





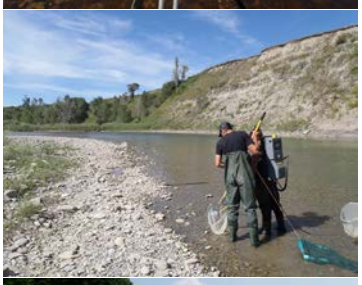


NSERC HYDRONET 4TH ANNUAL SYMPOSIUM

April 29th to May 2nd 2014
in partnership with BC Hydro and Ecofish Research Ltd.

BC Hydro, 6911 Southpoint Drive
Centre and Southpoint rooms (Auditorium Main Floor)
Burnaby, B.C., V3N 4X8

Acknowledgments

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Participating Organizations

BC Hydro
BC Ministry of Environment
BC Ministry of Forests, Lands & Natural Resource Operations
Canadian Wildlife Federation
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Ecofish Research Ltd.
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Université de Montréal
University of Alberta
University of British Columbia
University of Guelph
University of New Brunswick
University of Saskatchewan
University of Waterloo
WWF Canada

Agenda

Tuesday, April 29th 2014

09:00 *Introduction and welcome.* **D. Boisclair**, Université de Montréal

09:10 *Welcome address.* BC Hydro

09:30 *Response of resident trout to water diversion at run-of-river projects: preliminary results using standardized methods for long-term monitoring*. **A. Harwood**, Fisheries Scientist and Project Manager, Ecofish Research Ltd.; Adjunct Professor, University of Saskatchewan

09:50 *Mactaquac Aquatic Ecosystem Study: Environmental science in support of the Mactaquac Dam renewal project.* **A. Curry**, Science Director, Canadian Rivers Institute, University of New Brunswick

10:30 BREAK

11:00 *Recreational fish conservation under the new Fisheries Act: Key Components and Science Needs from an NGO Perspective.* **D. Browne**, Director of Conservation, Canadian Wildlife Federation

11:40 *Instream flow predictions from frequency vs. bioenergetic-based habitat suitability curves.* **J. Rosenfeld**, H. Beecher, R. Ptolemy, BC Ministry of Environment

12:00 LUNCH

13:00 *Tools to detect significant patterns of effects across multiple dammed systems or over very long river expanses: some findings from the HydroNet 2010-15 network data sets.* **M. Lapointe**, Theme Leader, McGill University

13:20 *Using regional flow regime classes to identify flow anomalies in a set of Canadian rivers regulated by dams.* **F. McLaughlin**, M. Lapointe, McGill University; G. Bourque, D. Boisclair, Université de Montréal

13:40 *Effects of hydrologic alteration on fish community structure in regulated temperate rivers.* **C.J. Macnaughton**, F. McLaughlin, G. Bourque, D. Boisclair, Université de Montréal, M. Lapointe, McGill University

14:00 *Riverscape: Development of a remote sensing method for describing fish wetted habitat, river structure and habitat sensitivity at various scales.* **F. Hugue**, M. Lapointe, McGill University; B. Eaton, University of British Columbia

14:20 *Remote sensing of channel reach morphology and hydraulic fish habitat using unmanned aerial vehicles.* **A. Tamminga**, B. Eaton, University of British Columbia; M. Lapointe, McGill University

14:40 BREAK

15:20 *Flow characteristics of pool-weir fishways with natural rock construction*. **C. Kupferschmidt**, M-È Jean, A.B. Baki, D. Z. Zhu, University of Alberta (presented by D. Zhu)

15:40 *Hydraulics of rock-ramp type fishways and their fish habitat suitability*. **A.B. Baki**, D.Z. Zhu, N. Rajaratnam, University of Alberta

16:00 *Behaviour and swimming dynamics of migrating fish during fishway passage*. **A.T. Silva**, C. Hatry, J.D. Thiem, J.W. Dawson, S.J. Cooke, Carleton University, D.Z. Zhu, University of Alberta

16:20 *Balancing species conservation and small hydropower development in British Columbia.* **W.J. Palen**, V.D. Popescu, E. Dubman, R. Munshaw, Simon Fraser University

16:40 *An independent review of potential run-of-river hydroelectric project impacts on salmonids in British Columbia.* **B.M. Connors**, D.R. Marmorek, E. Olson, A.W. Hall, P. de la Cueva Bueno, K. Bryan, E. Parkinson, D. Abraham, C. Alexander, C. Murray, L. Grieg, G. Farrell, ESSA Technologies Ltd.; A. Bensen, Simon Fraser University; C. Perrin, Limnotek Research and Development Ltd.; R. Smith, Water Smith Research

18:00 COCKTAILS SPONSORED BY ECOFISH RESEARCH LTD. (at Hilton Vancouver Metrotown – Crystal Ballroom 1, 6083 McKay Avenue, Burnaby – Metrotown station)

Wednesday, April 30th 2014

09:00 *Utilizing computational fluid dynamics to assess the hydraulic impacts of operations on resident fish at Mica Dam*. **M. Langford**, D.Z. Zhu, University of Alberta; E. Martins, Carleton University (presented by D. Zhu)

09:20 *Behavioural attributes of entrainment risk for adult bull trout in Kinbasket Reservoir, BC.* **E.G. Martins**, L.F.G. Gutowsky, S.J. Cooke, Carleton University, P.M. Harrison, M. Power, University of Waterloo, J.E. Mills Flemming, I.D. Jonsen, Dalhousie University, D.Z. Zhu, University of Alberta, A. Leake, BC Hydro, D.A. Patterson, Fisheries and Oceans Canada

09:40 *Personality-dependent spatial ecology of burbot, Lota lota in a large hydropower reservoir in British Columbia, Canada*. **P.M. Harrison**, M. Power, University of Waterloo, L.F.G. Gutowsky, E.G. Martins, S.J. Cooke, Carleton University, A. Leake, BC Hydro, D.A. Patterson, Fisheries and Oceans Canada

10:00 BREAK

10:40 *Comparing sampling methods to estimate production metrics of littoral zone fish based on habitat variables of a Manitoba reservoir*. **N.A. Satre**, G. Bourque, P. Legendre, D. Boisclair, Université de Montréal

11:00 *The impact of low flow on riverine food webs in south-central Newfoundland.* **J.M. Brush**, M. Power, University of Waterloo, K.D. Clarke, C. Pennell, Fisheries and Oceans Canada, J. Marty, Genivar Inc.

