

# SYMPOSIUM ON HYDROPOWER, FLOOD CONTROL AND WATER ABSTRACTION: IMPLICATIONS FOR FISH AND FISHERIES

Mondsee, Austria, 14-17 June 2006

## ABSTRACTS

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### SESSION 1 – ASSESSMENT OF ISSUES AND IMPACTS

SCHMUTZ, S.

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#### INFLUENCE OF EXPLOITATION OF ELECTROPOWER STATIONS ON STRUCTURE OF FISH POPULATION IN THE UPPER DUNAJEC RIVER (SOUTH POLAND)

Augustyn, L.<sup>1</sup> & Bartel, R.<sup>2</sup>

<sup>1</sup> School of Professional and Vocational Study Staszica 1, 33-300 Nowy Sącz, Poland

<sup>2</sup> Inland Fisheries Institute, Department of Migratory Fishes, Reduta Żbik 5, 80-7612 Gdańsk Poland

The Dunajec River is the biggest tributary of the upper Vistula River. Two reservoirs were built in the upper Dunajec in 1997: the upper Czorsztyn – Niedzica (capacity 231.9 million m<sup>3</sup>, 45 m deep) and the lower Sromowce Wyżne area 88 ha: capacity 7.7 million m<sup>3</sup>, 17 m high). Since 2001 water has been pumped periodically from the lower to the upper reservoir. This has caused rapidly lowering of water levels (up to 60 cm in 30 minutes) in the river below the lower reservoir. Observations on the structure of the ichthyofauna were carried out in 1964–1965, 1988–1992, 2001–2002 and 2004–2005 in two sections of the Dunajec R. below the lower dam and in one section of the Poprad River, a tributary of the Dunajec R., as a control. As a result of the changing water level six species disappeared (*Hucho hucho*; *Cottus gobio*; *Chondrostoma nasus*; *Alburnoides bipunctatus*; *Gobio gobio* and *Esox lucius*) from the Dunajec R. below the Sromowce Wyżne reservoir and three species disappeared (*Leuciscus leuciscus*; *C. nasus*; *A. bipunctatus*) from the river 50 km below the lower dam. No change in ichthyofauna was observed in the undammed Poprad River. The biggest changes in ichthyofauna in the Dunajec R. were observed in salmonids (*Salmo trutta m. fario*, *H. hucho* and *Thymallus thymallus*) and rheophilic cyprinids, mainly *C. nasus*, *Barbus barbus* and *Leuciscus cephalus*. The main reasons for these changes were: 1) rapidly changing water level that eliminated natural recruitment of juvenile fish; 2) inflows of cold water from the hypolimnion of the Czorsztyn-Niedzica reservoir that favoured fishes that preferred cold water; and 3) drift of non riverine cyprinid fishes from the upper reservoir.

## THE INFLUENCE OF SMALL HYDROELECTRIC PLANTS ON ICHTHYOFAUNA AND ENVIRONMENTAL CONDITION IN THE UPPER VISTULA CATCHMENT BASIN AND THEIR SHARE IN TOTAL ELECTRICITY PRODUCTION IN POLAND

**Bartel, R.<sup>1</sup>, Jelonek, M.<sup>2,3</sup> & Epler, P.<sup>4</sup>**

<sup>1</sup> *Inland Fisheries Institute, Department of Migratory Fish in Gdańsk, 80-761 Gdańsk, ul. Reduta Żbik 5, Poland. E-mail: [gdansk@infish.com.pl](mailto:gdansk@infish.com.pl)*

<sup>2</sup> *Institute of Nature Conservation, Polish Academy of Sciences, 31-120 Kraków, Al. Mickiewicza 33, Poland.*

<sup>3</sup> *Regional Water Management Authority in Kraków, 31-109 Kraków, ul. Marszałka J. Piłsudskiego 22, Poland. E-mail: [nzjelone@cyfronet.krakow.pl](mailto:nzjelone@cyfronet.krakow.pl)*

<sup>4</sup> *Agricultural University of Kraków, Department of Ichthyobiology and Fisheries, 30-059 Kraków, Al. Mickiewicza 24/28, Poland. E-mail: [rzbienia@cyfronet.krakow.pl](mailto:rzbienia@cyfronet.krakow.pl)*

The development strategy for the renewable energy sector in Poland aims to have 7.5 percent of total electricity generation from the renewable energy sector. As result of this strategy and some investor's preferences, there has been a great increase of the number of small water power plants over the few last years, whose power varied from 30 to 500 kW. One project proposes that eight 60 kW power plants be constructed on one river. These constructions have had a negative influence on quantity and the ecosystem services provide by the rivers have also declined. Negative impacts on fish populations, especially rheophilic, salmonid and cyprinid fish were observed after the construction of a reservoir with a small hydroelectric plant in the middle course of the Wisłoka river, a tributary of the Vistula river. Before the construction of the dam the Wisłoka River had 29 fish species, in 2001, two years after the dam was built, the number of species had declined to 23 and by 2004 only 21 fish species remained. This paper describes the influence of dams and electropower plants on river ecology and ichthyofauna in the upper Vistula river catchment.

## INFLUENCE OF THE WŁOCŁAWEK DAM ON MIGRATORY FISHES IN THE VISTULA RIVER

**Bartel, R.<sup>1</sup>, Wiśniewolski, W.<sup>2</sup> & Prus, P.<sup>2</sup>**

<sup>1</sup> *Inland Fisheries Institute, Department of Migratory Fishes, Reduta Żbik 5, 80-761 Gdańsk, Poland*

<sup>2</sup> *Inland Fisheries Institute, River Fisheries Department, Główna 48, Żabieniec, 05-500 Piaseczno Poland*

The Wloclawek dam was completed in 1968 at 675 km of the Vistula River, 266 km from the river mouth. A conventional pool fishway was constructed in 1970 in the dam but is not working properly. The dam stopped upstream migration of vimba (*Vimba vimba L.*) and sea trout (*Salmo trutta m. trutta L.*) and not a single individual reached the spawning grounds in the upstream tributaries.

In the 1950s and early 1960s the yearly catch of vimba in the river system was about 200 tonnes. Before the dam was completed the average yearly catches of vimba below Wloclawek were about 94.7 tonnes, and above Wloclawek to the mountain tributaries were about 16.4 tonnes. After damming yearly catches of vimba in the lower part of the river, below the dam, were 20.1 tonnes but in upper part, above the dam, dropped to only 100 kg. Sea trout showed a similar pattern. Before damming yearly catch below the future dam was 33.3 tonnes, but above the dam site was 14.7 tonnes. After damming catches of sea trout fell to 12.9 tonnes below the dam but upstream of it the yearly catch was only 6 kg.

An unconventional method of spawners transport was used to minimise the negative effects of damming on the vimba population during the 1970s and early 1980s. Vimba spawners were caught below the dam, transported by road and released into the reservoir above the dam. A total of 50 tonnes of vimba spawners was transported during the ten years from 1973 to

1982). This resulted in higher commercial catches in the Vistula River system. In 1979 catches amounted to only 3 tonnes, while in 1980–1982 as much as 20 tonnes were caught. The increase of catches in the five–six years after spawners transport was started was undoubtedly due to spawning migration of the offspring of the transported spawners. Despite such promising results spawners transport was stopped in 1982 due to lack of financial support.

Nowadays a salmon, sea trout and vimba rehabilitation programme is being developed in Poland, and in the Vistula River system the main obstacle to its full success is the Wloclawek dam. Apart of stocking there is an urgent need for a fishpass. Building of a new natural pattern of fish bypass channel is of high priority , as well as a need to return to vimba spawner transport as a method to enhance natural reproduction. Failing this the migratory fish rehabilitation programme in the Vistula River can not be fully successful.

#### **EFFECT OF FLOW REGULATION ON THE DISTRIBUTION OF FISH ABUNDANCE AND BIOMASS; COMPARISON OF CASCADE AND NON CASCADE RESERVOIRS**

**Draštík, V., Kubečka, J. & Tušer, M.**

Building weirs and reservoirs on European rivers is always connected with flow regulation. Reservoirs built in cascades usually influence the hydrological regime by hydropeaking. Fish distribution in terms of abundance and biomass was observed in four cascade reservoirs and compared to two non cascade reservoirs. Acoustic surveys revealed that typical fish distributions in reservoir with nonregulated inflow follow trophic longitudinal gradient. Great numbers of fish and fish biomass are found in the tributary area while the dam area is the least inhabited. Average weight shows opposite pattern; the biggest fish are located in the dam area. Water level fluctuation and water quality in cascade reservoirs degrade the amount of fish and its distribution. Most fish prefer the dam areas in cascade reservoirs while tributary area is usually empty. Water level and discharge fluctuations, oxygen deficits and availability of suitable spawning grounds make fish reproduction very hard in cascade reservoirs.

#### **WINTER MOBILITY PATTERNS OF JUVENILE ATLANTIC SALMON IN RELATION TO TURBULENCE AND ICE INFORMATION IN A REGULATED RIVER**

**Enders, E.C.<sup>1</sup>, Stickler, M.<sup>2</sup>, Pennell, C.J.<sup>1</sup>, Alfredsen, K.<sup>2</sup> & Scruton, D.A.<sup>1</sup>**

<sup>1</sup> *Fisheries and Oceans Canada, Ecological Sciences Section, 80 East White Hills Road, P.O. Box 5667, St. John's, NL, Canada, A1C 5X1*

<sup>2</sup> *Norwegian University of Sciences and Technology, Department of Hydraulic and Environmental Engineering, 7491 Trondheim, Norway*

Survival and development of juvenile Atlantic salmon (JAS, *Salmo salar*) during winter is often described as bottle neck for Atlantic salmon population. Availability of suitable overwintering habitat for JAS plays therefore a central role in the fish management in northern rivers. Habitat availability may be altered by dynamic ice regime in the river. Hydro developments may cause additionally unstable ice regimes during mid winter. Using Passive Integrated Transponder (PIT) technology, 50 JAS were tagged in a regulated river in Central Newfoundland, Canada before ice information. Consequently, JAS were tracked during three critical phases: freeze up period in early winter when first ice formation occurred, stable ice conditions during mid winter and ice break up in late winter. Results suggest that: (1) high individual variations in winter mobility occur, (2) at low water temperatures JAS use coarse substrate and low turbulence, and (3) JAS tended to avoid zones with ice concentrations.

## **MOBILITY AND SPAWNING MIGRATION OF ROACH (*RUTILUS RUTILUS*) IN THREE WEIR FRAGMENTED BELGIAN RIVERS**

**Geeraerts, C.<sup>1</sup>, Verbiest, H.<sup>1</sup>, Ovidio, M.<sup>2</sup>, Buysse, D.<sup>1</sup>, Coeck, J.<sup>1</sup>, Belpaire, C.<sup>1</sup> & Philippart, J.-C.<sup>2</sup>**

<sup>1</sup>Research Institute for Nature and Forest, Duboislaan 14, 1560 Groenendaal (Hoeilaart), Belgium, Phone: +32 2 658 04 10, Fax: +32 2 657 96 82, E-mail: [caroline.geeraerts@inbo.be](mailto:caroline.geeraerts@inbo.be)

<sup>2</sup>University of Liège, Biology of Behaviour Unit, Laboratory of Fish Demography and Hydroecology, 10 Chemin de la Justice, B-4500 Tihange, Belgium, Phone: +32 85 27 41 57, Fax: +32 85 23 05 92

Roach from three regulated Belgian rivers were radio tagged in order to study their spawning behaviour and their abilities to clear physical barriers. Two of the three studied rivers are representative for the lowland region, and belong to the bream zone of the river Scheldt basin. The upland river belongs to the grayling zone of the river Meuse basin.

In the three rivers roach displayed similar patterns of movements which were mainly influenced by the date of observation (movements increased in late April-May) and water temperature (travel distances were more important when water temperature ranged between 10-14 C). Roach sometimes cleared physical obstacles. The mean distances travelled in each river were relatively short (max. 2.5 km) and mainly influenced by the length of the study reach delimited by physical barriers.

A general discussion of these results focuses on the behavioural adaptations of roach to the living conditions in fragmented environments.

## **MIGRATION BARRIERS IN STREAMS OF UPPER AUSTRIA AND THE FIRST REALISATION PROJECT OF THE RESTORATION OF LONGITUDINAL INTEGRITY OF A STREAM**

**Gumpinger, C. & Siligato, S.**

*Technisches Büro für Gewässerökologie, Gärtnerstraße 9, 4600 Wels. E-mail: [gumpinger@blattfisch.at](mailto:gumpinger@blattfisch.at)*

According to the European Union Water Framework Directive we investigated seven stream basins in Upper Austria altogether covering about 15 percent of the countries area. The main aim was to analyse how intensively streams were fragmented by hydropower-engineering, flood control devices and migration barriers without any direct utilisation by man. We developed a registration method to characterise and evaluate the passability of all man made migration barriers as well as stream bank protection devices in the whole stream system. Protection and restoration guidelines are outlined on the basis of this register to restore the longitudinal integrity of the stream system. As a realised restoration example a project will be introduced, within which several barriers have been modified or removed in a brook. The restoration was accompanied by a monitoring of the fish assemblage who was directly affected by the stream fragmentation.

## **IMPACTS OF FLOOD CONTROL SCHEMES IN BANGLADESH AND GUIDELINES FOR MITIGATION**

**Halls, A**

*Aquae Sulis Ltd, Midway House, Turleigh, Wiltshire, BA15 2LR, UK. E-mail: [a.halls@aquae-sulis-ltd.co.uk](mailto:a.halls@aquae-sulis-ltd.co.uk)*

Flood control, drainage and irrigation (FCDI) schemes exist widely in Bangladesh, built to control water levels to improve agricultural production based upon high yielding varieties (HYV) of rice that cannot tolerate rapid inundation or require irrigation, and to provide protection from extreme flood events. The benefits to agricultural sector can be significant. At some sites in Bangladesh, farmers report up to 80 percent more agricultural production

inside the schemes compared to outside. However, fish production and species richness is typically lowered by these structures. Studies have shown that fish yields inside a typical flood control compartment can be 50 percent lower compared to outside with up to 25 species of fish absent or less abundant. Lower rates of recruitment of migratory whitefish species, whose lateral migrations are obstructed by the embankments, were found to be largely responsible for these differences. With a risk of more extreme flooding during the monsoon season but hotter and more arid dry season conditions predicted as a consequence of climate change, more FCDI schemes may need to be constructed to provide flood protection and to meet increasing irrigation needs.

Based on fisheries monitoring and mark-recapture studies undertaken at three sluice gates in Bangladesh since 1996, approaches to mitigate the combined impacts of FCDI schemes and increasing dry season irrigation demands within them on fish production and biodiversity are described. These focus upon simple, cost effective measures aimed at: (i) improving the passage of migratory species, and (ii) improving the production of resident (non-migratory) fish species based upon an integrated strategy of improved sluice gate management and alternative cropping strategies.

#### **THE EFFECT OF THE CONSTRUCTION OF ARTIFICIAL RESERVOIR ON THE FISH POPULATION IN THE INFLOWING RIVER**

**Hladík, M.<sup>1,2</sup> & Kubečka, J.<sup>2</sup>**

<sup>1</sup> Vltava River Basin Authority, state entertainment, Holečkova 8, 150 2 4 Praha 5, Czech Republic, E-mail: [milanhlad@yahoo.co.uk](mailto:milanhlad@yahoo.co.uk)

<sup>2</sup> Hydrobiological Institute, AS CR, Na Sádkách 7, 37005 České Budějovice, Czech Republic, E-mail: [kubecka@hbu.cas.cz](mailto:kubecka@hbu.cas.cz)

The construction of the Římov Reservoir in 1978 significantly affected fish population in the Malše River above the reservoir. Fish species, which successfully colonized the reservoir, migrated massively to the inflow river and the development of the riverine fish population reflected the succession of the fish stock in the reservoir. The boom of pike (*Esox lucius*) and perch (*Perca fluviatilis*) during first years after the impoundment impaired the pristine riverine fish population, which was further modified by cyprinids dominating the reservoir fish stock nowadays. Thousands of roach (*Rutilus rutilus*), bream (*Abramis brama*) and bleak (*Alburnus alburnus*) migrating to the tributary every spring influenced the riverine fish population up to the first impenetrable weir located 4 km above the reservoir. The roach became the most abundant fish. The proportion of pristine riverine fish – e.g. brown trout (*Salmo trutta m. fario*), chub (*Leuciscus cephalus*), dace (*Leuciscus leuciscus*), minnow (*Phoxinus phoxinus*) and bullhead (*Cottus gobio*) decreased in the parts adjacent to the reservoir and showed distinct upstream-directed gradient. Barbel (*Barbus barbus*) and riffle minnow (*Alburnoides bipunctatus*) disappeared from the whole basin of the Malše River. It seems that cyprinid-dominated stock is more aggressive in colonizing the river than the fish stock dominated by perch.

