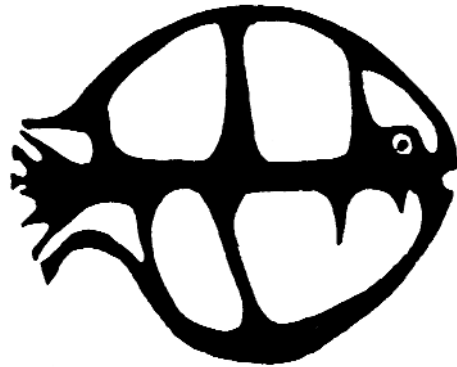


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FISHERIES RESEARCH SERVICES

Fish Habitat Ecology and Conservation

Introduction

The consideration of fish habitat, its ecology and conservation, is key to any form of ecosystem based approach to management and conservation. Fish use habitats for differing reasons at each stage of their life-history. Understanding the ecological relationship between fish and their habitat is therefore key to underpinning our attempts to improve our use and exploitation of fish resources. Freshwater ecologists have understood the importance of habitat for many years and have witnessed many changes in the manner in which humans manage aquatic habitats. Once we viewed canalisation and the clearing of woody debris as a positive management action - nowadays the view is the exact opposite and much money is spent correcting the mistakes of the past. In the much more open marine realm, these challenges appear somewhat more intractable, yet marine habitats have definitive boundaries described by oceanographic and geological features. Marine systems remain a challenging environment in which to understand the relationships between fish and their habitat and much basic science remains to be done. This symposium is a timely advance on the American Fisheries Society symposium held in 1998 that dealt with Fish Habitat. Our endeavour is to bring together expertise in freshwater and marine systems to enable an exchange of the most up-to-date and cross-cutting ideas. Both habitat realms have much to learn from each other.

In addition to providing a stimulating focussed symposium environment, we hope that you will enjoy the environment in Bangor to the full and partake of the entertainment provided for all. We look forward to meeting you in Wales.

Michel Kaiser
John Armstrong

Programme

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

Monday 18th July

14:00-18:30 **Registration in Ffriddoedd Halls of Residence**

18:45-19:45 **Ice-breaker - Ffriddoedd Bar**

1945 **Dinner in Plas Gwyn Dining Room, Ffriddoedd Halls of Residence**

Tuesday 19th July

07:30-09:00 **BREAKFAST** Plas Gwyn Dining Room

08:30 **Registration** Pritchard Jones Hall (PJH)

09:15 **Welcome address** Powis Hall (PH)

09:25 **Logistics**

Jack Jones Memorial Lecture

09:35 **UNDERSTANDING FISH HABITAT ECOLOGY TO ACHIEVE CONSERVATION** (p39)
Jake Rice

10:30 **COFFEE/TEA** PJH

Habitat quality

Chair: John Armstrong

11:00 **THE RELATIONSHIP BETWEEN POPULATION DENSITY AND HABITAT QUALITY (keynote)** (p19)
Jim Grant

11:45 **POPULATION DIFFERENCES IN RESPONSE TO HYPOXIA: BEHAVIOUR AND PHYSIOLOGY OF 3-SPINED STICKLEBACKS** (p34)
E.A. O'Connor, T.G. Pottinger, A.R. Cossins and L.U. Sneddon

12:05 **TERRITORIAL BEHAVIOUR AND THE VALUE ASYMMETRY HYPOTHESIS ? THE IMPORTANCE OF HABITAT QUALITY** (p24)
J.I. Johnsson

12:25 **DETERMINING STREAM QUALITY USING THE INDEX OF BIOTIC INTEGRITY: ARE CHANNELIZED STREAMS SPECIAL?** (p27)
J.K. Lau, and T.E. Lauer

12:45 **LUNCH** PJH

Chair: David Righton

14:00 **ONE FISH'S MEAT: DO ANTHROPOGENIC IMPACTS ON RIVERS PROVIDE STEPPING STONES AND STRONGHOLDS FOR PEST FISH?** (p49)
D. W. West, B J. Hicks, N. Ling, M. Van Den Heuvel and L. Tremblay

- 14:20 **AMPLIFICATION OF NEGATIVE IMPACT OF BEAVER DAMS ON FISH HABITATS OF RIVERS IN EXTREME CLIMATIC CONDITIONS** (p45)
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- 14:40 **THE IMPORTANCE OF HABITAT HETEROGENEITY TO FISH DIVERSITY AND BIOMASS** (p49)
A.E. Williams, K. Hendry, D.C. Bradley, R. Waterfall and D. Cragg-Hine
- 15:00 **THE INFLUENCE OF HABITAT CHARACTERISTICS ON THE ENERGY RESERVES OF FEMALE SPAWNERS OF RED MULLET (*MULLUS BARBATUS*) IN THE MEDITERRANEAN SEA** (p28)
J. Lloret, M. Demestre and J. Sánchez
- 15:20 **COFFEE/TEA** PJH
- Chair: Michel Kaiser**
- 16:00 **THE FEEDING STRATEGY OF DAB (*LIMANDA LIMANDA*) IN THE SOUTHERN NORTH SEA: LINKING STOMACH CONTENTS TO PREY AVAILABILITY IN THE ENVIRONMENT** (p22)
H. Hinz, I. Kröncke and S. Erich
- 16:20 **HADDOCK SELECT HABITATS THAT MAXIMIZE CONDITION** (p21)
J.G. Hiddink, S. Jennings and M.J. Kaiser
- 16:40 **DISTRIBUTION-ABUNDANCE RELATIONSHIPS FOR NORTH SEA COD: OBSERVATION VERSUS THEORY** (p10)
J.L. Blanchard, C. Mills, S. Jennings, C.J. Fox, B. Rackham, P. Eastwood and C. O'Brien
- 17:00 **THE HALL OF ILLUSION - Edward Povey**
- 17:45 **POSTER SESSION AND RECEPTION** PJH
Sponsored by Blackwell Publishing
- 19:45 **DINNER** Plas Gwyn Dining Room, Ffriddoedd Halls of Residence

Wednesday 20th July

07:30-09:00 **BREAKFAST** Plas Gwyn Dining Room

Habitats, life histories and adaptation

Chair: Barbara Knuth

- 09:00 **THE ROLE OF HABITAT IN DETERMINING RECRUITMENT OF JUVENILE MARINE FISHES: TESTING FORAGING ARENA THEORY (keynote)** (p25)
Francis Juanes
- 09:45 **NICHE CONVERGENCE OF SALMON AND TROUT WHEN IN COMPETITION** (p23)
J.Höjesjö, L. Stradmeyer, S.W. Griffiths and J.D. Armstrong
- 10:05 **AGGREGATION IN CANNIBALS: INTERACTIONS BETWEEN HABITAT AND DENSITY IN PIKE (*ESOX LUCIUS*)** (p21)
L.A. Hawkins, J.D. Armstrong and A.E. Magurran
- 10:25 **COFFEE/TEA** PJH

Chair: Keith Nislow

- 11:00 **IDENTIFYING THE EFFECTS OF ENVIRONMENTAL PARAMETERS ON SARDINE ABUNDANCE USING GENERALIZED ADDITIVE MODELS** (p18)
M. Giannoulaki, A. Machias, S. Somarakis, A. Siapatis and C. Papaconstantinou

11:20 **SEASONAL HABITAT CHOICE BY THORNBACR RAYS IN RELATION TO FISHERIES
MANAGEMENT** (p23)
E. Hunter, A.B. Buckley, C. Stewart, F. Berry and J.D. Metcalfe

11:40 **UTILISATION AND SIGNIFICANCE OF OFF-RIVER HABITATS TO LOWLAND RIVER
FISHES** (p26)
C.M. Knight, E.G. Gozlan, W.R. Beaumont, A.C. Pinder, L. Scott and M.C. Lucas

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

13:00 **LUNCH** PJH

Chair: Jim Grant

14:00 **INFLUENCE OF HABITAT DISTRIBUTION ON MOVEMENTS AND HABITAT USE OF
EUROPEAN GRAYLING** (p29)
M.C Lucas and D.H. Bubb

14:20 **HYDROLOGICAL PROCESSES IN THE HYPORHEIC ZONE DETERMINE SALMONID
EMBRYO SURVIVAL AND PERFORMANCE** (p30)
I.A. Malcolm, A.F. Youngson and C. Soulsby

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S. Malavasi, A. Franco, R. Fiorin, P. Franzoi, P. Torricelli and D. Mainardi

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SNAKEHEAD CHANNA STRIATA IN A RAINFED RICE FARMING LANDSCAPE** (p9)
E. Amilhat and K. Lorenzen

15:20 **COFFEE/TEA** PJH

Chair: Francis Juanes

15:50 **PUTTING ALL YOUR EGGS INTO ONE BASIN: HABITAT SELECTION OF SPAWNING
COD IN THE EASTERN BALTIC** (p32)
C. Mills, H. -H. Hinrichsen and D. Righton

16:10 **ASSESSING HABITAT OCCUPANCY OF ATLANTIC COD (*GADUS MORHUA*) IN THE
NORTH SEA** (p40)
D. Righton and C. Mills

16:30 **NEST DIVERSITY OF THREESPINE STICKLEBACKS: PROVENANCE AND
PLASTICITY IN RESPONSE TO ENVIRONMENTAL CHANGE** (p40)
B.J. Rushbrook and I. Barber

16:50 **JUVENILE FISH ABUNDANCE IN RELATION TO VEGETATION AND KEY ABOTIC
FACTORS IN SHELTERED BAYS IN THE NORTHERN BALTIC SEA** (p43)
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Johansson, M. Kilpi, J. Persson and M. Westerborn*

17:10 **THE INFLUENCE OF STREAM HABITAT ON INTER- AND INTRA-SPECIFIC
COMPETITION IN JUVENILE SALMONIDS** (p32)
N.J. Milner

19:15 **CELTIC SPIT ROAST PIG DINNER AT HENDRE**
Rhythm and blues by The Scapegoats - a fusion of Ocean and Biological Sciences
and guest performers
(Coaches leave at 18:45)

Thursday 21st July

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

Plas Gwyn Dining Room

Linking fish habitat to fisheries management

Chair: Siân Griffiths

- 09:15 **PRINCIPLES FOR LINKING FISH HABITAT TO FISHERIES MANAGEMENT AND CONSERVATION (keynote)** (p33)
Bob Naiman
- 10:00 **FISH AND ARTIFICIAL REEFS: AN ATTRACTIVE OR PRODUCTIVE ASSOCIATION?**
M.J. Brickhill, S.Y. Lee and R.M. Connolly (p12)
- 10:20 **HABITAT USE AND SWIMMING ENERGETICS OF ATLANTIC SALMON AND BROOK CHARR IN A NEWLY DEVELOPED COMPENSATION CREEK** (p16)
E.C. Enders, C.J. Pennell, K.E. Smokorowski, B. Sellars and D.A. Scruton
- 10:45 **COFFEE/TEA** PJH

Chair: Bob Naiman

- 11:15 **EFFECTS OF MANAGED FLOODING ON FISH ASSEMBLAGES IN MAN-MADE FLOODPLAIN WATER BODIES** (p24)
M. Janác, P. Jurajda, M. Ondracková, Z. Valová and M. Reichard
- 11:35 **BEHAVIOURAL RESPONSES OF JUVENILE ATLANTIC SALMON TO PRESENCE OF BOULDERS** (p25)
P.S. Kemp, J.D. Armstrong and D.J. Gilvear
- 11:55 **USING ARTIFICIAL HABITATS TO RESTORE OR ENHANCE INSHORE FISHERIES: AN OBSERVATION-BASED ECOSYSTEM SIMULATION** (p42)
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- 12:15 **THE ROLE OF RIVER MODIFICATION IN THE STRUCTURE AND SPATIAL DISTRIBUTION OF 0+ FISH ASSEMBLAGES** (p46)
Z. Valová and P. Jurajda
- 12:35 **LUNCH** PJH

Chair: Kevin Warburton

- 14:00 **THE 2005 BUCKLAND LECTURE: ATLANTIC SALMON HABITAT AND CONSERVATION. (keynote)** (p9)
John Armstrong
- 14:45 **AN APPROACH TO IDENTIFYING HABITAT TYPE AND ASSOCIATED FAUNA IN ESTUARIES** (p46)
F.J. Valesini, I.C. Potter and K.R. Clarke
- 15:05 **ESSENTIAL FISH HABITATS ON THE SWEDISH WEST COAST** (p44)
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- 15:25 **IS IT POSSIBLE TO PREDICT THE SPATIAL DISTRIBUTION OF NURSERY AREAS FOR FISHES IN SHALLOW AREAS OF THE BALTIC SEA? A FIRST ATTEMPT TO CONSTRUCT PREDICTIVE SPATIAL MODELS** (p41)
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15:45 **COFFEE/TEA**

Chair: Nigel Milner

16:25 **THREATENING PROCESSES IN URBAN FRESHWATER CREEKS AND IMPLICATIONS FOR FISH BIODIVERSITY: A QUEENSLAND CASE STUDY** (p48)
K. Warburton

16:45 **ESTABLISHING FLOW AND WATER LEVEL CRITERIA FOR THE MAINTENANCE AND CONSERVATION OF FISH ASSEMBLAGES IN RIVERS** (p15)
I.G. Cowx, R.A. Noble and R. Welcome

1705 **CAN THE POST-RELEASE PERFORMANCE OF HATCHERY FISH BE IMPROVED BY ENVIRONMENTAL ALTERATIONS?** (p12)
S. Brockmark, J.I. Johnsson and T. Bohlin

1915 **RECEPTION** Pritchard Jones Hall

1945 **SYMPOSIUM DINNER with musical accompaniment** Pritchard Jones Hall

Friday 22nd July

07:30-09:00 **BREAKFAST** Plas Gwyn Dining Room

Linking fish habitat to fisheries management (continued)

Chair: Jake Rice

0900 **FOREST CHANGE AND STREAM FISH HABITAT: LESSONS FROM 'OLDE' AND NEW ENGLAND (Keynote)** (p34)
Keith Nislow

0945 **HABITAT USE AND MOVEMENT OF SALMONIDS IN TWO NEWFOUNDLAND SYSTEMS IMPLICATIONS FOR MANAGEMENT** (p13)
K.D. Clarke, D.A. Scruton and J.H. McCarthy

1005 **PREFERRED HABITAT FOR JUVENILE HADDOCK ON THE CONTINENTAL SHELF OFF NOVA SCOTIA, CANADA** (p18)
D.C. Gordon, Jr., J.T. Anderson, E. Dalley, G.B. Fader, R. Courtney, R.S. Gregory, K.D. Gilkinson and E.R.L. Kenchington

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D. Boisclair, and N. Bergeron

1120 **ASSESSMENT OF THE HABITAT REQUIREMENTS OF ANGUILLA ANGUILLA IN RELATION CONSERVATION AND MANAGEMENT** (p26)
B. Knights, A. Bark, B. Williams and H. El-Hosaini

1140 **EFFECTS OF FOOD AVAILABILITY ON TEMPORAL ACTIVITY PATTERNS: SAFETY FIRST FOR SALMON IN SUMMER** (p35)
J.E. Orpwood, S.W. Griffiths and J.D. Armstrong

1200 **CONCLUDING REMARKS**

1220 **LUNCH AND CONFERENCE END** PJH

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HABITAT USE AND FEEDING ECOLOGY OF CHUB (*SQUALIUS CEPHALUS* (L.)) IN LAKE BANYOLES (NE SPAIN) (p50)

L. Zamora, M. Clavero and E. García-Berthou

ABSTRACTS

HABITAT USE, MIGRATION PATTERN AND POPULATION DYNAMICS OF SNAKEHEAD CHANNA STRIATA IN A RAINFED RICE FARMING LANDSCAPE

Amilhat, E. and Lorenzen, K

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Rain-fed rice farming landscapes account for over 50% of the total wetland area in Asia, and provide important habitat for freshwater fish. The snakehead *Channa striata* is a common fish species closely associated with rice farming landscapes in Asia, owing to its ability to migrate over land and utilize the mosaic of seasonal and perennial aquatic habitats characteristic of such landscapes. The fish is highly valued and intensively exploited by local people, who also practice a range of on-farm habitat management activities to attract and sustain populations of snakehead. To establish habitat use, migration, mortality and growth patterns of *C. striata* in rainfed rice farming landscapes we conducted a tagging study in Northeast Thailand. A total of 751 tagged fish were released during three distinct events in the late dry season, and in the beginning and at the end of the wet season. About 20% of tagged fish were recovered within one year of catch monitoring, 60 % of these within 2 months of release. Rice fields and man-made ponds provided important habitat for *C. striata*. Fish migrated from permanent to seasonal aquatic habitats at the beginning of the wet season. This up-migration involved longer distances and took place over a longer period of time than the down-migration at the end of the wet season. Natural mortality rates were found to be extremely high, particularly during the period of down-migration. Fishing mortality rates were high in absolute terms, but contributed less than 40% to total mortality. We discuss management implications of these results with particular reference to the role of active creation and management of fish habitat within rice farming landscapes.