11:20 *Stable isotope ecology of whitefish (Coregonus lavaretus) and vendace (Coregonus albula) in a regulated subarctic watercourse.* **B. Kelly**, M. Power, University of Waterloo, P.-A. Amundsen, University of Tromsø

11:40 *Spatial and temporal variation in fish condition and energy stores during flooding in the Saskatchewan River.* **D. Janz**, T. Jardine, H. Baulch, L. Weber, K. Steeves, University of Saskatchewan, D. Keeping, M. Bast, R. West, Saskatchewan Power Corporation

12:00 LUNCH

13:00 *Winter condition of Atlantic salmon parr and pre-smolts experiencing hydropeaking flow regimes*. **S. Vue**, R.A. Cunjak, University of New Brunswick, K. Clarke, Fisheries and Oceans Canada

13:20 *How do hypolimnion-release reservoirs affect fish growth?* **A.R. Hards**, R.A. Cunjak, University of New Brunswick

13:40 *The impact of dams on the winter thermal regime of streams.* **A. Maheu**, A. St-Hilaire, Institut national de la recherche scientifique, D. Caissie, Fisheries and Oceans Canada

14:00 *Empowering approaches to fish habitat modelling: new perspectives for the assessment of environmental changes.* **G. Guénard**, G. Lanthier, S. Harvey-Lavoie, C.J. MacNaughton, C. Senay, D. Boisclair, Université de Montréal

14:20 *Progress towards developing a framework and tools for the sustainable development of hydropower and healthy ecosystems.* **I.J. Dolinsek**, D. Boisclair, Université de Montréal

14:40 *The effect of flow on northern pike behaviour in a river subjected to hydropeaking and a natural river*. **S. Harvey-Lavoie**, D. Boisclair, Université de Montréal, S. Cooke, Carleton University

15:00 BREAK

15:40 *The research platform of HydroNet (2015-2020).* **D. Boisclair**, Université de Montréal

16:20 Discussion

Thursday, May 1st 2014

MONITORING TO INFORM DECISION-MAKING: THEORY AND REALITY
A SPECIAL SESSION DEDICATED TO PAUL HIGGINS

08:00 *Welcome, introductions, house-keeping.* **Graham Long**, CompassRM

08:10 *Monitoring to inform decision-making - a reminder of the theory.* **Basil Stumborg**, BC Hydro

08:30 *Reality 1: Water Use Planning Consultative Committees Expectations.* **Alf Leake**, BC Hydro

08:50 *Reality 2: Water License Requirements Realities.* **Todd Hatfield**, Ecofish Research Ltd.

09:10 *Reality 3: Active Adaptive Management in Hydro Operations - Perspective 1.* **Josh Korman**, Ecometric Research

09:30 *Reality 4: Active Adaptive Management in Hydro Operations - Perspective 2.* **David Marmorek**, ESSA Technologies Ltd.

09:50 *Reality 5: Monitoring for new projects.* **Brent Mossop**, Site C

10:10 BREAK

10:30 *Facilitated discussion.* CompassRM and others
- *What is experience telling us?*
- *What should we be more realistic about?*
- *What should we be more ambitious about?*
- *What key messages should we take home from this session?*

11:50 *Wrap-up and close.* **Graham Long**, CompassRM

13:00 JOINT RESEARCH MANAGEMENT COMMITTEE & BOARD OF DIRECTORS MEETING (EDME CONFERENCE ROOM 1)

SCIENTIFIC ADVISORY COMMITTEE MEETING (EDME CONFERENCE ROOM 3)

Friday, May 2nd 2014

WORKSHOP: *SCIENTIFIC COMMUNICATION - FROM JARGON TO TRANSPARENCY*

09:00 *Welcome and introductions*, **Michael Forrest**, Communications Officer, NSERC HydroNet, Université de Montréal

09:10 *Avoid the "eat-your-peas" approach for communicating science to the thinking public.* **Peter Calamai**, freelance science writer, editor and communications consultant

10:00 Discussion

10:15 BREAK

10:30 *Using 200 words to best advantage – press releases and talking to the media.* **Peter Calamai** and **David Pearson**, Science Communication, Laurentian University

11:00 *Know your audience*: *how people learn, mental models and misperceptions; Features and benefits communication.* **Chantal Barriault**, Science Communication, Laurentian University

12:00 Discussion

12:15 LUNCH

13:00 *Why should you care about public engagement? Ethical issues around the why and the how. Deliberative democracy as an example of bidirectional engagement.* **Holly Longstaff,** Associate Director, Office of Research Ethics, Simon Fraser University, partner Engage Associates, Vancouver

13:25 Discussion

14:00 *High quality presentations and powerful slide design.* **Chantal Barriault**
Planning the communication of HydroNet benefits to policy-makers and decision-makers. **David Pearson**

15:00 MEETING ADJOURNED

Conference Abstracts

Response of resident trout to water diversion at run-of-river projects: Preliminary results using standardized methods for long-term monitoring

**A. Harwood, S. Faulkner, T. Hatfield, and A. Lewis, Ecofish Research Ltd, Courtenay, BC (aharwood@ecofishresearch.com)*