## **ENTRAINMENT AND DAMAGE OF YOUNG-OF-THE-YEAR FISH BY THE POWER STATION ON THE DYJE RIVER, CZECH REPUBLIC**

**Janáč, M.<sup>1,2</sup>, Jurajda P.<sup>1</sup>, Prášek, V.<sup>3</sup> & Kružiková L.<sup>1,4</sup>**

<sup>1</sup>*Institute of Vertebrate Biology, Brno, Czech Republic*

<sup>2</sup>*Faculty of Science, Masaryk University, Brno, Czech Republic*

<sup>3</sup>*Moravian museum, Brno, Czech Republic*

<sup>4</sup>*Mendel University of Agriculture and Forestry, Brno, Czech Republic*

We studied drift of young-of-the-year (YOY) fish through the turbine of a hydraulic power station on the outlet of the Nové Mlýny water reservoir (Dyje River, Czech Republic, Danube basin). The study was conducted over three years from April to August of 2001–2003. The number of drifting species was relatively small in comparison to species richness in the reservoir. In total of twelve species were caught with drift nets, however only bream, zander and tubenose goby drifted in notable numbers. Fish drifted predominantly at night, and there was no correlation with water temperature or transparency. About ten percent of fish were damaged passing through the turbine, with a high proportion of fish being larger than 30 mm, although up to 30 percent of pikeperch were damaged.

## **HYDROPOWER AND THE FISH FAUNA ON ESTONIAN RIVERS**

**Järvekülg, R.**

*Estonian Agricultural University, Meelis Tambets, Tartu University, Jaak Tambets, Wildlife Estonia*

There are 20 hydroelectric power stations operating currently in Estonia, with the total capacity of 4 MW. Water power forms only 0.3 percent of the total production of electric energy in Estonia and would not exceed 1 percent even if the hydropower potential of all Estonian rivers were to be employed.

The low hydropower potential results from the fact that Estonian rivers are rather small, with low slope. Only two Estonian have annual average discharges over 50 m<sup>3</sup>/sec, and three rivers over 25 m<sup>3</sup>/sec. The Narva River, that forms the border between Estonia and Russia, is a special case with an average annual discharge of 400 m<sup>3</sup>/sec and a fall of 4 m/km. Today, the water power of the Narva River is employed by Russia; using a power station of 125 MW capacity.

Regardless of the small potential the current or planned production of hydroelectric energy, as well as damming of rivers for other reasons (there are about 600 man-made dams on Estonian rivers) has a clear impact on most of the Estonian important fish rivers. The fragmentation and change in water regime influence all of the 40 fish species living in Estonia rivers, but especially the migratory species. The impact of dams on the riverine fish fauna is especially strong because the dams still do not have effectively operating fish passes.

During last years several legislative measures have been implemented and some practical projects have been started in order to protect riverine fish through habitat protection.

## **PATTERNS OF DISTRIBUTION AND SPECIES COMPOSITION OF FRY COMMUNITIES IN RESERVOIRS UNDER DIFFERENT LEVEL OF HYDROPOWER EFFECTS**

**Kubečka, J., Draštík, V., Jůza, T. & Jarolím, O.**

Water level fluctuations, high discharge, oxygen deficits, hypolimnetic releases, and availability of suitable spawning grounds complicate fish reproduction and fry survival in

cascade reservoirs. Fish fry distribution and species composition were studied by fry trawling and fry beach seining in four cascade and two non cascade reservoirs. Hydropower exploitation results in replacing cyprinid communities (bream, roach and bleak) by the percids (perch, zander, ruffe) and many folds decrease of fish density. Non-cascade reservoirs have highest density in upper parts of reservoir while in cascade reservoirs, the dam area serves as a refuge. The gradient is very clear in offshore community while inshore fry depend rather on habitat selection. Small reservoirs (under 10 millions m<sup>3</sup>) have heavily modified communities while larger Slapy reservoir has only tributary part degraded.

## **EFFECTS OF HYDRO POWER OPERATION AND OTHER PRESSURES ON FISH IN AUSTRIAN RIVERS MIRR – A MODEL-BASED INSTRUMENT FOR RIVER RESTORATION IN AUSTRIA**

**Melcher, A., Zitek, A., Poppe, M., Muhar, S., Jungwirth, M. & Schmutz, S.**

*Institute of Hydrobiology and Aquatic Ecosystem Management, Department of Water, Atmosphere and Environment, Max-Emanuelstrasse 17, 1180 Wien, BOKU - University of Natural Resources and Applied Life Sciences*

In 2000 the European Union launched the most modern water legislation in the world, the Water Framework Directive (WFD). One of the key objectives is to achieve “good ecological status” by 2015. The objective of the MIRR project (model based instrument for river restoration), an ongoing project in Austria, is to provide a strategic instrument to identify important hydraulic and morphological restoration measures on current waters. Among aquatic organisms fishes are sensitive to hydraulic and morphological influences, in particular continuum interruptions. In accordance with the WFD, fishes are used for the assessment of the ecological status of rivers and employed as an indicator for the development of the instrument.

Within this project, an extensive database (with more than 1 000 sampling sites) was developed for Austria. The database contains information about anthropogenic pressures such as flow regulations, hydro peaking, flushing, other continuum interruptions and fish fauna.

Multivariate analyses on different spatial and temporal scales allow a quantification of the relationships between pressures and the fish fauna. The analyses provide information to predict the appropriate restoration measures to achieve good ecological status according to the WFD.

## **REGULATED DISCHARGE PRODUCES SEVERE EFFECTS ON FISH COMMUNITY IN THE GRAYLING ZONE OF A SMALL SALMONID STREAM.**

**Ovidio, M.<sup>1</sup>, Capra, H.<sup>2</sup>, Orban, P.<sup>3</sup> & Philippart, J.C.<sup>1</sup>**

<sup>1</sup>*University of Liège, Laboratory of Fish Demography and Hydroecology, 10 Chemin de la Justice, 4500 Tihange, Belgium - email: [m.ovidio@ulg.ac.be](mailto:m.ovidio@ulg.ac.be)*

<sup>2</sup>*Cemagref of Lyon, Quantitative Hydroecology Laboratory, 3 bis quai Chauveau CP 220 69336 Lyon, France- email: [capra@lyon.cemagref.fr](mailto:capra@lyon.cemagref.fr)*

<sup>3</sup>*Ministry of Walloon Region-Water Division, 15 Avenue Prince de Liège, 5100 Jambes, Belgium*

A hydroelectric power plant (HPP) came on line in December 2002 in the Lhomme, (mean flow: 1.78 m<sup>3</sup>.s<sup>-1</sup>; mean water temperature: 9.9 °C). The new HPP exploitation bypasses the river over a length of 1.2-km. The minimum flow allowed in the bypassed section is currently fixed at 0.220 m<sup>3</sup>.s<sup>-1</sup>. Before the construction of the HPP, two contrasted 150 m-long reaches of the Lhomme were selected to estimate their total fish population abundance. A first electric fishing was carried out in each of the reaches on 23 April 2002 in natural flow situation. The others inventories were carried-out in late April or early May in 2003, 2004 and 2005 under



by-pass flow conditions. The population biomass largely decreased in 2003 (mean reduction of 33 percent) and 2004 (mean reduction of 52 percent in comparison with 2002) and finally stabilised in 2005 (-56 percent). The effects of the flow reduction varied considerably depending on the size of the individuals, the species concerned and the availability of their habitats, causing important variations in the fish population structure.

## **STATUS OF HYDROPEAKING IN SWITZERLAND WITH A SPECIAL FOCUS ON THE RHONE RIVER**

**Peter, A., Meile, T., Fette, M. & Baumann, P.**

*Eawag, Aquatic research, CH-6047 Kastanienbaum, Switzerland, E-mail: armin.peter@eawag.ch*

About 58 percent of Swiss energy is generated by hydropower plants. In order to cover the peak load 30 percent of the hydropower plants (>30 kW) operate with a hydropeaking regime.

The Rhone River (upstream of Lake Geneva) is highly affected by hydropeaking and has a typical discharge regime dominated by daily peaks (except on the weekend). In addition the river is negatively impacted by severe river channelization and by water abstractions. Therefore it is often difficult to distinguish between the different effects on the biology. In order to identify the effect of hydropeaking historic data on hydrology and the hydropeaking regime was analysed. The hydrology of the Rhone River was heavily modified between 1950 and 1975. In this period a large number of dams were constructed. Together with river discharge and temperature also turbidity changed and affected the biology in the Rhone River.

Different groups of organisms reacted in a different way to hydropeaking. A deficit analysis in the Rhone River showed that turbidity, siltation of the river bed, catastrophic drift, effects on the shoreline community, lack of natural reproduction of brown trout, contributed to the very low fish biomass. A particular emphasis will be placed on the effect of riverbed siltation and its effect on groundwater.

In order to mitigate the biological deficits we propose measures to improve the river habitat quality by carrying out habitat restoration. River restoration is probably only successful if the negative impacts of hydropeaking are dampened by the construction of storage basin, construction of new channels for hydropeaking discharge.

## **DOES LOSS OF ICE COVER DURING WINTER IN A REGULATED ARCTIC RIVER EFFECT DRIFT OF POTENTIAL PREY FOR JUVENILE ATLANTIC SALMON?**

**Rikardsen, A.H.<sup>1,4\*</sup>, Thorstad, E.B.<sup>2</sup>, Koksvik, J.I.<sup>3</sup>, Ugedal, O.<sup>2</sup>, Jensen, A.J.<sup>2</sup>, Saksgård, L.<sup>2</sup>, Amundsen, P.A.<sup>4</sup> & Næsje, T.F.<sup>2</sup>**

<sup>1</sup> *Norwegian Institute for Nature Research, Polar Environmental Centre, N-9296 Tromsø, Norway.*

<sup>2</sup> *Norwegian Institute for Nature Research, Tungasletta 2, N-7485 Trondheim, Norway.*

<sup>3</sup> *Norwegian University of Science and Technology, N-7491 Trondheim, Norway*

<sup>4</sup> *Norwegian College of Fishery Science, University of Tromsø, N-9037 Tromsø, Norway*

*\*Author to whom correspondence should be addressed. Tel.: +47 77 64 44 75; Fax: +47 77 64 60 20.*

*E-mail: [audun.rikardsen@nfh.uit.no](mailto:audun.rikardsen@nfh.uit.no)*

To test if the loss of ice-cover reduced drift of invertebrates during winter in the regulated Alta River in northern Norway, drift samples from an area that had lost the ice-cover due to the construction of a hydropower dam were compared with an ice-covered area further down in the river. The drift in the ice-free area contained mainly small copepods that originated from the power dam and chironomid larvae, while drift in the ice-covered area contained mainly chironomid larvae. Other invertebrates contributed little to the drift in both areas, but



Simuliidae larvae and nymphs of stoneflies and mayflies was found slightly more frequently in the ice-covered compared to the ice-free area during March. Although some annual differences were observed, no clear differences were found between night and day samples. However, no copepods and few drifting invertebrates were found in the stomachs of Atlantic salmon *Salmo salar* L. parr, which mainly seemed to feed on benthic mayfly nymphs and caddis larvae during the same periods. These preys were also frequently found in benthos samples during the same period. Thus, loss of ice-cover due to the hydropower dam did apparently not reduce drift of potential prey for salmon parr, and drifting invertebrates contributed little to the diet of salmon parr during winter. Differences in drift between the areas with or without ice-cover during winter could therefore not explain earlier observed differences in energy contents of Atlantic salmon parr in the same areas.

### **MACROBRACHIUM GANGETICUM BATES IS ON THE VERGE OF EXTINCTION DUE TO FARAKKA DAM IN GANGA RIVER**

**Roy, D.**

*Department of Zoology, SMM Town PG College, Ballia, 277001, UP, INDIA*

*Macrobrachium gangeticum* Bates (Decapoda, Caridea, Palaemonidae), one of the three principal freshwater prawn species of India, is an inhabitant of the middle and lower reaches of the Ganga River in northern India. About four decades ago a large population of *M. gangeticum* was present in the river and its tributaries. However, now the species is rarely seen in the catches and then only as one or two individuals.

The life cycle of this species has remained in dispute for many years. However, a series of experiments has established that the animal leads a semi-migratory life, as do some other freshwater prawns. The adults of this species feed and breed in the freshwaters of the river. Spawning as well as hatching of larvae takes place in the river itself. The hatchlings, however, are swept along with the fast water currents to the brackish waters of the estuary where they complete the rest of their larval life. In all, they pass through nine larval (zoea) stages and a post-larval (juvenile) stage. The juveniles then migrate against the current into the river to attain adulthood.

However, since the construction of Farakka Dam in the Ganga River near the India-Bangladesh border, the species has suffered a serious setback. Though the hatchlings can reach the brackish waters down the current, the juveniles are unable to return to the river due to the dam. This constraint is the principal cause of the serious decline in population of this species and immediate rescue measures are needed to save it from extinction.

### **RESERVOIRS FISHERIES IN TURKEY**

**Tüfek, Ö.M.**

*Head of Fisheries Section., Dept. of Operation & Maintenance, General Directorate of State Hydraulic Works, 06100 Yüce-tepe, Ankara, Türkiye, E-mail: omtufek@dsi.gov.tr*

Turkey ranks third in the world for dam construction. The combined surface area of the reservoirs is about 415 thousands hectares at the end of 2005. If all dams planned by Governments and other institutions were constructed there would be approximately 860 000 hectares with other reservoirs. Comprehensive fishery studies have been carried out in 183 dam lakes and 12 natural lakes owned or managed by the General Directorate of State Hydraulic Works (SHW). One hundred and seventy eight reservoirs dam lakes, 320 ponds and 12 regulated natural owned by other institutions were restocked with 255 millions

fingerlings of different fish species propagated in eight fishery stations spread over the country since 1959. According to 2004 fishery statistics, a yield of 8 655 tonne was caught in reservoirs, corresponding to 20 percent of the inland fishery yield of 45 585 tonne, and 110 culture-based projects whose total project capacity is 6 200 tonne are being applied, and this capacity covers 15 percent of total annual aquaculture production (44 115 tonne). It has been determined that 45 fish species are found in reservoirs, 43 of which are economically important. This study also examined, optimal exploitation strategies in respect of reservoir fishery potential that is not used efficiently at present.

#### **ATLANTIC SALMON IN THE REGULATED RIVER ALTA: EFFECTS OF CHANGED ENVIRONMENTAL CONDITIONS DURING WINTER ON JUVENILE SALMON**

**Ugedal, O., Finstad, A.G., Forseth, T., Thorstad, E.B. & Næsje, T.F.**

*Norwegian Institute for Nature Research (NINA), Tungasletta 2, NO-7485 Trondheim, Norway, Phone: +47 73801400. E-mail: ola.ugedal@nina.no*

Cold winter conditions prevail during important parts of the year in northern rivers. Environmental disturbances during this season, both natural and man-made, may have large impacts on juvenile fish survival. In the sub-arctic River Alta, a dramatic decline in the juvenile fish population was observed in the upper part of the river downstream of a power plant. The operation of the power plant increased the winter temperature of the river-water, and the ice-cover disappeared over an area of approximately 0-5 km below the outlet of the power plant. The effects of reduced ice cover on juvenile salmon ecology have been investigated with studies of juvenile winter energetics and survival in the River Alta, together with laboratory experiments. These studies suggest that lack of ice cover may reduce salmon winter survival, and may have contributed to the serious decline in densities of juvenile salmon in the upper part of the River Alta after the hydropower development.

