smolt size of 1+ hatchery-reared smolt and fish caught in a smolt trap, and the size and incidence of precocious maturation among 1+ hatchery-reared parr and 1+ and`2+ parr caught in the river are compared between the families.

WHAT ARE THE REASONS OF THE PRUSSIAN CARP EXPANSION IN THE UPPER ELBE RIVER, CZECH REPUBLIC?

Slavík, Ondrej[1], Bartoš, Ludek[2], and Horký, Pavel [1]

[1]Water Research Institute, Podbabská 30, 160 62 Prague 6, Czech Republic

[2]Institute of Animal Production, Ethology Group, 104 00 Prague 10-Uhríneves, Czech Republic

Two theories of Prussian carp *Carassius auratus gibelio* (Bloch 1783) expansion into the rivers of the Czech Republic were tested: i) an escape from aquaculture facilities where the species was imported from East Europe together with the common carp *Cyprinus carpio*; ii) invasive expansion of migrating adults followed in conjunction with natural reproduction. Fifty-five Prussian carp were radio-tracked in the Elbe river over a 15 month period. Radio-tagged specimens originated from local populations, and two localities from Danube catchment. Downstream migration dominated during the whole study period, reaching the maximum distance of 85 km in spring. Migration ceased when fish found an inundation zone, where they occupied larger home ranges and showed higher behavioural variability when compared with the main stream. Upstream migrations were rare and did not exceed 2 km. No differences in migration were apparent between specimens from different localities. To further support these results, juvenile fish (0+) were sampled along a longitudinal profile of the Elbe river, and 15 fish ladders monitored. Juvenile Prussian carp accounted for only 0.11% of 5672 juveniles caught, and only one Prussian carp occurred in a sample of 10 382 fishes caught in fish ladders. These results suggest that upstream migration and natural reproduction in rivers does not represent the main mechanism of Prussian carp invasion into the Elbe catchment. Escapes of Prussian carp from aquaculture facilities are likely to be responsible.

NO EFFECT ON SURVIVAL AT SEA IN SECOND GENERATION AFTER OUTBREEDING OF COHO SALMON

Smoker, William[1], Wang, Ivan[1], Gharrett, Anthony[1], and Hard, Jeffrey[2]

[1]University of Alaska Fairbanks, Juneau Center, School of Fisheries & Ocean Sciences, 11120 Glacier Hwy, Juneau, AK 99801, USA

[2]US NOAA Fisheries, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097, USA

Outbreeding depression is recognized as a potential detriment to the fitness of populations of wild salmon which interbreed with populations of cultured salmon, particularly in the second generation after outbreeding. We hybridized three populations of coho salmon separated by over 300 km of coastline distance in 1997, released their offspring identified by coded wire tags in 1998, and created a second generation from returning adults in 2000 which was released as smolts with identifying tags in 2001 along with a new set of first-generation hybrid controls and a new set of parental controls. We cultured all freshwater life stages in a common research hatchery environment located at tidewater in Juneau, Alaska. We observed embryo mortality in offspring of parental control or hybrid matings made in 1997, i.e. offspring of 88 females and 67 males incubated in 469 replicate incubator cells. We observed 1738 returning adult salmon in 2003 in 15 groups. We detected no depression of embryonic survival or of marine survival of second-generation outbred groups as compared to parental controls and hybrid control groups. Heterogeneity among the groups of returning salmon ($p<0.05$) was related to the greater survival of one of the three parental control crosses, not to any survival advantage of controls compared to second generation outbred salmon. These observations contrast with other observations of depressed marine survival in outbred salmon in the second generation after hybridization.

LIFE HISTORY TRAITS OF THE COMMON PANDORA (*PAGELLUS ERYTHRINUS* LINNAEUS, 1758) INTERPRETED USING INFORMATION FROM AQUACULTURE EXPERIMENTS

Spedicato, M.T., Carbonara, P. And Lembo, G.

COISPA Tecnologia and Ricerca, Experimental Station for the Study of Marine Resources, Via dei Trulli 18-20, 70045 Bari-Torre a Mare, Italy.
E-mail: spedicato@coispa.it.

The common pandora Pagellus eythrinus is considered a promising species for Mediterranean aquaculture, due to its high market price and good reproduction in captive conditions. The aim of this paper is to clarify aspects of reproduction and growth in the common pandora, using data from both aquaculture studies and experimental fishing. Spawning time and behaviour, frequency of egg deposition, larval performance, growth of juveniles and adults and morphometric characteristics were studied in fish originating from a broodstock acclimatised to captivity since 1997. At the same time observations on length structure and other morphometric measures, age and patterns of sexual maturity were gathered from ten trawl-surveys between 1996 and 2002. The surveys were carried out in late spring and early autumn in the Central-Southern Tyrrhenian Sea, area where the breeders had been captured. Wild fish growth patterns were estimated using length frequency distribution analysis and age-based methods. The study showed that several micro-cohorts enter in the fishery over an extended period, and growth is faster than previously reported.

ECOLOGICAL MODEL OF INTERACTIONS BETWEEN ESCAPED AND WILD ATLANTIC SALMON (*SALMO SALAR*)

Stephens, Andi[1], and Cooper, Andrew B.[2]

[1]Ocean Sciences Ph.D. Program, Mangel Lab, Applied Math and Statistics, University of California Santa Cruz, Santa Cruz, CA 95060, USA

[2]College of Life Sciences and Agriculture, University of New Hampshire, Taylor Hall, Durham, NH 03824, USA

Atlantic salmon in Maine were once abundant but have become depleted, and are listed as endangered under the federal Endangered Species Act. Historically, salmon numbers in Maine may have been as high as 100,000 adults, but habitat loss, pollution and overfishing have contributed to the decline of the species. In 2000, only 110 adults returned to spawn in Maine rivers. Maine produces about 15,000 metric tons/year of aquacultured Atlantic salmon from a total of nearly 600 coastal net pens. Escapees from these pens may interact with the wild salmon. The dynamics of salmon populations under such conditions are poorly understood. In order to illuminate the role aquaculture may play in such a system, we have developed a model for simulating population trajectories for both wild salmon and competing populations derived from aquaculture escapes. The model simulates a small population of wild salmon based in a stream/estuary system, into which an aquaculture facility is losing fish to escapes. Biological parameters in the model were estimated as much as possible from data in the USFWS report on Maine salmon. We used the model to investigate the consequences of a variety of ecological interactions between the wild and cultured fish including competitive, genetic and disease effects. Initial results indicate that many of these effects allow the aquaculture-derived population to supplant the wild fish, but that wild populations may still persist under some conditions.