SPATIAL VARIATION IN POPULATION DYNAMICS OF JUVENILE ATLANTIC SALMON: IMPLICATIONS FOR CONSERVATION AND MANAGEMENT

Armstrong, John D.

Fisheries Research Services Freshwater Laboratory, Faskally, Pitlochry, Perthshire, PH16 5LB, Scotland, UK

Application of habitat models has been hampered by a lack of generality in their fit to data from different systems. It is believed that this problem results at least in part from difficulties of effectively integrating factors that act across a range of spatial and temporal scales. Here, as an aid to developing more robust modelling and sampling methodologies, a simple process-based model for local-scale dynamics of salmon juveniles is developed from first principles by integrating contemporary understanding of self-thinning, density-dependent growth and dispersal. The aim is to present a readily understood structure to illustrate the links between spawning and stocking strategies, habitat, migration and fish production. Based on this structure, contemporary understanding of the more complex biological processes that affect density, growth and habitat are discussed in relation to some of the key requirements of managers, including stocking for rehabilitation, assessment of predation impact and development of strategies for sampling populations effectively when deriving habitat-production models. A major conclusion is that more structured, integrated research is required to provide the basic parameters needed to model links between local and global scale habitat and fish production effectively. Nevertheless, application of our current understanding of the biology of salmon should be of great benefit to managers in extracting key information from field surveys.

METHODOLOGICAL CONSIDERATIONS FOR INTERTIDAL SAMPLING OF BENTHIC FISH

Augley¹, J. A., Huxham¹, M., Fernandes¹, T. F. and Lyndon², A. R.

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² School of Life Sciences, Heriot-Watt University, Riccarton, Edinburgh, EH14 4AS, United Kingdom

Gears used to sample benthic fish intertidally have traditionally been based on various nets and traps (e.g. seine nets, block nets, trawls, push nets or fyke nets). These methods, while useful for fairly rapid large-scale quantitative sampling, may have problems of selectivity associated with them. This selectivity can act upon size, species or some aspect of the organisms' ontogenetic stage (e.g. behaviour, microhabitat preference, age). In order to allow rapid quantitative measurements of e.g. growth, mortality, densities and weight-length relationships, gear must be shown to be non-selective and/or efficiencies and selectivities known and calibrated. Two labour and time-intensive methods of sampling intertidally, with, theoretically, 100% efficiency and no selectivity, are drop traps and stake nets. A drop trap has been used to determine efficiency and size-selectivity of 1.5m and 2m beam trawls in a previous study (Wennhage *et al.*, 1997). Stake nets have been used in various studies to sample pelagic and demersal organisms in mangrove stands (Huxham *et al.*, 2004, Rönnbäck *et al.*, 1999 and Vance *et al.*, 1996). In this study, drop traps and stake nets were used to sample juvenile plaice (*Pleuronectes platessa*) on various beaches in the Firth of Forth, East Central Scotland. Results from these two methods were compared and efficiencies/selectivity assessed and evaluated against results obtained using a 1.5m Riley push net.

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- Huxham, M. et al. (2004). "Mangrove fish: a comparison of community structure between forested and cleared habitats." *Estuarine Coastal and Shelf Science* **60**(4): 637-647.
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DISTRIBUTION-ABUNDANCE RELATIONSHIPS FOR NORTH SEA COD: OBSERVATION VERSUS THEORY

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Density dependent habitat selection has implications for fisheries management and for the recovery of depleted fish populations. According to ideal free distribution (IFD) theory, populations contract into areas of highest habitat suitability as their size decreases. This can increase their vulnerability to fishing and predation. We detected density-dependent habitat selection by juvenile cod (ages 1 and 2) in the North Sea and compared the observed distribution- abundance relationships with those predicted from a model based on IFD theory and knowledge of optimal temperatures for growth, where temperature was used as a measure of suitability. As predicted by the model, in years when stock size was low, the catches were largely confined to regions with near- optimal bottom temperatures. Conversely, when population size was high, catches were spread across a larger area including regions with sub-optimal temperatures. The spatial extent of optimal habitat appears to have decreased from 1977 to 2002, reflecting a gradual warming of the North Sea. The combined negative effects of increased temperature on recruitment rates and the reduced availability of optimal habitat may have increased the vulnerability of the cod population to fishing mortality.

HABITAT PARTITIONING WITHIN CONGENERIC SPECIES IN MEDITERRANEAN BASINS AT DIFFERENT SPATIAL SCALES

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In this work we analyse the distribution patterns of two pairs of Mediterranean congeneric species belonging to the genus *Squalius* and *Chondrostoma*, to test the level of habitat partitioning within them at three scales: reach, small basins and large basins. The study was located in the southwest of Iberian Peninsula in an scenario that provides a good opportunity to investigate complementary distribution at different spatial scales. Based on multivariate (PCA) and univariate (ANOVA) analysis we found spatial segregation within congeneric species. Both genus were influenced by the spatial gradient running from the headwaters to the lower reaches, with congeneric species alternatively inhabiting upstream or downstream and intermediate zones where both species coexisted. *Ch. lemmingii* and *S. pyrenaicus* occupied upstream stretches being replaced by *Ch. willkommii* and *S. alburnoides* towards downstream. Moreover, *Chondrostoma* spp. never coexisted in isolated systems (small basins or isolated pools). Differences in habitat requirements and/or past and present intrageneric competition could be responsible for this pattern. Further, the effect of exotic fish species should also be considered to explain the observed habitat partitioning within these small-medium congeneric cyprinids.

MULTISCALE ASSESSMENT OF THE DETERMINANTS OF EARLY-WINTER HABITAT SELECTION BY PARRS OF ATLANTIC SALMON (SALMO SALAR).

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The quality of riverine habitats for parrs of Atlantic salmon is often modelled using variables estimated at the scale of microhabitats ($\times 10^0$ m²) or habitat patches ($\times 10^1 - 10^2$ m²). Characteristics observed at spatial scales ranging from the landscape ($\times 10^6 - 10^8$ m²) to the reach ($\times 10^3 - 10^5$ m²) have been hypothesized to affect habitat quality at finer spatial scales. We tested the relative importance of local (water depth; flow velocity; riverbed substrate composition), lateral (distance from shore; slope of the shores; distance from a road), and longitudinal variables (distance upstream or downstream from a spawning site or a tributary; distance from river mouth) on the early-winter density of parrs at fifty 100 m² sites of the Sainte-Marguerite River (Saguenay Region, Québec, Canada). Variations of parr density (0-16 fish/100 m²) were largely determined by the percentage of coarse substrate and the flow velocity at a site ($R^2=0.54$). Characteristics of the shores ($R^2= 0.12$) and the distance between a site and the closest spawning site upstream ($R^2= 0.06$) had a relatively small effect on parr density. Our work suggests the effect of environmental variables on early-winter habitat use measured at the scale of 10² m² decreases from local to global spatial scales.

FISH AND ARTIFICIAL REEFS: ATTRACTIVE OR PRODUCTIVE ASSOCIATION?

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Two widely-recognised hypotheses propose that increases in fish abundance at artificial reefs are caused by (a) the *attraction* and redistribution of existing individuals, with no net increase in overall abundance; and/or (b) the addition of new individuals by *production*, leading to a net increase in overall abundance. Inappropriate experimental designs have prevented many studies from discriminating between the two processes. Ten out of thirteen reviewed experiments comparing fish abundances on artificial reefs with those on adjacent soft bottom habitats were compromised by a lack of replication or spatial interspersions in the design itself. Only three studies featured proper controls and replicated designs with the interspersions of reef and control sites. Contingency table analyses of abundance data for 67 fish species from these studies indicated that more fish occur on reefs than on controls, particularly for species that typically occur over hard substrata. Conversely, seagrass specialists favour controls over reefs. Changes in the appearance of fish abundance trajectories driven by manipulation of sampling intervals highlight the need for adequate temporal sampling to encompass key life history events - particularly juvenile settlement. The ultimate goal, to determine whether attraction or production is responsible for increased abundances on reefs, requires two experimental features: 1) control sites both interspersed among artificial reefs and at reef/non-reef locations outside the test area, and 2) incorporation of fish age/length data over time.

CAN THE POST-RELEASE PERFORMANCE OF HATCHERY FISH BE IMPROVED BY ENVIRONMENTAL ALTERATIONS?

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Many fisheries increasingly rely on restocking from artificial reared salmon in an attempt to maintain commercially viable populations. Hatchery-reared complementary fish are raised under conditions far different from those of natural waters, which negatively affects post-release performance, even if wild parents are used. Using first feeding Atlantic salmon under conventional hatchery rearing environments, we manipulated two factors known to influence development: density (normal hatchery density or half of normal) and habitat structure (plain tanks or tank enriched with rocks and plastic substrate). After three months in the hatchery, some fish from each treatment were individually pit-tag marked and released in a nearby stream. These fish were recaptured at two occasions, before and after the winter. The remaining fish were kept in the hatchery until next spring. Fish from the treatments will be compared with respect to growth, survival and smoltification status using wild reared salmon as controls. The results will be evaluated to determine if structural enrichment and lowered density can produce a more nature-like hatchery fish for release.

HABITAT USE AND MOVEMENT OF SALMONIDS IN TWO NEWFOUNDLAND SYSTEMS: IMPLICATIONS FOR MANAGEMENT.

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Habitat management systems tend to focus on distinct physical habitats, quite often with a limited view of the spatial and temporal variation that can occur in habitat use. Habitat use patterns and movement between habitats was investigated in two Newfoundland systems. The first system is a headwater system, inhabited by brook charr with habitats comprised of small primary streams and associated ponds. Charr tend to utilize the fluvial habitats for spawning and growth of one/two year old fish, older individuals tend to move into the ponds for growth opportunities. Movements between the fluvial and lacustrine habitats are dominated by a spawning run during fall and the gradual downstream movement of two/three year olds. The second system has a more diverse fish and habitat assemblage. Habitat use of the main lacustrine habitat sampled, Stoney Pond, had a very distinct seasonal pattern. Juvenile Atlantic salmon utilized the pond throughout the year with the immigration of two/three year old fish occurring during the early summer period. Pre-smolts also tended to over winter in the pond. Brook charr used the pond in fall, post spawning, and through the winter into early spring but moved out of the pond by early summer, dispersing throughout the watershed. Fluvial habitats were dominated by one/two year old fish, especially salmon, and while there was a difference in abundance between riffle and slower (flat/pool) habitats, the age class structure did not differ. The main habitat types in these systems were interdependent during the life cycle of the species present and inter-habitat movement was pronounced. This suggests that the management of distinct physical habitats in isolation may not be an appropriate scale and a population view should be adopted.

ONTOGENETIC PATTERNS IN THE MICROHABITAT USE OF THREE SMALL ENDANGERED FISHES IN A MEDITERRANEAN COASTAL STREAM

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We analysed the microhabitat use of three endangered fish species, Andalusian toothcarp (*Aphanius baeticus*), Iberian loach (*Cobitis paludica*) and sandsmelt (*Atherina boyeri*), in a coastal stream stretch. We used over 1400 plastic minnow traps to capture 4024 toothcarps, 1813 loaches and 904 sandsmelts. Traps were laid at day and night time, as well as on the bottom and at the surface of the water column. For each trap we noted the presence/absence of effective cover (e.g. vegetation) and its depth. To assess ontogenetic changes in microhabitat use individuals of each species were classified in three size classes. Captures were expressed as CPUE and analysed using generalised linear models. The three species used preferentially bottom positions in the water column, though this trend was more evident in the case of loach. Loach was also the only species that remained active at night. The differences in activity between night and day for toothcarp and sandmelt were stronger in large individuals. There was a high overlap in the use of the different depths among species, with small size classes selecting shallow areas and larger classes deeper ones. Small loaches and small sandsmelts preferentially occupied cover areas at night, while large toothcarps consistently preferred exposed microhabitat at any time. Small toothcarps and loaches used deeper microhabitat in the presence of cover during the day. Small fish occurrence was positively associated in traps independently of species, while individuals of the same species were positively associated independently of fish size.

LIVING WITHOUT WATER: LIFE HISTORY STRATEGIES OF FISHES IN INTERMITTENT MEDITERRANEAN STREAMS

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Multi-scale (sites, river reaches and rivers) and short term temporal (monthly) variability in the freshwater fish assemblages of the tributaries of Guadiana River catchment were examined over a 5-year period to understand how fish communities respond to the Mediterranean climate conditions of long summer droughts and wet winters, encountered. Considerable temporal and spatial variation in species distribution was found between rivers, depending on the intensity of drought conditions. Fish community assemblages in the rivers were severely affected by drought, i.e. reduced to a few isolated pools in the summer period, and dominated by species able to tolerate the harsh environmental conditions in the pools (especially low DO and high temperature). These tended to be small-sized individuals and species. Species assemblages were disrupted by abstraction of water from the refuge pools, removal of riparian vegetation thus raising the ambient water temperature in the pools, nutrient enrichment and dispersion of predatory, exotic species, especially large mouth bass, from reservoirs, resulting in a high proportion of the species being registered as threatened or endangered on the IUCN Red Data List. Mechanisms to help conservation the endemic species of the catchment are suggested.

AN INTEGRATED APPROACH TO FISH ASSEMBLAGE CONSERVATION IN A MEDITERRANEAN STREAM UNDER A DAMMING PROCESS: WHAT FUTURE FOR THE HIGHLY ENDANGERED SPECIES?