#### **MULTI-YEAR CHANGES OF THE FISH STOCKS IN HEATED KONIN LAKES (CENTRAL POLAND) AND POSSIBILITIES OF USING OUTLET HEATED WATERS IN FISHERIES MANAGEMENT**

**Zdanowski, B., Wołos, A. & Ciepielewski, W.**

*Inland Fisheries Institute, ul. M. Oczapowskiego 10, 10-719 Olsztyn-Kortowo, Poland, E-mail a.wolos@infish.com.pl*

Changes of environmental conditions and status and perspectives of the fisheries in the system of heated Konin Lakes were determined on the basis of the analyses of multi-year data (1958-2004). This system is the receiver of heated outlet waters from two power and consists of five lakes, one artificial reservoir and approximately 15 km<sup>2</sup> of fish ponds, interconnected by a 26 km network of canals (cool and warm). The basic factors connected with the use of the waters by the power stations, determining status of environment and ichthyofauna are the increase of water temperature (3-80 °C on the average) and shortened period of water retention up to ten days. Artificially sustained thermal and hydrological regime caused an increase of water deterioration and eutrophication, changes in species composition of the ichthyofauna, changes in behaviour and life strategies of the native fish species, resulting in the decrease in the fish stocks of valuable species (pike, perch, pikeperch), and on the contrary – increase of the stocks of less-valuable cyprinid species. The water system has been used for stable stocking with herbivorous (bullhead, silver and grass carps) and native (pike, perch, wels) fish species, and the heat energy in recirculated system for the rearing and culture of valuable species: rainbow trout, sturgeon, wels, pikeperch and common carp.

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**SESSION 2 – REHABILITATING AND MITIGATING MECHANISMS**
**ARMSTRONG, G.**


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**EEL PROTECTION MEASURES WITHIN THE MANAPOURI HYDRO-ELECTRIC POWER SCHEME, SOUTH ISLAND, NEW ZEALAND**
**Boubée, J.<sup>1</sup>, Jellyman, D.<sup>2</sup> & Sinclair, C.<sup>3</sup>**
<sup>1</sup> NIWA, Box 11-115 Hamilton, New Zealand. Tel: +64 (7) 8561706, Fax: +64 (7) 9560151. E-mail: [j.boubee@niwa.co.nz](mailto:j.boubee@niwa.co.nz)
<sup>2</sup> NIWA, Box 8602 Riccarton, Christchurch, New Zealand. Tel: 03 3437846, Fax: 03 3485548. E-mail: [d.jellyman@niwa.co.nz](mailto:d.jellyman@niwa.co.nz)
<sup>3</sup> Meridian Energy, Private bag, Manapouri, New Zealand Tel: +64 (3) 2498725, Fax: +64 930 2498702. E-mail: [colin.sinclair@meridianenergy.co.nz](mailto:colin.sinclair@meridianenergy.co.nz)

Freshwater eels appear to be in decline worldwide. In New Zealand, although longfin eels (*Anguilla dieffenbachii*) and shortfin eels (*A. australis*) are still amongst the most common freshwater fish species, there are concerns about the scarcity of large specimens. There are also indications that elver recruitment, especially of the endemic longfins, is declining. Mitigation activities have been implemented at the Manapouri Power Scheme in an attempt to reverse present trends. The power scheme uses lakes Manapouri and Te Anau for storage with control structures at each outlet. The Manapouri control structure also diverts flows from the Mararoa River into the lake. Mitigation measures include the release of compensation flow at the Manapouri Lake outlet, the reconstruction of a fish pass, and a catch and transfer programme for upstream and downstream migrants. Ongoing studies are aimed at evaluating and improving interception and other passage possibilities such as targeted flow releases.

**FUNCTIONING OF FISH LADDERS IN THE RIVER MEUSE FOR UPSTREAM MIGRATION OF SALMONIDS AND THE EFFECT OF MANAGEMENT OF THE NEARBY WEIR**
**Breukelaar, A.W.<sup>1</sup>, Kemper, J.<sup>2</sup> & de Vaate, A.<sup>1</sup>**
<sup>1</sup> Institute for Inland Water Management & Waste Water Treatment, The Netherlands

<sup>2</sup> Visadvies, The Netherlands, address: P.O. Box 17, 8200 AA Lelystad, The Netherlands, Tel. no. ++31 320 297624, Fax no. ++31 320 298398. E-mail [a.breukelaar@riza.rws.minvenw.nl](mailto:a.breukelaar@riza.rws.minvenw.nl)

To evaluate the functioning of fish ladders (pool type) at the weirs in the Dutch part of the River Meuse, 11 Atlantic salmon and 84 sea trout were radio tagged during upstream migration in the period (2000-2003). The NEDAP TRAIL System® was used in this telemetry study which was performed at the Sambeek weir. Most of the tagged fish passed the weir by using the fish ladder within some days. Observed delay in migration was used as a metric for the estimation of the functioning of the weir. A weak relation was found between the condition of the fish and the passing success.

To get extra information about the effect of river discharge on the working of the fish ladder experiments have to be done by using different parts of the weir to carry of the water.

**STRATEGY FOR THE MITIGATION OF THE EFFECT OF THE KUBAN RIVER FLOW REGULATION ON STURGEON REPRODUCTION**
**Chebanov, M.S., Galich, E.V. & Ananyev, D.V.**

Regulation of river flows in the Kuban River hampers natural propagation of sturgeons. The spawning grounds of sturgeon (*A. stellatus*) were located 300 km upstream from the mouth.

Following the construction of dams, reduction in flow velocity caused the formation of sand bars which blocked access for sturgeons to the river mouth. Increases in salinity at the river mouth, diminished the silt load discharge of the Kuban R. and turbidity has also contributed to the decrease in migrating sturgeons numbers. Artificial spawning sites below the dams proved to be of only restricted efficiency due to changes in water regime.

In this paper the following measures for the mitigation of negative impact of these factors are discussed:

- amelioration of conditions at the river mouth;
- methods for increasing the efficiency of fish ways;
- elaboration of a new design for the offstream spawning site with a controlled hydrological regime;
- establishing of new sturgeon fisheries in up stream reservoirs;
- assessment of the environmental impact of hatchery based stock enhancement.

## **THE SWIMMING PERFORMANCE OF SELECTED EUROPEAN FRESHWATER FISHES**

**Clough, S.<sup>1</sup>, Turnpenny, A.<sup>2</sup> & Clifton-Dey, D.<sup>3</sup>**

<sup>1</sup> *Technical Director, Jacobs Babbie Aquatic.*

<sup>2</sup> *Divisional Director, Jacobs Babbie Aquatic.*

<sup>3</sup> *Technical Specialist, The Environment Agency, Thames Region, Reading, UK.*

In order to specify appropriate fish protection measures at water intakes, or to design suitable fish passage facilities it is necessary to have a detailed knowledge of the swimming performance of the fish species in question.

Two measures of swimming performance are particularly important. Critical burst swimming is an anaerobic process utilising the white muscle, and is used in the ascent of fish passes. Endurance swimming is aerobic, utilises the red muscle, and is used to maintain station, and to avoid entrainment into water intakes.

Since 1998, in excess of 15 000 individual swimming measurements have been taken from ten species, covering various temperature bands and length ranges.

This paper summarises the findings of a suite of experimental studies to test the critical burst and endurance swimming performance of freshwater fish, and describes the predictive computer model "SWIMIT".

## **STUDY ON UPSTREAM AND DOWNSTREAM MIGRATION FACILITIES AT THE SIEG RIVER - TECHNICAL SOLUTIONS, EFFICIENCY OF UPSTREAM MIGRATION, TOTAL MORTALITY OF DOWNSTREAM MIGRATION, COSTS AND ENERGY LOSS AT HYDRO POWER STATIONS**

**Dumont, U.**

The Sieg is one of the mid-size rivers in the Rhine-system, running from east to west with the mouth opposite to the city of Bonn, Germany. Rehabilitation of salmon has been carried out there since the 1990s, as water quality and the morphological structure seems to have been suitable for some 10–20 years.

There are a number of weirs and dams still remain in the barbel and grayling zones that obstruct upstream migrating fish. Technical proposals are made for the installation of fish ways at each dam – even for very wide weirs and difficult situations. Costs and risks were evaluated. For six existing hydro power stations solutions were designed using mechanical barriers with a slot width of 10–15 mm. Discharge of the largest station is about 30 m<sup>3</sup>/s.

There are no similar mechanical barriers for hydro power facilities in Europe. Target species are Atlantic salmon and eels.

The total efficiency of upstream migration and the total mortality of downstream migrating diadromous fish was calculated and the overall development of the salmon population can be predicted on the basis of this.

Overall costs and energy loss of hydro power stations caused by fish ways and fish screens were evaluated.

This study is part of a pilot project to develop the Sieg River as one of the main habitats for diadromous fish in North-Rhine Westphalia.

### **ECOLOGICAL OPTIMISATION OF HYDRO-ELECTRIC POWER PLANTS BY THE RE-ESTABLISHMENT OF CONDITIONS SIMILAR TO "FREE FLOWING RIVER SECTIONS" IN RIVER IMPOUNDMENTS**

**Eberstaller, J. & Koeck, J.**

*ezb-Eberstaller-Zauner-Bueros - Vienna*

Impounding rivers or raising the level of existing impoundments at old weirs causes the clogging of gravelbeds (hyporheic interstitial) and the loss of riffle sections and shallow water zones. Thus, spawning areas and juvenile habitats for the dominant species as well as the main habitat of macro invertebrates are lost, especially from mountain rivers.

By placing gravel bars in the upstream parts of the impoundment, which correspond in their shape, slope and substrate composition to natural riffles or shallow water zones, ecologically functional habitats can be "re-created". These provide for the sustainable preservation of rheophilic fish species.

Hence, negative ecological effects of the impoundment can be reduced without disadvantages for energy production, which fulfils the requirements of the WFD.

Limiting factors are the preservation of flood protection at the head of the impoundment and the avoidance of any influence on any power station upstream.

Presently these mitigation measures are tested with the modernisation of an old power station in Lower Austria.

### **WEIR REMOVAL IN SALMONID STREAMS: IMPLICATIONS, CHALLENGES AND PRACTICALITIES IN THE IBERIAN PENINSULA**

**Garcia de Leaniz, C.**

*University of Wales Swansea, Department of Biological Sciences, Swansea SA2 8PP, UK., Tel +44 0179 2295383. E-mail: [c.garciadeleaniz@swansea.ac.uk](mailto:c.garciadeleaniz@swansea.ac.uk)*

Old, unused weirs can greatly limit the distribution and abundance of Atlantic salmon and other migratory fish. Weirs can significantly increase the vulnerability of migratory fish to anglers, alter natural migration patterns, and exacerbate the effects of opportunistic predators. Overcrowding of fish at downstream pools can also facilitate the spread of parasites and infectious diseases, magnify the impact of pollution incidents, and increase the risk of mass mortalities, particularly at low flows. Not surprisingly, augmenting the accessible stream area constitutes one of the best ways to restore depleted salmonid populations. In this context, the removal of unused or illegal weirs can be an efficient, cheap solution to increase stream

accessibility. Here I examine some impacts of weirs on Atlantic salmon populations, and document with case studies the implications, challenges and practicalities of weir removal in several Iberian streams.

### **ROTATION SCREEN PREVENTS FISH DAMAGE IN HYDROELECTRIC POWER STATIONS**

**Hartvich, P., Dvořák, P. & Vrána, P.**

*University of South Bohemia, Faculty of Agriculture, Studentská 13, CZ – 370 05 České Budějovice, Czech Republic*

A rotation screen has been operating at a hydroelectric power station in Hadamar/Hessen, Germany since March 1998. The goal of this study was to monitor and evaluate the functionality and efficiency of the screen in order to prevent fish from getting into the Kaplan turbine of 4m wide intake, 3.0 m<sup>3</sup>.s<sup>-1</sup> flow and 0.78 m.s<sup>-1</sup> flow velocity. Two metres high-grade-steel metal bands with 15 x 8 mm mesh with adjustable rotation were installed at a 45 ° angle to keep fish out of the turbine. Tests in 2002–2004 showed that these reliably transport all arriving fish, including eels and salmon smolts, in scoop buckets to a V-shaped water channel without injury during downstream migrations. Only few juveniles and fish smaller than 1–2 cm can pass the mesh. Suggestions for further improvement were worked out. The rotation screen requires little maintenance, and its functionality met expectations. The system can be employed in smaller hydroelectric power stations up to water capacity of 20 m<sup>3</sup>.s<sup>-1</sup> per turbine.

### **THE CANOE-FISHWAY - A COMBINATION OF FISH MIGRATION AND CANOE PASSAGE IN THE SAME CHANNEL**

**Hassinger, R.**

*University of Kassel, Germany*

Brush-furnished fishways are currently accepted as a new type of fishpass that provides suitable hydraulic conditions for the migration of fish and macrozoobenthos. In addition this type of pass can be used by kayakers and rowers to bypass a dam or at least to draw a boat across the obstruction without any effort. Thus, the Canoe-Fishway provides a solution for the mitigation of the impact of dams on ecology and human activities on the water.

### **MEASUREMENT OF DISCHARGE IN FISHWAYS BY THE BACKWATER-VENTURI-FLUME**

**Hassinger, R.**

*University of Kassel, Germany*

Since discharge is a main parameter for the function of a fishway it should be adjusted rather accurately. Subcritical flow conditions only exercise weak hydraulic control, so the control of the discharge is normally not very reliable. Thus a discharge measurement is not only useful to adjust and control the discharge but also to detect clogging. The paper presents a method and a hard- and software system for measuring the discharge under the typical flow conditions encountered in fishways. The system is able to send a warning message as a SMS to a mobile phone or an E-mail account when low flow events occur.

## **NUMERICAL FLOW SIMULATION OF POOL-TYPE FISHWAYS - NEW WAYS WITH WELL-KNOWN TOOLS**

**Heimerl, S. & Hagemeyer, M.**

*EnBW Kraftwerke AG, Lautenschlagerstr. 20, D-70174 Stuttgart. E-mail: s.heimerl@enbw.com*

Fish passes are generally built at weirs and other obstacles to ensure longitudinal connectivity of rivers. Detailed knowledge of the flow structure is needed to evaluate if the ladder is to operate correctly hydraulically. Observations can only give an idea as to what is happening in the pools. In the course of an research project of the EnbW Energie Baden-Württemberg AG, Germany, the path the water takes through the pools is resolved primarily for special developed pool-type passes but also for vertical slot fishways. The visualised numerical simulated flow in pool-type fishways can be a significant help to fishery biologists and other experts. As a first step extensive velocity measurements have been conducted in a pool-slot fishway using a hydrometric vane and an ADV. The disadvantage is that measurements data cannot be collected at all points at the same time without a great deal of effort. The results represent the velocity at the sampling points but not how the water is flowing through the pool or even the successive cascade of pools. With the assistance of the Institute of Fluid Mechanics and Hydraulic Machinery of the University of Stuttgart numerical models of the fishways have been set up, computed and the results depicted. The model development is in no way trivial, but raises various problems related to the realisation of the free surface, the effect of bed substrate and further boundary conditions. The final resulting numerical simulation shows in colour how the water is streaming through the pool and is influenced locally by guide elements and the bed substrate. The exclusive depiction of measurements is not sufficient up to now to understand flow patterns at large. Investigations are ongoing to gain further insights with detailed parameter studies amongst others.

## **DEVELOPMENT OF NEW DIMENSIONING SPECIFICATIONS FOR FISH PASSAGE STRUCTURES WITH PERTURBATION BOULDERS**

**Heimerl, S. & Wurster, H.**

The investigations presented in this paper were performed to optimise the dimensioning of fish passage structures with perturbation boulders. During their detailed analyses the authors found that the procedures described in the German DVWK 232 technical bulletin will not always result in fully functional structures. Therefore a new design practice has been developed, based on the results of several hydraulic model test series and first realisations in new fish passage structures in southern Germany. The new dimensioning specifications will be integrated in the new German technical bulletin, which being updated and will replace the old DVWK 232 technical bulletin.

## **THE RESTORATION OF UNOBSTRUCTED FISH MIGRATION WITHIN A "HEAVILY MODIFIED WATER BODY", EXAMPLE OF THE LOWER RIVER RUHR**

**Jäger, S.**

*Ruhrfischereigenossenschaft Essen, Stauseebogen 23, 45246 Essen, Deutschland  
Tel: 0049 (0)201 46 61 46, E-mail: rfglotalota@t-online.de*

The Ruhr has a drainage area of 4 500 km<sup>2</sup> and a length of 217 km and is an important right bank tributary of the river Rhine in Northrhine-Westfalia. Multi-user interests shaped the drainage and the morphology of the Ruhr. Including: production of drinking water, sewage purification, energy production, flood prevention, navigation, recreation and fishing.