WHY DO SOME FISH DO IT YOUNGER THAN OTHERS? LEARNING FROM EXPERIMENTS.

Suquet, Marc[1], Rochet, Marie-Joëlle[2] and Gaignon, Jean Louis[1]

[1]Laboratoire Adaptation - Reproduction - Nutrition, IFREMER, BP 70, 29280 Plouzané, France
E-mail: Marc.Suquet@ifremer.fr and Jean.Louis.Gaignon@ifremer.fr

[2]Laboratoire MAERHA, IFREMER, B.P. 21105, 44311 Nantes Cedex 03, France
E-mail: Marie.Joelle.Rochet@ifremer.fr

Reproductive traits of fish such as age at first maturation or fecundity are not fixed: there is growing evidence that they change through time under the influence of various environmental factors, including fishing. Because these parameters are important in determining population dynamics, a better understanding of these changes is important to fisheries stock assessment. However, field studies are often inconclusive with respect to the ultimate causes of a given change. Although numerous experimental studies have been assessed the influence of environmental factors such as temperature on the reproduction in fish, these generally focus on single factors and do not consider the effects of the origin and individual history of experimental fish. There is scope for the development of ecological experiments to investigate the effects of interacting environmental factors on reproduction at the individual and population levels. This presentation will review experiments that could be used to predict environmental influences in the wild and the limits to such extrapolations. Finally, we will present a set of experiments designed to study maturation reaction norms in fish, i.e. the size at first reproduction as a function of age. We will investigate the effects of genotypes and environmental effects (feeding and temperature) on growth, age at maturity and subsequent spawning performances in reared cohorts.

COMPARISON OF THE GROWTH AND CONDITION OF CULTURED BARBEL *BARBUS BARBUS* (L.) INTRODUCED INTO STILLWATER CATCH AND RELEASE FISHERIES WITH WILD BARBEL IN RIVERINE HABITATS

Taylor, Ayesha[1], Britton, J. Robert[2], Cowx, Ian. G[3] and Axford, Stephen A[4]

[1]National Fisheries Technical Team, Environment Agency, Richard Fairclough House, Knutsford Road, Latchford, Warrington, Cheshire WA4 1HG, UK
Email: ayesha.taylor@environment-agency.gov.uk; Tel: 01925 415 961

[2]National Fisheries Laboratory, Environment Agency, Bromholme Lane, Brampton, Huntingdon, Cambridgeshire PE28 4NE, UK

[3]The University of Hull, International Fisheries Institute, Cottingham Road, Hull HU6 7RX, UK

[4]National Fisheries Technical Team, Environment Agency, Coverdale House, Aviator Court, Amy Johnson Way, Clifton Moor, York YO30 4UZ, UK

The preferred habitat of the Barbel *Barbus barbus* (L.) are rivers characterised by moderate to strong flow, high oxygen concentration and a substrate of sand, gravel and rocks. However, a trend in England and Wales during the past decade has been for barbel to be introduced into small (<1 ha.), landlocked lakes in order to provide increased angling opportunities for the species. In general, these introductions are of cultured barbel at lengths of 120 to 180mm and at 1 to 2 years old. Using case studies from catch and release lake fisheries which have received introductions of cultured barbel, comparative growth and condition studies between the lacustrine barbel and barbel sampled from rivers across England between 2001 and 2003 were completed. Outputs were related to factors including the contrasting habitats of the lacustrine and fluvial environments and differences in diet composition. As the cultured barbel were introduced into the lakes at a known age on a known date, scale ageing validation was completed by comparing estimated age to actual age. Scales taken from barbel of age 1+ and 2+ that were still on the culture site were used to reveal potential sources of ageing error. The outputs were discussed in relation to the widespread practice of enhancing wild riverine fish populations in England and Wales by stocking with cultured cyprinids.

LIFE HISTORY RESPONSES OF FISHES TO CULTURE

Thorpe, John E.

Institute of Biomedical & Life Sciences, University of Glasgow, Glasgow G12 8QQ, UK

The genetic responses of animals, through physiological mechanisms, to external and internal environmental signals, determine their patterns of life history. Culture simplifies the range of environmental signals to which animals are exposed, and permits the cultivator to manipulate those animals as physiological machines for high growth rate or gamete production. Genetic modification enables further variations on these environmentally achieved possibilities. For a given genotype, increased energy intake relative to wild stocks, through increased food availability and enhanced quality, leads usually to accelerated development, and so to shortened life-cycles. This has both advantages and disadvantages in culture. It permits higher turnover of material, but in fishes, as reproduction has developmental precedence over somatic growth, accelerated processes may lead to early maturity at uneconomically small sizes. So fish culture requires deceleration techniques at critical seasons to overcome this life-history response. Also, in culture-based conservation, shortened life-cycles imply simplified population age structures, and potentially reduced ecological stability. In species with strongly environmentally determined sex, accelerated development distorts sex ratios. Examples contrasting wild and cultured populations will be drawn from a range of fish species.