A surge in new hydropower development in British Columbia in the 2000s, coupled with an absence of clear guidance on scientific requirements for long-term monitoring, led BC and Canadian government agencies to develop monitoring protocols for these projects. The protocols require a minimum of two years of pre-project (baseline) data and five years of post-project (operational) data. The recommended experimental design was based on a target power of 0.8 to detect a 50% decline in target fish species abundance or biomass. Here we present preliminary results of fish community monitoring after four years of operation for a group of six run-of-river projects operated by Innergex Renewable Energy. The experimental design for fish community monitoring at these facilities used a BACI design, with sampling conducted in the project diversion reaches (n=5 per stream) and control sites (n=5 per stream). The primary sampling method was closed-site electrofishing. Data on water flow, temperature, chemistry, habitat and geomorphology, were also collected, along with invertebrate abundance. After four years of operational monitoring, increases in Rainbow Trout, Cutthroat Trout and Bull Trout total density were observed in the diversion reaches (+17% to +189%), relative to control and baseline conditions. Biomass density increased in five streams (+33% to +197%) and decreased in one stream (-22%). Most of these differences are not statistically significant on a single stream basis. An additional year of data collection will improve power and understanding of responses by resident trout populations. Integrated analysis of physical and biological metrics will facilitate understanding of causal mechanisms.

Mactaquac Aquatic Ecosystem Study: Environmental science in support of the Mactaquac Dam renewal project

**R. Allen Curry, T. Linnansaari, W. Monk, G. Yamazaki, A. Bielecki2, G. Porter2. Canadian Rivers Institute, University of New Brunswick, Fredericton, NB; 2NB Power Corporation, Fredericton, NB (racurry@unb.ca)*

The Canadian Rivers Institute is working with NB Power to provide the aquatic science in support of an upcoming decision to rebuild or remove, and the resultant environmental impact assessment (EIA) for the Mactaquac Dam which is coming to the end of its service life. The integrated river and reservoir science is the beginning of the long-term (15-20 years) Mactaquac Aquatic Ecosystem Study (MAES) designed as a whole-river ecosystem study and manipulation (to remove or rebuild the dam). MAES is an assessment of the structure and function of a large river ecosystem and the predictive

analyses of the proposed manipulations, i.e., what are the environmental challenges and opportunities for either replacing or removing the dam. The research establishes baseline environmental conditions, appropriate metrics for biomonitoring, and predicts the water, sediment, thermal regimes, and future habitats for a dam removal scenario. In the dam rebuilding scenario, the research examines the consequences for species at risk and fish passage, and models future management options for environmental flows. The premature ageing of the MD and the pressing consideration of future options for the dam and the river's ecosystem goods and services is a precedent setting case for Canada. The MAES will create a template of approaches and methods for informed decision making and management for future hydropower projects and the science of river restoration. It will set new standards for EIAs in Canada. A comprehensive study and planned manipulation of an ecosystem of this scale is one of the largest freshwater studies and experiments attempted worldwide.

Instream flow predictions from frequency vs. bioenergetic-based habitat suitability curves

**Jordan Rosenfeld, Hal Beecher, Ron Ptolemy, B.C. Ministry of Environment, 2204 Main Mall, Vancouver, BC Canada V6T 1Z4 (jordan.rosenfeld@gov.bc.ca)*

Predictions of optimal flows using PHABSIM are extremely sensitive to the shape of velocity and depth habitat suitability curves (HSCs). HSCs therefore need to accurately reflect the fitness (or population level) consequences of habitat use for model predictions to be meaningful. Frequency-based habitat suitability curves use the observed frequency of use of different velocity and depth micro-habitats to infer habitat quality for the target species; however, HSCs may be misleading for territorial taxa if competition by dominant fish displaces subordinates into poor quality (e.g. low-velocity) habitat at high densities. HSCs based on density-independent growth rate potential estimated with bioenergetic models offer an alternative to frequency-based HSCs. We compared known smolt production to instream flow predictions generated using frequency vs. bioenergetic-based HSCs for juvenile coho to evaluate the potential for bias in estimation of optimal juvenile rearing flows. Frequency-based HSCs overestimated habitat quality at low velocities and greatly underestimated the consequences of summer low-flow for smolt production relative to the bioenergetic-based HSCs. Results demonstrate the potential for serious underestimation of optimal flows using frequency-based HSCs, and support the additional use of generic bioenergetic HSCs for more robust flow assessments, particularly for juveniles of pool-rearing salmonids that display strong territoriality.

Using regional flow regime classes to identify flow anomalies in a set of Canadian rivers regulated by dams

**Fraser McLaughlin and Michel Lapointe, McGill University, Department of Geography (fraser.mclaughlin@mail.mcgill.ca)*

It is well established that a river's natural flow regime is a key determinant of ecological integrity and that dam regulated-flow releases can in some cases be detrimental to biotic communities and even affect river ecosystem structure (e.g. Poff and Zimmerman, 2010). Regional flow classes, groups of rivers that share similar natural flow regimes (called 'river types' by Poff and Zimmerman (2010)) and to which regional fish communities are 'adapted', have been proposed as units of analysis to identify significant damming related flow alteration (e.g. Poff, 1996; Poff and Zimmerman, 2010; McManamay et al., 2012a). Specifically, the natural range of flow behaviour within regional classes can be used to identify clearly anomalous flow features in rivers regulated by dams. Through ordination analysis on 70 ecologically important flow indices, we isolated five distinctive regional groupings of natural flow regimes among 96 unregulated rivers in South-Eastern and South-Western Canada that were selected as possible references for the regulated NSERC-HydroNet study rivers. These 16 regulated rivers were then assigned to one of the five flow classes through discriminant function analysis based on shared geographic location and watershed characteristics. Anomalous flow features in the regulated rivers were then characterized by type and strength, based on identification of flow indices that are significantly different from observed natural variability in the relevant regional class. We also discuss the potential biological implications of the dominant flow anomalies in this set of rivers regulated by hydro dams.