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Damming is probably one of the most damaging human perturbations in streams, once it generates a complex web of impacts, affecting the biological and physical components of the environment. Stream fish assemblages are particularly sensitive to such habitat changes, which often result in the loss of biodiversity at both local and regional scales. The new Odelouca reservoir is now under construction in a typical Mediterranean-type drainage in southern Portugal (Arade). Local fish assemblages are dominated by two endemic cyprinids (*Chondrostoma almacai* and *Squalius aradensis*), largely confined to this region and highly threatened. Therefore, some mitigation and compensation measures were defined and started to be implemented in May 2004. These include a three year integrated approach aiming to assess: i) the life-histories and habitat use patterns of the endemic cyprinids, ii) the genetic structure of these and of closely related species in nearby drainages; and iii) the impacts of damming on fish assemblage and habitat persistence. This research programme was outlined simultaneously with other projects relating to environmental, floristic, and human land use assessments. All these components will additionally be linked through a detailed Environmental Information System, in order to allow the integration of all analytical and modelling data available for the drainage. This follow-up process that will be presented in here, is expected to generate an important database in real time, that may be used in developing innovative conservation approaches, recognizing the value of both endangered species and native assemblages, and that emphasize the protection of key landscape processes.

ESTABLISHING FLOW AND WATER LEVEL CRITERIA FOR THE MAINTENANCE AND CONSERVATION OF FISH ASSEMBLAGES IN RIVERS

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The potential role of flow and water level criteria on fish species and populations in English and Welsh rivers was determined to provide, for various river reach types, generic seasonal flow and water level regime requirements for key life stages of freshwater fish species to advise and influence the management of flow regimes. Fish community types in rivers were modelled based on the Environment Agency fisheries data and complementary environmental data. The models discriminated eight major fish community types that broadly followed the classical zonation theory with river gradient from upland salmonid to lowland cyprinid communities. It was concluded that the influence of flow and the potential impacts of abstractions and releases should be considered within the context of each of these main fish assemblages, linking key species per community type to their functional ecology and flow requirements. The relationship between the rate of flow, the rate of change of flow, the duration of high/low flow events and their seasonal timing, and their influence over the functioning of fish populations (spawning, recruitment and growth) therefore needs to be considered more fully when evaluating anthropogenic changes to flow patterns, and establishing environmental flow regimes.

A SATELLITE TRANSMITTING ACOUSTIC LISTENING STATION FOR MONITORING THE SMALL-SCALE MOVEMENTS OF MARINE FISH

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Studying the behaviour of marine fishes under natural conditions is a problem that continues to challenge behavioural technologists worldwide. Acoustic telemetry methods provide high-quality data in real-time, but long-term studies can be difficult for many practical and technical reasons. CEFAS has developed an unmanned, low maintenance data logging and retrieval system named 'The Acoustic Telemetry Buoy' (ATB). This system has evolved from a simple real-time acoustic to radio repeater, to a data logging system and, finally, to an autonomous acoustic data telemetry system capable of detecting and logging data over an extended period and transmitting that data from almost anywhere in the world. Further developments will permit telemetry of environmental data such as temperature and depth. The ATB has successfully been used to monitor the small-scale movements of cod on a feeding ground in the North Sea over periods of more than 3 months at a time. These results, collected during the summers of years 2000 through 2002, provide an illustration of the system's potential.

HABITAT USE AND SWIMMING ENERGETICS OF ATLANTIC SALMON AND BROOK CHARR IN A NEWLY DEVELOPED COMPENSATION CREEK

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Degradation and destruction of valuable spawning and rearing habitat due to anthropogenic changes (e.g. flow modification and channelisation) is known to have dramatic impacts on fish populations. To compensate for habitat losses due to hydropower development, an artificial fluvial habitat channel ('Compensation Creek') was constructed in Central Newfoundland, Canada. The creek was designed to include appropriate habitat features for the two dominant salmonid fish species, landlocked Atlantic salmon (*Salmo salar* L.) and brook charr (*Salvenius fontinalis* MITCHELL). The study examines the habitat use of Atlantic salmon and brook charr in the compensation creek using electromyogram (EMG) radio telemetry. This technique allowed both the analyses of habitat choice in relation to physical habitat characteristics and the energy expenditure associated with fish activity and habitat selection. Ten Atlantic salmon and eight brook trout were captured before their spawning period and tagged with EMG tags. In laboratory experiments, the EMG signals were calibrated against swimming speed, tailbeat frequency and oxygen consumption rate. Fish were then released in the compensation creek and tracked on a daily basis until the end of the spawning period. The results show that: (1) EMG signals of both species were positively related to swimming speed, tailbeat frequency and oxygen consumption rate; (2) both species used preferentially the habitat features designed to match their spawning and rearing habitat preferences; and (3) the energy expenditures for residence, migration, tailrace attraction and spawning activity differed significantly from each other and between the two species.

HABITAT CHOICE OF PIKE LARVAE (ESOX LUCIUS) AND THE CONSEQUENCES FOR FITNESS

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The structure of the habitat is known to be crucial for growth and survival of young life stages. We studied the influence of two different habitats on habitat choice of pike larvae (*Esox lucius*) in the presence of a predator or a competitor, and tested whether the choice is adaptive in increasing survival under predation threat. In contrast to expectations, pike larvae preferred a habitat with filamentous algae (*Cladophora glomerata*) to a bladder wrack (*Fucus vesiculosus*) habitat with more diverse structure. However, the survival of the larvae was higher in the habitat with filamentous algae in the presence of predators, which suggested that the habitat preference of the larvae was adaptive. The structure of the bladder-wrack habitat was probably too open for newly hatched larvae, which implies that bladder wrack and other large brown algae are not as important refuges for young larvae as previously thought. It is likely that habitat preferences of pike larvae change with ontogeny and that newly hatched larvae perform habitat choice differently than juveniles. Further, hypoxic conditions may arise in filamentous algae, especially during night. Thus, pike larvae have to trade between different costs and benefits when choosing a habitat. Presently, the habitats of pike larvae are changing due to increased growth of filamentous algae in fertilized environments. The consequences this may have for pike populations will depend on the costs and benefits of occupying the changing habitats.

REPRODUCTIVE BIOLOGY OF DOCTOR FISH, *GARRA RUF*A (CYPRINIDAE: GARRINAE) IN SOUTHEWEST OF IRAN

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A study was conducted on 290 specimens of *Garra rufa* (Heckel, 1843), including 152 males and 138 females, collected from Zanjiran spring-stream system, Fars province, southwest of Iran. Data revealed that gonadosomatic index, modified gonadosomatic index and dobriyal index showed increasing trends from November to April when indices were as high as 16.98, 20.45 and 1.27 respectively. There was a sharp fall in the values during May which is an indication of heavy spawning in this month. There was a slight increase during June and a slight fall in July which may be due to late spawning of some fishes. The ova diameter ranged from 0.006mm to 1.75mm with a mean of 0.428mm (± 0.368 mm), increasing with fish size. The total fecundity ranged from 184.33 to 2396.23 eggs with a mean of 760.96. The mean relative fecundity was 86.84. There was a significant relationship between fecundity and fish size (total length and total weight) and also gonad weight. The fecundity of this fish is very low in comparison with the other cyprinid fishes. Presence of many atretic oocytes in the ovary, low fecundity, hermaphroditic specimens and abnormality in caudal fin and lateral line of this carp show that the population of this fish in Zanjiran spring-stream system is under stress. Presence of only two other fish species in this spring indicates poor condition of this natural habitat. Pollution, habitat destruction and drought are the main factors which affect the fish population in this spring.

IDENTIFYING THE EFFECTS OF ENVIRONMENTAL PARAMETERS ON SARDINE ABUNDANCE USING GENERALIZED ADDITIVE MODELS

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Acoustic survey data were combined with environmental data in order to identify parameters that characterize the habitat of sardine in the oligotrophic eastern Mediterranean. Acoustic and concurrent hydrological (vertical profiles of temperature, salinity, fluorescence) and mesozooplankton sampling was carried out in the Ionian Sea in June 1999 and December 1999. Generalised additive models were applied in order to identify the effect of environmental features on sardine's echo abundance. Results showed that productivity parameters (zooplankton biovolume or chlorophyll-a concentration) were the key elements affecting the abundance and characterizing sardine's habitat. The surveyed area consists of many semi-enclosed gulfs, where productivity is increased, that should be taken into account for a successful management scheme of the sardine stocks inhabiting the coastal waters of the eastern Mediterranean. Findings are discussed in terms of species biology, since winter is the spawning season for sardine in Greek waters and early summer is after the species' recruitment period.

IDENTIFYING THE EFFECTS OF HYDROGRAPHIC FEATURES AND PRODUCTIVITY ON SARDINE ABUNDANCE USING GENERALIZED ADDITIVE MODELS

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Acoustic survey data were combined with environmental data in order to explore the environmental parameters that potentially characterize sardine 's Essential Fish Habitat. Acoustic and concurrent hydrological and zooplankton sampling was carried out in Ionian Sea (Eastern Mediterranean Sea) during June 1999 and December 1999. Echoes were registered continuously along predetermined transects and were integrated over one nm, that served as the Elementary Distance Sampling Unit (EDSU). Hydrographic sampling was performed over a grid of predetermined stations. At each station vertical profiles of temperature, salinity and fluorescence were obtained with a Seabird 25 CTD, as well as zooplankton samples using a WP2-net. Generalised additive models were applied in order to identify the effect of hydrographic features and zooplankton on sardine echo abundance. Results showed that productivity (zooplankton volume or chlorophyll a concentration) was the key factor affecting sardine's abundance and defining species habitat in both seasons. Results are discussed in relation to species biology, since winter is the spawning season for sardine in the Greek seas whereas early summer is the period following recruitment. As closed gulfs are the main productive areas in the study region, consisting at the same time locations where the fishing pressure increases especially during the winter, a successful management scheme should incorporate a consideration of the sardine's habitat and the environmental parameters that characterize it.

PREFERRED HABITAT FOR JUVENILE HADDOCK ON THE CONTINENTAL SHELF OFF NOVA SCOTIA, CANADA

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We are conducting a multiyear study (2002-2005) of the relationships between seabed habitat and juvenile haddock on the Scotian Shelf. Using survey data (1970-2001), three paired study sites (10 x 10 km) (39-84 m) were selected on Emerald, Western and Sable Island Banks to represent regions with the highest and lowest probabilities of finding juvenile haddock. State-of-the-art acoustic, imaging and sampling equipment is being used to collect georeferenced data on bathymetry, seabed geology, sediment dynamics, benthic communities, and fish over spatial scales of 1-100 km². Trawl surveys conducted in 2002 confirmed that juvenile haddock continue to be much more abundant at the preferred sites on Western and Sable Island Banks. Bathymetric relief (rugosity) is greater at the preferred sites on all banks suggesting that preferred habitats are more complex. All sites have mixtures of sand and gravel (including boulders and bedforms). Sidescan sonar mosaics (1 x 5 km) show a wide variety of seabed classes, and patchiness appears to be greater at preferred sites. Acoustic metrics are being developed for seabed classification. Analysis of towed video indicates that juvenile haddock are contagious in their local distribution over the seabed, prefer sand, and are more abundant at night. Acoustic data also demonstrate diurnal differences in haddock. Benthic communities are being described using photographs and traditional grab samples, and substrate-related differences are apparent. Analysis of stomachs indicates that haddock are feeding on a wide variety of benthic taxa but significant differences between preferred and non-preferred sites have yet to be identified. When completed, this project will provide needed information on what constitutes preferred habitat for juvenile haddock, why they select it, and the spatial scales of these habitats on the Scotian Shelf.

SWIMMING CAPACITY AND METAMORPHOSIS: AN INTEGRATED APPROACH TO ORGANISM-ENVIRONMENT RELATIONSHIPS?

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We examined the influence of early life development on the swimming capacity of the endangered fish species, *Chondrostoma toxostoma*, to highlight trends in organism-environment relationships. Knowledge of the ecological interactions during an organism's early ontogeny is important to quantify how ecological disturbances during this critical period might affect population survivorship. We developed an index to quantify swimming capacity in aquatic organisms and applied it to *Chondrostoma toxostoma* larvae and juveniles to determine whether development of swimming ability follows a saltatory pattern. We integrated our results into the analysis of habitat shifts during early life history in nature. We found that sudden changes occurred in integrated function and these were most decisive, in particular with respect to habitat use, between the larval and juvenile periods of development. The fact that 'stabilisation' of relative growth coincided with dramatic shifts in habitat use (organism needs) as well as in swimming capacity (organism skills) suggests a more 'decisive' type of change in organism-to-environment interaction than one purely of form.

THE RELATIONSHIP BETWEEN POPULATION DENSITY AND HABITAT QUALITY

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Habitat quality is a heuristically simple and powerful concept and yet is notoriously difficult to quantify. Ideally, one could measure population growth rate at the macro-habitat level or some component of individual fitness at the microhabitat level. I will use the ideal free distribution (IFD) as a theoretical framework to ask how habitat quality changes with population density and whether one can use population density to estimate habitat quality. Young-of-the-year Atlantic salmon in Catamaran Brook show distinct preferences for habitats with fast current velocities and moderate depths. Consistent with the IFD, however, the growth rate and loss rate of salmon did not differ between preferred and not preferred habitats. Hence, the IFD predicts density-independent growth at small spatial scales. At larger spatial scales, however, high travel costs violate the assumptions of the IFD, leading to negative density dependent growth. Surprisingly, the growth rate of young-of-the-year salmonids decreased with increasing density more at low than at high population densities. Hence, scatter stocking is preferable to point stocking to avoid the negative effects of density dependent growth. Finally, we ask whether one can improve habitat quality such that population density increases without causing growth rate to decrease? As originally suggested by Kalleberg (1958), by adding boulders to a small section of stream, we were able to double the density of salmon parr without negatively affecting growth rate. In summary, the IFD is a useful heuristic framework for investigating the effects of population density on habitat quality and vice versa.

SEAGRASS ECOSYSTEMS OF THE WESTERN INDIAN OCEAN – ECOLOGICAL SIGNIFICANCE FOR COASTAL FISHERIES

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Seagrass meadows occupy shallow coastal waters all over the world and support a variety of ecosystem services of which the functions as nurseries and feeding areas for fish are of particular interest as they provide an ecological basis for plentiful tropical coastal fisheries. This is also the case in the Western Indian Ocean (WIO) region where extensive seagrass areas are used intensively in the subsistence fisheries. The present work is a synthesis of different seagrass studies from Inhaca Island (Mozambique) and Chwaka Bay (Zanzibar, Tanzania) where I have conducted research between 1999 and 2004. Using an interdisciplinary approach the specific focus has been to emphasise the significance of seagrass meadows for coastal fisheries in the region, but also to illustrate potential threats and evaluate monitoring techniques for prediction of ecological values important for conservation. The studies have shown that seagrass systems of the WIO region could be extremely important as habitat for fish and local fisheries. Results suggest strong interactions between fish and seagrass habitats, at least during parts of their life stages. This distinctness and spatial heterogeneity of fish assemblages were mainly influenced by species composition and structural complexity of the seagrass meadows. Hence, knowledge of basic seagrass characteristics may give information essential for habitat protection and fisheries management. The studies further suggest that production of seagrass is inhibited by top-down regulating processes following overgrazing events by herbivorous fish and/or sea urchins, and thus functioning together with other processes such as nutrient enrichment and sediment overloading.