HERITABILITY OF PRECOCIOUS MATURATION, SMOLTING AND GROWTH IN ANADROMOUS AND DERIVED FRESHWATER POPULATIONS OF STEELHEAD (*ONCORHYNCHUS MYKISS*)

Thrower, Frank[1], Hard, Jeff[2] and Joyce, John[1]

[1]National Marine Fisheries Service, Alaska Fisheries Science Center/Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, Alaska 99801, USA

[2]National Marine Fisheries Service, Northwest Fisheries Science Center, Conservation Biology Division, 2725 Montlake Boulevard East, Seattle, Washington 98112, USA

Wild juvenile anadromous steelhead captured from Sashin Creek, Alaska were planted above a barrier falls into Sashin Lake in the 1920s. In 1996 and 1997, descendants of these fish were captured and spawned to create 75 families of pure resident, pure anadromous and reciprocal hybrid crosses. The yearling progeny (approximately 100 per family) were tagged with passive integrated transponder tags and combined by line in common freshwater rearing containers until age two. At age two, fish were graded into three categories: mature, smolt, or rearing (undifferentiated). Heritabilities of early male maturity and smolting were high (0.5 and 0.77 respectively) while heritability of growth was moderate (.45) and the genetic correlation between growth and smolting was low (0.02). Early male maturity and smolting were highly variable within and among crosses. All four cross types produced significant numbers of smolts at age two. The high heritability of smolting, coupled with the inability of smolts that leave the lake to return to it, indicates that the genetic mechanism for smolting can lie dormant and maintain high heritability for decades. The results have significant implications for the preservation of threatened anadromous stocks in freshwater and the legal status as it relates to the Endangered Species Act of formerly anadromous populations currently trapped behind long-standing barriers to migration.

POPULATION GENETICS, CONSERVATION AND EVOLUTION IN SALMONIDS AND OTHER WIDELY CULTURED FISHES: SOME PERSPECTIVES OVER SIX DECADES

Utter, Fred

School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195 USA

This paper explores my shifting understandings of interactions primarily between salmonid fish culture and fish conservation during the latter half of the 20th century. The idea that conspecific natural and cultured fish were largely interchangeable among phenotypically similar populations began to change with the advent of molecular genetic markers. With the gradual clarification of major geographic lineages beginning in the 1970s came awareness that translocations among anadromous lineages were generally destined for failure; in contrast, gene flow more readily occurred among non-anadromous lineages and sometimes, species. Concurrently, data were accumulating that adaptations to their respective environments distinguished cultured and wild populations within a lineage. Reduced obstacles to gene flow at this level often resulted in homogenizations among wild and cultured fish in areas where widespread hatchery releases occurred; conversely, adaptive radiations in vacant habitats sometimes occurred over a few decades from single source hatchery releases. Current ideas relating to salmonid interbreeding, population substructure and culture germinated from these observations. Among lineages, resistance to gene flow is much greater between anadromous than purely freshwater populations or species. Ease of within-lineage gene flow in both groups is problematical with regard to cultured and wild populations because large-scale supplementation programs erode local adaptations and fine-scale population substructures. A potential ability to regenerate natural substructure upon relaxation of supplementation is offset by uncertainties of time scales and intrinsic capabilities homogenized populations. However these losses can be minimized by a management that separates harvest and reproduction of wild and cultured subpopulations. Some generality of this strategy to other fishes is supported by losses of local adaptations and outbreeding depression in black basses following population admixtures that parallel those observed in salmonids.

EFFICIENCY OF ALLELE FREQUENCY-BASED BAYESIAN PROGRAMMES FOR DETECTING HYBRIDIZATION BETWEEN FARMED AND WILD SALMON

Vähä, Juha-Pekka K. and Primmer, Craig R.

Department of Ecology and Systematics, P.O. Box 65, University of Helsinki, FIN-00014 Helsinki, Finland

Large escapes of cultured salmon from net-pens have become inevitable disasters linked to the growth of aquaculture in coastal areas. Hybridization between farmed and wild salmon has been witnessed; but the extent of eventual genetic introgression is controversial as selection against hybrids can maintain distinct gene pools. Individual assignment tests based on genetic data have been widely used in fisheries, due to the importance of accurate population assignment for a variety of purposes including distinction between individuals of native and stocked origin. However the ability of these Bayesian programs to detect hybrids and subsequent generations between closely related populations has been little investigated. Here we present results regarding the efficiency of two new computer programs, *structure* and *New Hybrids* in detecting hybridization between farmed and wild salmon from the river Teno (Northern Europe) based on genetic data obtained from 17 microsatellite loci.

THE CALPASTATIN/CALPAIN SYSTEM IN TROUT *SALMO TRUTTA TRUTTA* MUSCLE

Varricchio, E.[1], Rubino, T.[1], Paino, S.[1], Di Lascio, T.[1], Paciello, O.[2] and Langella, M. [1]

[1]Department of Animal Production Sciences, University of Basilicata, Potenza, Italy

[2]Department of Pathology and Animal Health, University of Naples “Federico II”, Naples, Italy

Many recent reports suggest that the calpastatin/calpain system plays a role in cellular growth and differentiation. Defects of the calpastatin/calpain system have been linked to cellular dysfunctions, apoptosis, myocardial infarct, and dystrophies. The calpastatin/calpain system has also been implicated in postmortem tenderization of skeletal muscle through degradation of key myofibrillar and associated proteins, a process of key importance to meat quality. In the present study we investigate the presence and activity of the calpastatin/calpain system in trout muscle samples, collected at 0, 3, 18 and 28 hours post mortem, by immunohistochemistry method. Calpastatin is a specific endogenous enzyme of cytosol, modulating the ubiquitous calpains. Calpastatin was found in samples obtained in vivo and immediately post mortem, but its concentration declined rapidly in samples obtained 3, 18 and 28hours post mortem. The ubiquitous m e m-calpains, which are localized on Z line proteins and activated by intracellular Ca^{2+} increase, showed a rapid decline within 3 hours post mortem. By contrast p94 calpain, which is specific to skeletal muscle, showed a slow decrease post mortem which was independent of intracellular Ca^{2+} increase. Our results suggest that the mechanism of activation and activity of the calpastatin/calpain system in trout is similar to that described in mammals.

COMPENSATORY RELEASES REDUCE GENETIC DIFFERENTIATION AMONG ATLANTIC SALMON POPULATIONS IN THE BALTIC SEA: EVIDENCE FROM THE RIVER UME-VINDELÄLVEN

Vasemägi, Anti

Swedish University of Agricultural Sciences, Department of Aquaculture, S-901 83 Umeå, Sweden

About 90% of salmon smolts in the Baltic Sea derive from hatchery enhancement programmes designed to compensate for loss of catches and genetic resources due to the damming of salmon rivers. The potential threat of genetic homogenization from extensive hatchery releases, however, has not been thoroughly investigated. We provide evidence that straying from deliberate releases poses a threat to indigenous populations by identifying the origin of 127 fin-clipped (hatchery) salmon caught in the River Ume-Vindelälven during 1997 to 2000, using mtDNA and six microsatellite loci. The analysis of eight potential donor stocks revealed that compensatory releases from the R. Ångerman and R. Luleälven hatcheries have resulted in a significant amount of straying to the river Ume-Vindelälven (at least 10 and 12 migrants per year). As predicted to due to increased migration, the analysis of temporal samples from the wild population of R. Vindelälven showed a decreasing trend in genetic differentiation estimates (measured as F_{st}) relative to hatchery the hatchery strains of R. Ångermanälven and R. Luleälven. Our results suggest that gene flow from compensatory releases poses a serious threat to the genetic makeup of the existing wild populations in the Baltic.