Sources:

McManamay, R. A., Orth, D. J., & Dolloff, C. A. (2012a). Revisiting the Homogenization of Dammed Rivers in the Southeastern US. *Journal of Hydrology*, *424-425*, 217-237.

Poff, N. L. (1996). A Hydrogeography of Unregulated Streams in the United States and an Examination of Scale-Dependence in some Hydrological Descriptors. *Freshwater Biology*, *36*, 71-79.

Poff, N. L., & Zimmerman, J. K. H. (2010). Ecological Responses to Altered Flow Regimes: A Literature Review to Inform the Science and Management of Environmental Flows. *Freshwater Biology*, *55*(1), 194-205.

Effects of hydrologic alteration on fish community structure in regulated temperate rivers

Camille Macnaughton[*1], *Fraser Mclaughlin*[2], *Guillaume Bourque*[1], *Caroline Senay*[1], *Gabriel Lanthier*[1], *Simonne Harvey-Lavoie*[1], *Michel Lapointe*[2], *Pierre Legendre*[1] *and Daniel Boisclair*[1] *(camille.macnaughton@umontreal.ca)*

[1]*Département de Sciences Biologiques, Université de Montréal, Pavillon Marie-Victorin, 90 ave Vincent-d'Indy, Montréal, QC H2V 2S9, Canada*

[2] *Geography Department, McGill University, Burnside Hall Building, 805 Sherbrooke St. West, Montréal, QC H3A 0B9, Canada*

Alterations to the seasonal patterns, temporal variability and magnitudes of discharge in rivers caused by dams can have a variety of severe ecological consequences for freshwater systems. However, little has been done to develop a holistic approach to assessing the effects of hydrological alterations on fish communities (i.e., abundance, diversity indices and guild variables) across different geographic scales and between different types of regulation strategies. To address this, we used daily and hourly hydrologic data from streamflow gauges in 24 rivers, comprising 10 regulated and 14 unregulated systems, from 1997 to 2009. While some regulated rivers did not appear to exhibit flow characteristics differing from regional unregulated reference systems, others demonstrated significantly greater attenuation of high flows as well as increased periods of low flows or low flashiness. Extensive community surveys to estimate fish abundance, biomass, diversity indices and habitat guild representation were conducted on these same rivers. In regulated systems, deviations from mean fish community measures relative to unregulated rivers were regressed against tabulated alterations from streamflow norms. Our results demonstrate that biological impairment consisting of significant alterations to fish community indices from the unregulated means is directly proportional to the degree of flow alteration, with run-of-river systems experiencing the fewest changes and large storage capacity or hydro-peaking type schemes experiencing the greatest alterations. The findings of this novel approach emphasize the potential range of ecological consequences of anthropogenic alterations to natural flow regimes on freshwater fish communities.

Riverscape: Development of a remote sensing method for describing fish wetted habitat, river structure and habitat sensitivity at various scales

[1]*F. Hugue, [1]M. Lapointe, [2]B. Eaton

[1]McGill University, Department of Geography, [2]UBC, Department of Geography (fabien.hugue@mail.mcgill.ca)

Given the growing awareness of extensive riverscapes as units of ecosystem management, exploiting the power of aerial or satellite imagery is becoming essential in multi-river studies. Furthermore, the use of such imagery allows getting around the issues related to poor accessibility of remote sites and thus helps balancing with few field data collection. This study presents a satellite remote sensing method, developed for the NSERC HydroNet network, that helps describe fish wetted habitat structure and

reach scale heterogeneity at a finer scale and with less subjectivity than classical meso-habitat classifications. Fish habitat metrics are extracted from the combination of computed depth-velocity maps over 10 - 20 km reaches. We assess the capability of the method to characterize river structure within a geographic context by performing a multi-river analysis. Results from this study yield a reasonably accurate characterization of hydraulic habitat over large extents, without the need of intensive field surveys. Complementary to our scientific interpretation, this method allows the detection of alluvial reaches and thus helps locating areas where habitats are more sensitive to alteration due to upstream damming. Applications include 1) understanding how river habitat heterogeneity affects fish distribution; 2) describing fish wetted habitat variability across Canadian rivers; 3) identifying any systematic variations in habitat structure between the regulated sites and the natural rivers; 4) assessing the habitat alteration due to dams in sensitive reaches and 5) understanding the importance of scaling when working with riverscape questions.

Remote sensing of channel reach morphology and hydraulic fish habitat using unmanned aerial vehicles

A.D. Tamminga[1]*, C.H. Hugenholtz[2], B.C. Eaton[1] & M.F. Lapointe[3]
[1]Dept. of Geography, University of British Columbia, Vancouver, British Columbia, V6T 1Z2 (tamminga@geog.ubc.ca)
[2]Dept. of Geography, University of Calgary, Calgary, Alberta, T2N 1N4
[3]Dept. of Geography, University of McGill, Montreal, Quebec, H3A 2K6

In this study we assess the capabilities of an unmanned/uninhabited aerial vehicle (UAV) to characterize the channel morphology and hydraulic habitat of a 1 km reach of the Elbow River, Alberta, Canada, with the goal of identifying the advantages and challenges of this technology for river research and management. Using a small quadcopter UAV to acquire overlapping images and softcopy photogrammetry, we constructed a 5 cm resolution orthomosaic image and digital elevation model (DEM). The orthomosaic was used to map the distribution of geomorphic and aquatic habitat features, including: bathymetry, grain sizes, undercut banks, forested channel margins, and large wood. The DEM was used to initialize and run River2D, a two-dimensional hydrodynamic model, and resulting depth and velocity distributions were combined with the mapped physical habitat features to produce refined estimates of available habitat in terms of weighted usable area. Based on 297 check points, the vertical root mean squared error of the DEM was 8.8 cm in exposed areas and 11.9 cm in submerged areas following correction of the DEM for overprediction of elevations due to the refractive effects of water. Overall, we find several advantages of UAV-based imagery including low cost, high efficiency, operational flexibility, high vertical accuracy, and centimeter-scale resolution. We also identify some challenges, including vegetation obstructions of the ground surface, turbidity which can limit bathymetry extraction, and an immature regulatory landscape which may slow adoption of this technology for operational measurements. However, by enabling dynamic linkages between geomorphic processes such as large

floods and aquatic habitat changes to be established, we believe the advantages of UAVs make them ideally suited to river research and management.