Historically, the Ruhr has been an important salmon river but has lost its stocks of migratory fishes. For that reason the Ruhr has been classified as ‘endangered’ under the EU Water Framework Directive and has been temporarily classified as a HMWB. For the Ruhr to comply with a ‘good ecological condition’, the anadromous fish species have to be reintroduced. For the successful reintroduction of salmon and sea trout it is necessary to restore the unobstructed migration of these species. The report will show the efforts to restore unobstructed fish migration from the Ruhr’s confluence with the Rhine upstream to the town of Hagen, for a total length of 110 km. It will explain the advantages and deficits of various fish passes

### **RECONSTRUCTION OF CONCRETE WEIR TO ROCKY CHUTE – EVALUATION OF THE FISH PASSES ABILITY**

**Jurajda, P.<sup>1</sup>, Loyka, P.<sup>2</sup>, Adámek, Z.<sup>1</sup>, Valová, Z.<sup>1</sup> & Janáč, M.<sup>1</sup>**

<sup>1</sup> *Institute of Vertebrate Biology, Brno, Czech Republic*

<sup>2</sup> *Town council of the Olomouc town, Olomouc, Czech Republic*

In the upper section (river 276 km) of the River Morava (Danube basin, Czech Republic), a concrete weir (height 1.55 m) was rebuilt in the form of a rocky chute in autumn 2003. The chute was built from large stones across the entire channel section at a slope of 1:23 to enable upstream and downstream fish migration and support the reproduction of rheophilic fishes in the river upstream. The aim of our three years study is to evaluate the proportion of fish passing the rocky chute and to compare the 0+ fish assemblages between the stretches. In April 2004, 16 and seven fish species, dominated by *Leuciscus cephalus*, *L. leuciscus*, and *Rutilus rutilus* were registered downstream and upstream of rocky chute respectively. A visible implant elastomer was used to mark all captured fish larger than 5 cm with colour codes for upstream and downstream stretches, respectively. The positions of marked fish are registered twice a year.

### **ASSESSING AND RESTORING GOOD ECOLOGICAL STATUS IN IMPOUNDED WATER COURSES – GRABIA RIVER (POLAND) PERSPECTIVE**

**Kaczowski, Z.<sup>1</sup>, Frankiewicz, P.<sup>1</sup>, Malgorzata, Ł.<sup>1</sup> & Zalewski, M.<sup>2</sup>**

<sup>1</sup> *Department of Applied Ecology University of Lodz; 90-237 Łódź, ul. Banacha 12/16, Poland*

<sup>2</sup> *International Centre of Ecology Polish Academy of Science, 90-364 Łódź, ul. Tylna 3, Poland*

Fish populations in European lowland rivers are not only influenced by availability of suitable habitats but also by flow-modifying structures. While loss of migratory species from river system is easily detected, the question that arises is whether the goal of the Water Framework Directive for good ecological status can be fulfilled by the remaining fish fauna. The impact of forty two man-made migration barriers in the 81 km long lowland Grabia River (Central Poland, Warta River drainage) was assessed using the European Fish Index and compared with traditional biodiversity indexes. The results are discussed in relation to recreational fishery pressures, mitigation strategies and the connectivity of the Warta River system. Restoration scenarios based on Regional River Connectivity Restoration Plans are discussed.

## **MITIGATING IMPACTS OF WATER INFRASTRUCTURE ON FISH MOVEMENTS: A CANADIAN PERSPECTIVE**

**Katopodis, C.**

*Freshwater Institute, Fisheries and Oceans Canada, 501 University Crescent, Winnipeg, MB., Canada, R3T 2N6, E-mail: KatopodisC@dfo-mpo.gc.ca*

Mitigating impacts of various river flow management structures on fish movements is a key consideration in modifying or removing existing structures and in designing, constructing and decommissioning new ones. Canadian experience in assessing such impacts, developing mitigation options and evaluating their effectiveness is presented through general concepts, specific projects and guideline development efforts. Conventional, physiomimetic (nature-mimicking) and structure removal approaches to fish passage for upstream and downstream movements for diverse sets of fish species are offered.

## **FISH BEHAVIOUR AND PASSAGE EFFICIENCY: LESSONS FROM NORTH AMERICA**

**Kemp, P.S.<sup>1</sup>, Gessel, M.H.<sup>2</sup> & Williams, J.G.<sup>2</sup>**

<sup>1</sup> *School of Civil Engineering and the Environment, University of Southampton, Highfield, Southampton, SO17 1BJ. UK. Tel. +44 (0)23 8059 5871. E-mail. [P.kemp@soton.ac.uk](mailto:P.kemp@soton.ac.uk)*

<sup>2</sup> *National Oceanic and Atmospheric Administration National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, Washington 98112-2097. USA.*

The guidance efficiencies associated with many mechanical structures designed to divert fish are often much lower than expected. Existing models of fish passage often ignore fish behaviour or are based on assumptions that may be false. A series of experiments were conducted at McNary dam, USA, to assess the influence of hydraulic transition and overhead cover on the behaviour of seaward migrating juvenile Pacific salmon. Fish passing through a flume encountered a choice of route that varied based on hydraulic factors and overhead cover. Direct observation revealed that individuals elicit strong avoidance behaviour when they encounter areas where hydraulic conditions change rapidly or are covered. Our findings have implications relevant to fish pass design and culvert restoration in Europe. The behavioural component of fish migration must be considered in order to improve current fish pass design and to develop alternative mechanisms that block access and divert fish.

## **THE USE OF A PORTABLE FISHWAY TO TEST THE SWIMMING ABILITY OF MIGRATING FISH IN RIVERS**

**Kotze, P.J., Ross, M.J., Deacon, A.R. & Niehaus, B.H.**

A portable model vertical slot fishway was used to test the swimming ability of fish during active migration in the Sabie River in the Kruger National Park in South Africa during November 2004. A gauging weir acted as a migration barrier at the time of the survey, resulting in the concentration of fish directly downstream from the barrier. The model fishway entrance was placed directly into a pool at the bottom of the weir. The fishway was tested at gradients of 1:5, 1:4 and 1:3

In total, eight species negotiated the vertical slot model fishway successfully at a slope of 1:5, while four species were successful at a gradient of 1:3. The ability of small fish (35–55 mm in length) to overcome turbulence levels of up to 900 watt/m<sup>3</sup> is far in excess of expected performance based on published values in the literature.

## IMPROVEMENT OF THE EFFECT OF FISWAYS BY LEADING CURRENTS AND THE DESIGN OF STRUCTURES IN THE RIVER CHANNEL

**Kraetz, D., Voelker, J. & Hassinger, R.**

*University of Kassel*

At flow conversions downstream of hydro-power plants or at the inflow of fishways into the main channel there is often a major problem in that fish continue migration into the power-channel rather than into the river reach or the fishway, where flow are lower. The paper is a report on investigations in the hydraulics laboratory at the Kassel University and shows how the migration of fish can be influenced by artificially induced flow and the design of structures on the river bottom. The efficiency of fishways can be increased significantly in this way by enabling the fish to find the structure.

## FROM SEA TO SOURCE: MANUAL OF FISH MIGRATION IN EUROPE

**Kroes, M.<sup>1</sup>, Wanningen H.<sup>2</sup>, Vriese, T.<sup>1</sup>, Ordeix<sup>3</sup> M. & Roura<sup>3</sup> M.**

<sup>1</sup> *FishConsult (VisAdvies), Vondellaan 14, 3521 GD Utrecht, the Netherlands. E-mail: [kroes@visadvies.nl](mailto:kroes@visadvies.nl)*

<sup>2</sup> *Water Board Hunze en Aa's, Aquapark 5 p.o.box 195. 9640 AD Veendam, the Netherlands. E-mail: [h.Wanningen@hunzeenaas.nl](mailto:h.Wanningen@hunzeenaas.nl)*

<sup>3</sup> *Centre d'Estudis dels Rius Mediterranis (Center for the Study of Mediterranean Rivers), Fundació Museu Industrial del Ter (Ter Industrial Museum Foundation), Passeig del Ter, SN. E-08560 Manlleu, Catalonia (Spain). E-mail: [cerm@mitmanlleu.org](mailto:cerm@mitmanlleu.org)*

Population diversity and abundance of fish is a primary element in designation of good ecological status of rivers according to the European Water Framework Directive. Natural fish migration is central to the maintenance of faunal diversity and abundance. Barriers exist in many rivers and waterways and the possibilities for fish migration are poor. Well-designed fish passages in several European countries have proven to be effective in solving this problem. Water managers have a lot of knowledge of the water bodies they are responsible for. However, in many water management organizations there is a lack of knowledge how to tackle the fish migration problems.

Therefore the project group “Community Rivers” (INTERREG IIIC program of the EU; 2004–2006) created a practical manual for restoration of fish migration in European waters. The partners of Community Rivers intend to structure and combine pan-European information by creating a document that helps local water management organisations solve their migration problems. This manual – a practical guide for fish migration – will provide a practical approach for restoration of fish migration.

Knowledge and information from different European countries can help in constructively approaching problems around fish migration and the exchange of knowledge between the various countries is used to execute the following assignments: 1) the creation of a practical guide “fish migration”, 2) research and monitoring of efficiency of different types of fish passes, and 3) the exchange of knowledge with the aim to develop fish passes suitable for Mediterranean rivers; a study for the starting points, designs and possibilities of fish passes in Mediterranean rivers.

As to benefit from existing experience and knowledge, experts on fish migration in European countries are asked to contribute by responding to a questionnaire on matters of upstream and downstream facilities for fish migration in their respective countries.

## **FISH PASSAGE EXPERIENCE AT SMALL SCALE HYDRO POWERPLANT IN FRANCE**

**Larinier, M.**

*CSP-Cemagref, Institute of Fluid Mechanics, Avenue du Professeur C. Soula, 31400 Toulouse France.  
E-mail :larinier@imft.fr*

More than 1 700 small-scale hydropower stations exist today in France, on the majority of rivers supporting migratory species. This paper provides an overview of the different types of fish facilities in use at these small-scale hydro projects. The relative advantages and drawbacks of each type of fish pass are discussed, with reference to the requirements of migratory species and the site-specific constraints. Emphasis is placed on the problems of attraction and maintenance. The paper also mentions the various techniques used to evaluate existing or newly constructed fish passes. Experience in using bypass facilities associated with trash racks for downstream juveniles salmonids and eels is presented. The author points out the severe cumulative impact, which can result from the existence of several small-scale hydro projects on the same river. He presents his view on the priorities for research on fish passage facilities, especially on “fish friendly” small-scale hydropower intakes.

## **EFFECTS OF HYDROPOWER INSTALLATIONS AND ASSOCIATED RIVER REGULATION ON RIVER SHANNON EEL POPULATIONS: HISTORICAL PERSPECTIVES, FISHERY MANAGEMENT RESPONSES AND CURRENT RESEARCH OBJECTIVES**

**Mc Carthy, T.K.<sup>1</sup>, Cullen, P.<sup>1</sup>, Blaszkowski, M.<sup>1</sup>, O'Connor, W.<sup>1</sup>, Doherty, D.<sup>2</sup>, & Frankievich, P.<sup>3</sup>**

<sup>1</sup> *Department of Zoology, National University of Ireland, Galway*

<sup>2</sup> *Electricity Supply Board, Ballyshannon, Co Donegal, Ireland*

<sup>3</sup> *Department of Applied Ecology, University of Lodz, Poland*

The Shannon, Ireland's largest river, has been used for hydroelectricity generation since 1929. Subsequently, the Electricity Supply Board assumed responsibility for management of its eel stocks, due to the impact of the hydro-dam on recruitment to the commercial fishery. Management has focused on stocking lakes with juvenile eels, trapped at the hydropower facilities and in estuarine tributaries. Due to declining natural recruitment, attempts have also been made to use estuarine glass eels. Annual surveys monitor population trends of juvenile (glass eel, elver), growing phase (yellow eel), and downstream migrating pre-spawners (silver eels). Survey results and fishery management programmes will be reviewed. Effects of natural environmental and anthropogenic factors on eel populations and migratory patterns will be illustrated. Current research on seaward migrating silver eel populations, suggests that spawner escapement rates should be increased by trapping them at fishing weirs up-stream of the power station and transporting them towards the estuary.

## **THE SPAWNING GROUNDS OF GRAYLING, *THYMALLUS THYMALLUS L.*, IN THE RIVER AARE BELOW LAKE THUN: MITIGATING THE IMPACT OF PLANNED FLOOD CONTROL MEASURES**

**Müller, R.<sup>1</sup> & Guthruf, J.<sup>2</sup>**

<sup>1</sup> *Eawag: Swiss Federal Institute of Aquatic Science and Technology, Fish Ecology and Evolution, CH-6047 Kastanienbaum, Switzerland*

<sup>2</sup> *Aquatica GmbH, Hängertstrasse 13G, CH-3114 Wichtrach, Switzerland*

The River Aare at Thun, at the outflow from Lake Thun, holds one of the most important grayling spawning areas in Switzerland. The shallow river bottom impedes the outflow of the water at low to medium lake levels. Therefore, the lake level occasionally rises to flood the lower parts of villages and towns. In order to reduce the risk of floods, the authorities planned

to dredge the river, which met with considerable resistance from anglers who feared that the unique spawning grounds would be destroyed. A more moderate dredging project might have been accepted by all, provided that adequate substitute spawning grounds for grayling would be created and their functionality proven before dredging. In winter 2002/2003, substitute spawning sites were created by depositing gravel and by loosening the hard substrate. Furthermore, additional larval habitat was created by inserting woody structures along the shores to offset the severe lack of larval habitat. In spring 2003, 2004 and 2005, grayling spawned on the substitute spawning sites. Grayling larvae in these years were significantly more abundant than in earlier years. In 2004 the authorities decided not to dredge but to construct a large separate tunnel to evacuate the water. As a consequence, the conditions for grayling to reproduce in the River Aare have been significantly improved.

#### **UTILIZATION OF LENTIC WATERBODIES FOR FISH REPRODUCTION AND PARASITE DISPERSAL**

**Ondračková, M.<sup>1,2</sup>, Dávidová, M.<sup>2</sup>, Dušková, M.<sup>2</sup> & Jurajda, P.<sup>1</sup>**

<sup>1</sup> *Institute of Vertebrate Biology, Academy of Sciences of the Czech Republic, Květná 8, 603 65 Brno, Czech Republic*

<sup>2</sup> *Department of Zoology and Ecology, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic*

During June–August 2003, 0+ juvenile fish were observed in ten lentic waterbodies (natural oxbows and man-made borrow pits) in the floodplain of the lower Morava and Dyje Rivers, Czech Republic. The number of 0+ fish species was higher in borrow pits than in oxbows, but species diversity did not differ significantly. Relative abundance of 0+ juvenile fish was equal in both natural and man-made waterbodies, but borrow pits showed a trend to be more suitable habitat for successful fish recruitment. Two most frequent species perch *Perca fluviatilis* and bitterling *Rhodeus sericeus* were examined for metazoan parasites. Community of metazoan parasites composed mainly of larval bivalves and crustaceans in perch and of monogeneans and digeneans in bitterling. Inhabiting shallow banks exposed the fish during their juvenile stage to high abundance of parasites such as glochidia and larval digeneans, which can be dispersed by the parasitized fish into the river during floods.

#### **ECOLOGICAL AND BEHAVIOURAL BACKGROUND OF CONSTRUCTIONS FACILITATING MIGRATIONS AND PREVENTING MASS LOSS OF FISH IN REGULATED RIVERS**

**Pavlov, D.S., Lupandin, A.I. & Mikheev, V.N.**

*A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences. Leninskii prospect, 33, Moscow 119071, Russia.*

Knowledge of various aspects of fish behaviour and ecology is needed to ensure suitable conditions for upstream and downstream movements of fish within regulated rivers. Field and laboratory studies on behavioural mechanisms of fish migrations and spatial distribution have been carried out in the Laboratory of Fish Behaviour for more than 40 years. One of the practical outputs of these studies is related to the control of fish behaviour in water flows. More specifically, these studies include assessment of impacts of current velocity gradients, turbulence of different scales and fluctuating pressure on elementary behavioural responses of fish, especially in early ontogeny. Foraging, antipredator behaviour, social and exploratory activities as well as upstream and downstream migrations were the focus of our studies. The results have been used to develop constructions facilitating fish passage through dams (different types of fish ladders and lifts) and devices deterring fish from types of various water pump and turbine.