DOMESTICATION AND ABSOLUTE OWNERSHIP OF FISH IN THE ENGLISH COMMON LAW

Walrut, Bernard P, 43 Wright Street, Adelaide, SA 5000, Australia
E-mail: bwalrut@bpwc.biz

The English common law has, for the purpose of describing the rights of ownership of animals, divided them into two classes, those the subject of absolute ownership and those the subject of a limited property right. In this system, fish have long been regarded as the subject of a limited property right, one dependent on possession.
The principles underlying those concepts follow the Roman law concepts applicable to the proprietorship of animals and adopted in much of Europe. Those principles were further developed and adapted over many centuries in England, but more significantly in the common law countries outside of England, over the last century. They are principles that have a limited relationship to domestication. Drawing on the recent decisions outside of England it is possible to refashion the commonly presented tests as to the absolute ownership of animals. Based on those decisions, it may be asserted, that a person may absolutely own an animal that is a member of a population of animals that have had a long association with humans, or are exploited by a community in a recognised manner, other than by hunting. When applied to fish, particularly those from stock enhancement, sea ranching and aquaculture escapes, those principles raise a number of questions. Does the aquaculturist remain the owner of the fish that have escaped? Is it possible to retain ownership of stock enhancements and sea ranched fish? In some cases they may also raise an issue as to the liability for those fish at large.

HATCHING TIME AS AN INDICATOR OF ENVIRONMENTAL INCOMPATIBILITY AND OUTBREEDING DEPRESSION IN INTRASPECIFIC SALMON HYBRIDS

Wang, Ivan A., Smoker, William.W., Gilk, Sara.E., Oxman, Dion.S., and Gharrett, Anthony J.

University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, 11120 Glacier Hwy, Juneau, AK 99801, USA

We analyzed hatching times of hybrids between two spatially separated pink salmon (*Oncorhynchus gorbuscha*) populations. We repeated the experiment in independent even- and odd-year broodlines. In 1996 and in 1997, we made F1 hybrids from Auke Creek (Juneau, Alaska) females and Pillar Creek (Kodiak, 1000 km away) males and F1 controls from Auke Creek parents. Families were reared and released at Auke Creek. F2 hybrids, controls, and backcrosses were made from F1 returns in 1998 and 1999. In 2001, we made F1 hybrids at Pillar Creek with native females and Auke Creek males. Pillar Creek ancestry prolonged development: At Auke Creek, hybrid families (half Pillar Creek ancestry) developed more slowly (more Accumulated Temperature Units between fertilization and hatch; $p < 0.0001$) than did controls (only Auke Creek ancestry). At Pillar Creek, families with only Pillar Creek ancestry developed more slowly than did hybrids with half Auke Creek ancestry. Development times of backcrosses were intermediate between those of hybrids and controls. The variation in development times between Auke Creek and Pillar Creek pink salmon has a genetic component that probably results from local adaptation and illustrates a mechanism that can lead to outbreeding depression in intercrosses between salmon populations (e.g., occurring between wild and translocated stocks).

Names and Addresses of Participants

Dr Ira **Adelman**, American Fisheries Society, 144 S. Mississippi River Blvd., St. Paul, MN 55105, USA
Tel: +1 512 624 4228; Fax: +1 612 625 5299; E-mail: ira@umn.edu

Miss Jennifer **Adrah**, Department of Biological Sciences, Kwame Nkrumah University of Science & Technology, Kumasi, Ghana
Tel: +233 208 161399; E-mail: jennystarblue@yahoo.com

Mr Emmanuel **Afful**, Department of Biological Sciences, Kwame Nkrumah University of Science & Technology, Kumasi, Ghana
Tel: +233 208 179523; E-mail: stengoj@yahoo.com

Mr Ricardo **Almuly**, Israel Oceanographic & Limnological Research, Tel Shikmona, POB 8030, Haifa 31080, Israel
Tel: +972 4 856 5274; Fax: +972 4 851 1911; E-mail: ricardo@ocean.org.il

Mr Kwaku **Antwi-Frempong**, Department of Biological Sciences, Kwame Nkrumah University of Science & Technology, Kumasi, Ghana
Tel: +233 208 113456; E-mail: kwaku_af@yahoo.co.uk

Rosa Maria **Araguas Sola**, Laboratori d'Ictiologia Genètica, University of Girona, Campus Montilivi s/n, E-17071 Girona, Spain
Tel: +34 972 41 81 68; Fax: +34 972 41 82 77; E-mail: rosa.araguas@udg.es

Dr John **Armstrong**, Fisheries Research Services, Freshwater Laboratory, Faskally, Pitlochry, Perthshire PH16 5LB, UK
Tel: +44 (0)1224 294418; Fax: +44 (0)1796 473523; E-mail: j.armstrong@marlab.ac.uk

Mr Jan **Baer**, Fisheries Research Station Baden-Württemberg, Untere Seestrasse 81, 880885 Langenargen, Germany
Tel: +49 7543 930814; Fax: +49 7543 930820; E-mail: Jan.Baer@LVVG.BWL.de

Miss Claire **Bale**, Cardiff School of Biosciences, Cardiff University, P.O. Box 915, Main Building, Museum Avenue, Cardiff CF10 3TL, UK
Tel: +44 (0)2920 876907; E-mail: balecl@cardiff.ac.uk

Mr Nigel **Balmforth**, Blackwell Publishing, 9600 Garsington Road, Oxford, OX4 2DQ, UK
Tel: +44 (0)20 8367 5387; Fax: +44 (0)20 8367 5387;
E-mail: nigel.balmforth@oxon.blackwellpublishing.com