THE INFLUENCE OF SALINITY ON THE DISTRIBUTION, POPULATION STRUCTURE AND DENSITY OF YELLOW PHASE EUROPEAN EELS.

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Anguillid eels are in decline worldwide, and numbers of European eels are currently reported to be less than 10% of those in the 1970s. Recent discoveries have shown that not all eels enter freshwater and suggest that a significant proportion of escapement is from marine or mixohaline eels. There are a number of established paradigms reflecting how eel populations structure themselves along salinity gradients, but these have often been questioned in the literature. There is a pressing need to increase our understanding of eel ecology, especially with regards to how it varies with salinity. We examined an unexploited population of yellow-phase eels along a short (2 km) but acute salinity gradient (0-34‰). During 2004, eels were collected twice monthly in four areas of contrasting salinity (mean benthic salinities = 0, 12, 25, and 34 ‰). Results showed that some aspects of eel ecology varied significantly along the salinity gradient. Size-structure differed between sites, but with no obvious relationship with salinity. Condition was highest in fresh and moderately brackish waters and lowest in fully marine eels. Paired comparisons of CPUE data recorded from each salinity zone gave no evidence of marked differences in relative abundance in the different salinity zones. A total of 1202 individuals were marked using PIT tags. Recapture rates were relatively low (~12%), but consistent across salinity zones, again suggesting little variation in relative abundance between the different salinity zones. Sex ratios were dominated by females at all sites (mean m:f = 1:9).

AGGREGATION IN CANNIBALS: INTERACTIONS BETWEEN HABITAT AND DENSITY IN PIKE (ESOX LUCIUS)

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Intense interference among animals tends to result in despotic use of preferred habitats by dominant individuals and avoidance of dominant individuals by subordinates. These basic tenets form the foundation for models seeking to relate individual behaviours to population distribution as a function of habitat structure. However, there is documented the case of a highly cannibalistic fish, the northern pike (*Esox lucius*), aggregating rather than dispersing among habitat patches. The advantages to cannibals of aggregating in the absence of other predators and food constraints are not immediately obvious given the clear risks involved. In this study we adopt a stepwise approach to exploring the basis for this form of cannibal grouping by observing how spatial distributions of pike are mediated by the presence of conspecifics. We conclude that an analysis of the role of population density in determining habitat-dependent mortality risk is an important component of the development of habitat models.

HADDOCK SELECTS HABITATS THAT MAXIMIZE CONDITION

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Organisms select habitats that maximize their fitness, for example by maximizing food intake, minimizing metabolic costs and reducing the risk of predation. Bottom trawling negatively affects biomass and production of benthic communities, and thus may also affect the food availability for benthivorous commercial fish which has implications for fitness and habitat quality. The condition of haddock (*Melanogrammus aeglefinus*) was examined to study if habitat quality is related to the energy balance of fish. At sites in the North Sea, the condition of the very numerous 1999-year class haddock was examined in relation to its abundance in August 2004, to examine if their energy balance plays a role in habitat selection of haddock. The main source of variation in the condition of haddock was attributed to the lipid content of the liver. Haddock condition was positively correlated with abundance, while it was negatively correlated with bottom temperature. This suggests that haddock select locations where they can maintain a favourable energy balance, either through high food intake or the association with a favourable temperature regime. Stable isotope analysis of muscle samples was used to examine if haddock could evade competition over food at high abundance sites by feeding at a lower trophic level. The results indicate that food may limit the condition of haddock. As haddock egg production is higher for fish in a good condition, it is likely that the reduction in benthic secondary production associated with bottom trawling disturbance may negatively affect the fitness of haddock in the North Sea.

THE FEEDING STRATEGY OF DAB (*LIMANDA LIMANDA*) IN THE SOUTHERN NORTH SEA: LINKING STOMACH CONTENTS TO PREY AVAILABILITY IN THE ENVIRONMENT

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Dab (*Limanda limanda*) is one of the most abundant flatfish species in the southern North Sea. Although exploitation pressures in this part of the North Sea are extremely high, population levels of dab have remained relatively stable in comparison to other similar flatfish species such as plaice, which has shown a continuous decline over past decades. The reasons for these differences are so far not fully understood, and thus more detailed studies are needed to determine species-specific behaviour patterns. We investigated the feeding ecology of dab within a medium scale area (10nm²) of the German Bight by relating the availability of potential prey items in the environment to the stomach contents of dabs, condition factor and dab distribution. Benthic fauna, dabs and stomachs were sampled at different stations within the area and during three time periods in summer 2000, 2001 and in winter 2001-2002 allowing for spatial and temporal comparisons. While temporal trends in food availability were well reflected in stomach contents, condition factors and flatfish distribution, small scale spatial trends were less evident. To establish the underlying preference behaviour of dab for certain prey species, each species present in the benthos was described by specific categorical factors such as mobility, position in the sediment (e.g. surface, interface, buried), palatability (e.g. shelled, hard cuticle, soft bodied) and density. These factors then were related to the density of prey items in the stomach by multivariate (PCA) and univariate (GLM) methods. Both approaches showed that the prey choice of dab was mainly influenced by density and the position of the prey item in the environment. Palatability and mobility of the prey were not crucial factors. These results show that dab is a relatively unspecific feeders and is able to utilize a wide spectrum of prey items which might contribute to their success in keeping population levels stable despite high exploitation rates.

NICHE CONVERGENCE OF SALMON AND TROUT WHEN IN COMPETITION

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Facilitation, the process whereby the presence of one species enhances the population of another has mainly been reported in plants, for example, where large trees provide shade that enables ivy to grow profusely. Facilitation in animals is less well known but has, for example, been a hypothesis used to explain habitat partitioning and coexistence in African Ungulates. Here we report an experiment in which direct observations of fish were used to elucidate detail of the interactions between trout and salmon. The experiment was designed to test whether salmon prefer riffle to pool habitat when given a free choice, and whether the habitat preference of salmon is altered by the presence of trout. Our experiment confirmed that trout are dominant over salmon and prefer pool to riffle habitat and also showed that dominant salmon tended to use pools rather than riffles when in homogenous groups. Overall, the proportion of salmon using pools was higher when salmon were in mixed groups with trout than when in homogenous groups. Interestingly foraging efficiency was higher in the pool than on the riffle for salmon living with trout whereas the opposite was true for salmon in homogenous groups. The results from this study suggest that presence of trout may facilitate the production of salmon and certainly may influence habitat use in a manner that counters the established view based on competitive exclusion.

HABITAT COMPLEXITY SELECTS AGAINST AGGRESSIVE BEHAVIOUR IN BROWN TROUT

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Animals often prefer areas containing physical structure, and population density often increases with structural complexity, presumably because physical complexity in habitats may offer protection from predators and aggressive competitors. Consequently, increased habitat complexity often results in reduced territory size, lower aggression levels and reduced resource monopolisation by dominants. If behavioural plasticity is limited at early life stages, increased habitat complexity may reduce the relative fitness of aggressive, dominant strategies. Here we tested this hypothesis in an experiment on newly-emerged brown trout (*Salmo trutta*) fry. We show, for the first time, that increased habitat complexity reduces the fitness (i.e. growth rate) of aggressive dominant individuals in relation to subordinates, and that this relation is reversed in simple habitats. Variation in environmental complexity may thus induce fluctuating selective pressures, maintaining behavioural variation in natural populations and allowing subordinate and dominant strategies to coexist.

SEASONAL HABITAT CHOICE BY THORNBACK RAYS IN RELATION TO FISHERIES MANAGEMENT

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The declining abundance of many commercially exploited elasmobranchs in recent years has highlighted the lack of high quality fisheries data, and the general absence of sustainable management strategies, for sharks and rays in the north east Atlantic. Within this management context, we aimed to describe the spatial and temporal distribution of thornback rays in the Thames Estuary (United Kingdom), by releasing 197 fish tagged with electronic data storage tags between October 1999 and December 2000. Tags were returned through the commercial fishery, and a method of geolocation, based on tidal data recorded when rays remained on the sea-bed over a full tidal-cycle, was used to reconstruct the movements of the fish throughout their liberty period. Contrary to predictions based on conventional tagging experiments, our results show that rays were not restricted to the Thames Estuary (ICES rectangles 31F0, 31F1, 32F0, 32F1 and 33F1), but moved more widely in the southern North Sea (ICES division IVc), with a seasonal pattern of migration. Distribution in ICES area IVc was more widespread during the autumn and winter, at depths of 20-35 m (occasionally > 35 m), then the range contracted during the spring, when the fish moved into shallow water (< 20 m depth) in the inner Thames Estuary to reproduce. No obvious behaviour differences were observed between male and female fish. The availability of rays to capture by the U.K. and Dutch fishing fleets, and to different fishing gears, is discussed in relation to the seasonal habitat preference of the fish.

EFFECTS OF MANAGED FLOODING ON FISH ASSEMBLAGES IN MAN-MADE FLOODPLAIN WATER BODIES

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The loss of flood plain through river channelization can have adverse effects on riverine fish fauna through a reduction in the abundance and diversity of species. Most of the lowland floodplain rivers in Central Europe have been channelized and regulated. The area along the lower River Dyje (Danube basin) is an exception where a fragment of the flood plain remains. The southern part of this area is under an experimental managed flooding regime to support fish reproduction. The effectiveness of managed flooding was investigated by comparing adult and 0+ juvenile fish assemblages in two types of borrow pits (lakes created after excavation of material for dike construction) during four years. All man-made borrow pits had uniform habitats without shelters and with limited spawning and nursery areas. The habitat conditions in three borrow pits were improved by managed flooding during spring and summer of differing extension and duration. Three control sites were not flooded. The species diversity of adult fish did not differ between flooded and non-flooded sites, but the fish density was higher in flooded borrow pits. Considerable differences between flooded and non-flooded sites were found in species richness, species composition and fish density of 0+ fish assemblages. No difference was observed between flooded and non-flooded sites during short-duration managed flooding. We could conclude that managed flooding is an important factor for supporting fish diversity and production in the substitute man-made lentic water bodies, however the duration of flooding plays an important role.

TERRITORIAL BEHAVIOUR AND THE VALUE ASYMMETRY HYPOTHESIS – THE IMPORTANCE OF HABITAT QUALITY

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Several hypotheses have been proposed to explain the striking ability of territory owners to repel intruders. According to the value asymmetry hypothesis, owners win because their valuation of the territory increases with time making them more motivated to fight than the intruders. However, the mechanisms by which territory value increases are not well understood. In two experiments on brown trout we examined how habitat quality affects investment in territorial defence. In the first study, we hypothesised that owners of preferred habitats should invest more resources in defence than owners of non-preferred habitats. Fish were first individually tested for habitat preference (i.e. gravel) and then provided with either a preferred or non-preferred habitat, whereupon they were staged against a naïve intruder. As predicted, satisfied owners attacked sooner and were more aggressive towards intruders. In a second study, we hypothesised that cover increases the valuation of a territory in relation to the perceived level of predation risk. First, trout were allowed to establish ownership in territories with or without overhead cover. Second, predation risk was manipulated by simulating predator attacks in half of the territories of each type. Third, owners were staged in dyadic contests against naïve intruders. Owners of territories with cover were more aggressive against intruders if they had been subjected to predator attacks the day before the conflict. These results suggest that territory holders are able to evaluate habitat characteristics in relation to changing environmental factors, which provides strong support for the value asymmetry hypothesis.

THE ROLE OF HABITAT IN DETERMINING RECRUITMENT OF JUVENILE MARINE FISHES: TESTING FORAGING ARENA THEORY

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The relative importance of specific early life stages in determining future year-class strength of marine fishes depends on the duration and the respective mortality rates experienced during each stage. The transition phase describes a distinct juvenile stage associated with the recruitment to benthic habitats by pelagic life stages. The habitat shift is often accompanied by feeding shifts and metamorphosis. Density-dependent settlement, growth and mortality are often the major factors controlling recruitment success of this phase and may lead to the evolution of behavioural flexibility during the transition. Habitat use also becomes more pronounced after settlement. During this stage, juvenile fishes generally have spatial refuges from predation, and forage in limited but risky areas near refuges. Models of food density dynamics within such limited foraging areas predict that food availability and feeding rates per time spent feeding should depend strongly on juvenile density and habitat. Selection should act on the time that juveniles spend foraging, so as to strike a balance between growth and predation risk. Because the risk of predation also varies with habitat, we expect variation in foraging times and resulting growth and mortality rates to be habitat-specific and density-dependent. These concepts will be tested by focusing on the early life history of Atlantic cod (*Gadus morhua*) and cunner (*Tautoglabrus adspersus*) in the northwest Atlantic. The results suggest that future recruitment studies should include examination of spatial habitat use by juveniles, and the behavioral and physiological mechanisms for adjusting behavior to varying food density and predation risk.

BEHAVIOURAL RESPONSES OF JUVENILE ATLANTIC SALMON TO PRESENCE OF BOULDERS

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The placement of structures in streams and rivers has increasingly been used to enhance the density and biomass of economic species of fish. The influence of boulder presence on the behaviour of juvenile Atlantic salmon (*Salmo salar*) was investigated experimentally in an indoor flume fed by a 16 l s⁻¹ flow of natural river water. The flume was divided into 16 arenas (each 1m²) that were landscaped with river gravel and standardised boulders, to represent relative “complex” or “simple” habitats. Each arena housed three wild-caught fish. In a three-week trial, the effects of landscape on aspects of individual behaviour were recorded. Food intake was highest in the simple landscape and directly related to social status and time spent in the water column. The fish in the complex chambers actively maintained station in the water column significantly more than fish in simple landscapes and therefore partially compensated for reduced foraging rates associated with complexity. Fish in simple chambers spent more time orientated upstream than those in complex landscapes. There was no evidence that habitat complexity influenced levels of aggression, average aggressive distance, “constrained” territory size, or dominance. Activity and space use varied with social status. Overall, this study illustrates that addition of boulders can result in costs to Atlantic salmon parr, which can be expected to offset to some extent benefits brought about by increased stream complexity

UTILISATION AND SIGNIFICANCE OF OFF-RIVER HABITATS TO LOWLAND RIVER FISHES

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Off-river habitats such as drainage ditches, natural and man-made streams and oxbow lakes offer fish reduced flow and more highly vegetated habitats away from the main river channel. Fish may use these habitats as refuge from high flows and predation, feeding or spawning grounds. However, these habitats must be positively managed and protected from development in order to remain available for use by fish, birds and invertebrates. An understanding of their significance to fish populations is important in developing effective management and conservation of these habitats. We investigated the level of use and thus importance of several off-river habitats to fish on the River Frome, Dorset, UK. Seasonal fish abundances were measured in the off-river habitats by electric fishing the first 200 m of three drainage ditches, one man-made stream and two natural streams. Fish movements in and out of two drainage ditches and both ends of the man-made millstream were also measured on a finer temporal scale by passive integrated transponder (PIT) telemetry. 1200 fish, predominantly pike (*Esox lucius*), roach (*Rutilus rutilus*), dace (*Leuciscus leuciscus*) and eels (*Anguilla anguilla*) were PIT tagged in the off-river channels and main river and their movements between habitats monitored continuously with PIT detectors placed near the channel entrances. Fish community assemblage and level of utilisation was found to vary seasonally and also between channels. The PIT telemetry demonstrated that patterns in diel and seasonal use also varied between off-river channels. The significance and frequency of off-river habitat utilisation also varied both between species and individually.