## THE USE OF ARTIFICIAL SPAWNING SUBSTRATES AS MEDIA TO SUPPORT THE REPRODUCTION OF EURASIAN PERCH IN LAKE PIEDILUCO

**Pedicillo, G.<sup>1</sup>, Merulli, F.<sup>1</sup>, Carosi, A.<sup>2</sup>, Viali, P.<sup>2</sup> & Lorenzoni, M.<sup>1</sup>**

<sup>1</sup> *Dipartimento di Biologia Cellulare e Ambientale, Università di Perugia, Via Elce di Sotto, 06123, Perugia, Italy.*

<sup>2</sup> *Provincia di Terni, Servizio Programmazione Ittico-Faunistica, Via Plinio il Giovane 21, 05100, Terni, Italy.*

Lake Piediluco is a naturally regulated lake used for hydroelectric power generation. Current lake management and the eutrophic conditions of its waters had negative effects on the fish population and particularly on Eurasian perch (*Perca fluviatilis* L.). In order to increase natural reproduction of this species an experimental program was undertaken, in 1997-2003, to support the reproduction of perch by means of artificial spawning substrates. In Lake Piediluco perch spawned from March to May. Egg ribbons length goes from 30 to 180 cm with a number of eggs from 12 740 to 205 466. The largest egg ribbons, corresponding to the larger reproducing females, were laid earlier, contained mean number of eggs per gram and a lower percentage of degenerated eggs. The mortality of eggs seems to be correlated with egg ribbons length and is higher in the early stages of embryogenesis.

## RIVER REHABILITATION FOR FISH IN CENTRAL ITALY: THE RIVER PANARO PROJECT

**Pini Prato, E.<sup>1</sup>, Ferri, M.<sup>1</sup>, Comoglio, C.<sup>2</sup>, Gianaroli, M.<sup>3</sup>, Marconato, E.<sup>4</sup>, Maio, G.<sup>4</sup>, Larinier, M.<sup>5</sup> & Marmulla, G.<sup>6</sup>**

<sup>1</sup> *Università degli Studi di Firenze, Dipartimento di Ingegneria Agraria e Forestale(DIAF), Via S. Bonaventura, 13, Firenze 50145, Italy (corresponding author)*

<sup>2</sup> *Politecnico di Torino, Dipartimento di Ingegneria del Territorio, dell'Ambiente e delle Geotecnologie(DITAG), Corso Duca degli Abruzzi, 24, Torino 10129, Italy*

<sup>3</sup> *Provincia di Modena, U.O. Programmazione Faunistica*

<sup>4</sup> *Associazione italiana ittiologi acque dolci (AIAD), Aquaprogram s.r.l. Vicenza*

<sup>5</sup> *Groupe d'hydraulique appliqué aux aménagements piscicoles et à la protection de l'environnement (GHAAPPE), Institut du mécanique des fluides, Toulouse.*

<sup>6</sup> *Food and Agriculture Organization (FAO), Inland Water Resources and Aquaculture Service, Rome*

The Provincia di Modena, Italy, has been promoting river rehabilitation for fish migration since 1984 and was the first Local Authority in Italy to carry out specific training programmes on fish passes. In 2002 it financed a river rehabilitation project aimed at safeguarding fish species of local and European interest (*Barbus plebejus*, *Leuciscus cephalus cabeda*, *Leuciscus souffia muticellus*, *Chondrostoma genei*, *Padogobius martensii*, *Gobio gobio*, *Cobitis taenia*) in a watercourse of high ecological value (Panaro river) through the design of fish passes for the restoration of the river continuum. In this paper the main steps and the expected results of this project are presented that will represent a model to be proposed also for other sites. The gained experience is compiled in the manual: "Guide lines for the correct approach in fish passes design", that is the first Italian manual on fish passes. It was prepared by a technical and scientific committee consisting of international and national experts of six cooperating institutions, i.e. the Province of Modena, the Department of Forest and Agricultural Engineering of the University of Florence, the Association of Italian Freshwater Ichthyologists, the Politecnico di Torino, the French GHAAPPE and the Food and Agriculture Organization of the United Nations.

## PROVISION OF UPSTREAM FISH PASSAGE BY MEANS OF NATURE-MIMICKING FISH PASSES

**Redeker, M.**

*Ruhr River Association (Ruhrverband), Kronprinzenstr. 37, 45128 Essen, Germany, Tel. 0201 / 178-2616.*

*E-Mail: [mrd@ruhrverband.de](mailto:mrd@ruhrverband.de). Internet: [www.ruhrverband.de](http://www.ruhrverband.de)*

Many rivers worldwide have seen severe anthropogenic modifications due to various uses of water. Numerous dams, weirs, hydropower plants and locks interrupt the continuity of rivers and their tributaries and delay, hinder or block migrations and other movements of fish. As fish populations are highly dependent upon the characteristics of their habitat, for reproduction, recruitment and growth, up- and downstream fish passage has to be provided at water management structures in order to mitigate their impacts. In those cases where water management structures are still required, i.e. where decommissioning is impossible, fish passes facilitate upstream and downstream passage over or around the obstacles. Nowadays in Germany, Austria, Switzerland, Australia and recently in Northern America nature-mimicking fish passes are preferred wherever their construction is feasible. The design philosophy for these fish passes is ecologically minded, aiming to achieve a good fit with the specific riverine environment as well as the landscape they are constructed in. In Germany these fish passes are designed according to the 1996 guidelines "Fish Passes – design, dimensions and monitoring". The presentation will give an overview of the various types of nature-mimicking fish passes, e.g. pooltype channels, stream-like bypass channels and rock ramp fishways. It will focus on the basic idea for their construction, specific designs (structural and hydraulic), building methods and materials, monitoring as well as costs and will identify the latest findings as well as new ideas and approaches for the design of nature-mimicking fish passes.

## FISH PASSAGE AND HYDROELECTRICITY: A SYNOPSIS OF COMPREHENSIVE STUDIES OF UPSTREAM AND DOWNSTREAM PASSAGE OF ANADROMOUS WILD ATLANTIC SALMON, SALMO SALAR, ON THE EXPLOITS RIVER, CANADA

**Scruton, D.A.<sup>1</sup>, Pennell, C.J.<sup>1</sup>, Bourgeois, C.E.<sup>1</sup>, Goosney, R.F.<sup>1</sup>, Porter, T.R.<sup>1</sup>, Ollerhead, L.M.N.<sup>1</sup>, Clarke, K.D.<sup>1</sup>, Booth, R.K.<sup>2</sup> & Eddy, W.<sup>3</sup>**

<sup>1</sup> *Fisheries and Oceans Canada, Science Branch, P.O. Box 5667, St. John's, NL, A1C 5X1 CANADA, phone (709)-772-2007; FAX (709)-772-5315. E-mail: [scrutond@dfo-mpo.gc.ca](mailto:scrutond@dfo-mpo.gc.ca)*

<sup>2</sup> *Lotek Wireless, 115 Pony Drive, Newmarket, ON L3Y 7B5 CANADA*

<sup>3</sup> *Abitibi Consolidated Inc., P.O. Box 500, Grand Falls-Windsor, NF A2A 2K1 CANADA*

Government (Fisheries and Oceans Canada), industry (Abitibi Consolidated Company of Canada), and public interest groups (Exploits River Management Association) have been working cooperatively to protect and enhance wild Atlantic salmon populations on the Exploits River, insular Newfoundland, Canada. Since the mid-1960s, enhancement programs and construction of fish passage facilities at natural and man made barriers in the watershed have expanded the range and increased the returning adult population. Recently (since 1998), attention has been paid to improving passage and survival of downstream migrating smolts and kelts at two hydroelectric facilities at Grand Falls-Windsor and Bishops Falls. At Grand Falls-Windsor a floating louver and bypass system was installed in a power canal and extensive biological, hydraulic, and modeling studies have been conducted to assess, modify, and optimize fish passage. At Bishops Falls, a retrofitted surface spill bypass system was installed in an existing spill gate and similar studies have been conducted to improve passage success. Studies have also been conducted on the upstream migrating adults at these facilities and associated fishways, using conventional and physiological telemetry, to assess tailrace attraction and residency, and the relative energy cost of upstream migration to bypass the



hydro plants and fishways. This paper reviews the results of these various studies to demonstrate how cooperative work has improved passage of anadromous salmon in coexistence with hydroelectric development.

#### **BEHAVIOURAL PATTERNS OF IBERIAN BARBELS' UPSTREAM MOVEMENTS THROUGH AN ARTIFICIAL POOL-TYPE FISHWAY**

**Silva, A.T., Franco, A.C., Santos, J.M., Ferreira, M.T., Pinheiro, A.N., Melo, J.F. & Bochechas, J.H.**

Knowledge on the behaviour of cyprinid Iberian barbel *Barbus bocagei* migrating upstream through fish passes is scarce and poorly understood.

The behaviour of Iberian barbel in response to different patterns of flow conditions was studied in a scaled-down laboratory facility, a pool-type fishway, by means of direct observation through a glass side-wall supplemented by video records.

Forty-five barbel with a total length range of 10–30 cm were subjected to twelve experiments characterized by four different hydraulic conditions based on flow patterns – streaming and plunging flow – and notch width, 20 and 30 cm. Fish were also offered a choice of two types of entrances: notches and orifices.

There was a strong selection for submerged orifices whereas a combination of larger notch width (30 cm) with streaming flow patterns seemed to be preferred for upstream movements. These results add to the impression that main behavioural characteristics of Iberian barbel migrating upstream through pool-type fishways may be independent of size and life stage.

#### **FACILITIES FOR UPSTREAM MIGRATION OF EELS AND ELVERS AT MAN-MADE OBSTRUCTIONS**

**Solomon, D.**

A year-long study of passage facilities has been funded by the Environment Agency involving examination of installations and research in the British Isles, France and North America. Good and poor features of existing installations are identified, and an approach to provision of facilities is developed. The most common limitations are failure to operate over the appropriate range of headwater and tailwater levels, sub-optimal location of downstream entrance of the pass, poor design of the upstream exit allowing the fish to be carried back downstream, and lack of maintenance.

A number of current developments in design of substrates for eel passes in France and Canada are described. Future developments and requirements for further R&D are discussed.

#### **AN EXPERIMENTAL AND NUMERICAL STUDY OF TURBULENT FLOW IN VERTICAL SLOT FISHWAYS**

**Tarrade, L., Texier, A., David, L., Larinier, M. & Manceau, R.**

*Laboratoire d'Etudes Aérodynamiques, Université de Poitiers, Téléport 2, boulevard Marie et Pierre Curie, BP 30 179, 86962 FUTUROSCOPE CHASSENEUIL*

The upstream migration of fishes through engineering constructions or natural obstructions in rivers are managed with hydraulic structures called fishways. Vertical slot fishways consist in different successive stair pools, separated by slots, through which the water flow is regulated. The flow patterns must be optimized in order to guide fishes and make possible their way

along the structure. However classical fishways are not initially conceived for small fish species which can remain blocked within the currents. The aim of this experimental and numerical study is to characterize and better understand the turbulent flow in a typical vertical slot fishway. Then the possible hydraulic and geometric evolutions of the structure can be studied (width and angles of the pool, slope, obstacles and deflectors in the pool) to modify the turbulence scale, the eddies dimensions and facilitate the migration of little fish species.

## **EVALUATING VERTICAL-SLOT FISHWAY DESIGNS IN TERMS OF FISH SWIMMING CAPABILITIES**

**Teijeiro Rodríguez, T.<sup>1</sup>, Agudo, J.P.<sup>2</sup> & Mosquera, L.P.<sup>3</sup>**

<sup>1</sup> Prof., EPS, Santiago de Compostela University, Campus universitario, s/n, 27002, Lugo. Spain.

<sup>2</sup> Prof., Civil Engineering School, A Coruña University, Campus de Elviña, s/n, 15912, A Coruña. Spain.

<sup>3</sup> Res., CITEEC, A Coruña University, Campus de Elviña, s/n, 15912, A Coruña. Spain.

One of the major problems in fishway design is that optimal parameters depend on an interplay of hydraulic and biological variables. This study presents a methodology for evaluating fishway designs in terms of the swimming capabilities of the “client” fish. Specifically, we evaluate two vertical-slot designs whose hydraulic properties were empirically characterized in a previous study. In view of these empirical data, we estimate for each design: a) minimum discharges giving minimum fish-acceptable depths; b) maximum pool sizes ensuring flow velocities low enough to be overcome by the fish; c) maximum pool sizes ensuring turbulence low enough to be acceptable to the fish. These design constraints are calculated for different slopes (~6 percent or ~10 percent), for different water temperatures (10, 15 or 20 °C), and for different fish lengths. This methodology constitutes an effective means of taking fish swimming capabilities into account at the fishway design stage.

## **EVALUATION OF SURFACE AND BOTTOM BYPASSES TO PROTECT EEL MIGRATING DOWNSTREAM AT SMALL HYDROELECTRIC FACILITIES IN FRANCE**

**Travade, F., Larinier, M., Gosset, C., Durif, C., Rives, J. & Elie, P.**

Efficiencies of bypasses for downstream migrating European eels (*Anguilla anguilla*) were tested at two hydroelectric power plant in Southwest France. At Halsou 74 individuals were radiotracked and a total of 637 eels were trapped during the three-year study. At Baigts, 40 individuals were radiotracked. These experimental studies has shown that a downstream migration device composed of a bypass with a discharge of 2–3 percent of the turbine discharge located near a trash rack with 3 cm bar spacing could be partially efficient for adult eels and that a bottom bypass was preferable to a surface bypass. The efficiency of such a device is only partial (18–60 percent) and not sufficient for most power plants given the high mortality induced by the passage into the turbines. Efficiency could be improved by reducing the bar spacing of the trash rack (close to 2 cm) which would block the major part of the eel population.

## **ADVANCES IN INTAKE & OUTFALL FISH SCREENING**

**Turnpenny, A.**

*Divisional Director, Jacobs Babbie Aquatic*

The traditional legal requirements in Britain to screen water intakes and outfalls against the entry primarily of migratory salmonids have broadened out in recent years to encompass a much wider spectrum of species. The drivers for this process included angling pressures and

improved attitudes towards biodiversity and conservation and are reflected elsewhere in Europe and North America.

This has given rise to the need for a better understanding of the processes leading to fish entrainment, of the ecological significance of entrainment mortalities and for the development of a wider range of more flexible techniques to adapt to the different intake and outfall screening challenges.

The array of available technical options often leaves environmental regulators bemused and there is a need to define best practice. This paper reviews the development of a 'best practice guide' on behalf of environmental regulators in England and Wales.

## **DEVELOPMENT OF A FISH MIGRATION RAMP - FIELD AND LABORATORY EXPERIMENTS**

**Ullmann, M.<sup>1</sup>, Stephan, U.<sup>2</sup> & Haunschmid, R.<sup>3</sup>**

<sup>1</sup> *Office of the State Government of Upper Austria, Department of Water Management, Kärntnerstraße 10-12, 4021 Linz, Austria. E-mail: melanie.ullmann@ooe.gv.at*

<sup>2</sup> *Institute for Hydraulic Engineering and Calibration of Hydrometrical Current-Meters, Federal Agency for Water Management, Severingasse 7, 1090 Vienna, Austria. E-mail: ursula.stephan@baw.at*

<sup>3</sup> *Institute for Water Ecology, Fishery, Biology and Lake Research, Federal Agency for Water Management, Scharfling 18, 5310 Mondsee, Austria. E-mail: reinhard.haunschmid@baw.at*

The present situation in Austria shows that sills, ramps and weirs, which originally were built in order to stabilise a degrading river bed, now often act as barriers against fish migration. Hence, river reaches upstream of these structures are in danger of ecological impoverishment due to a lack of natural fish reproduction. The research project focuses on the development of a ramp type pass which accomplishes both stabilisation of the river bed and fish migration especially for the hyporhithral and epipotamal systems characterised by the grayling and barbel region. The ramp is developed mainly to replace low weirs, sills and ramps. The investigations are divided into field experiments and a laboratory experiment. For the field experiments two existing sills will be replaced by step-pool-ramps with varying slopes, step heights and pool volumes to analyse different hydraulic parameters such as flow velocity and turbulence regarding the hydraulic acceptance of the concerned fish species. The laboratory experiment focuses on the ramp stability as well as the morphological development of the upstream and downstream river reach.