Professor Eugene **Balon**, University of Guelph, R.R. # 3, Rockwood, Ontario N0B 2K0, Canada
Tel: +1 419 843 2570; E-mail: ebalon@uoguelph.ca

Dr Marie-Laure **Begout Anras**, CNRS CREMA L'Houmeau, Place du Séminaire, B.P.5, 17137 L'Houmeau, France
Tel: +33 5 46 50 06 95; Fax: +33 5 46 50 06 00; E-mail: mlbegout@ifremer.fr

Dr Malcolm **Beveridge**, FRS Freshwater Laboratory, Faskally, Pitlochry, Perthshire PH16 5LB, UK
Tel: +44 (0)1224 294410; Fax: +44 (0)1796 473523; E-mail: m.beveridge@marlab.ac.uk

Mrs Kathleen **Beyer**, CEH Dorset, Winfrith Technology Centre, Winfrith Newburgh, Dorchester, Dorset DT2 8ZD, UK
Tel: +44 (0)1305 213572; Fax: +44 (0)1305 213600; E-mail: kabe@ceh.ac.uk

Ms Elizabeth **Black**, Environment Agency, Ghyll Mount, Gillian Way, Penrith 40 Business Park, Penrith CA11 9BP, UK
Tel: +44 (0)8708 506506; Fax: +44 (0)01768 865606; E-mail: liz.black@environment-agency.gov.uk

Dr Randall **Brummett**, WorldFish Center, BP 2008 (Messa), Yaounde, Cameroon
Tel: +237 988 0200; E-mail: r.brummett@cgiar.org

Dr John **Burke**, NOAA Laboratory, Center for Coastal Fisheries and Habitat Research, 101 Pivers Island Road, Beaufort, NC 28516, USA
Tel: +1 252 729 8602; Fax: +1 252 729 8784; E-mail: john.burke@noaa.gov

Mr Jonathan **Carr**, Atlantic Salmon Federation, P.O. Box 5200, St. Andrews, New Brunswick E5B 3S8, Canada
Tel: +1 506 529 1385; Fax: +1 506 529 4985; E-mail: jonwcarr@nbnet.nb.ca

Mr Ravi **Chatterji**, The Game Conservancy Trust, 11 Burford Road, Salisbury, Wiltshire SP2 8AN, UK
Tel: +44 07718 480025; E-mail: rchatterji@gct.org.uk

Dr Prof Mikhall **Chebanov**, Krasnodar Research Institute of Fisheries, 12 Oktyabrskaya St, Krasnodar, 350063, Russia
Tel: +7 8612 62 25 59; Fax: +7 8612 62 27 07; E-mail: Chebanov@sturg.kuban.ru

Dr Deirdre **Cotter**, Marine Institute, Furnace, Newport, Co Mayo, Ireland
Tel: +353 98 42300; Fax: +353 98 41112; E-mail: deirdre.cotter@marine.ie

Mr Stephen **Cotterell**, School of Earth, Ocean and Environmental Science, University of Plymouth, Drake Circus, Plymouth PL4 9PY, UK
Tel: +44 (0)1752 232411; Fax: +44 (0)1752 232407; E-mail: scotterell@plymouth.ac.uk

Dr John **Craig**, Journal of Fish Biology, Whiteside, Dunscore, Dumfries, , DG2 0UU, UK
Tel: +44 (0)1287 820860; Fax: +44 (0)1287 820860; E-mail: journal.fishbiology@btopenworld.com

Mrs Hilary **Craig**, Journal of Fish Biology,Whiteside, Dunscore, Dumfries, , DG2 0UU, UK
Tel: +44 (0)1287 820860; Fax: +44 (0)1287 820860; E-mail: journal.fishbiology@btopenworld.com

Mr Matthieu **Duchemin**, Institut Universitaire Européen de la Mer (IUEM) - LEMAR, Place Nicolas Copernic, Technopôle Brest-Iroise, Plouzane, 29280, France
Tel: +33 (0)29 84 98 677; Fax: +33 (0)29 84 98 645; E-mail: matthieu.duchemin@univ-brest.fr

Professor Brian **Eddy**, Faculty of Life Sciences, University of Dundee, University of Dundee, Scotland DD1 4HN, UK
Tel: +44 (0)1382 344292; E-mail: F.B.Eddy@dundee.ac.uk

Mrs Tricia **Ellis-Evans**, Symposium Administrator, Pace Projects, 65 High Street, Toft, Cambridgeshire, CB3 7RL, UK
Tel: +44 (0)1223 263477; Fax: +44 (0)1223 264663; E-mail: tricia@paceprojects.co.uk

Dr Eva **Enders**, Département de Sciences Biologiques, Université de Montréal, C.P.6128, Succursale Centre Ville, Montréal, QC H3C 3J7, Canada
Tel: +1 514 343 8037; Fax: +1 514 343 2293; E-mail: eva.enders@umontreal.ca

Dr Inigo **Everson**, Environmental Sciences Research Centre, Department of Life Sciences, Anglia Polytechnic University, East Road, Cambridge CB1 1PT, UK
Tel: +44 (0)1223 363271 x2805; Fax: +44 (0)1223 417712; E-mail: i.everson@apu.ac.uk

Dr Elizabeth **Fairchild**, Department of Zoology, University of New Hampshire, 46 College Road, Spaulding Hall, Durham NH 03824, USA
Tel: +1 603 433 1290; Fax: +1 603 862 3784; E-mail: elizabeth.fairchild@unh.edu

Professor Andy **Ferguson**, School of Biology & Biochemistry, Queen's University Belfast, MBC97 Lisburn Road, Belfast, N. Ireland BT9 7BL, UK
Tel: +44 (0)28 9094 2024; E-mail: a.ferguson@qub.ac.uk

Dr Ian **Fleming**, Ocean Sciences Centre, Memorial University of Newfoundland, St. John's, Newfoundland, A1C 5S7, Canada
Tel: +1 709 737 3586; Fax: +1 709 737 3220; E-mail: ifleming@mun.cas

Dr Bruria **Funkenstein**, Israel Oceanographic & Limnological Research, POB 8030, Tel-Shikmona, Haifa, Israel
Tel: +972 4 8565233; Fax: +972 4 8511911; E-mail: bruria@ocean.org.il