ASSESSMENT OF THE HABITAT REQUIREMENTS OF ANGUILLA ANGUILLA IN RELATION TO CONSERVATION AND MANAGEMENT

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Anguilla spp. are K-selection periodic strategists characterised by relatively long generation times, large size at maturation and high fecundity. It will be argued that these traits are adaptive in their catadromous life cycle, with potentially very high mortality during prolonged oceanic, shelf and estuarine migratory larval stages. Also, eels in their continental growth stages are robust generalists and opportunists, enabling them to inhabit a very wide range of geographical and local habitat types. Further probable adaptive strategies involve density-dependent migrations and sex determination. However, recruitment and stocks of N. Hemisphere species have declined over the last 20-30 years. Whilst ocean-climate and regime shifts may be important, only the facultative freshwater continental life stages are amenable to detailed study and to practical conservation and management interventions. Data from electrofishing, habitat, GIS and modelling studies on *Anguilla anguilla* in England and Wales will be discussed (plus reference to other European waters and other species) to determine key habitat and environmental parameters that influence intra- and inter-catchment population distributions, structures and dynamics in space and over time. Results (at micro- and macro-scales) are critically reviewed in relation to practical approaches to conserve stocks and spawner escapement. Specific objectives are (a) detecting whether recent changes in the extent and quality of habitat could have affected stocks and spawner escapement and thus the potential benefits of habitat improvements and protection and (b) clarifying the potential applications of Habitat Suitability Indices and Habitat Evaluation Procedures in developing practical Biological Reference Points to inform management.

AN OVERVIEW OF THE NATIONAL FISH HABITAT INITIATIVE IN THE UNITED STATES

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The American Fisheries Society is working with partners in the International Association of Fish and Wildlife Agencies, several US federal agencies, and non-government organizations to develop and implement a progressive plan to address fish habitat restoration and conservation needs across the United States. The National Fish Habitat Initiative (NFHI) was conceived as a means to focus national attention and resources to establish common priorities for reversing the decline of aquatic habitat health in the United States. Aquatic habitat was one of the six major priority areas identified by the U.S. Fish and Wildlife Service in its report, "Fisheries Programs for the Future." The NFHI operationalizes recommendations from the USFWS and others by joining together a diverse group of stakeholders to develop an implementation strategy that brings national focus, coordination, broad strategies, and adequate funding to bear on fish habitat improvements and supports locally-driven joint ventures. The highly-successful North American Waterfowl Management Plan (NAWMP) provides a useful model, although aquatic habitat issues are more complex than the issues addressed through the NAWMP. The NFHI leadership may aim to broaden the NFHI into a continental initiative rather than solely national. Regional stakeholder meetings and a science/measurement workshop have provided initial direction. Future efforts will focus on building consensus for actions needed, through a broad coalition of states, tribes, federal agencies, and private conservation organizations.

DETERMINING STREAM QUALITY USING THE INDEX OF BIOTIC INTEGRITY: ARE CHANNELIZED STREAMS SPECIAL?

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The objective of this study was to determine the relationship between fish community structure and habitat in streams dominated by an agricultural landscape. Fishes from 20 unchannelized and 20 channelized streams were sampled using electrofishing gear in East Central Indiana, USA. Streams that had been channelized showed a lower quality fish community as measured by the Index of Biotic Integrity (IBI). Stream habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) and also indicated that channelized streams had lower quality primarily due to a loss of heterogeneous habitat. Linear regression analysis relating IBI and QHEI was positive and significant, and demonstrated that a reduction in riffle and pool areas associated with channelization was the most significant factor influencing the fish community. Furthermore, species lost when streams are channelized are predictable, and often represent environmentally sensitive species. The results of this study suggests that stream channel alterations have a negative and lasting influence on the fish community that should be recognized when any stream development occurs.

HABITAT LOSS AND POTENTIAL HABITAT RESTORATION FOR NEW ZEALAND'S ENDEMIC MUDFISH SPECIES

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New Zealand has five endemic mudfish (*Neochanna*) species that have specific but differing habitat preferences. All species, with the possible exception of the newly recognized Chatham Island mudfish, have suffered significant population reductions due to habitat loss. All five species are now regarded as threatened to some degree. Potential solutions to mudfish recovery are therefore:

1. establish new populations in virgin habitat
2. restore past mudfish habitats
3. improve or expand existing habitats.

The potential for success of each of these strategies will depend on a detailed knowledge of the species' habitat preferences, the biology of each species, and the potential availability of suitable locations for habitat restoration. The establishment of new mudfish populations is further complicated by the requirements for large-scale captive breeding or rearing of animals, and legislative restrictions on the translocation of aquatic life. Captive rearing and the transfer of fish to new sites must also seek to preserve the genetic diversity of each species. The enhancement of existing habitats, on the other hand, involves improving habitat quality and addressing anthropogenic and other impacts that threaten the long-term viability of each population.

This paper examines the potential for establishing new mudfish populations with respect each species' biology, diversity and habitat requirements. On the basis of their specific habitat preferences and the potential lack of suitable environments, the black and Northland mudfishes are possibly the most problematic species with which to expand existing populations or to establish new populations. These species are therefore most dependent on habitat enrichment for their recovery.

THE INFLUENCE OF HABITAT CHARACTERISTICS ON THE ENERGY RESERVES OF FEMALE SPAWNERS OF RED MULLET (*MULLUS BARBATUS*) IN THE MEDITERRANEAN SEA

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This study aims to describe the effect of habitat characteristics on the energy reserves of red mullet (*Mullus barbatus*) in the north-western Mediterranean. We compare the energy reserves between individuals inhabiting different areas of the seabed (e.g. areas close to the Ebre and Rhône River mouths vs areas not influenced by river run-off; seabed areas strongly impacted by trawling activities vs areas less impacted). This study also attempts to establish a relationship between female adult condition (i.e. energy reserves in the muscle) and their reproductive potential (i.e. energy reserves in the gonad). To evaluate energy reserves, wet and dry weights of tissue were measured and concentrations of total lipid were estimated with the Soxhlet method for the muscle and gonad of female spawners from samples collected during spring 2004. Absolute lipid levels in each tissue were analyzed to describe the distribution and storage of lipids during spawning. We also study the relationship between the total lipid content and the triacylglycerol levels (TAG), which is the most important lipid class for energy storage purposes in fish. Finally, we establish the relationships between total lipid content and simple indicators of condition such as Fulton's K index.

INFLUENCE OF HABITAT DISTRIBUTION ON MOVEMENTS AND HABITAT USE OF EUROPEAN GRAYLING

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A wide variety of studies has been carried out to determine the habitat use of freshwater fishes, including salmonids such as grayling *Thymallus thymallus*. However, in many cases, freshwater habitats, such as rivers, have been modified to a greater or lesser degree, influencing the availability of habitats and access to these. Yet there is limited information on how such differences between neighbouring river reaches affect the spatial ecology of river fishes. This study used radio-telemetry and PIT telemetry to examine patterns of movement and habitat of grayling use in relation to habitat heterogeneity in adjacent reaches and to accessibility between river reaches. Results indicated in relatively homogenous habitats, strongly modified by human activities, adult grayling moved greater distances than those in more heterogeneous habitats. Habitats use varied between seasons and in response to environmental conditions. Habitats use by grayling in relation to availability is discussed. PIT telemetry studies suggested that sloping, cross-river barriers greater than about 0.3 m had a substantial influence. The influence on habitat structure at the reach scale on patterns of spatial behaviour is discussed.

THE SHALLOW WATER GOBIID ASSEMBLAGE OF THE VENICE LAGOON: ABUNDANCE, SEASONAL VARIATION, AND HABITAT PARTITIONING

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The gobiid assemblage of the Venice Lagoon shallow waters was investigated by means of a semi-quantitative standardised sampling (using a beach seine), stratified into 5 main types of shallow water habitats and conducted on a seasonal basis during one year. Spatial and temporal variation in abundance, size distribution and reproductive status were analysed for six goby species, as well as the relationship between species abundance and some abiotic factors. Patterns of spatial overlap between species were also investigated. Small sized species, and especially the marbled goby *Pomatoschistus marmoratus*, dominated the local assemblage. Although the cycle of shallow water colonization and variation in total abundance were basically similar, species showed differences in timing of reproduction and recruitment, as well as in habitat preference. The large sized species belonging to the genera *Gobius* and *Zosterisessor* tend to overlap their habitat use, being more abundant in seagrass habitats than in the unvegetated habitats, whereas the small sized species belonging to the genera *Knipowitschia* and *Pomatoschistus* avoid seagrasses, preferring in most cases mudflats and salt marsh creeks. Within these two groups of species some further slight differences in habitat preference, relationship with abiotic factor and reproductive ecology could be detected. Results were discussed in the light of both ecological mechanisms underlying coexistence in closely related species and the current knowledge on the life history characteristics of each species.

HYDROLOGICAL PROCESSES IN THE HYPORHEIC ZONE DETERMINE SALMONID EMBRYO SURVIVAL AND PERFORMANCE

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Salmonid eggs are buried in redds, typically to depths of between 50 and 300mm beneath the streambed, in the hyporheic zone where groundwater and surface water mix. The over-winter, in-redd phase is protracted (ca. 5 months) and accounts for a large but highly variable proportion of total lifetime mortality. Embryo survival and development depend on the delivery of oxygen to redd habitat via interstitial flow. Previous studies of interstitial water quality have focused on the intrusion of fine sediment and resultant impairment of surface water delivery. However, these mechanisms are only partially explanatory in some locations. Long-residence groundwater is often depleted of oxygen and therefore potentially negative for embryo performance. In this paper we demonstrate that locally variable contributions of groundwater and surface water can have a substantial effect on in-redd water quality and therefore embryo performance. In-redd water quality was investigated in the Girnock Burn, a tributary of the Aberdeenshire Dee between 2002 and 2005 and was shown to vary at a wide range of temporal and spatial scales. Where groundwater dominated the hyporheic zone, DO concentrations were low and so too was embryo survival. At surface water-dominated sites, water quality was generally good and approached that found in surface water. At intermediate sites where embryo survival was generally good, significant sub-lethal effects were evident. This paper highlights the importance of inter-disciplinary awareness for fisheries science.

PROTECTING MIGRATORY FISH: HABITATS DIRECTIVE REVIEW OF CONSENTS IN THE RIVERS USK & WYE

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The EA has a statutory responsibility through the Habitats Regulations to review the impact of currently permitted abstraction licences on designated features within the Special Area of Conservation concerned (in this case the Rivers Usk and Wye in south east Wales). There are nine species designated for each of these two rivers: Atlantic salmon, sea lamprey, river lamprey, brook lamprey, allis shad, twaite shad, bullhead, otter and communities of *Ranunculus* vegetation, plus the native white-clawed crayfish for just the River Wye. This poster paper guides you through the threats, assessment and protection of the migratory species concerned: salmon, sea lamprey, river lamprey, allis shad and twaite shad. These species all enter the freshwater environment to find suitable habitat for spawning and juvenile development. The abstraction of water from the river and its tributaries can threaten the designated features if too much water is taken, or if that water is taken at the worst times of the day or year or for too long a period. All life stages can be affected including eggs, juveniles, and adults migrating upstream. The periods of potential conflict between water abstraction and species lifecycles can therefore occur at various times of the year for each species and will depend upon the flow, depth and velocity requirements of the species and life-stage concerned. Knowledge of the water resources requirements of these species is minimal so determining ecological impact can be a challenging task.

VITAL POPULATION RATES ACROSS HABITAT GRADIENTS

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Vital population rates such as growth, survival, and mortality are influenced by multiple ecological factors. Much research has demonstrated that habitat type can affect vital rates in some demersal fish species via mediation of predator-prey interactions at local spatial scales. How these localized effects scale up to influence population-level patterns of abundance and distribution at broad spatial scales is less clear. Using data from NOAA's National Marine Fisheries Service, Northeast Fisheries Science Center bottom trawls and food habits databases, we employed a set of bioenergetic equations to compute the daily *per capita* rate of consumption and mortality via predation for individual groundfish species in the N.E. U.S. Continental Shelf Ecosystem. An annualized, population-level average was determined for the 1999-03 time period. Geographic information system (GIS) methods were used to integrate this synoptic information on vital rates with spatially referenced datasets for bottom depth, bottom temperature, and surficial sediment grain size. Multivariate statistical methods were used to explore the variation in consumption and mortality rates across gradients in these abiotic habitat characteristics. We found that rates of consumption and mortality varied spatially and that this variation was associated with habitat. Rates were maximized along particular portions of the habitat gradients and these patterns were species-specific. Our results demonstrate the challenge of evaluating key population processes at the spatial scales on which marine fish populations and their associated fisheries operate. Yet the demonstrated ability to integrate individual, population, and habitat information should enhance our ability to manage our living marine resources.

THE METABOLIC BENEFIT OF SHELTER IN JUVENILE ATLANTIC SALMON, *SALMO SALAR*

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Although many studies have demonstrated the importance of shelter for many species of fish, none as yet have looked at the effect a refuge has on its basal metabolic rate (BMR). The effect shelter has on standard metabolic rate in Atlantic salmon parr was investigated. Single fish were placed into respirometer chambers in which a shelter was either present or absent and their metabolic rate was measured. The BMR of the fish when a shelter was present was significantly lower than those without a shelter. It is concluded that a lack of available shelter can cause a significant increase in BMR, possibly by increased stress levels, and therefore imposes a metabolic disadvantage.

PUTTING ALL YOUR EGGS INTO ONE BASIN: HABITAT SELECTION OF SPAWNING COD IN THE EASTERN BALTIC

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Until recently, the ability to determine the detailed movement of cod at an individual level has not been technically possible. The advent of data storage tags (DSTs) now makes it feasible to resolve horizontal and vertical movement and, by integrating these movements with environment data, understand the relationship between fish behaviour and habitat. The aim of this paper is to describe a GIS-approach to analysing the movements of individual fish in relation to their habitat. As a case study, we have analysed the movements of cod in the Baltic Sea, where cod egg survival is restricted to the deeper, more saline basins. First, we reconstructed the movement paths of 10 cod by matching the pressure, salinity and temperature recorded from DSTs with an environmental spatial database. Second, for each movement path, the suitability of the environment for spawning (based on oxygen, salinity and temperature) was compared to the conditions cod would have experienced had they moved randomly. The results show that most cod undergo a switch from a pelagic to a demersal habit, and restrict their horizontal movements to the areas in which egg survival is likely to be maximised. This remarkable transition in behaviour during the spawning season demonstrates a strong link between individuals and their environment, and suggests that cod are capable of selecting habitat in order to optimise their reproductive success.

THE INFLUENCE OF STREAM HABITAT ON INTER- AND INTRA-SPECIFIC COMPETITION IN JUVENILE SALMONIDS.

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Brown trout (*Salmo trutta* L.), in migratory (sea trout) and non-migratory forms, commonly live sympatrically with salmon (*Salmo salar* L.) and have broadly similar habitat requirements and life cycles. Most reported studies on density dependent regulation in these species have been based on single species responses often using data from sites sampled simultaneously, but having different habitat features. Under these circumstances species- and age-specific habitat preferences, coupled with inter-site habitat variation, introduce the potential to confound estimates of loss rates and hence exploration of population dynamics. This paper incorporates habitat effects into the analysis of inter and intra-specific interactions.