## **MITIGATING THE EFFECTS OF HIGH HEAD DAMS ON THE COLUMBIA RIVER, USA: EXPERIENCE FROM THE TRENCHES**

**Williams, J.G.**

*National Oceanographic and Atmospheric Administration, Northwest Fisheries Science Center, Seattle, WA 98112 USA*

Billions of US dollars over the past 40 years have gone into efforts to mitigate for losses of anadromous fish as a result of hydroelectric dam construction on the Columbia River, USA. The dams and reservoirs inundated a >500 km stretch of free-flowing river. Initial efforts consisted of designing and installing effective ladder systems to attract and pass adult salmon upstream of the dams. Efforts then turned toward decreasing mortality to juveniles that must migrate through eight or nine reservoirs, then Kaplan turbines at dams with 13-33 m of head. These include: 1) releases of water to increase reservoir flow; 2) elaborate screening systems to: a) intercept juveniles from turbine intakes and route them to barges that will transport them downstream for release below the hydropower system, or b) bypass them to the tailrace of the

dams; spilling water at dams; and developing surface-oriented devices to attract juveniles and route them to the tailrace of the dams.

## **WATERWHEELS – THE POSSIBLE COMPROMISE BETWEEN GAINING RENEWABLE ENERGY AND FISH ECOLOGICAL INTEGRITY**

**Wolter, C.<sup>1</sup> & Müller, G.<sup>2</sup>**

<sup>1</sup> *Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany*

<sup>2</sup> *University of Southampton, Southampton, UK*

The sustainable development goals of renewable energy, river restoration, and species conservation increasingly conflict with man-made interventions in the landscape. For example, damming is a major threat to riverine species but water retention or generation of renewable energy are common aims of sustainable management. Equipping dams with migration facilities is a generally accepted restoration measure for dams that are impassable to aquatic organisms. Technical solutions exist to facilitate upstream passage of fish and invertebrates but downstream migrations are accompanied by substantial injuries and kills because they follow the main current through the turbines. Technical devices to protect fish from being sucked into turbines are costly and high maintenance. They rarely work properly and if they do it is at the expense of power generation.

Water wheels are suggested as a solution to this problem. Downstream passage through a water wheel meets the migratory behaviour of fish and should cause only little damage because of its slow speed, low water velocities, operation under atmospheric pressures, and lack of rotating blades. A water wheel combined with an upstream migration facility would significantly improve longitudinal connectivity and thus, the ecological integrity of river systems.

## **RE-ESTABLISHING CONNECTIVITY IN A DANUBE-TRIBUTARY SYSTEM**

**Zitek, A., Schmutz, S. & Jungwirth, M.**

*Institute of Hydrobiology and Aquatic Ecosystem Management, Department of Water, Atmosphere and Environment, Max-Emanuelstrasse 17, 1180 Wien, BOKU - University of Natural Resources and Applied Life Sciences*

The European Union (EU) is currently establishing the Natura-2000 network of protected areas. Within these areas, LIFE-Nature projects, aiming to conserve natural habitats and wild fauna and flora of EU-interest, are funded by the EU Commission. The LIFE-Nature project “Living space of Danube salmon” (LIFE99 NAT/A/006054) in particular re-established the river continuum by the installation of 11 fish passes at formerly impassable weirs, and improved habitat conditions by channel restoration and purchase of land, over a Danube/tributary river network of 78 km length. Fish migration facilities were designed as nature-mimicking bypass channels (n=4), rock-ramps (n=6), or pool-and-weir passes (n=1). Efficiency of restoration measures were assessed by: (1) testing the efficiency of individual fish migration facilities, (2) assessing re-colonisation path ways of re-opened river sections, and (3) evaluating re-colonisation of restructured river sections.

Successful migrations were documented within the whole study area, varying between eight and 33 species and 38 and 2098 individuals passing the fish migration facilities. In total ten individuals of the “Danube salmon”, *Hucho hucho* (L.), were caught at fish ladders, but the most frequent species in traps was *Barbus barbus* (L.). Some individuals of *Barbus barbus* (L.), but also of small-sized species like *Alburnus alburnus* (L.) and *Gobio gobio* (L.), belonging to the Danube population, were found to migrate more than 9 km into the

tributaries passing three fish-ladders during one season. Marked individuals of *Barbus barbus* (L.) from different river sections were found to use the same winter habitats in tributaries, documenting the re-connection of formerly fragmented populations. Restoration of regulated river sections led to the creation of spawning places for lithophilous species like *Hucho hucho* (L.) and *Chondrostoma nasus* (L.), and to strongly increased fish densities. The re-opening of the river continuum resulted in an increase of river-type specific species within the whole tributary system, for some of them successful reproduction has been re-established in areas from which they had disappeared.

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**SESSION 3 ENVIRONMENTAL FLOW CRITERIA; METHODOLOGY AND PRACTICE**


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**I. COWX**


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**DAM OPERATION RULES BASED ON BROWN TROUT FLOW REQUIREMENTS: DESIGN OF ENVIRONMENTAL FLOW REGIMES IN REGULATED STREAMS**

**Alonso-González, C.<sup>1,2</sup>, Gortázar, J.<sup>2</sup>, Baeza Sanz, D.<sup>2</sup>, & García de Jalón, D.<sup>2</sup>**

<sup>1</sup>*Sciences Faculty. Catholic University of Ávila. Ávila. Spain*

<sup>2</sup>*Ecohidráulica. Laboratory of Hydrobiology. Polytechnic University of Madrid. Madrid. Spain*

Changes on stream flow regimes due to small hydroelectric dams are usually observed in mountain streams. These changes concern not so much the intensity of flow as the variability and frequency of high and low-flow episodes. Former studies showed the influence of flow variability on the dynamics of a resident brown trout population, especially those related to the stream flow regime during spawning, incubation and emerging periods. As these stages are known to determine the population dynamics in older fish, stream flow variability appears to be a major factor in the regulation of a wild brown trout population. Thus, mean flow discharge should not be the only parameter taken into account when establishing ecological flow regimes in order to re-establish proper flow conditions for the enhancement of altered trout populations in mountain streams. Setting ecological stream flow regime characteristics, on the basis of conclusions obtained from a former study (Alonso-González *et al.*, 2004), is propounded as a tool for the design of environmental flow regimes in mountain reaches downstream hydroelectric devices. Case studies conducted in a high mountain basin in Central Spain (River Tormes) over five years showed that the relationship between duration and frequency of high low-flow episodes during egg incubation could be linked to young of the year recruitment and quantified in terms of flow management units. Duration and frequency of flow discharges can be set so as to reach desirable population levels in brown trout populations affected by hydropower flow regulation.

**METHOD FOR SETTING ECOLOGICAL RIVER FLOW FOR STURGEON PROPAGATION**

**Chebanov, M.S., Galich, E.V. & Ananyev, D.V.**

Flood control and water abstraction (for agriculture) cause serious damage to the aquatic ecosystem (modify river hydrology and morphology regime) and impact on the natural propagation of sturgeon.

In this paper we discuss the method for ecological discharge estimation.

The critical values of the most significant hydrological parameters for sturgeon reproduction were calculated for different parts of the river for most dry years (90-95 percent certainty of discharge).

The following hydroecological criteria of the Kuban River flow management were established to characterize the lower limit of the water regime parameters at which natural reproduction of sturgeon did not occur:

- decrease in average flow velocity (<0.5 m/s) at spawning sites;
- lowering of water level in deltaic lakes (lower than in the Sea);
- increase in average water salinity (up to 6‰ of deltaic lakes aimed for sturgeon fingerlings adaptation);
- decrease in load discharge (<50 m<sup>3</sup>/s) and depths (up to 0.3 m) at the mouth.

## **CALIBRATION OF HYDROLOGIC EMPIRICAL METHODS FOR ESTIMATING THE FLOOD PEAK IN THE UROMIA LAKE WATERSHED IN IRAN**

**Jamali, A.A.<sup>1</sup>, Ayyoubzadeh, S.A.<sup>2</sup> & Mahdavi, M.<sup>3</sup>**

<sup>1</sup> Faculty Member of Agriculture & natural Resources college, Islamic Azad University, Mayboud Unit, Mayboud, Iran E-mail: [jamhek@yahoo.com](mailto:jamhek@yahoo.com)

<sup>2</sup> Assistant Professor, Dept. of Irrigation Structures Engineering, Faculty of Agriculture, Tarbiat Modarres University

<sup>3</sup> Professor of Faculty of Natural Resources, Tehran University

The design flood is an important criterion for many water projects. Unfortunately, many developing countries, including Iran, are faced with a lack of sufficient recorded hydrologic data. In order to cope with scarcity of data and to study ungauged catchments, application of developed empirical models based on other gauged catchments are applied as a common strategy by hydrologists. The present research work is an effort to evaluate ten general empirical models for flood estimation with different return periods, including Dicken, Creager, Gray, Bremner, Waitt, Inglis, Cramer, Murphy, Ocornell, and Cooley Models. Methods used the best coefficient with RSS (Residual Sum of Square) factor in the Solver programmer of Microsoft Excel. The objective data of peak discharge collected and processed with hydrologic statistic models. Objective discharges compare with estimated discharges. The models have been tested in the Uromia Lake watershed. In the Uromia Lake watershed, all models except the Gray are applicable.

## **EFFECTS OF REDUCED WATER FLOW ON ATLANTIC SALMON MIGRATION IN THE RIVER VEFSNA, NORWAY**

**Jensen, A.J., Johnsen, B.O. & Forseth, T.**

*Norwegian Institute for Nature Research, Tungasletta 2, NO-7485 Trondheim, Norway*

A plan has recently been presented for hydropower development of the Vefsna watercourse, primarily based on energy interests. It aims at transferring water from the upper part of the river to a neighbouring watershed, and also at building a power station in a tributary. As a result, water flow will be reduced, with highest changes in the upper part. The salmon has to pass several high and difficult migration barriers to reach the uppermost spawning areas. We have studied the ascent of salmon in relation to water flow and water temperature through the most important obstacles. The proposed regulation would have reduced the number of days favourable for ascent in the lowermost waterfall in most years. Farther upstream, the salmon would meet even higher difficulties, especially in dry years. Based on our study, the hydropower company is now adjusting its plan to provide more water during migration in dry periods and years.

## **WHAT IS SUFFICIENT WATER FLOW IN STRONGLY REGULATED SALMON RIVERS?**

**Johnsen, B.O. & Hvidsten, N.A.**

*Norwegian Institute for Nature Research, Tungasletta 2, NO-7485 Trondheim, Norway*

Four small, strongly regulated Atlantic salmon rivers draining to the Trondheim fjord has shown different salmon fishery. One of the rivers (Vigda) had a good salmon fishery in most years, another river (Børselva) had a good salmon fishery in many years. In the third river (Skjenaldelva) the salmon fishery was good only in some of the years while there was no salmon fishery at all in any year in the fourth river (Mossa). Two years of investigations of both the young and the adult salmon populations, indicate that this was probably due to different kinds of hydropower development resulting in different regimes of water flow. The



river Mossa has strongly reduced water flow throughout the whole year because of transferring of water from the river. In the other three rivers there is a power station situated in the upper part resulting in varying, periodically strongly reduced water flow.

#### **APPROACHES FOR SETTING ECOLOGICAL FLOWS: A CANADIAN PERSPECTIVE**

**Katopodis, C.**

*Freshwater Institute, Fisheries and Oceans Canada, 501 University Crescent, Winnipeg, MB., Canada, R3T 2N6.  
E-mail: KatopodisC@dfo-mpo.gc.ca*

Assessing impacts and setting ecological flows for various river flow management structures is a key consideration in modifying or removing existing structures and in designing, constructing and decommissioning new ones. Canadian experience in assessing such impacts and arriving at ecological flow regimes (environmental or instream flow regimes) for ice-free or ice-covered rivers, is presented through general concepts, modeling approaches and specific projects. Methods range from relatively simple desktop calculations based primarily on hydrological data to sophisticated hydrodynamic and habitat modeling followed by time series analyses. Physiomimetic or nature-mimicking concepts are employed to enhance the ecological integrity of estimated flow regimes by imitating key elements of natural hydrographs and geomorphic features.

#### **REGIONALISATION OF INSTREAM FLOW RESULTS IN TIBER BASIN**

**La Porta, G., Spigonardi, M.P., Lorenzoni, M. & Mearelli, M.**

Instream flow research was begun in 1997 in the Tiber river basin (Italy) to define a methodological approach for the planning and management of natural water resources. Field activities were conducted in 18 streams belonging to the brown trout and barbel zone, that were studied in more than 40 sampling reaches. In each site hydrological and biological features were analyzed to develop an habitat model to predict WUA (weighted usable area) values for four fish species (brown trout, barbel, chub and roach). Conventional instream habitat model PHABSIM, modified by authors for the Tiber river, was run to link fish densities and standing crop to channel depths and velocities. With this incremental methodology a relation between optimal instream flow for fish and discharge was found. These results contribute to identify the influence of hydraulic variables on fish suitability and they should facilitate habitat studies in multiple streams, at the basin or larger scales.

#### **LIVING WITHOUT WATER: ESTABLISHING ENVIRONMENTAL FLOWS FOR FISH**

**Noble, R.A.<sup>1</sup>, Cowx, I.G.<sup>1</sup> & Welcomme, R.<sup>2</sup>**

<sup>1</sup> *University of Hull, International Fisheries Institute, Hull HU6 7RX, UK*

<sup>2</sup> *Long Barn, Clare Road, Stoke by Clare Sudbury, Suffolk CO10 8HJ  
(E-mail – i.g.cowx@hull.ac.uk)*

Demand for what in the UK is now exceeding supply and flows in rivers are subject to high abstraction volumes that may impact on aquatic fauna. To ensure the maintenance and conservation of fish populations, 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 CASE STUDY FOR THE DETERMINATION OF THE D.M.V.(MINUM FLOW RELEASED) ON BIOLOGICAL BASIS FOR A NEW ARTIFICIAL BASIN**

**Nocita, A., Pini, G., Bartali, S., Pini Prato, E. & Schweizer, S.**

The D.M.V. released by the new built Bilancino artificial basin (province of Florence, Arno river watershed), that has been operational since year 2000 was determined. The outflowing Sieve river was studied on four different reaches. The IFIM (Instream Flow Incremental Methodology) was applied for the calculation of the D.M.V. and the PHABSIM software was used for the hydraulic simulation. Moreover a specific sampling for the analysis of the ichthyofauna was made on every reach studied. The partners involved in the project were the Authority for the Arno Watershed, the Province of Florence and the Museum of La Specola. The results of this study have been used for the flow regulation of the tailwater from the Bilancino basin in order to diminish implications for fish.

**EFFECTS OF RAPIDLY VARYING FLOWS FROM HYDROELECTRIC FACILITIES ON THE FISH FAUNA OF SOME AUSTRIAN RIVERS DEPENDING ON STREAM MORPHOLOGY**

**Petz-Glechner, R. & Petz, W.**

*Umweltgutachten Petz OEG, Consulting Office for Ecology and Environmental Protection, Hallwanger Landesstrasse 32a, A-5300 Hallwang, E-mail: petz@umweltgutachten.at*

Hydroelectric powerplants with fluctuating water discharge often cause severe effects on aquatic biocoenoses. The quality and quantity of the fish fauna are suitable indicators for the degree of this disturbance. We investigated species composition and fish stock in several Austrian rivers influenced by varying flows and related these to stream bed morphology and current velocity across the river channel. This showed an enormous influence of river morphology. Adverse effects of varying flow conditions on the fish stock increase in regulated rivers where current velocities are higher than in natural meandering stretches. In canalized rivers, increased flow velocities during 'peak-situations' affect even the shallower areas along the river banks and leave almost no living space for fish. In contrast to this, effects of strong currents decrease in running waters with a natural morphology. For instance, in a meandering river a daily discharge ratio of 1:8 had only little effects on the ichthyocoenosis. Based on the results, we provide suggestions for minimizing adverse effects of a fluctuating water discharge.