Mr Willliam **Gale**, US-FWS Abernathy Fish Technology Center, 1440 Abernathy Creek Road, Longview, WA 98632, USA
Tel: +1 360 425 6072; Fax: +1 360 636 1855; E-mail: tempete@ecosip.com

Dr Elena **Galich**, Krasnodar Research Institute of Fisheries, 12 Oktyabrskaya St, Krasnodar, 350063, Russia
Tel: +7 8612 62 25 59; Fax: +7 8612 62 27 07; E-mail: Chebanov@sturg.kuban.ru

Carlos **García de Leániz**, Centro Ictiológico de Arredondo, 39813 Arredondo, Cantabria, Spain

Dr José Luis **García-Marín**, Laboratori d'Ictiologia Genètica, University of Girona, Campus Montilivi s/n, E-17071 Girona, Spain
Tel: +34 972 41 89 61; E-mail: joseluis.garcia@udg.es

Mr Vyron **Georgalas**, Dipartimento di Scienze Ambientali, Universita Ca' Foscari di Venezia, Campo della Celestia, Castello 2737/b, Venezia 30122, Italy
Tel: +39 041 234 7748; Fax: +39 041 528 1494; E-mail: bgeorgalas@virgilio.it

Dr Robin **Gibson**, Dunstaffnage Marine Laboratory, Oban, Argyll, PA37 1QA, UK
Tel: +44 (0)1631 559239; Fax: +44 (0)1631 559001; E-mail: Robin.Gibson@sams.ac.uk

Dr Jim **Gilliam**, Department of Zoology, North Carolina State University, 2112 N. Gardner Hall, Raleigh, NC 27695-7617, USA
Tel: +1 919 515 5978; Fax: +1 919 515 1801; E-mail: james_gilliam@ncsu.edu

Dr Sian **Griffiths**, Cardiff School of Biosciences, Cardiff University, P.O. Box 915, Cardiff CF10 3TL, UK
Tel: +44 (0)2920 876422; Fax: +44 (0)2920 874305; E-mail: GriffithsSW@cardiff.ac.uk

Dr Jeffrey **Hard**, Northwest Fisheries Science Centre, Conservation Biology Division, 2725 Montlake Boulevard East, Seattle, Washington 98112, USA
Tel: +1 206 860 3275; Fax: +1 206 860 3335; E-mail: jeff.hard@noaa.gov

Mr Bill **Harrower**, BC Government Access Centre, Ministry of Agriculture, Food and Fisheries, 2500 Cliffe Avenue, Courtenay, BC V9N 5M6, Canada
Tel: +1 250 897 7547; Fax: +1 250 334 1410; E-mail: Bill.harrower@gems9.gov.bc.ca

Dr Paul **Hart**, Department of Biology, University of Leicester LE1 7RH, UK
Tel: +44 (0)116 252 3348; Fax: +44 (0)116 252 3330; E-mail: pbh@le.ac.uk

Miss Lorraine **Hawkins**, Division of Environmental & Evolutionary Biology, Gatty Marine Laboratory, University of St Andrews, St Andrews, Fife KY16 8LB, UK
E-mail: pippabox@hotmail.com

Dr Sean **Hayes**, NOAA Fisheries, Santa Cruz Laboratory, 110 Shaffer Road, Santa Cruz, CA 95060, USA
Tel: +1 831 420 3937; Fax: +1 831 420 3977; E-mail: sean.hayes@noaa.gov

Dr Heikki **Hirvonen**, Dept of Biological and Environmental Sciences, PO Box 65, University of Helsinki, FIN-00014 Helsinki, Finland
Tel: +358 9 1915 7729; Fax: +358 9 1915 7694; E-mail: heikki.hirvonen@helsinki.fi

Ms Kathrine **Holten**, VESO Trondheim, Tungasletta 2, NO-7485 Trondheim, Norway
Tel: +47 7358 0746; Fax: +47 7358 0788; E-mail: kathrine.holten@veso.no

Dr Hunt **Howell**, Department of Zoology, University of New Hampshire, Spaulding Life Sciences Building, Durham, New Hampshire 03824, USA
Tel: +1 603 862 2109; Fax: +1 603 862 3784; E-mail: whh@cisunix.unh.edu

Dr Sophie **Hubert**, National Diagnostic Center, Galway, Ireland
Tel: +353 91 52 44 11 ext 2816; E-mail: sophie.herbert@nuigalway.ie

Professor Felicity **Huntingford**, University of Glasgow, Graham Kerr Building, University Avenue, Glasgow G12 8QQ, UK
Tel: +44 (0)141 330 5975; Fax: +44 (0)141 330 5971; E-mail: F.Huntingford@bio.gla.ac.uk

Professor Jeffrey **Hutchings**, Department of Biology, Dalhousie University, 1355 Oxford Street, Halifax, Nova Scotia B3H 4J1, Canada
Tel: +1 902 494 2687; Fax: +1 902 494 3736; E-mail: Jeff.Hutchings@Dal.ca

Dr Enrico **Ingle**, Istituto Zooprofilattico Sperimentale delle Regioni Lazio e Toscana, Via Appia Nuova 1411, Rome, Italy
Tel: +39 67 909 9312; Fax: +39 67 934 0157; E-mail: eingle@rm.izs.it

Dr Asiful **Islam**, Kazan Institute of Biochemistry and Biophysics, Russian Academy of Science, 420111 Kazan, Russia

Mr Ivan **Jaric**, Center for Multidisiplinary Studies, Belgrade University, Kneza Viseslava 1a, 11030 Belgrade, Serbia and Montenegro
Tel: +381 11 2078 475; Fax: +381 11 3055 289; E-mail: ijaric@ibiss.bg.ac.yu

Mr Knut **Jørstad**, Institute of Marine Research, P.O. Box 1870, Nordnes, 5817 Bergen, Norway
Tel: +47 55 236347; Fax: +47 55 6379; E-mail: knut.joerstad@imr.no

Mr John **Joyce**, U.S. National Marine Fisheries Services, Alaska Fisheries Center, P.O. Box 210081, Auke Bay, Alaska 99821, USA
Tel: +1 907 789 6618; Fax: +1 907 789 6094; E-mail: john.joyce@noaa.gov