Flow characteristics of pool-weir fishways with natural rock construction

*Cody Kupferschmidt, Marie-Ève Jean, Abul Basar Baki, David Z. Zhu (ckupfers@ualberta.ca)
Civil and Environmental Engineering, University of Alberta, 9105 116th Street, Edmonton, Alberta, T6G 2W2

The flow characteristics of a pool-weir fishway were evaluated using the water surface profile and an acoustic doppler velocimeter (ADV). A fishway was constructed in a 0.92 m wide flume on a 3% bed slope and eight weirs with a v-shape facing in the downstream direction were constructed using 14 cm diameter natural rocks. The fishway was evaluated for flows ranging from 30 L/s to 150 L/s and was found to be operating in the plunging flow regime for all flowrates evaluated. The head over the weir was less than predicted for equivalent flows in tradition pool-weir fishways. Velocity and turbulence field plots were created based on ADV data.

Hydraulics of rock-ramp type fishways and their fish habitat suitability

*Abul Basar Baki, David Z. Zhu, Nallamuthu Rajaratnam
University of Alberta, Department of Civil and Environmental Engineering (baki@ualberta.ca)

Nature-like fishways are designed to re-connect river corridors or to re-establish stream continuity and provide suitable aquatic habitat for all organisms and biota living in a waterbody. Recently, the performance evaluations of this fishways have yielded promising results. This study experimentally investigated the detailed mean and turbulence flow characteristics generated by a staggered arrangement of boulders in a rock-ramp type nature-like fishways at different discharges. Next, a three-dimensional Computational Fluid Dynamics (CFD) solver was used to investigate the flow characteristics in a rock-ramp fishways under different flow conditions and geometric variables to optimize the design. The experimental and numerical results showed that this type of fishpass can produce adequate water depth and favourable flow velocity and turbulence suitable for fish passage. Some general correlations were developed for predicting the flow depth, velocity, turbulent intensity, and turbulent kinetic energy as a function of normalized discharge and streamwise distance in a rock-ramp fishpass. Finally, this study evaluated the physical fish habitat suitability in a rock-ramp fishway using a River2D hydrodynamics model for the small and large young-of-the-year Artic grayling. Results from this study will increase our ability to predict and understand the possible effects of flow structure on fish passage and would be useful to both fishpass designers and fish biologists.

Behaviour and swimming dynamics of migrating fish during fishway passage

*A.T. Silva, C. Hatry, J.D. Thiem, D.Z. Zhu, J.W. Dawson, S.J. Cooke
Fish Ecology and Conservation Physiology Laboratory, Department of Biology, Carleton University, Ottawa,Canada (anamftsilva@gmail.com)

For the last decades freshwater fish populations have been compromised by river fragmentation as result of the burgeoning development of anthropogenic barriers. Fishways have become one of the most common tools for the restoration of connectivity in rivers. Nevertheless, despite their potential for aiding fish passage, using the fish passage may be associated with significant energetic costs. The understanding of biological criteria to inform fish passage design is still limited, partially due to the lack of understanding of biological motivators and constraints, as well as a lack of biological performance evaluations based on the physiological capacity and relative swimming ability of fish. In this study we examined swimming activity and behaviour of the migrating silver redhorse (*moxostoma anisurum*), during their upriver spawning migration in a vertical slot fishway at the Richelieu River, Quebec. Twelve redhorse were tagged with pit tags and monitored by an extensive pit antenna array to determine location within the fishway. Individuals were also fitted with data logging accelerometer tags to determine location-specific activity and behaviour. Our study is one of the first applying accelerometer methods to characterize swimming behavior within a fishway. The results of this study are expected to contribute to the knowledge and understanding of the behaviour and physiological effort during transposition of fishways by this species and, hence, optimize access to habitat upstream from dams, weirs and other man-made obstructions.

Balancing species conservation and small hydropower development in British Columbia

Wendy J. Palen, Viorel D. Popescu, Evgenia Dubman, Robin Munshaw; Earth2Ocean Research Group, Simon Fraser University, 8888 University Drive, Burnaby BC V5A 4G (wpalen@sfu.ca)

Small, distributed sources of renewable energy are increasingly used to meet future energy demand, and are viewed as minimum-impact alternatives to traditional technologies. BC's progressive carbon-neutral mandate provided the impetus for rapid development of small hydropower facilities, which lacks strategic level oversight. British Columbia has a rich small hydropower potential, with >7000 technologically feasible development sites identified throughout the province. Using potential development locations, we examined the trade-offs between the economics of renewable energy development (unit energy cost, annual energy) and species distributions using the systematic conservation planning framework Zonation. We focused on 34 fish species (including anadromous salmonids) and 40 riparian vertebrate species, and identified economically feasible small hydropower development sites that minimize overlap with our focal species. We present a range of alternative scenarios that attempt to balance

energy gains and species conservation, and conclude that energy / biodiversity conflicts could be partially mitigated by strategic spatial planning.