## **RIVER FLOOD CONTROL BY RESTORING TRIBUTARIES CREATES NEW HABITATS FOR THE FISH FAUNA – A FEASIBILITY STUDY FOR THE RIVER ASCHACH (UPPER AUSTRIA)**

**Scheder, C.<sup>1</sup>, Hochhold, A.<sup>2</sup>, Humer, G.<sup>2</sup> & Gumpinger, C.<sup>1</sup>**

<sup>1</sup> *Technisches Büro für Gewässerökologie, Gärtnerstraße 9, 4600 Wels, [scheder@blattfisch.at](mailto:scheder@blattfisch.at)*

<sup>2</sup> *Ingenieurbüro für Kulturtechnik und Wasserwirtschaft, 4682 Geboltskirchen*

Two tributaries to the River Aschach, the Sandbach and the Leitenbach brooks, were heavily regulated in the early twentieth century. As a result the flood peaks of these tributaries discharge almost simultaneously into the River Aschach. Their combined effect causes unnaturally heavy inundations of the surrounding land. Furthermore, there is a massive loss of habitat structure, and the weir at the mouth of one of the two brooks is an impassable barrier to fish migration. A feasibility study is now being carried out dealing with the restoration of the two tributaries. In flood situations, the restored meandering course should retain discharge within the catchment. The influence of the intended rehabilitation is analysed using a 2-D flow model dealing with both the effects on the two tributaries and the River Aschach. Moreover, the project will establish a basis for the development of a natural fish assemblage.

## **ENVIRONMENTAL EFFECTS OF ‘HYDROPEAKING’ POWER GENERATION: EXPERIMENTAL STUDIES OF RESPONSE OF JUVENILE SALMON AND TROUT TO FLOW MODIFICATION**

**Scruton, D.A.<sup>1</sup>, Pennell, C.<sup>1</sup>, Ollerhead, L.M.N.<sup>1</sup>, Robertson, M.<sup>1</sup>, Clarke, K.D.<sup>1</sup>, Alfredsen, K.<sup>2</sup>, Strickler, M.<sup>2</sup>, Harby, A.<sup>3</sup> & LeDrew, L.J.<sup>4</sup>**

<sup>1</sup> *Fisheries and Oceans Canada, Science Branch, P.O. Box 5667, St. John's, NF A1C 5X1 CANADA, [scrutond@dfo-mpo.gc.ca](mailto:scrutond@dfo-mpo.gc.ca)*

<sup>2</sup> *Norwegian Technical University, Department of Hydraulic and Environmental Engineering, Trondheim, NORWAY*

<sup>3</sup> *SINTEF, Water Resources, Trondheim, NORWAY*

<sup>4</sup> *Newfoundland and Labrador Hydro, P.O. Box 12400, St. John's, NL A1B 4K7 CANADA*

Global deregulation of the electric power market has focused attention on the ecological impacts associated with ‘hydro peaking’ power generation. In insular Newfoundland, Canada, a five year study has been conducted on the effects of ‘simulated’ hydro peaking power generation on juvenile salmonids. In 1998 and 1999, Atlantic salmon and brook trout were implanted with radio transmitters and released into an experimental reach of the West Salmon River, below the Upper Salmon hydroelectric facility. Flow was manipulated over a range of discharge (1.0 to 4.2 m<sup>3</sup>s<sup>-1</sup>) during a series of ‘experiments’ simulating hydro peaking in both summer and fall. Fish were manually tracked, precisely located ( $\pm 1$  m), habitat selection evaluated, and movement response determined. As discharge increased, velocity and depth used by both species increased, and salmon adapted behaviourally by increased contact with the substrate. Salmon also exhibited two distinct movement patterns; site fidelity or considerable movement during trials. Salmon moved greater distances than trout under all experimental conditions, and during both seasons. Experiments were continued in 2003 and 2004 to contrast response of salmon between summer and winter. Absolute flow changes were greater (0.7 to 5.2 m<sup>3</sup>s<sup>-1</sup>) and made more rapidly (instantly). Salmon were more mobile during all flow conditions and throughout the diel cycle in the summer than winter, adopting greater home ranges and utilizing more of the stream reach. In the winter, fish were more active in response to flow changes and at dawn. Results of all experiments suggest that hydro peaking regimes can be energetically costly, which may potentially affect production and survival as over-winter survival may be related to energy reserves obtained during summer. Collectively these studies provide comprehensive information on the response of juvenile

salmonids to hydro peaking, on both diel and seasonal scales, and will assist hydro producers and regulatory agencies design and operate hydro peaking regimes to minimize ecological impact.

#### **ASSESSING AND VALIDATING ENVIRONMENTAL FLOWS IN AUSTRIAN RIVERS**

**Unfer, G., Zeiringer, B., Jungwirth, M. & Schmutz, S.**

*Institute of Hydrobiology and Aquatic Ecosystem Management; BOKU - University of Natural Resources and Applied Life Sciences, Vienna*

Water diversion by hydroelectric power plants causes one of the severest impacts on running waters. In Austria the amount of diverted water often depends on the time of construction of the power stations. In former times (1920–1970), when ecological awareness was not developed, it was common to divert the whole flow, which led to dry river beds and the loss of the whole biotic community within extensive stretches. This tendency persists to the present day in some areas. With the commencement of the EU-Water Framework Directive (EU-WFD) in December 2002, a new European legislative basis for water protection was created, which consequently focuses on the improvement of the ecological situation in residual flow stretches.

In the presented study we defined environmental flows for 12 power plants. The observed rivers differed in the amount of natural flow (MQ 3-7m<sup>3</sup>/s), as well as flow regime and fish-region (trout- to barbel-zone). In order to determine suitable amounts of flow, the actual situation of the fish-stock was surveyed first. Quantitative electro-fishing was done in stretches affected by diversion as well as in reference sections upstream and downstream of the water extractions. Suitable amounts of environmental flows were defined by applying different hydraulic modelling approaches. Assessment and validation was done by using ecological parameters, such as species distribution, guild composition, densities, age-structure etc.

#### **THE IMPORTANCE OF NATURAL HYDROLOGICAL REGIME FOR FISH RECRUITMENT IN LOWLAND RIVERS**

**Valová, Z.<sup>1,2</sup>, Jurajda, P.<sup>2</sup> & Janáč, M.<sup>1,2</sup>**

<sup>1</sup>*Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic*

<sup>2</sup>*Institute of Vertebrate Biology, Academy of Sciences of the Czech Republic, Květná 8, 603 65 Brno, Czech Republic*

Many European floodplain rivers have been regulated and channelised during the previous century for flood control, navigation and electricity production. These activities led to the depauperation of channel structural heterogeneity and affected fish reproduction. The 0+ juvenile fish assemblage was studied in the channelised and partially regulated (low weirs) lowland River Morava (Danube basin). Due to the absence of navigation and dams upstream in the main channel, the hydrological variability remains almost natural (varying between 4 and 370 m<sup>3</sup>s<sup>-1</sup> annually). The spatial distribution of 0+ juveniles and ecological requirements of particular species were investigated by a point abundance sampling strategy with electrofishing over five years. Absence of all off-channel habitat entirely limited phytophils (rudd, pike) and partially limited some phyto-lithophils (bream, perch). Remaining torrential shallow stretches support reproduction of rheophilic species such as chub, barbel and gudgeon. Seasonal discharge variability in the channelised river seems to support the recruitment of many fish species.

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## **SESSION 4: SOCIAL, ECONOMIC AND CONSERVATION ISSUES GUIDELINES, REGULATIONS AND LEGAL ASPECTS**

**CASTELNAUD, G. & BRENNER, T.**

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### **DAMS AND THE ENVIRONMENT: A BIBLIOGRAPHIC DATABASE**

**Baer, A.**

*Victoria, Canada*

One of the FAO's on-going projects is a bibliographic database on the environmental effects of dams. The most promising aspect of the database is that rather than merely cite a record of 300 pages that may contain 200 pages of discussion on many different riverbasins and species, the database breaks the record down into separate citations on the varied subjects and indexes the records and abstracts to specific controversies (e.g. turbine passage for juveniles vs. spill vs. transportation by barge). Built on simple-to-use commercial software, the database currently contains approximately 12 600 citations, many with abstracts, and many indexed by country, riverbasin, dam, and aquatic species affected. The proportion of citations from scientific journals continues to decline as the database uploads more records from government, university bodies, and environmental trusts. Not only NGOs, fisher communities, scientists and hydroelectric utilities are embroiled in the debate over dams: farmers, recreational boaters, sports fishermen, and river-transportation companies also have their interests.

### **THE SALMON IN RIVER ALTA: A SYMBOL OF SUSTAINABLE HYDROPOWER DEVELOPMENT?**

**Bremset, G.**

*Norwegian Directorate for Nature Management, Tungasletta 2, NO-7485 Trondheim, Norway, Phone: +47 73580500. E-mail: Gunnbjorn.Bremset@Dirnat.no*

The River Alta is arguably the most important Atlantic salmon river in Norway due to its ethnic (Sámi people), socio-economic and recreational importance. The hydro power project in the river has been highly controversial, resulting in a special focus on the environment in general and the salmon in particular. As a consequence, the operating routines of the power plant have been designed to sustain a high-producing salmon stock, at the sacrifice of the general economical priority. Since 1981, comprehensive research programs have given invaluable scientific support for a more environmental-friendly operation of the power plant. A network of fishing right holders, researchers, power company and managers at all levels is established. At present, the status for the salmon stock is satisfactory in River Alta, in contrast to several stocks in other regulated rivers. However, it is still important to monitor the salmon stock to discover detrimental long-term effects.

### **EXAMPLES FROM THE DANISH MANAGEMENT SCENE: MIGRATORY FISH AND RIVER OBSTACLES**

**Jepsen, N. & Rasmussen, G.**

There has been a significant improvement in the Danish salmon and sea-trout stocks over the last ten years. There has been a positive trend in smolt production, sea survival and return rates and many rivers have more, bigger and earlier salmon and sea-trout than previously. New methods like telemetry and genetics has clearly shown a high potential for providing

long-needed information, to improve efforts to enhance fish habitats, identify key factors for fish populations and thus help conserve and strengthen fish stocks. Telemetry has the obvious benefit of demonstrating problems in a clear and easily accepted way, using a limited number of individuals through relatively short study periods. These assets make such studies well suited to influence both political and management decisions.

Basic telemetric methods and population genetics were first used ten years ago in fisheries research in Denmark. Since then, results from studies using and combining these methods have provided the basis for a more scientifically based management of rivers and lakes. This new type of management includes close links between science, managers and politicians, and much of the improvement of the migratory fish stocks is a result of better management. This paper presents some examples of how results from scientific studies have influenced or improved the management. The cases involve changes in stocking practise, new regulations on land based fish farms, design of fish passes and removal of obstacles. These examples may serve as inspiration for researchers to design their studies and communicate the results in a manner that makes it easy to use in the management system.

## **FISHES AS PROMOTORS FOR NEW APPROACHES IN INTEGRATIVE RIVER MANAGEMENT**

**Jungwirth, M., Muhar, S., Schmutz, S. & Unfer, G.**

*Institute of Hydrobiology and Aquatic Ecosystem Management, Department of Water, Atmosphere and Environment, Max-Emanuelstrasse 17, 1180 Wien, BOKU - University of Natural Resources and Applied Life Sciences*

Throughout history, freshwater fishes have been highly attractive and interesting organisms for humans. Therefore, the autecological characteristics and demands of many species and their different life stages are comparatively well known. Since running waters worldwide are heavily used and degraded by pollution, shipping, flood protection measures and hydroelectric power plants (impoundments, reservoir flushing, hydro peaking, water diversion, etc.), fish stocks are affected in manifold ways. With the increasing demand for preserving, restoring and managing healthy running waters/riverine landscapes, fishes have turned out to be of especially high value as indicator organisms. That fact is accommodated by the EU-Water Framework Directive, which specifies fishes as obligate objects for assessing/evaluating the ecological integrity (the ecological status) of running waters. Against that background, the present paper deals with the value of fishes as key indicators for quality control, demonstrating newly developed evaluation methods and introducing different projects as examples. Special importance is attached to issues of hydro-morphological dynamics, connectivity, structural heterogeneity and habitat availability. The examples given comprise evaluations of natural reference sites as well as of degraded systems and restored reaches at different scales.

## **PRIORITY LIST FOR RE-ESTABLISHING THE RIVER CONTINUITY IN AUSTRIAN RIVERS**

**Mader, H.**

*Department of Water Management, Hydrology and Hydraulic Engineering, University of Agricultural Sciences Vienna, Muthgasse 18, A-1190 Vienna, Austria, e-mail: [helmut.mader@boku.ac.at](mailto:helmut.mader@boku.ac.at), Web: [http://iw.hw.boku.ac.at/personen/mader\\_deu.html](http://iw.hw.boku.ac.at/personen/mader_deu.html)*

River continuity is one of the hydro-morphological criteria supporting the classification of the ecological status of rivers (EU-WFD, 2000). In order to achieve good ecological status, the continuity of rivers may show impacts of anthropogenic activities to the extent that some fish

age classes may be missing and only slight changes in species composition and abundance from the type specific communities are permitted.

Austrian rivers are cut into small sections as a result of their systematic use for water power and river regulation measures. River continuity is heavily interrupted and an unacceptable loss of diversity and ecosystem function has resulted.

The goal of the project is to create a priority list for removing interruption-points within a time period of 12 years to re-establish river continuity so as to allow undisturbed migration of aquatic organisms. More than 200 interruption points at around 170 km of river length were evaluated in this paper to examine the ecological status of the river, the costs – benefit - ratio of restoration of the continuum and the distance between discontinuities..

The ecological status, classified by comparing the present versus the potential natural morphological conditions (Leitbild), as well as the cost – benefit - ratio have been used to weight the distance between two separation-points within river reaches. On the basis of this a priority list of discontinuities to be removed is established.

The financial policy and a schedule of removals for the period 2003–2015 is based upon the results of the priority list.

#### **STRATEGIES FOR THE CONSERVATION OF ENDANGERED FISH COMMUNITIES AFFECTED BY FLOW REGULATION AND INCREASING URBANIZATION. APPLICATION TO RIVER PERALES BASIN (SPAIN)**

**Marchamalo, M., Alonso, C., Baeza, D., Vizcaíno, P., & García de Jalón, D.**

*ECOHIDRAULICA. Laboratorio de Hidrobiología. E.T.S.I. Montes. Universidad Politécnica de Madrid. Spain*

Increasing urban and rural demands for water have triggered dam construction in Spain which have now reached 1 200 large dams in number (World Commission of Dams, 2000) On the other hand, biodiversity of fishes in Spain accounts is high, and is adapted to the unpredictable and shifting Mediterranean conditions (Corbacho and Sánchez, 2001). Less specialized alien species are favoured by regulation whereas native species, which are adapted to the previous shifting conditions, tend to disappear. River Perales is a small sandy tributary of River Alberche in Central Spain that presents a unique fish community with endangered native cyprinids like *Squalius alburnoides* (Steindachner, 1866) and *Chondrostoma lemmingii* (Steindachner, 1866) that still dominate alien species like sunfish (*Lepomis gibbosus* L.) and catfish (*Ictalurus melas* Rafinesque, 1820). The objective of present study was to summarize and evaluate proposals for the conservation of River Perales fish community, including dam removal (Marchamalo et al., 2000), habitat restoration and artificial breeding. As a result we assessed the effect of habitat changes on the survival of River Perales fish community, finding that a key for the maintenance of native fish species dominance over alien species is to allow natural Mediterranean hydromorphological shifting conditions over the year. We can conclude that a multi-approach strategy should be adopted to ensure the conservation of this fish community, including a habitat restoration, land use planning and a scientific-based breeding program.