The study uses long-term data sets from sympatric trout and salmon populations in contrasting migratory (River Conwy, North Wales) and non-migratory trout (River Wye, Mid Wales) populations, living in eight different tributaries. Populations were sampled by electro-fishing over five to ten years and habitat features were sampled and evaluated using the HabScore empirical habitat model. Habitat quality indices were incorporated into statistical analyses to explore the remaining influence of density dependent processes on loss rates. The results describe habitat variation across the stream types, salmonid population characteristics and explore the combined roles of inter- and intra-specific density dependence and habitat features in determining abundance of juvenile trout and salmon. The simultaneous analysis of habitat and density effects is informative and not previously reported in this context. The results are reviewed in the light of current knowledge on juvenile salmonid population dynamics and habitat usage in streams.

THE IMPORTANCE OF SOUTH-ATLANTIC BIGHT OVER-WINTER HABITAT TO YOUNG-OF-THE-YEAR BLUEFISH

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In the autumn adult and young-of-the-year (YOY) bluefish *Pomatomus saltatrix* undertake a southerly migration from the Mid-Atlantic bight (MAB) to the South-Atlantic Bight (SAB). It is believed the SAB provides important over-winter habitat for bluefish before their spring northward migration. Surprisingly, relatively little is known about winter habitat for this commercially and recreationally important species. This study builds upon previous work showing for the first time the occurrence of YOY bluefish in northeastern Florida, particularly in inshore habitats, including estuaries and ocean beaches. Here we will sample both inshore estuarine and beach locations as well as offshore sites along a 60 mile stretch of coast from St. Augustine Inlet to Daytona Beach using otter and Methot trawls. Sites range from being heavily residential to fairly pristine. To distinguish different habitats, substrate, environmental factors and prey fish will be analyzed. Here we will present preliminary results comparing winter and summer distribution and diets. Preliminary results show that bluefish stomachs taken from summer fish ranging in fork length from 50mm – 80mm yielded 100% piscine prey by weight and only 2.5% of stomachs were empty. Winter caught bluefish, which had a greater size range, 8.3% of stomachs were empty and piscine prey made up 93.5% of prey weight. Moreover, estuaries have yielded greater abundances of bluefish prey than ocean beach habitat. Currently the role of SAB estuaries for over-wintering bluefish is unknown, and any further degradation of habitat could have wide-ranging implications for this declining species.

PRINCIPLES FOR LINKING FISH HABITAT TO FISHERIES MANAGEMENT AND CONSERVATION

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Habitat is a product of an evolving and dynamic environmental system with broad and often ill-defined borders. Therefore, does 'habitat' underpin effective fish management and conservation, or is the issue more complex? We propose a set of eight simple ecological and social principles that could enhance the understanding of what constitutes fish 'habitat' and, if implemented, could contribute to improved management and conservation strategies. The habitat principles are a small, interrelated subset that may be coupled with additional ones to formulate comprehensive guidelines for management and conservation strategies. We propose that, 1) Habitat can be created by keystone species and interactions among species; 2) The productivity of aquatic and riparian habitat is interlinked by reciprocal exchanges of material; 3) The riparian zone is fish habitat; 4) Fishless headwater streams are inseparable from fish-bearing rivers downstream; 5) Habitats can be coupled — in rivers, lakes, estuaries, and oceans, and in time; 6) Habitats change over hours to centuries; 7) Fish production is dynamic due to biocomplexity – in species and in habitats, and finally; 8) Management and conservation strategies must evolve in response to present conditions, but especially to the anticipated future. We contend that the long-term resilience of native fish communities in catchments shared by humans depends on incorporating these principles into management and conservation strategies. Further, traditional strategies dimly reflect the dynamic nature of habitat, the true extent of habitat, or the intrinsic complexity in societal perspectives. Forward-thinking fish management and conservation plans view habitat as more than water. They are multilayered; ranging from pools to catchments to ecoregions – and from hours to seasons to centuries. They embrace, as a fundamental premise, that habitat evolves through both natural and anthropogenic processes, and that patterns of change may be as important as other habitat attributes.

FOREST CHANGE AND STREAM FISH HABITAT: LESSONS FROM 'OLDE' AND NEW ENGLAND

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The North Atlantic region has a long history of land use change that has influenced and will continue to influence stream ecosystems and fisheries production. In this paper, I explore and compare the potential consequences of these changes in New England, USA and the United Kingdom. Both regions were extensively deforested (< 20% forest cover) and essentially no extensive overmature or old growth forest stands remain. In New England, recovering forests, consisting almost entirely of native species, now cover > 80% of the landscape, and natural regeneration is sufficient to maintain commercial harvest. Associated with this large-scale reforestation, agricultural and early successional landscapes, common from the 18th through most of the 20th century, are currently rare and declining in this region. Unexpectedly, forest recovery has not led to across-the-board increases in fisheries production, and in some cases appears to be associated with population declines. In the UK, forests still cover < 20% of the landscape, and existing forests frequently consist mainly of exotic conifer plantations stocked at high stand densities and harvested at frequent rotations, requiring cultivation and site preparation to regenerate. Far from increasing in response to forest cover, upland trout production in the UK appears to be reduced in the presence of pine plantations; as of yet, there is insufficient information to assess the effects of native, mature forest recovery. The overall picture suggests a potential production peak in early-successional, open, non-forested habitats, provided that associated deleterious effects (temperature change, siltation, excessive nutrients, etc.) are not excessive, and further suggests a potential production trough in landscapes dominated by second-growth, aggrading forest stands. Understanding the ultimate effects of forest restoration continuing beyond the second-growth stage will depend on the extent to which factors potentially supporting productivity in these intact systems (terrestrial/aquatic linkages, fish migrations, nutrient loss from old growth stands, Large Woody Debris recruitment) are allowed to be re-established.

POPULATION DIFFERENCES IN RESPONSE TO HYPOXIA: BEHAVIOUR AND PHYSIOLOGY OF 3-SPINED STICKLEBACKS

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Three-spined sticklebacks inhabit a diverse range of habitats and show a remarkable suite of adaptations to enable them to colonise various environments. Populations from different locations experience specific environmental variation and local adaptation may develop. One such environmental variable is dissolved oxygen and a reduction in environmental oxygen can deleteriously affect both behaviour and physiology. The constraint it imposes upon metabolism may limit energetically expensive behaviours such as aggression, which is crucial in the maintenance of dominance hierarchies in fish communities. Fish chronically exposed to different levels of environmental hypoxia during development or over many generations may be more tolerant of hypoxia thereby maintaining aggressive behaviour and dominance hierarchies in the face of a low oxygen environment. This prediction has been tested by comparing populations of 3-spined stickleback (*Gasterosteus aculeatus*) from different natural habitats such as static ponds and flowing rivers. Fish were exposed either to hypoxia (20% oxygen saturation) or normoxia and dominance ranks constructed by monitoring aggressive interactions and feeding rates. The fish were killed and L-lactate, glucose and cortisol assays were performed on whole body homogenates to record physiological responses. In order to calibrate the level of stress activated by hypoxia the same physiological parameters were measured after a standard stressor- confinement. Microsatellite analysis of the populations was also carried out in order to identify whether population differences were matched by genetic variations. Results for populations from different habitat types will be compared and the differences between the population's responses to environmental stress discussed.

EFFECTS OF FOOD AVAILABILITY ON TEMPORAL ACTIVITY PATTERNS: SAFETY FIRST FOR SALMON IN SUMMER

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Spatial and temporal variations in habitat use can have profound effects on the optimal trade-off between growth (G) and mortality (M)

POST RELEASE BEHAVIOUR OF WILD AND DOMESTICATED RESIDENT BROWN TROUT (*SALMO TRUTTA*) IN CANALISED AND MEANDERING STREAM SECTIONS.

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Post-release behaviour of transplanted adult wild and hatchery-reared trout (*Salmo trutta*) was studied in two small macrophyte-rich lowland streams. The behaviour of released trout was studied in four regulated- and in four naturally meandering sections (length 105 – 119 m, area 326 – 585 m²) of the streams, screened from the rest of the stream with grids. In each experiment 16 – 30 trout (mean length 25.6 – 35.5 cm) were released yielding densities between 3.9 and 6.3 individuals 100 m⁻². Trout were tagged with transmitters only or with a combination of transmitters and Data Storage Tags (DST's), and located at least daily. Initial movement was vigorous and mainly downstream. Wild trout moved more than hatchery trout during the first few hours and tended to continue to do so during frequent positioning after 3 – 5 days. Hatchery trout tagged with DSTs had a distinct pattern of movement between different depths at different times of the day associated with light conditions. Wild trout tagged with DST's displayed a more variable pattern of movement, probably associated with previous experience. Hatchery DST tagged trout had more changes in depth position than wild trout. They exposed themselves to higher potential risk of being predated by holding a position close to the surface at high light conditions more frequently than wild trout.

PRODUCTION OF JUVENILE FISH IN SHALLOW SHELTERED BAYS IN THE NORTHERN BALTIC SEA – TOOLS FOR SURVEYS AND MANAGEMENT OF SHALLOW AREAS

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In the northern Baltic Sea, shallow sheltered bays provide habitats for diverse plant and animal life. In exposed localities the vegetation is dominated by some vascular plant species, e.g. *Myriophyllum spicatum* and *Zannichellia palustris*, but also the marine algae *Fucus vesiculosus* is found. These areas serve mainly as recruitment areas for marine fish, e.g. gobies and sticklebacks. Protected localities are covered by *Chara* spp., *Najas marina* and *Potamogeton* spp., and draw freshwater species, e.g. perch, pike and cyprinids. Due to land uplift, shallow bays with an opening threshold are slowly cut off from the open sea. These land uplift areas (flads and glos) are classified as highly threatened biotopes and respond quickly to changes. Some of the plants that occur here (*Chara* spp.) are red listed. An international joint project between Finland, Åland and Sweden has carried out extensive field studies in the land uplift areas of the Finnish-Swedish archipelago during 2002-2004. Methods for surveys in shallow areas, e.g. point abundance sampling of fish and an improved transect line method for vegetation surveys, have been developed within the project. The results show that the interrelationship between morphometric parameters total depth, opening depth, exposure and total size of the bay form an important basis for species composition and occurrence of vegetation and for abundance and diversity of fish. Vegetation structure and amount of coverage play an important role for the presence of fish. The method development and project results serve decision making in conservation ecology (e.g. Natura 2000) and management (e.g. fisheries policy and areal planning) of coastal areas.

THERMAL HABITAT AND POPULATION VARIATION IN COD

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Determining the range of temperatures under which a species can exist is central to understanding their population dynamics. A critical environmental factor in influencing phenotype is the thermal environment. Cod populations persist over a wide temperature range from 20°C in the southern North Sea to sub-zero in Iceland and Arctic Canada. The cod population is highly sub-structured and each sub-population has evolved a suite of life history traits specific to its local environment. In the light of climate change, it is vital that we understand the thermal responses of each population in order that we can predict future changes in cod growth and distribution. I am currently experimenting on two Scottish populations of cod from different thermal environments. The east coast population experience low but highly variable temperatures while the west coast population has a warmer and less variable thermal regime. Preliminary trials have shown that these cod vary in competitive ability and in certain morphometric characteristics. Common garden experiments are being used to assess population differences in temperature for egg development, growth, respiration and maturation.

THE EXPLOITATION OF RED MULLET (*MULLUS BARBATUS*) IN THE SOUTHERN SARDINIAN SEA (CENTRAL-WESTERN MEDITERRANEAN): PROTECTION OF THE NURSERY AREAS AND IMPLICATIONS FOR MANAGEMENT

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The red mullet (*Mullus barbatus* Linneo, 1758) is among the species of greatest commercial interest in Sardinian waters; typically demersal, it is fished throughout the year, mainly with trawl nets, at depths of less than 200m. Its state of exploitation in the seas around Sardinia (Central-Western Mediterranean) is constantly monitored since 1994, as for other commercial species, both through experimental trawl surveys and analysis of the landings. The above actions enabled us to study the spatio-temporal distribution of the species in three sea areas off southern Sardinia. The population structure demonstrated that the greatest concentrations of young specimens were at depths inferior to 50m, locating nursery areas in this bathymetric interval. The temporal evolution of biomass indexes (kg/km² e N/km²) were examined in the three areas between 1994-2004. The state of exploitation of the red mullet, evaluated through Pope's cohort analysis (1972), proved to be different in the three areas investigated. Variations in the fishing mortality rate (F) and the relative trend was related to the evolution of the fishing efforts over the years (TGT/area). In order to evaluate the effects of protecting the coastal area and to plan management of the resource, a number of possible scenarios are here delineated, through the use of predictive models to hypothesise the protection of nursery areas.

ONTOGENETIC INDUCED SHIFTS IN THE ECOLOGY OF SUNBLEAK, *LEUCASPIUS DELINEATUS* DURING EARLY DEVELOPMENT

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From egg activation, to maturation, senescence and death, ontogeny plays a clear role in the ecology of fishes. The complex and rapid changes in morphology and physiology that occur during early development make this a particularly dynamic period, in terms of synchronisation of ontogeny and ecology, with major implications for species recruitment. This is particularly important where invasive species are concerned, as understanding their ontogenetic ecology will highlight the traits involved in successful recruitment. Using the non-native sunbleak, *Leucaspius delineatus* as a model, the relationship between ontogeny and ecology was studied with a view to identifying specific morphological and physiological processes involved in influencing ecological niche shifts. Following a predefined saltatory model for the early ontogeny of sunbleak, field studies examined the temporal use of microhabitat, diet and morphological change throughout early development. Following a dramatic shift in both morphology and ecology between free embryo and larval periods, habitat use and diet showed little change during the larval period, with habitat use confined to marginal, vegetated areas and prey items associated with these habitats well represented in the diet. During the final larval step (L5), transition to the juvenile stage resulted in the stabilisation of relative growth, acquisition of the adult morphotype and was associated with a clear shift in diet and habitat use. During this period, sunbleak moved for the first time into open, deeper water, away from the banks, and utilized the same food spectrum as the adults. Specific relationships between form and function are further discussed.

COMMON SOLE (*SOLEA SOLEA*; LINNAEUS, 1758) SPATIAL DISTRIBUTION IN THE NORTHERN ADRIATIC SEA

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The common sole (*Solea solea*; Linnaeus, 1758) is a migratory species representing one of the most important demersal resource in the Northern Adriatic Sea. To date the analyses of the spatial distribution of this species and its links with oceanographic and benthic habitat features have been poorly studied in this area. In order to provide better insights on this topic a first trawl survey was conducted during May 2005. 17 standardized hauls were carried out towing 4 “rapido” gear simultaneously (each 3.59 m wide; cod-end mesh size: 48 mm). A systematic sampling design was followed with sampling stations laying along four transects in the E-W direction, whose depths ranged from 7 to 33 m. Common sole catch per unit of effort (as abundance and biomass), size distribution and sex ratio were assessed at each station along with oceanographic parameters such as sea-bottom temperature, salinity, density and oxygen saturation. Furthermore the benthic assemblage and habitat features were described through the analyses of the mega-epifauna collected by “rapido” gear. Common sole showed higher densities in the shallowest areas; furthermore results pointed out the presence of individuals of smaller sizes in the shallow stations in comparison with the deeper ones (1-way ANOVA; $p < 0.001$). The average sex ratio on the whole dataset was close to 1:1 despite marked deviations from this value in some stations. Results are also discussed with the aim at exploring the relationship between common sole distribution, oceanographic parameters and benthic habitat features.