An independent review of potential run-of-river hydroelectric project impacts on salmonids in British Columbia

*Connors, B.M., D.R. Marmorek, E. Olson, A.W. Hall, P. de la Cueva Bueno, A. Bensen, K. Bryan, C. Perrin, E. Parkinson, D. Abraham, C. Alexander, C. Murray, R. Smith, L. Grieg, and G. Farrell
*ESSA Technologies Ltd, Vancouver, British Columbia, V6H 3H4 (bconnors@essa.com)

Concerns about the potential for run-of-river hydroelectric projects to adversely affect resident and anadromous salmonids in BC led industry, government and an NGO to commission an independent review of run-of-river hydroelectric projects. To carry out the review we developed and applied a weight of evidence approach to available information to determine the relative likelihood of hypothesized impact pathways describing ways in which run-of-river hydroelectric projects may affect salmonids. These pathways included barriers to migration, mortality due to entrainment in the penstock, changes in habitat, alteration of the natural hydrograph, movement of sediment and organic material, changes in food production, stranding due to fluctuation in the wetted width of stream channels, and loss of habitat connectivity. We found that mortality to individual fish (due to entrainment or stranding downstream of a facility) and changes to salmonid habitat (due to changes in flow or movement of sediment and organic matter) were likely or very likely at a number of facilities. However, at the population level, we found evidence of changes in salmonid abundance or composition attributable to facility operations in only a few instances. For most of the impact pathways we considered, data limitations or currently inconclusive monitoring studies preventing us from concluding these overall pathways were either likely or unlikely. However, some of the facilities evaluated are part of the way through monitoring programs that should enable subsequent evaluations of ongoing monitoring efforts, coupled with targeted research, to help deliver more definitive conclusions regarding impacts on salmonids in the near future.

Utilizing computational fluid dynamics to assess the hydraulic impacts of operations on resident fish at Mica Dam

M. Langford[1], *D. Zhu[1], E. Martins[2]
[1]University of Alberta, Department of Civil and Environmental Engineering
[2]Carleton University, Department of Fish Ecology and Conservation Physiology
mathew.langford@ualberta.ca
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Seasonal variation in the forebay flow field and thermal structure generated by hydropower facilities has been identified as one of the key factors in fish entrainment. Kinbasket Reservoir, located on the Columbia River in BC, has an annual reservoir surface elevation fluctuation of approximately 30m. This annual fluctuation, coupled

with seasonal variation in thermal stratification and hydropower demands creates a hydrodynamically complex and dynamic system. As increased entrainment is generally seen during the winter months (October-March), as the reservoir is draining, a computational fluid dynamic (CFD) solver has been used to resolve the forebay flow field under multiple scenarios during this timeframe. The physical conditions experienced by 97 fish in the vicinity of Mica Dam have been numerically simulated in this study to assist in identifying the key hydraulics parameters (i.e. velocity, spatial velocity gradient, turbulence kinetic energy, vorticity, shear strain rate) affecting fish behaviour proximal to hydropower facilities. The physical location, and thus response of fish to these physical parameters has been tracked via fine scale telemetry by our collaborators.

Behavioural attributes of entrainment risk for adult bull trout in Kinbasket Reservoir, BC

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Fish entrainment through turbine intakes is one of the major issues for operators of hydropower facilities because it causes injury and/or mortality and adversely affects population abundance. Here we used fine-scale acoustic biotelemetry and state-space modeling to investigate behavioural attributes associated with entrainment risk for adult bull trout (Salvelinus confluentus) in Kinbasket Reservoir, British Columbia, Canada. We found that adult bull trout resided longer in the vicinity of the powerhouse and moved closer to the turbine intakes in the fall and particularly in the winter. Bull trout were more likely to engage in exploratory behavior (characteristic of foraging or reduced activity) during periods when their body temperature was < 2 °C. We also detected diel changes in behavioural attributes, with bull trout distance to intakes and probability of exploratory behaviour increasing slightly at night. We hypothesize that these behaviours are associated with foraging for kokanee (non-anadromous form of Oncorhynchus nerka), which have been shown to congregate near the dam of hydropower reservoirs in the winter. Study findings should be applicable to bull trout populations residing in other reservoirs and indicate that entrainment mitigation (e.g., use of deterrent devices) should be focused on the fall and winter.

Personality-dependent spatial ecology of burbot, Lota lota in a large hydropower reservoir in British Columbia, Canada

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Heterogeneity in spatial ecology is often observed within fish populations, yet few researchers have investigated whether these between-individual differences are temporally consistent and thus represent personality-dependent behaviour. Furthermore, the relationships between dispersal and site fidelity, home range, activity,

and movement have rarely been tested. In this study, we explore between-individual differences in home-range, vertical activity, movement, dispersal, and site fidelity of burbot Lota lota in Kinbasket Reservoir, BC, Canada, over 2 years, using acoustic telemetry. We test whether burbot spatial behaviours meet personality-dependent criteria of repeatability, cross contextual consistency, and test for correlations between traits indicative of a behavioural syndrome. Our results demonstrate repeatable, cross-contextually consistent, personality-dependent, home range, movement, dispersal, and site fidelity. Our results suggest a spatial behavioural syndrome occurs independently from dispersal, with behavioural types ranging from 'resident' individuals with small home-ranges, high site fidelity and minimal movement, to 'mobile' individuals with large home ranges and little site fidelity. Our results indicate that the mean measures of space use often used in conservation policy, may not adequately capture the diversity of space use requirements of fish populations with similar behavioural diversity. Indeed, the behavioural diversity we observed may be; important for habitat carrying-capacity, result in differing vulnerabilities to anthropogenic disturbance, and contribute resilience to environmental change. Accordingly, identification and conservation of this spatial behavioural diversity should be an important consideration in the sustainable management of existing and future hydropower operations and developments.