## LEGISLATION AND EXPERIENCE IN ASSESSMENT THE HYDROPOWER IMPACT ON FISHERIES IN LATVIA

**Mitans, A.**

*Latvian Fish Resources Agency*

In Latvia there are three big hydropower stations (HPS) and 149 small-scale stations (maximum power 2 MW). The small HPS has been developed recently as the renewable energy sources to strengthen national independence in energy. However, most of the small HPS are reconstructed former water-mills and only a few new dams were built on the rivers. Permission for design and terms for exploitation of HPS has been regulated by several general and specific laws and rules. For the calculation of the hydropower effects on fisheries the legislation requires that "Rules for assessment the impact the economy activities on the fish resources and for ordering the relevant compensation" be followed. The maximum compensation was ordered to Riga HPS that was constructed near the mouth of the River Daugava. Destruction of the Baltic Salmon, sea trout, river lamprey and some other Daugava fish stocks resulted in 372 789 LVL (1 LVL= 1,37 EUR) as a yearly compensatory payment. For the small HPS operated on the old dams the yearly payment usually does not exceed 100 LVL but in some cases there is no evidence for calculation of damage to fish resources. The compensatory payments have been used for the fish stocking programme.

## LOKKA RESERVOIR, THE WATER RESERVOIR OF POWER ECONOMY, AS A WINTER FISHERY IN NORTHERN FINLAND

**Mutenia, A.<sup>1</sup> & Huttula, E.<sup>2</sup>**

<sup>1</sup> *Finnish Game and Fisheries Research Institute, Inari Fisheries Research and Aquaculture, Saarikoskentie 8, FIN-99870 Inari, Finland. E-mail: ahti.mutenia@rktl.fi*

<sup>2</sup> *Kemijoki Oy, Valtakatu 9-11, FIN-96101 Rovaniemi, Finland. E-mail: erkki.huttula@kemijoki.fi*

The Lokka reservoir was dammed in the late 1960s; to serve as a water reservoir for the power plants of the Kemijoki river system. The reservoir is the largest in the European Union, and it collects spring melt and flood waters which drain through the winter into the 16 power plants of the river system. The maximum area of the reservoir is 417 km<sup>2</sup>. The normal regulation range of Lokka is 2.0-2.5 m, and its average depth is 4.95 m at maximum drawdown. The bottom of the reservoir mainly consists of peat, which consumes the oxygen reserves of the water when decaying. The area is one of the coldest in Finland: ice covers the lake for seven months of the year. The quality of the water running into the reservoir is excellent.

The reservoir has a natural fish stock, which has been strengthened through stocking. Commercial fishing is important in the area and total catch is 130 tonne/year. A winter fishery with nets for coregonids is one of the most important in the reservoir.

During the lowest water level in winter, the oxygen concentration of the surface water is good in the central parts of the reservoir but poor in the fringe areas. Near the bottom, the oxygen concentration is close to zero in the whole reservoir. The oxygen levels affect the fishery and the catches of coregonids. Coregonids migrate from the low oxygen fringe areas to the centre of the reservoir, and fishery also takes place there. The lack of oxygen benefits the fishery because it forces whitefish to rise to the surface waters and move more than is usual during winter. Therefore, the CPUE of coregonids in net fishing is high in winter. In winter fishing, the nets are raised to the surface in order to prevent the fish from dying in the nets. According



to fishery records, 10-20 percent of the whitefish caught in the nets die there, when the nets and the fish in them sink in anoxic water. By improving net fishing and water regulation, the catch losses could be decreased.

#### **ATLANTIC SALMON IN THE REGULATED RIVER ALTA: CHANGES IN JUVENILE AND ADULT ABUNDANCE**

**Næsje, T.F., Thorstad, E.B., Ugedal, O. & Forseth, T.**

*Norwegian Institute for Nature Research (NINA), Tungasletta 2, NO-7485 Trondheim, Norway, Phone: +47 73801400. E-mail: tor.naesje@nina.no*

In 1983-1987, a hydroelectric power plant was built in the River Alta. The populations of juvenile and adult Atlantic salmon in the river have been studied since 1981 to monitor effects of the hydropower plant. The density of juvenile salmon in the upper part of the river, just downstream of the power plant, decreased drastically in the years following the regulation. This decrease in the juvenile population was subsequently followed by reduced catches of adult salmon in this part of the river. To improve salmon recruitment in the upper part of the river, a catch-and-release fishery was implemented from 1997. In addition, the routines for operation of the power plant were improved. In the later years, the densities of juveniles in the upper part of the river have increased, but not to pre-regulation levels. Reasons for the changes in the salmon population over the study period will be discussed.

#### **ENJEUX DE L'HALIEUTIQUE DANS LE DÉVELOPPEMENT ET L'UTILISATION DES RESSOURCES EN EAU DOUCE DANS LES PAYS ARIDES EN VOIE DE DÉVELOPPEMENT : EXEMPLE DU BURKINA FASO**

**Ouedraogo, M.R.**

*MSc en Politique et Planification des Pêches, Direction Générale des Ressources Halieutiques, 03 BP 7010 Ouagadougou, Burkina Faso*

La politique internationale de sauvegarde de l'environnement a contraint les pays sous développés à adopter des mesures législatives appropriées. Mais de toute évidence, leur mise en oeuvre rencontre des problèmes d'ordre social, économique, technique, financier et politique tant au niveau national qu'au niveau international.

Depuis une décennie, le Burkina a élaboré plusieurs textes législatifs tendant à protéger les ressources halieutiques. La loi d'orientation de la gestion de l'eau exige la construction de passes à poisson sur tout barrage entravant la migration des poissons. Malheureusement, aucun de nos barrages n'en est pourvu, même les plus grands barrages construits après l'adoption de ces textes. En réalité, la pêche est un secteur d'activités auquel on n'accorde pas suffisamment d'intérêt dans le développement et l'utilisation des ressources en eau.

Des stratégies nationales de promotion de la pêche dans les usages conflictuels des ressources hydriques doivent être développées et mises en oeuvre. Elles devront être supportées, voir exigées par les bailleurs de fonds intervenant dans la construction des barrages et dans la gestion de l'eau qui y est contenue. Le rôle de l'expertise internationale en sciences halieutiques sera d'inciter et d'assister aussi bien les bailleurs de fonds, les gouvernements que les techniciens en développement des ressources en eau.

## **ANALYSIS OF IMPACTS ON STREAMS BY EVALUATING THE FISH ECOLOGICAL STATUS, AND DEVELOPMENT OF A DECISION MATRIX FOR SUSTAINABLE RESTORATION OF STREAM INTEGRITY**

**Siligato, S. & Gumpinger, C.**

*Technisches Büro für Gewässerökologie, Gärtnerstraße 9, 4600 Wels; [siligato@blattfisch.at](mailto:siligato@blattfisch.at)*

The fish ecological integrity of a stream catchment was evaluated, and analysed according to the principles of the European Union Water Framework Directive, together with data on migration barriers, stream bed alteration and water quality criteria. In general the data show that fish ecological integrity is better in reaches with little altered stream morphology than in more modified ones. Nevertheless impacts such as fragmentation, water diversion and non-point inputs clearly affect the fish assemblage in the latter. On the basis of this analysis a restoration matrix was developed for the stream that focuses on economical and technical feasibility for the restoration and sustainable conservation of the fish assemblage within the stream catchment.

## **A LEGAL FRAMEWORK FOR GRANTING PUBLIC FINANCIAL AID, TO CONSTRUCT NEW OR MODERNIZE EXISTING FISH PASSES IN POLAND**

**Stachowiak, P.M.**

*Ministry of Agriculture and Rural Development, the Department of Fisheries, the Unit of Inland Fishery, Warsaw, Poland*

For centuries the development of agriculture and industry has been affecting freshwater wild life. In Poland it is difficult to find catchments that are unchanged in terms of longitudinal connectivity of running waters and quality of water and fish habitats. Hydropower, flood protection and waterways entailed engineering works that cause serious obstacles to migration of aquatic organisms. In the past, an environmental impact assessment procedure (EIA) was not always applied in an investment process, and undisturbed movement of fish was not usually taken into account in an analysis of costs and effects on the environment. These days the EIA procedure is a part of a legal system, but there are still many hydro constructions which proved to be the major obstacle for migration of diadromous fish and led to a reduction of the abundance of migratory fish population. Specific legal and financial measures for restoring the fish migration in freshwaters has been undertaken since the Polish government decided that Poland would join the European Union. As a part of the UE structural fund system a public financial aid scheme was established in 2004 to enhance investments in construction of new or modernization of existing fish passes in freshwaters. This scheme had to be adjusted for regulations concerning freshwater property rights and the license system for water usage for industrial, agricultural or communal purposes. It is obvious that not every hydro construction can be decommissioned and not every investment cost can be accepted. In the scheme four major rules have been adopted: an inventory of obstacles to the migration of diadromous fish is made by a competent authority; a list of priorities is drawn; a public financial aid is offered to every physical or legal person that is prepared to carry out the task of restoring the longitudinal connectivity; only best available practices are applied in designing new facilities enabling fish movement in waters and all expenses of the investment are refunded, if a designed facility fulfills specified standards of fish passage efficiency and a cost analysis.

## **HOW TO OPERATE A POWER STATION IN A SENSITIVE RIVER: CHALLENGES AND EXPERIENCES**

**Tvede, A.**

*Senior environmental adviser, Statkraft Energy, Pb. 200, Lilleaker, NO-0216 Oslo, Norway, Phone: +47 24067000. E-mail: arve.tvede@statkraft.com*

This paper will illustrate how the Alta Power Station in Northern Norway is operated, taking into account the fact that sensitive environmental interests are present in the river system. These interests are: The ecological status and the Atlantic salmon fishing activity, the river ice as a recreation area and the prevention of damages from floods in the populated areas. These interests have to be combined with the need to produce electricity and obtain the best prizes in a liberated energy market.

## **EXPERIENCES FROM ACROSS THE POND: MODELING DOWNSTREAM MIGRATION AND SURVIVAL OF JUVENILE PACIFIC SALMON THROUGH THE COLUMBIA RIVER HYDROPOWER SYSTEM**

**Zabel, R.W.**

*Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, WA, USA*

The development of Hydroelectric dams on the Snake and Columbia Rivers in the northwestern United States, along with other anthropogenic impacts, has taken a toll on Pacific salmon populations: 13 “evolutionarily significant units” of Pacific salmonids that migrate through the hydropower system are listed as threatened or endangered. We have developed a model of the downstream migration and survival of juvenile salmon through the hydropower system. The model represents detailed hydrological conditions such as river velocity and temperature. Dam operations, such proportion of river flow spilled, are configurable by the user. The model tracks cohorts of fish as they migrate downstream through the river system. Movement patterns and relationships between survival and river conditions are based on over ten years of PIT tag mark-recapture studies. We use the model to compare the effectiveness of several alternative management scenarios, including dam removal.

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**POSTERS OF GENERAL INTEREST**


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**INLAND FRESHWATER ECOSYSTEM - DEGREE AND DIVERGENCE OF DEPOSITS THAT IMPEDED THE RIVER SYSTEM FOR FISH DYNAMICS, PRODUCTIVITY AND SOCIO-ECONOMICS OF FARM-FISHERIES**
**Puste, A.M.<sup>1</sup>, Pramanik, B.R.<sup>1</sup>, Roy, A.<sup>1</sup>, Jana, K.<sup>1</sup> & Das, D.K.<sup>2</sup>**
<sup>1</sup> Department of Agronomy, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya (Agricultural University), Mohanpur-741 252, Nadia, West Bengal, India. E-mail: [ampuste\\_bckv@yahoo.co.in](mailto:ampuste_bckv@yahoo.co.in);

<sup>2</sup> Department of Agricultural Chemistry & Soil Science, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya (Agricultural University), Mohanpur-741 252, Nadia, West Bengal, Indi. E-mail: [dkdas1231@rediffmail.com](mailto:dkdas1231@rediffmail.com)

Inland wetlands are important elements of main river system and their tributaries particularly in the north-eastern part of the Indian sub-continent. These are immensely valuable, for fish and aquatic diversity, and as sources, sinks and transformers of chemical, biological and genetic material. As such they sustain economic stability to millions of people in the regions. Prolong sedimentation due to upstream damming for hydropower in most of the main river systems has resulted in the formation of numerous islands, resulting in the raising of the river bed, and lowering the capacity to store runoff water during peak rainy months. This increased the frequency of flooding and the formation of swamps in adjacent areas. The swamps have taken areas out of normal cultivation and caused losses of fish diversity. Studies on the dynamics and fish populations of the Ganges and three of its tributaries (Ajoy, Mayurakshi and Damodar) reveal that the physico-chemical properties of embanked soils as well as water quality influenced the habitats, migratory habits, stocks of the fish, which reflected the productivity as well as socio-economic viability of fish-farmers, who are inextricably linked to the system. It may be concluded that it is imperative to improve this vast wetland ecosystem by mechanical means to ensure the sustainability of the fishery and the economic stability of rural people.

**THE REVIEW OF THE RESTORATION OF MIGRATING FISH RESOURCES OF THE REPUBLIC OF LITHUANIA AND MEANS FOR THEIR IMPLEMENTATION**
**Ratkus, G.V.**

Lithuanian State Pisciculture and Fisheries Research Centre, Konstitucijos pr. 23, LT-08105 Lithuania. E-mail: [gediminasr@zuvivausa.lt](mailto:gediminasr@zuvivausa.lt)

The following migrating fish species live and reproduce in the inland waters of the Republic of Lithuania: lamprey (*Lampetra fluviatilis* (L.)), shad (*Alosa fallax* (Lacepede)), salmon (*Salmo salar* L.), sea-trout (*Salmo trutta trutta* L.), whitefish (*Coregonus lavaretus* L.), smelt (*Osmerus eperlanus* (L.)), vimba (*Vimba vimba* (L.)) and eel (*Anguilla anguilla* (L.)). Lamprey, shad and salmon are listed in the Red Book of Lithuania, and sea-trout, whitefish and vimba are protected fish in Lithuanian waters. Their resources are not great. In Lithuanian river communities, lamprey occupies 0.06 percent, salmon – 0.01 percent, sea-trout – 0.64 percent and eel – 0.27 percent of the total biomass.

The resources of migrating fish have declined in consequence of the negative anthropogenic and biologic activity. The rapid and intensive exercise of river and stream outflow adjustment work – straightening of stream watercourse, building weirs, developing agriculture production – in the second part of the twentieth century, migration routes to the spawning grounds situated in the upper reaches were prevented for migrating fish, which led to impairment of biologic development conditions. The decrease in intensity of beaver hunts in the last decade

of the twentieth century has led to the start of rapid growth of beaver weirs in rivers and streams, which also disturbed fish migration.

Having noticed the evident decline in fish resources, greater focus was laid on their restoration. After the Second World War, new pisciculture companies engaged in the restoration of fish resources were started to be established in the territory of the Republic of Lithuania. Between 1995 and 2005, 652 000 sea-trout of various age and 560 000 young salmon and smolt were taken from the pisciculture enterprises and bred in inland water bodies.

In order to ensure favourable conditions for the restoration and development of migrating fish, proper laws regulating the protection of fish resources against the negative anthropogenic and biologic impact should have been framed. In 1998, the Programme of restoration and protection of salmon resources in Lithuanian waters was passed. In 2003, the Programme of restoration of sea-trout resources was approved; requirements for environmental protection in the migration routes of the protected fish species were settled. The length of fish migration routes is 4 443.6 km, encompassing 147 rivers. Construction mounting works of 29 fish passes in the present weirs are to be exercised in these routes; beaver weirs are to be eliminated in the river and stream watercourses; the remains of the former weirs are to be destroyed. Since the beginning of 2003, three fish passes have been built, and one is still under construction. Currently 17 fish passes have been built and have been functioning in the territory of the Republic of Lithuania. Twenty-five more fish passes are to be built; the tentative price of construction works is approximately 5 million LTL or 1.5 million Euros. The technical working projects have been prepared for seven fish passes.

One of the obstacles for fish migration is beaver weirs. According to calculations made by scientists, about 300 beaver weirs exist in Lithuania. In 2005, having received the approbations and permission for the destruction of beaver weirs from the institutions involved, 37 beaver weirs have been removed. They are going to be further destroyed.

In 2004, the prohibition to build weirs in the river Nemunas and other valuable rivers from the point of view of ecology and culture – their list was approved the same year, comprising 169 rivers with a total length of 4 725 km – was set by the law.

The monitoring is being performed to assess the efficiency of the restoration of fish resources.