Mr Zbigniew **Kaczkowski**, Department of Applied Ecology, University of Lodz, ul Banacha 12/16, Lodz, 90-237, Poland
Tel: +48 42635 4438; Fax: +48 42665 5819; E-mail: kaczko@biol.uni.lodz.pl

Miss Sandra **Krah**, Department of Biological Sciences, Kwame Nkrumah University of Science & Technology, Kumasi, Ghana
Tel: +233 244 536790; E-mail: agyeiwaa20@hotmail.com

Miss Pearl **Krah**, Department of Biological Sciences, Kwame Nkrumah University of Science & Technology, Kumasi, Ghana
Tel: +233 244 776241; E-mail: boadiwaa@blackplanet.com

Dr Ewa **Kulczykowska**, Department of Genetics and Marine Biotechnology, Institute of Oceanology Polish Academy of Sciences, sw. Wojciecha 5 Str, 81-347 Gdynia, Poland
Tel: +48 58 6208913; Fax: +48 58 6201233; E-mail: ekulczykowska@iopan.gda

Dr Marek **Kulczykowski**, Department of Genetics and Marine Biotechnology, Institute of Oceanology Polish Academy of Sciences, sw. Wojciecha 5 Str, 81-347 Gdynia, Poland
Tel: +48 58 6208913; Fax: +48 58 6201233; E-mail: marek@ibwpan.gda.pl

Professor Michele **Langella**, Università degli Studi della Basilicata, Via dell'Ateneo 10, 85100 Potenza, Italy
Tel: +39 971 206262; Fax: +39 971 205099

Dr Kai **Lorenzen**, Department of Environmental Science & Technology, Imperial College London, Prince Consort Road, London SW7 2BP, UK
Tel: +44 (0)20 7594 9312; Fax: +44 (0)20 7589 5319; E-mail: k.lorenzen@imperial.ac.uk

Mr Guillaume **Mairesse**, Laboratoire de Sciences Animales, Université Henri Poincaré, 34 rue Sainte Catherine, 54000 Nancy, France
Tel: +33 3 83 30 28 41; Fax: +33 3 83 32 36 13; E-mail: Guillaume.Mairesse@lsa-man.uhp-nancy.fr

Dr Stefano **Malavasi**, Dipartimento Scienze Ambientali, Universita Ca' Foscari di Venezia, Campo della Celestia Castello 2737/B, Venezia 30122, Italy
Tel: +39 041 2347740; Fax: +39 41 5281494; E-mail: mala@unive.it

Professor Marc **Mangel**, Center for Stock Assessment Research, Department of Applied Mathematics and Statistics, University of California, Santa Cruz, CA 95064, USA
Tel: +1 831 234 2970; Fax: +1 831 688 6879; E-mail: msmangel@ucsc.edu

Mr Derek **Marbell**, Department of Biological Sciences, Kwame Nkrumah University of Science & Technology, Kumasi, Ghana
Tel: +233 208 153716; E-mail: marbell020@yahoo.com

Dr Valeria **Micale**, Istituto per l'Ambiente Marino Costiero, CNR, Spianata S. Raineri 86, 98122 Messina, Italy
Tel: +39 90 669003; Fax: +39 90 669007; E-mail: micale@ist.me.cnr.it

Professor Ugo **Muglia**, Dipartimento di Morfologia, Biochimica, Fisiologia e Produzioni Animali, Facoltà di Medicina Veterinaria, Università di Messina, Polo Universitario dell'Annunziata, 98168 Messina, Italy
Tel: +39 90 356607; Fax: +39 90 355246; E-mail: ugo.muglia@unime.it

Mr Michael **New**, 25 Institute Road, Marlow, Buckinghmshire SL7 1BJ, UK
Tel: +44 (0)1628 485631; E-mail: Michael_New@compuserve.com

Dr Keith **Nislow**, USDA Forest Service Northeastern Research Station, 201 Holdsworth Natural Resource Center, University of Massachusetts, Amherst, MA 01003, USA
Tel: +1 413 545 1765; Fax: +1 413 545 1860; E-mail: knislow@fs.fed.us

Mr James **Orpwood**, Cardiff School of Biosciences, Cardiff University Main Building, PO Box 915, Cardiff CF10 3TL, UK
Tel: +44 (0)2920 876907; Fax: +44 (0)2920 874305; E-mail: OrpwoodJEC@Cardiff.ac.uk

Miss Elizabeth **Osborne**, Scottish Association for Marine Science, 20 Donich Park, Lochgoilhead, Argyll, Scotland PA24 8AB, UK
Tel: +44 (0)1301 703 137; E-mail: elos@sams.ac.uk

Dr Costas **Papaconstantinou**, Hellenic Centre for Marine Research, Institute of Marine Biological Resources, Agios Kosmas, 11604 Hellinikon, Greece
Tel: +30 210 982 1354; Fax: +30 210 981 1713; E-mail: pap@ncmr.gr

Dr Paula **Paulo Videira da Silva**, Laboratório de Histologia e Embriologia, Instituto de Ciências Biomédicas Abel Salazar, Largo Prof. Abel Salazar, No. 2, 4099-003 Porto, Portugal
Tel: +351 222 062 220; Fax: +351 222 062 200; E-mail: psilva@icbas.up.pt

Mr Helge **Paulsen**, Danish Institute for Fisheries Research, North Sea Centre, PO Box 101, DK-9850 Hirtshals, Denmark
Tel: +45 33 96 32 11; Fax: +45 33 96 32 60; E-mail: hep@dfu.min.dk

Dr Edmund **Peeler**, Centre for Environment, Fisheries & Aquaculture Science, Barrack Road, The Nothe, Weymouth DT4 8UB, UK
Tel: +44 (0)1305 206719; Fax: +44 (0)1305 206627; E-mail: e.j.peeler@cefas.co.uk

Dr Josep Marti **Pujolar**, Katholieke Universiteit Leuven, Deberiotstraat 32, B3000 Leuven, Belgium
Tel: +32 16 32 39 66; Fax: +32 16 32 45 75; E-mail: marti.pujolar@bio.kuleuven.ac.be