Comparing sampling methods to estimate production metrics of littoral zone fish based on habitat variables of a Manitoba reservoir

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In recent years, government and industry have sought clear definitions and effective means in which to estimate and predict metrics of fisheries productivity. This study seeks to address this question in part by comparing gillnet, seine and electrofishing methods to determine which method (or combination thereof) produce models having the greatest explanatory capacity of fisheries productivity metrics based on local, lateral and contextual habitat variables. During the summer of 2012 and 2013, fish communities in 43 littoral sites were sampled from Lac du Bonnet, a reservoir in southeastern Manitoba. In addition to fish sampling, habitat assessments were made at the local (e.g. depth, substrate composition, macrophyte cover), lateral (utilization of shores) and contextual (position relative to landscape attributes such as main channel and tributaries) scale in order to characterize sampling locations, and furthermore provide a base for our models. Using a series of redundancy analysis, we seek to determine which statistical models hold the greatest explanatory power as a function of local, lateral and contextual habitat variables, an important step further enabling us to better predict metrics of fisheries productivity.

The impact of low flow on riverine food webs in south-central Newfoundland

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Low flow events can reduce food availability and decrease feeding niche of consumers within rivers. Stable carbon (δ13C) and nitrogen (δ15N) isotope and stomach content analysis was employed to evaluate resource use and resource overlap between fish species, a natural and regulated river, in normal and low flow years. There was no significant inter-annual difference in the δ13C variance for fish from the regulated river, whereas there was a significant reduction and increase, respectively, in δ13C and δ15N variation in the natural river in the low flow year. Feeding niche decreased within the natural river and resource overlap values were highest in the low flow year, when flows were similar in the regulated and unregulated river. Ellipse area decreased from spring to summer, and inter-specific resource overlap was higher in the summer than in the spring in both rivers.

Stable isotope ecology of whitefish (*Coregonus lavaretus*) and vendace (*Coregonus albula*) in a regulated subarctic watercourse

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Hydro-electric dams alter the physical features of a watercourse, causing shifts in the habitat availability of aquatic organisms. These habitat shifts have the potential to facilitate the establishment of invasive species, shifting resource allocation within the system and affecting productivity at multiple trophic levels. The Pasvik watercourse, which separates northern Norway and Russia, was invaded by vendace (Coregonus albula) in 1989. Prior to the invasion, whitefish (Coregonus lavaretus) were the dominant fish species, with up to three morphotypes occurring in lake environments. In upstream lakes, vendace have successfully taken over the pelagic zone, forcing out the predominant whitefish morphotype and causing a decrease in zooplankton abundance and size and a shift in zooplankton community composition. In downstream lakes vendace and whitefish coexist within the pelagic zone, with more moderate alterations of the zooplankton community. This study investigates the stable isotope ecology of one upstream and one downstream lake in the Pasvik system. Carbon and nitrogen stable isotopes will be used to confirm the feeding behaviour of vendace and whitefish and examine resource overlap between fish species and morphotypes. Results will contribute to our understanding of ecological interactions in regulated systems affected by an invasive species.

Spatial and temporal variation in fish condition and energy stores during flooding in the Saskatchewan River

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To investigate the timing and magnitude of the biological response to flooding, we initiated a semi-controlled study at the EB Campbell hydroelectric facility on the Saskatchewan River. We logged dissolved oxygen concentrations in the reservoir, the river below the dam, and a spillway that is periodically inundated during high flows, and examined the condition and energy stores of spottail shiner (Notropis hudsonius) and juvenile yellow perch (Perca flavescens) inhabiting these three habitats. Heavy rains in late June in the Rocky Mountain headwaters produced a massive flood pulse, leading to the highest peak daily flows since river regulation began in the 1960s. Reservoir drawdown in anticipation of this flood peak led to an anoxic event upon refilling that lasted for three days, likely due to high biological oxygen demand from decaying organic matter. Temporal variation in fish energy stores was higher than spatial variation, with hepatosomatic index and triglyceride concentrations in liver and muscle peaking during mid-summer floods, and limited differences occurring among sampling locations. However, both species had higher body condition (Fulton's K) in the reservoir compared to the river (ANCOVA, $p < 0.05$), suggesting better overall growth conditions in the former habitat, a shallow and highly productive system. Taken together, this information suggests that reservoir operation and flooding can influence the health and condition of fish through multiple mechanisms.

Winter condition of Atlantic salmon parr and pre-smolts experiencing hydropeaking flow regimes

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For many overwintering stream fishes, winter represents the period when significant energy reserves (i.e. lipids) are reduced along with lower condition. Some Atlantic salmon spend 2-3 winters in freshwater streams that experience hydropeaking flow regimes where fluctuations in flow (2-50 times) are realized on a daily basis. We investigated the effects of winter hydropeaking flows on wild Atlantic salmon parr (49 – 183 mm), by introducing daily peaking flow regime changes in large outdoor mesocosms with natural substrate and various habitats. We assessed changes in the overwintering condition of Atlantic salmon parr by evaluating changes in condition factor (K), estimated fat content (using bioelectrical impedance analysis (BIA)), and the ability of

parr to complete smoltification (Na K ATPase activity). Two experiments were conducted to test for any changes in condition by simulating hydropeaking flow regimes with higher instream velocity (2 fold and 3-4 fold increases) compared to the control. We found no significant changes in growth, condition factor or lipids between hydropeaking and control mesocosms suggesting that low-moderate increases in flow and velocity do not affect the overwintering condition of Atlantic salmon parr. We also found our hydropeaking flow regimes did not affect the ability of parr to complete smoltification.

How do hypolimnion-release reservoirs affect fish growth?