HABMAP - HABITAT MAPPING FOR CONSERVATION AND MANAGEMENT OF THE SOUTHERN IRISH SEA

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HABMAP is a three-year seabed mapping project covering the southern part of the Irish Sea. The project will start by bringing together existing information on seabed habitats for the southern Irish Sea. Relationships between physical data (e.g. sediment type, tidal currents) and biological data will be examined to develop a model to predict biological community type based on physical parameters. Data will be collected to fill in knowledge gaps and to test our model during two surveys in summer 2005. The resulting seabed habitat maps will be used to help inform management of the seabed, e.g. marine spatial planning. The project is partly funded by the INTERREG IIIA programme.

UNDERSTANDING FISH HABITAT ECOLOGY TO ACHIEVE CONSERVATION

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Habitat science can provide the unifying concepts to bring together ecological studies of physiological tolerances, predator avoidance, foraging and feeding, reproduction, and life histories. Its unifying role is built on two assumptions, imported from terrestrial habitat science and not always stated explicitly: that competition is present inter-specifically and/or intra-specifically under at least some conditions, and that habitat features have some persistence and predictability in space and time. Consistent with its central conceptual position in ecology, habitat science has contributed importantly to scientific advice on pollution, coastal zone management, and many other areas of environmental quality, although it has been largely divorced from developments in fish population dynamics done in support of fisheries management. Commitments by most management agencies to apply an integrated, ecosystem approach to management of human activities in marine systems, poses new challenges to marine science advisors to management. Integrated management and ecosystem approaches both inherently require spatial thinking and spatial tools, making habitat science a particularly relevant advisory framework, particularly because of the unifying role of habitat in ecology. However, the basic mechanisms behind ocean biological dynamics – productivity, concentration, and retention, present much weaker opportunities for competition and less persistence and predictability – weakening the foundations of theory and concepts behind current habitat science. The paper highlights the new types of thinking about “habitat” that will be required, if habitat science is to meet the advisory needs of the new approaches to management.

ASSESSING HABITAT OCCUPANCY OF ATLANTIC COD (*GADUS MORHUA*) IN THE NORTH SEA

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Atlantic cod (*Gadus morhua*) is a migratory species of great economic importance. Despite centuries of exploitation however, cod migrations between spawning and feeding grounds are relatively little understood. We developed a GIS-application to reconstruct the post-spawning migrations of 30 Atlantic cod in the North Sea from depth and temperature data from electronic data storage tags (DSTs). The results show that most cod exhibited highly directed migrations to specific feeding grounds, where they then remained for up to six months before beginning a pre-spawning migration. The level of detail we were able to achieve has enabled us to quantify habitat occupancy by these cod and, by integrating the detailed results with conventional tagging data, to assess the importance to cod of particular areas/ habitats of the North Sea.

NEST DIVERSITY OF THREESPINE STICKLEBACKS: PROVENANCE AND PLASTICITY IN RESPONSE TO ENVIRONMENTAL CHANGE

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Patterns of behaviour can become specialised to suit prevailing ecological conditions, either as a result of population-level genetic adaptation or of individual-level behavioural plasticity. The two mechanisms make opposite predictions for the ability of species to respond in the face of rapid, anthropogenic environmental change, so distinguishing between them is important. Threespine sticklebacks *Gasterosteus aculeatus*, the males of which build nests to serve as receptacles for developing embryos, inhabit a wide variety of aquatic habitats, from still waters to fast-flowing streams. Here we detail laboratory studies examining nest construction of male sticklebacks from two lake and two river populations in mid-Wales. First we quantified diversity in the structure of nests, built under common-garden conditions, and determined whether this was related to provenance. In a second set of experiments individual males were allowed to build nests under their 'natural' flow regime and under a novel flow regime. We discuss the results in the context of the ability of sticklebacks to adjust a critical aspect of their reproductive biology in the face of changing environmental conditions. Understanding the extent to which fish are able to adjust patterns of behaviour following rapid environmental disruption, such as anthropogenic flow manipulation, is likely to be valuable in improving fish conservation strategies.

IS IT POSSIBLE TO PREDICT THE SPATIAL DISTRIBUTION OF NURSERY AREAS FOR FISHES IN SHALLOW AREAS OF THE BALTIC SEA? –A FIRST ATTEMPT TO CONSTRUCT PREDICTIVE SPATIAL MODELS

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Shallow areas have for long time been viewed as important recruitment areas of fishes, in both marine and freshwater systems. The shallow parts of the wide-stretched archipelago region of the Baltic Sea are no exception and several freshwater and marine species depend on shallow areas during early life-stages. Our aim was to test if such important nursery areas can be identified by using estimates of fish habitat requirements to produce geographical predictions by combining several layers of habitat information. The predictive models were mainly based on data from an extensive field survey conducted in shallow inlets. The data-set contains detailed information on the abundance of young fishes and other parameters such as the coverage of underwater vegetation. The relationships between the habitat demands of early life-stages in fish and environmental factors were applied to geographical space by combining several of the environmental factors as layers in a GIS-based analysis. Among the important layers tested were depth, wave-exposure, vegetation coverage, temperature and turbidity. The model outputs were validated against data from other surveys of nursery areas. The results imply that the model outputs and method of working are promising for many species. They may thus provide information of importance for future management of coastal areas and facilitate the protection of these sensitive habitats, and also complete or substitute more costly field surveys.

USING ARTIFICIAL HABITATS TO RESTORE OR ENHANCE INSHORE FISHERIES: AN OBSERVATION-BASED ECOSYSTEM SIMULATION

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The Loch Linnhe artificial reef system is a large-scale multi-reef deployment on the west coast of Scotland that has been constructed to examine how reef design, habitat complexity and reef size affect developing fish assemblage structure and fish numbers within the contexts of fishery protection, enhancement or restoration. Preliminary field observations indicate that the provision of artificial habitat of varying design does alter the numbers and types of fish present over differing spatial scales. In order to examine the potential fishery management effects of reef design over a range of temporal scales a series of ecosystem models were constructed based on holistic simulations for the west coast of Scotland. Based on the large-scale mass-balance models numerous smaller-scale simulations were derived containing a matrix of forcing and management functions that were driven by habitat type and reef design for open, restricted and closed fisheries. Finally, spatial simulations were run over a range of temporal scales that examined the presence and absence of artificial habitat with or without natural reefs within realistic environmental situations. The simulated trends supported preliminary field observations that artificial reefs with the most complex habitat supported more diverse and numerous fish aggregations and were more productive than natural reefs. Reef designs that maximised the reef edge as a function of the total reef volume were more productive compared with larger single deployments. Limiting fishing activity within some or all of the artificial reef system resulted in significant fishery exports from the protected area into an open fishery.

A CASE STUDY OF HABITAT COMPENSATION TO AMELIORATE IMPACTS OF HYDROELECTRIC DEVELOPMENT; EFFECTIVENESS OF RE-WATERING AND HABITAT ENHANCEMENT OF AN INTERMITTENT FLOOD OVERFLOW CHANNEL

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Development of the Rose Blanche River, insular Newfoundland, Canada, for hydroelectricity resulted in destruction of fluvial habitat (flooding and dewatering) and *habitat compensation* was required to offset habitat loss according to Fisheries and Oceans Canada's Policy for the Management of Fish Habitat (circa 1986). This Policy requires that mitigation and compensation alternatives are examined in order to strive to result in 'no net loss' of habitat productive capacity. The preferred compensation alternative involved modification of a natural high flow, flood bypass channel, which was wetted only during peak flow snow melt events. The channel consisted of 99 units (100 m²) of habitat and was modified, with hydraulic control structures, to ensure a constant regulated flow to the channel year round. Physical enhancement of the channel included addition of smaller substrate materials (primarily spawning gravels), bank stabilization, protection dykes to prevent flooding from the main river, and installation of low head barriers to create pools. A three year study (2001-2003) was undertaken to assess: (i) habitat stability in the channel; (ii) re-population of the compensatory channel (fish density and biomass); (iii) biological characteristics (age, growth, and survival) of fish utilizing the channel; and (iv) movement and migration (i.e. dispersal and recruitment) between the compensatory channel and the river main stem. Study results indicated an evolution of meso-habitat characteristics post-construction, with distribution of spawning gravels and increased input of organic matter, which reflected a geomorphological and hydrological response to establish stable conditions in the re-watered channel. The channel was utilized preferentially by brook trout (*Salvelinus fontinalis*), with a mix of size/age classes, indicating the compensatory channel was providing habitat for all life stages. Total fish biomass over three years increased in the compensation channel while it decreased in the river main stem. Young of the year production was particularly strong for both brook trout and Atlantic salmon (*Salmo salar*) within 2001 and 2002 suggesting good spawning and incubation conditions. Year class strength was not as apparent in the main stem indicating differential (improved) survival in the compensatory habitat. Tag returns did not provide evidence of much movement within the channel and lesser movement between the main stem and the channel.

STRUCTURAL ATTRIBUTES OF ARTIFICIAL REEFS AND ASSOCIATED FISH ASSEMBLAGES

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For the last 12 years our group has been involved in 11 experimental studies examining differing aspects of artificial reef structure on the formation of reef fish assemblages. For example, we have looked at the effects of reef complexity, void space, predator exclusion caging, reef size and spacing on associated assemblages. Further, in excess of 1000 visual census have been done on natural reef. This paper looks across studies to examine the structural attributes of artificial reefs that enhance species richness and abundance; primarily of juvenile fishes. Further, we compared fish assemblages on artificial reefs to neighboring natural reef thereby providing insight into the mitigation or restoration potential of the varying artificial reef designs. All the studies were performed offshore Broward County Florida in water depths of 7-22m with concrete reefs of varying design but all of approximately 1m³ in size. Treatment replicates varied from 2 to 40 and fishes were inventoried monthly or quarterly by visual census for periods ranging from 12 to 48 months. As a whole, our data indicate that, in order of importance: overhang structure, predator exclusion, and complexity are the most important attributes for the acquisition of a diverse and abundant fish assemblage on artificial reefs. In terms of abundance per m², some artificial reefs were more than 100 times greater than natural reef. This fact calls into question the current use of footprint, or areal, exchange (m² of artificial for m² of natural reef) in coral reef restoration or mitigation.

JUVENILE FISH ABUNDANCE IN RELATION TO VEGETATION AND KEY ABOTIC FACTORS IN SHELTERED BAYS IN THE NORTHERN BALTIC SEA

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In the archipelagos of the northern Baltic Sea, several freshwater fishes use shallow sheltered bays for spawning and nursery. The high potential for recruitment depends largely on beneficial temperature conditions during spring, but other important biotic and abiotic factors such as vegetation and level of exposure may also be of great importance. The post-glacial land uplift in the archipelago region causes a slow isolation process of bays with a threshold at the mouth, and subsequently they become cut off from the sea. As many of this type of bays are under influence of human activities, a wider understanding of their functioning under natural conditions is needed. In order to assess the suitability of these areas as habitats for juvenile fish, 75 undisturbed bays of differing isolation stage were studied between 2002-04. The study was conducted in the Finnish-Swedish archipelago region. Vegetation structure and coverage as well as depth were investigated by diving along transect lines across each bay. Juvenile fish were sampled using a point abundance sampling according to the vegetation-depth stratification data. The fish abundance data were tested against several environmental factors. Cyprinids, perch and pike were the most common species, and considerable differences in fish abundance were seen among regions, archipelago zones and isolation stages. Within bays, especially habitats with dense beds of *Chara* and *Potamogeton* species inhabited high numbers of juveniles. Conclusively, major differences in habitat preference of juveniles were seen at several scales, reflecting the heterogeneous environments in the archipelagos of the northern Baltic Sea.

PERCA FLUVIATILIS L. SPAWNING SITE SELECTIVITY IN SHALLOW AREAS OF THE BALTIC SEA

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Choosing the right spawning site and substrate is of crucial importance for offspring survival and reproduction success of fish. In the northern Baltic Sea, shallow sheltered areas are important spawning and nursery habitats for several sea dwelling freshwater fishes. The aims of this study were to study substrate and site selection of perch and to assess the determinants of habitat quality in a number of shallow areas along the Finnish and Swedish Baltic Sea coastline. Knowledge on spawning preference may benefit the on-going efforts to map essential fish habitats in the Baltic and to assess potential problems with substrate reduction in disturbed areas. The substrate and depth distribution of Eurasian perch *Perca fluviatilis* L. egg strands were investigated during April-June 2003 in a total of 22 shallow sites. Mapping of vegetation and egg strands were conducted simultaneously by snorkelling along parallel transect lines drawn perpendicular from the shore. Visible egg strands within one metre from the transect line were registered. The depth and substrate on which the strand was attached was noted. Egg strands were observed at 15 of the 22 sites. Water temperature was higher at sites with egg strands. Perch selectively spawned in shallow areas within the sites as the mean depth of egg strand locations was clearly below the overall mean water depth. A tendency to increase in spawning depth over time was observed. Perch preferred *Phragmites australis* and *Potamogeton pectinatus* as main spawning substrates. The results indicate that spawning of perch is highly selective in respect to depth and substrate.

ESSENTIAL FISH HABITATS ON THE SWEDISH WEST COAST

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The littoral zone of the Swedish West Coast house more than 50 fish species of which 1/3 are of commercial interest. A basic input into the knowledge of how coastal habitats can sustain fisheries is an identification and mapping of Essential Fish Habitats in the coastal zone. Such habitats include shallow sediment bottoms, seagrass (*Zostera marina*) and vegetated (*Fucus*-communities) and non-vegetated rocky bottoms. An extensive field survey was conducted to quantify the shallow habitats (0-10 m depth) on the Swedish West Coast by using echo sounder, visual sensing and geographical information systems (GIS). For each of the identified habitat types the abundance of fish food organisms and the composition of fish assemblages was determined. By combining this information with knowledge of diet, life history and ontogenetic habitat shifts of the fish species, the importance of different habitats for fish populations on the Swedish West Coast was evaluated. The results showed that the area covered by the different habitat types varied considerably along the Swedish West Coast. Further, the habitat quality (food availability) differed between soft- and rocky bottom habitats, which was reflected in the fish assemblage composition. Although the coastal zone only constitutes a small proportion of the sea, the contribution to fisheries production in terms of nursery ground value and fish food production may be disproportional high compared to the large area of adult habitats in the Skagerrak and Kattegat region on the Swedish West Coast.

AMPLIFICATION OF NEGATIVE IMPACT OF BEAVER DAMS ON FISH HABITATS OF RIVERS IN EXTREME CLIMATIC CONDITIONS

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In many parts of Estonia the years 2002-2003 were extremely poor in precipitation. A number of smaller rivers, upstream areas in particular, suffered from drying up. To find refuge fish migrated downstream in most of the rivers. Recolonisation of habitats took place after the refill of rivers with water. This kind of migration was not possible in rivers with beaver dams functioning as migration barriers. The Esna River (length 25 km) that has been considered one of the best habitats of brown trout suffered seriously from draught. The length of the section of Esna River that dried up was 13 km. Fish was monitored before the draught period, during the draught as well as after it in 2004. Along the upstream section of 10 km there are 9-11 beaver dams on the river. The beaver dams caused problem when the river dried up, as the dams blocked the downstream migration of fish. Fish gathering into small reservoirs above the dams (apart from ninespine stickleback) did not survive. In 2004, Esna River was filled up with water. Investigations showed the restoration of fish fauna up to the first large beaver dam. The latter proved to be a major migration obstacle. In the river sections upstream of the beaver dams no brown trout or other species except for the ninespine stickleback were recorded. Thus, the beaver dams may seriously inhibit the restoration of riverine fish fauna after it has become extinct due to extreme climatic conditions (e.g. draught) or other factors.