Mr Nick **Read**, British Trout Association, Bow Business Centre, London E3 2SE, UK
Tel: +44 (0)7957 144028; E-mail: n.read@btinternet.com

Mr Andy **Reid**, Hydrosphere UK Ltd, Units C & D, West End Centre, Upper Froyle, Hampshire GU34 4JR, UK
Tel: +44 (0)1420 520374; Fax: +44 (0)1420 520373; E-mail: email@hydrosphere.co.uk

Dr Anthea **Rowlerson**, Applied Biomedical Research Group, Shepherd's House 4.2, GKT School of Biochemical Sciences, Guy's Campus, London Bridge, London SE1 1UL, UK
Tel: +44 (0)207 848 6292; Fax: +44 (0)207 848 6292; E-mail: anthea.rowlerson@kcl.ac.uk

Ms Annamari **Salonen**, Department of Biological and Environmental Sciences, University of Helsinki, P.O. Box 65, FIN-00014 Helsinki, Finland
Tel: +358 9191 57694; E-mail: annamari.salonen@helsinki.fi

Núria **Sanz Ball-Llosera**, Department of Biology, University of Girona, Campus Montilivi Sn, E-17071 Girona, Spain
Tel: +34 972 41 81 68; Fax: +34 972 41 82 77; E-mail: nuria.sanz@udg.es

Dr Ove **Skilbrei**, Institute of Marine Research, P.O. Box 1870, N-5817 Norones, Norway
Tel: +47 55236894; E-mail: ove.skilbrei@imr.no

Dr Ondrej **Slavik**, Water Research Institute T.G.M., Podbabská 30, 160 62 Prague 6, Czech Republic
Tel: +420 220 197224; E-mail: ondrej_slavik@vuv.cz

Dr William **Smoker**, University of Alaska Fairbanks, 11120 Glacier Hwy, Juneau, Alaska 99801, USA
Tel: +1 907 465 6441; Fax: +1 907 465 6447; E-mail: Bill.Smoker@UAF.edu

Dr Maria Teresa **Spedicato**, COISPA Tecnologia & Ricerca, via Dei Trulli 18, 70045 Bari, Italy
Tel: +39 80 5433596; Fax: +39 80 5433586; E-mail: spedicato@coispa.it

Ms Andi **Stephens**, Department of Applied Mathematics and Statistics, Jack Baskin School of Engineering, University of California, Santa Cruz, CA 95064, USA
Tel: +1 831 459 5385; E-mail: andi@soe.ucsc.edu

Marc **Suquet**, Institut Français de Recherche pour l'Exploitation de la Mer, 29280 Plouzane, France
Tel: +33 (0)22 98 43 94; Fax: +33 (0)2 98 22 43 66; E-mail: msuquet@ifremer.fr

Ms Ayesha **Taylor**, Environment Agency, Richard Fairclough House, Knutsford Road, Warrington, Cheshire WA4 1HG, UK
Tel: +44 (0)1925 653 999; Fax: +44 (0)1925 415 961; E-mail: ayesha.taylor@environment-agency.gov.uk

Dr John **Taylor**, Environment Agency Wales, Cynrig Fish Culture Unit, Llanfrynach, Brecon, Powys LD3 7AX, UK
Tel: +44 (0)1874 665212; Fax: +44 (0)1874 665212; E-mail: john.taylor@environment-agency.gov.uk

Dr Marielle **Thomas**, Laboratoire de Sciences Animales, Muséum Aquarium de Nancy, 34 rue Sainte Catherine, 54000 Nancy, France
Tel: +33 3 83 30 28 41; Fax: +33 3 83 32 30 16; E-mail: thomas.marielle@lsa-man.uhp-nancy.fr

Mr Frank **Thrower**, National Oceanic and Atmospheric Administration, National Marine Fisheries Services, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801, USA
Tel: +1 907 789 6055; Fax: +1 907 789 6094; E-mail: frank.thrower@noaa.gov

Professor Fred **Utter**, School of Fisheries and Aquatic Sciences, University of Washington, Box 355020, Seattle, Washington 98195, USA
Tel: +1 206 685 8196; Fax: +1 206 685 7471; E-mail: fmutter@u.washington.edu

Mr Juha-Pekka **Vaha**, Department of Biological and Environmental Sciences, P.O. Box 65, University of Helsinki, FIN-00014 Helsinki, Finland
Tel: +358 9 19157715; E-mail: juha-pekka.vaha@helsinki.fi

Professor Ettore **Varricchio**, Dipartimento di Scienze delle Produzioni Animali, Università della Basilicata, Campus Macchia Romana, 85100 Potenza, Italy
Tel: +39 971 205008; Fax: +39 971 205008; E-mail: varricchio@unibas.it

Mr Anti **Vasemägi**, Department of Aquaculture, Swedish University of Agricultural Sciences, Umeå SE 901 83, Sweden
Tel: ; Fax: +46 90 12 37 29; E-mail: anti.vasemagi@vabr.slu.se

Dr Bernard **Walrut**, 43 Wright Street, Adelaide, South Australia 5000, Australia
Tel: +61 412 288 163; Fax: +61 88410 1855; E-mail: bwalrut@bpwc.biz

Dr Robin **Welcomme**, Renewable Resources Assessment Group, Imperial College, Long Barn, Clare Road, Stoke by Clare, Sudbury, Suffolk CO10 8HJ, UK
Tel: +44 (0)1787 278017; E-mail: welcomme@dial.pipex.com

Mr Vidar **Wennevik**, Institute of Marine Research, PO Box 1870 Nordnes, N-5817 Bergen, Norway
Tel: +47 5523 6378; Fax: +47 5523 6379; E-mail: Vidar.Wennevik@imr.no

Professor Peter **Williams**, Strand House, The Strand, Ringmore, Shaldon, Devon TQ14 0ES, UK
Tel: +44 (0)1626 872696; E-mail: peter.williams.portisaac@virgin.net

Dr Ian **Winfield**, Centre for Ecology and Hydrology, Centre for Ecology and Hydrology, Lancaster Avenue, Bailrigg, Lancaster LA1 4AP, UK
Tel: +44 (0)1524 595846; Fax: +44 (0)1524 61536; E-mail: ijw@ceh.ac.uk