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Hypolimnetic releases from storage reservoirs can alter the natural thermal regime of rivers downstream. The degree to which water temperature is altered varies in both space and time; typically, hypolimnetic releases elevate water temperatures in the winter and lower them in the summer. Thermal regimes recover with distance downstream of dams, resulting in a gradient of thermal conditions. As poikilotherms, fish are sensitive to changes in ambient water temperature. Alterations to natural thermal regimes may therefore alter fish growth. This study compares longitudinal patterns of water temperature and fish growth between rivers downstream of a hypolimnion-release reservoir and analogous unregulated rivers. Fish growth was estimated from repeated measurements of condition. Slimy sculpin (*Cottus cognatus*) were the primary species sampled owing to their ubiquity, limited mobility, and lack of commercial fishing pressure. The study area consists of two regulated rivers, the Dee and the Serpentine, and two unregulated rivers, the Gulquac and the Wapske; each is within the Tobique River Basin, New Brunswick. The data I will present are from my 2013 field season.

The impact of dams on the winter thermal regime of streams

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River water temperature is a very important ecological variable, especially for the management of fisheries and aquatic resources. Dams can alter different aspects of the thermal regime of streams and although the winter period has important implications for the survival of fish, most impact studies have focused on the summer period. The objective of this study was to assess the degree of thermal modification of regulated rivers for two different types of dams (run-of-river and storage) in Eastern Canada. Water temperature was monitored downstream of four regulated streams (St-Jean, Etchemin, Fourchue, Dee) as well as four reference unregulated streams from June 2012 to August 2013. Temperature duration curves and thermal indices were used to describe the thermal regime of the regulated and reference reaches. Run-of-river dams did not

have a significant impact on the thermal regime of streams in the winter and both the magnitude and timing of the winter water temperature cycle were comparable between the regulated and reference reaches. On the other hand, storage dams raised water temperatures, eliminated freezing conditions and modified diel variability during the winter period. The impact of storage dams varied throughout the year: the winter period was generally associated with an extended longitudinal zone of influence downstream of the dam compared to transitions seasons (i.e. fall and spring). This study highlights the importance of year-around monitoring and assessment to understand the impacts of dams on the thermal regime of rivers.

Empowering approaches to fish habitat modelling: new perspectives for the assessment of environmental changes

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Hydronet's goal is to provide hydro-electric power companies with helpful science to develop their industry in a sustainable manner. My research in Hydronet focusses on developing modelling approaches to synthesize the ecological processes occurring in rivers and assessing the effects of changes. Here, I present two such approaches: spatially-explicit modelling and phylogenetic modelling, and show their utility for Hydronet and partners. Spatially-explicit modelling is relevant when analyzing observational data, where sampling locations have a wide range of distances from one another, and that are commonly the starting point for habitat modelling. Processes shaping ecosystems are spatially organized and the ensuing spatial heterogeneity acts as a confounding factor hindering pattern detection. Fortunately, methods exist to quantify spatial variation. We used one such method to quantify and control for spatial heterogeneity in assessing flow control impact on total fish density measured in 28 rivers whose flow was either natural or controlled (three types of flow control: run-of-the-river, storage, and flow peaking), thereby significantly increasing statistical power.
Phylogenetic modelling is relevant for the analysis of multiple species data. Evolution, like space, is known to induce correlation patterns in such data (child species share similarity with ancestral ones); failure to assess these patterns entails confusion and poor statistical power. Methods also exist to model phylogenetic variation and make predictions for species outside models. We use phylogenetic modelling to build general fish habitat models, on the basis of the phylogeny of habitat preference, using data on the distribution of species present.

Progress towards developing a framework and tools for the sustainable development of hydropower and healthy ecosystems

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The use of water to produce electricity often conflicts with the need of water to preserve a healthy environment. A key challenge to the sustainable development of hydropower is the lack of knowledge and tools to adequately measure the effect of hydropower on the environment and, in particular, on aquatic ecosystems. Here we present some of the progress towards developing a framework and tools needed to achieve these goals. A conceptual model identified 11 themes, including 7 sub-themes, where there remained uncertainties associated with the assessment of the effect of hydropower on aquatic ecosystems. The hope is that this model can serve as a framework towards setting priorities for developing sustainable hydropower, as well as to develop new or improved tools to address some of the uncertainties. Studies examining features shaping fish structure across multiple rivers have identified that hydrological features were the most prominent drivers of community structure variation, and that physiographic region and the presence of a dam did not affect the model. Further studies examining the relationship between fish diversity and habitat heterogeneity in Canadian rivers showed that habitat heterogeneity explained up to 32% of the total variation in biodiversity indices, and showed no significant differences in habitat heterogeneity between unregulated and regulated rivers. Taken together, these results would indicate that procedures and protocols can be homogenized across various regions and river usage types, facilitating interactions amongst biologists from different regions and with hydroelectric dam managers.

The effect of flow on northern pike behaviour in a river subjected to hydropeaking and a natural river

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Hydrological variables associated with the flow (i.e. flow velocity and depth) act as important determinants of fish habitat selection in rivers. Even so, very few studies address flow as a key factor explaining fish behaviour. The present study aims at acquiring knowledge on the movement of northern pike in response to frequent and drastic changes in river flow. To achieve this goal, a comparative study has been designed in two rivers subjected to highly different flow patterns. Data on northern pike daily movement were collected in Northern Ontario on a total of 40 individuals in both Mississagi River, regulated by hydropeaking operations, and Aubinadong River, a natural free-flowing control river. Using radio-telemetry equipment, fish tracking was conducted twice a day between July 10th and August 16th 2013 by canoe navigation. The tracking was performed at two time periods that matched the low and high daily flows: in the morning, i.e. between 5 a.m. and 2 p.m. and at night, i.e. 5 p.m. to 2 a.m. Results show

that fish can adapt their behaviour in regard to flow conditions. This study provides new knowledge on how fish cope with frequent flow changes in their habitat. We also hope that our findings will provide essential information on the northern pike ecology in river and contribute to the concerted conservation efforts in order to mitigate the generalized population decline of this species.


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