HABITAT SELECTION IN GOBIES AND PIPEFISHES OF THE VENICE LAGOON SEAGRASS MEADOWS

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Two species of gobies – the black goby *Gobius niger* and the grass goby *Zosterisessor ophiocephalus* – and three species of pipefishes – *Nerophis ophidion*, *Singnathus abaster* and *Singnathus typhle* – occur sympatrically in the shallow water seagrasses of the Venice Lagoon. Since these two groups are composed of taxonomically and ecologically similar species, testing for their habitat choice in experimental tanks could be useful for the understanding of the mechanisms underlying resource partitioning among them. In a first experiment we assessed the habitat choice between seagrass and bare sand in the black goby and the grass goby both when alone and when together, testing therefore for the interaction between habitat selection and competition. In a second experiment, we compared habitat choice between seagrass and bare sand across the pipefish species (both female and male), observing also patterns of activity and typical postures on the bottom and/or in the water column. Results of the first experiment showed that both species tend to choose seagrass over sand in each situation, but the difference is fully significant only for the black goby when together with the grass goby. This indicates a slight effect of competition on the habitat choice in the black goby. Results of the second experiment showed that the three pipefishes preferred in every case seagrass over sand, without any significant differences among species or between sexes. By contrast, some patterns of activity and the postures adopted within the seagrass habitat were highly specific of each species.

AN APPROACH TO IDENTIFYING HABITAT TYPE AND ASSOCIATED FAUNA IN ESTUARIES

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The physico-chemical characteristics of estuaries are continually subject to change as a result of either natural processes or human activity, both within those systems and their catchments. However, in many cases, there is insufficient understanding of the implications of these environmental changes for estuarine fauna. This is due primarily to a lack of knowledge of the types of habitats that are present within those systems and the composition of the biotic assemblages that are typically associated with those habitat types. Environmental managers and scientists working in estuaries thus require a readily-usable and quantitative method for identifying the various habitats within a particular system and their characteristic faunas, such that they can better predict the ecological impact of proposed environmental changes to any site within that system. The current scheme, which is being developed in diverse range of estuaries in south-western Australia, addresses this need by providing a quantitative method for (1) assigning any site within a given estuary to its appropriate habitat type, using readily-obtainable measurements for a suite of environmental criteria that have been selected statistically as those which best distinguish among the habitats in that system and (2) ascertaining, on the basis of that habitat classification, the faunal species that are most likely to occur regularly at that site. The environmental variables that form the basis of this approach to identifying habitat type and their characteristic fauna are able to be easily modified to accommodate any estuary.

THE ROLE OF RIVER MODIFICATION IN THE STRUCTURE AND SPATIAL DISTRIBUTION OF 0+ FISH ASSEMBLAGES

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Many European floodplain rivers have been regulated and channelised during the previous century. Modified rivers often lack some off-channel habitats which present major spawning and nursery areas for fluvial fishes. As a consequence, the reproduction success of many fish species depends largely on the availability of suitable spawning and nursery habitats within the river channel. This study investigates the 0+ fish assemblages in three, differently modified, connected lowland stretches during three seasons. The three study stretches exhibit marked differences in the character of the habitat used as spawning and nursery areas. The first stretch has been straightened, completely isolated from its flood plain and off-channel habitats, and regulated by five weirs. The other two stretches communicate with its last backwaters and its flood plains during high discharges, and the longitudinal continuity was not interrupted by weirs. The river shoreline was stabilized in all stretches by boulders of differing size. The results document the differences in natural fish reproduction and the utilization of mesohabitat of 0+ juvenile fish. According to hypothesis, the indices of species diversity was highest in less modified stretches. On the contrary, the highest density of 0+ juveniles was found in the most modified stretch. Eurytopic and phyto-lithophilous fish have become dominant in all stretches. It seems that the character of potential shoreline plays a crucial role in fish reproduction and 0+ fish assemblages in modified river stretches. The disconnected oxbow lakes seem to play a more important role as nurseries than connected backwaters in the flood plain.

SEASONAL SPECIES ASSEMBLAGES IN AN ARTIFICIAL REEF IN NORTH AEGEAN SEA-GREECE

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The first artificial reef in Greece was created in the wider region of Fanari, prefecture of East Macedonia and Thracian, North Greece. Seasonal changes in fish assemblages were examined using bottom trawl in the area surrounding the artificial reef four years after it was emerged. Statistical analysis comparing species densities between months January, June and October indicated seasonal differentiation of species assemblages in 2002. Variation in species of the families Labridae, Sparidae, Serranidae, Centranchidae, were responsible for dissimilarities between January and June - *Coris julis*, *Symphodus cinereus*, *S. rostratus*, *Diplodus annularis*, *D. vulgaris*, *Pagrus pagrus*, *Serranus hepatus*, *S. cabrilla*, *S. scribea*, *Spicara maena* and *S. smaris*. Variation in the species *Mullus surmuletus*, *Sarpa salpa*, *Mullus barbatus*, *Serranus hepatus*, *Blennius ocellaris*, *Boops boops*, *Spondyliosoma cantharus*, *Dentex dentex*, *C. julis*, *Symphodus ocellatus*, *S. smaris*, *S. cinereus*, *Gobius niger*, *D. annularis*, *S. scribea*, *Scyllarus arctus*, *Pagellus erythrinus*, *Symphodus mediterraneus* and *Diplodus sargus* were responsible for dissimilarities between June and October. Furthermore by visual census we observed that the presence and abundance of species in the artificial reef vary seasonally and depend on the depth of thermocline. The artificial reef has affected the piscatorial resources in the region by providing shelter and food to species. It has affected positively in marketable species such as, *Pagellus bogaraveo*, *Diplodus vulgaris*, *Palinurus elephas*, *Hommarus gamarus*, *Trisopterus minutus capelanus*, *Seriola dumerili* and species of Labridae family.

SELECTION OF PREY BY FLOUNDER, PLATICHTHYS FLESUS, IN THE DOURO ESTUARY, PORTUGAL

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Prey selection behaviour of the flounder, *Platichthys flesus* (Linnaeus, 1758) in an estuarine nursery was investigated and the major factors influencing food choice by this species were assessed. Diet breadth was narrow, reflecting the low prey diversity observed in the benthos. A gradual ontogenetic shift from small prey such as amphipods to larger prey like polychaetes and bivalves was observed. Amphipods had positive electivity values in the upper estuary and negative values in the lower estuary. Polychaetes showed the inverse pattern. Bivalves' electivity values were always positive. Differential selectivity throughout the estuary was mainly related to spatial segregation of flounders according to size, with the smaller individuals concentrating in the upper estuary and larger individuals concentrating in the lower estuary. Amphipods such as *Corophium* spp. play a crucial role in flounder's diet because of its small size, low mobility and diel activity pattern. Polychaetes' value as prey increases throughout flounder ontogeny, since their size range is compatible with larger specimens' mouth gapes and detection ability. Bivalves' value for flounder is mainly related to its high caloric value. The absence of *Crangon crangon* (Linnaeus, 1758) from the diet may be due to the low water temperature since the cost-benefit relation involved in the capture of highly mobile prey is too high at low temperatures. It was concluded that flounder must use various sensory features to detect and capture prey in turbid estuarine waters and that field studies provide important background information on the actual predator preferences under natural conditions.

THREATENING PROCESSES IN URBAN FRESHWATER CREEKS AND IMPLICATIONS FOR FISH BIODIVERSITY: A QUEENSLAND CASE STUDY

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Because of the wide variety of disturbances that can affect urban and peri-urban waterways, such systems provide valuable opportunities to assess the resilience and ecological requirements of native fish species. This paper identifies a range of physical, chemical and biological factors affecting fish in disturbed creeks in southeast Queensland and considers how these factors interact to threaten essential ecological processes. Threatening factors include riparian clearing, flow modification, channelisation, barriers to movement and migration, reduced water quality and invasions by exotic species. Biodiversity impacts are likely to occur through reductions in the extent and diversity of habitat and food, heightened physiological stress and increases in the intensity of interspecific interactions. During repeated monitoring of creek catchments during 2000-2004, reference sites differed widely in terms of the number of native fish species collected (2 -12) and could be characterised by species assembly curves based on ubiquity. There was an inverse relationship in the occurrence of natives and exotics but the percentage of exotic individuals was always high (68-97%). Multiple regression indicated that fish species ubiquity could be predicted from stream width, stream depth, instream plant diversity and native riparian cover. Comparisons of species-rich and species-poor sites suggested that pelagic species (e.g., rainbow fish, smelt) and demersal species (e.g., gudgeons) were similarly vulnerable to disturbance. In recent years there have been increasing efforts to rehabilitate disturbed Brisbane creeks through riparian planting and natural channel designs, and early monitoring results suggest that such activities can increase the local biodiversity of native fish species.

RECENT EXPERIENCE AND FORAGING IN THE THREESPINE STICKLEBACK

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Prey type, quality and yield can vary between patches within a habitat. These patterns of distribution are often linked to heterogeneity in structure and form at the subhabitat level. In order to forage optimally a predator should recall and relate the profitability of recent foraging forays to the subhabitat type in which they took place, and allocate future foraging effort accordingly. Recalled previous experience is used by a variety of vertebrate groups, but little is known about its use by foraging fish. In a series of experiments we used the threespine stickleback (*Gasterosteus aculeatus*) as a model organism to investigate the use of previous experience in the mediation of foraging decisions. We held fish in tanks with two different substrate types, representing different subhabitat units. Prey was provided on one or the other substrate only. Experimental analyses revealed that following this treatment fish allocated significantly more foraging effort, defined as time spent foraging and strikes against prey items, to the subhabitat type on which they had previously encountered prey. This was independent of the experimental prey density, and was contrary to the predictions of the Marginal Value Theorem. We recorded the rate at which these preferences were acquired and showed that they diminish and are replaced when prey provision switches from one substrate type to another. We consider the adaptive value of using prior experience to mediate foraging decisions, and suggest that they could play a significant role in the active enhancement of prey encounter rates in free ranging fish.

ONE FISH'S MEAT: ANTHROPOGENIC IMPACTS ON RIVERS PROVIDE STEPPING STONES AND STRONGHOLDS FOR PEST FISH?

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It is now well established that anthropogenic disturbance may enhance habitat quality for invasive organisms while simultaneously degrading habitat quality for indigenous species. New Zealand's indigenous freshwater fish fauna is predominantly lowland, coastal, and therefore coincident with the greatest pressure from anthropogenic habitat modification. In a study of fish health in sites downstream of industrial discharges in the Waikato River, New Zealand, the introduced brown bullhead catfish (*Ameiurus nebulosus*) was used as an indicator species. The three downstream sites where heat and, in one case, nutrients were a significant component of the discharge had bullhead populations that exhibited larger maximum length, suggesting increased growth rates, and better condition. At two of these sites, fish exhibited earlier, more successful spawning and recruitment. It is suggested that such areas of anthropogenic disturbance provide strongholds for pest fish species, providing recruits for further invasion and increasing propagule pressure on nearby, less suitable habitats. They also allow pest fish species to expand through reaches of rivers or lakes that may have previously resisted colonisation. Within the Waikato River system these effects are further enhanced by hydroelectric impoundments, channelization and eutrophication. Ramifications for native fish communities that generally require cooler water temperatures, riparian vegetation, greater complexity of flow and river structures, and less degraded environments are discussed.

THE IMPORTANCE OF HABITAT HETEROGENEITY TO FISH DIVERSITY AND BIOMASS

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Between 1995 and 2001 large scale coarse fish population surveys were undertaken on two artificial channels running through Heathrow Airport. Both rivers have areas of naturalised habitat together with featureless shallow canalised reaches. Hence, the 1km study area presented difficulties in terms of site selection for representative habitat. Consecutive habitat types were isolated with stop nets and electric fished. Each section was around 40m in length. Three stop nets were deployed, the first two isolating the section to be fished whilst the third isolated the downstream end of the next section. On completion of a section, the first of the three nets was 'leap-frogged' above the upper net isolating a further section and so the process continued along the rivers. This was undertaken to overcome problems associated with herding / frightening fish away from a study section. Fish habitat surveys were undertaken in conjunction with the fish surveys with in-river and littoral vegetation identified and mapped. Fish diversity and biomass varied between river sections and years. A total of 16 species of coarse fish were caught and biomass within sections, ranged from 0 to 780 kg ha⁻¹. There was a consistently strong relationship between fish species diversity and biomass and the distribution of emergent and submerged macrophytes. In all vegetated stretches the surveys produced substantially higher catch estimates relative to unvegetated sections. Overall the lack of habitat appears to limit fish production. Structural features such as macrophytes and bridges increase habitat and flow heterogeneity providing a range of spawning, feeding and refuge options for fish. Furthermore the study revealed important information for general survey design in coarse fish systems, confirming the need for larger sites encompassing all habitat types and suggesting that intra site habitat partitioning will result in more representative biomass and diversity estimates.

HABITAT USE AND FEEDING ECOLOGY OF CHUB (*SQUALIUS CEPHALUS* (L.)) IN LAKE BANYOLES (NE SPAIN)

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The chub (*Squalius cephalus*) is the largest native cyprinid of the Iberian Peninsula, where there is almost no published information on the ecology of this species. We investigated the ecology of chub in Lake Banyoles, the second largest lake of the Iberian Peninsula, as a part of comprehensive studies of its fish assemblage. Sampling was conducted quarterly at several depths, habitats and basins of the lake by trammel nets and an electrofishing boat. Diet was determined by examination of gut contents. Movement patterns and habitat use of four chubs (361-436 mm in fork length) were also analyzed using ultrasonic telemetry and a radio-linked acoustic positioning system. Chub exhibited changes in habitat use with seasonal variation. In winter and spring they were detected in both the limnetic (mostly in the first 5 m of the water column) and littoral zone, whereas in summer and autumn catches were higher only in the littoral zone and fish often left the lake to occupy the streams or canals connected with the lake. The diet of chub was based on large littoral prey, mostly terrestrial, such as toads, rest of birds and mammals, unidentified fish and crayfish (*P. clarkii*). This diet is only similar in the Lake with those of the few eel (*Anguilla anguilla*) remaining and introduced largemouth bass (*Micropterus salmoides*). Tracked fish were more active during night-time, showing a large range of non-random movements between a nocturnal activity zone and a daylight resting place which changed after few days.

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Useful Information

Reception and Shop on the Ffriddoedd Site

The Reception and Shop is open every day from 08:00 until 22:00. It is clearly signposted when you enter the Ffriddoedd Site

Check-out

All rooms must be vacated by 10:00 on your day of departure and keys returned to Reception.

Lost Keys

Please note that there is a charge of £15.00 for lost keys

Launderettes

A launderette can be found on each Residential Site

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