Regulated Rivers: Environment, Ecology and Management Conference

May 6-7, 2015
Selkirk College, Castlegar, British Columbia
Canada

Columbia Mountains Institute of Applied Ecology

Print or CD copies of this document are available at cost plus shipping from the Columbia Mountains Institute of Applied Ecology.

This document is available as a free PDF download from the website of the Columbia Mountains Institute, at www.cmiae.org in the "Past Events" section. Look for the write-up for this conference.

Pages have been left blank intentionally to allow for correct pagination when this document is printed in double-sided format.

Columbia Mountains Institute of Applied Ecology
Box 2568, Revelstoke, British Columbia, Canada V0E 2S0
Phone: 250-837-9311 Fax: 250-837-9311
Email: office@cmiae.org
Website: www.cmiae.org

Acknowledgements

This conference was hosted by the Columbia Mountains Institute of Applied Ecology.

Thank you to our financial and In-kind supporters

Our presenters and the people who brought posters and displays travelled from various communities in British Columbia, Alberta, Saskatchewan, Washington and Idaho. We are grateful for your willingness to share your expertise with us, and for the support of your agencies in sending you to our conference.

Special thanks go to our volunteers who helped with the conference logistics: **Laura Smit** from FLNRO, **David Greaves** and **Blair Smith** from Selkirk College and the conference committee members for their help in keeping the event running smoothly.

We are appreciative of the work of our conference organizing committee, and others who contributed expertise as the conference developed. The members of the organizing committee were:

- Heather Lamson, Ministry of Forests, Lands and Natural Resource Operations, CMI Director
- Mike Miller, LGL Ltd., CMI Director and MC
- Carrie Nadeau, Summit Environmental Consultants Inc., CMI Director and MC
- Janean Sharkey, LGL Ltd.
- Harry van Oort, Cooper Beauchesne and Associates, CMI Director and MC
- Brendan Wilson, Selkirk College, CMI Director, MC

Table of contents

Conference description

Regulated waterways provide important services such as flood regulation, power generation with low greenhouse gas emissions, and energy storage. Nevertheless, the damming and regulation of rivers incurs ecological costs via the operation of reservoirs and alteration of downstream flows, combined with the often permanent loss of valley bottom habitat. Regulation can affect both upstream (reservoir) and downstream environments. A recent increase in smaller hydro-electric projects (e.g. run-of-river projects) has led to a flourish in the study of their unique impacts. Over half of the world's large rivers are regulated, including the Columbia River and its tributaries. Despite inevitable footprint impacts, considerable ecological function may remain in these systems, supporting a diversity of plants, fish, and wildlife. Within the Columbia Basin, a wealth of research has recently emerged to increase our understanding of ecosystem processes within regulated river environments, with the potential to aid in mitigating footprint and operational impacts to plants, fish, and wildlife.

This conference provided a cutting-edge opportunity for scientists and managers to share results of recent research on regulated river environments, processes, and operations in the Pacific Northwest and elsewhere.

Through 2 days of presentations, an evening keynote speaker (open to the public), a poster session and opportunities for informal dialogue, participants learned about new research and mitigation techniques for regulated river environments in the Columbia Basin and elsewhere.

Our event included nineteen presentations and 13 posters and displays. About 110 people attended the conference. Participants were a multidisciplinary group of people, including: resource managers, public interest groups, consultants, researchers, industry representatives, and academics.

The conference was held Selkirk College, Castlegar, BC, May 6-7, 2015

About the Columbia Mountains Institute of Applied Ecology
www.cmiae.org

The Columbia Mountains Institute of Applied Ecology (CMI) is a non-profit society based in Revelstoke, British Columbia. CMI is known for hosting balanced, science-driven events that bring together managers, researchers, educators, and natural resource practitioners from across southeastern British Columbia. CMI's website includes conference summaries from all of our events, and other resources.

Summaries of presentations

The summaries of presentations in this document were provided by the speakers. Apart from small edits to create consistency in layout and style, the text appears as submitted by the speakers.

The information presented in this document has not been peer reviewed.

1. *The operational realities of river regulation: A Kootenay River example*

Marko Aaltomaa, Manager Network Services, FortisBC Inc.
100 Bingay Rd, Trail British Columbia
Marko.Aaltomaa@fortisbc.com

Introduction

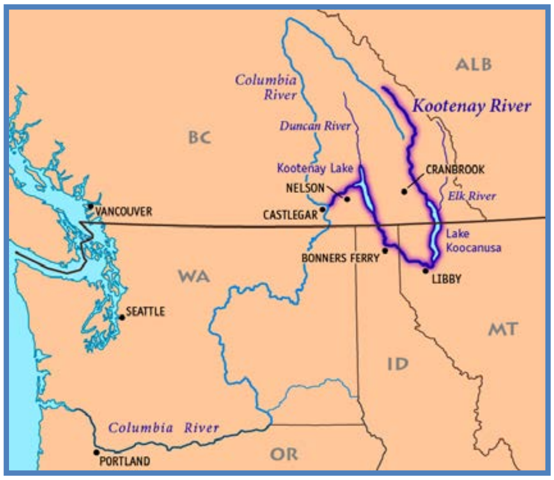
FortisBC is an electric and gas utility in West Kootenays that owns and operates four hydroelectric generating facilities on the Kootenay River between Nelson and Castlegar and is the holder of the International Joint Commission (IJC) Order that dictates the water levels in the Kootenay Lake.

From an Operational perspective there are often changes in operational constraints driven by societal values, environmental issues and the priorities of day and can conflict with the historical priorities of flood protection and hydro power generation, which were the priorities when the Kootenay River projects were proposed and developed.

The presentation FortisBC delivered at the 2015 Columbia Mountain Institutes Regulated Rivers conference provides as overview of the regulation and operational constraints of managing a regulated river system using the Kootenay River system as an example. The Kootenay river runs almost 800 km and originates in the Canadian Rockies in the East Kootenay's coming within a couple of km's of the Columbia River headwaters. From there the Kootenay River flows south from British Columbia (BC) into Montana, and into Northern Idaho and the Kootenay flats area between Bonners Ferry and extending up into Creston, BC before flowing into the Kootenay Lake – which is one of the largest lakes in BC (100 km long).

The discharge from Kootenay Lake is via the west arm of the lake at Nelson, BC where the Kootenay River flows through Grohman Narrows, a natural constriction that regulates the Kootenay Lake water levels

From the Grohman Narrows the Kootenay River continues through to Castlegar, BC where it meets the Columbia River north of the international border with the USA.



History of Kootenay Dam Construction

Generation on the section of the Kootenay River between Nelson and Castlegar began with West Kootenay Power over 100 years ago with the construction of the Lower Bonnington plant in 1898 driven by power requirements for gold mining activities in the Rossland area.

As demand for residential electricity grew, additional plants were constructed, including Upper Bonnington in 1907 and South Slocan in 1928. These three plants are “run of river plants” which means that there is no storage reservoir or capability to store water behind the dam. Corra Linn was the next plant to be constructed in 1932 to meet society’s demand for power. Between 1932 and 1938 Corra Linn was operated as a “run of river” plant as well. Up to this point in history there were no real anthropomorphic impacts on the natural flows out of Kootenay Lake. The natural restriction at Grohman Narrows was the only flow regulator.

At around the same time period that the Kootenay River plants were constructed there were discussions between the USA and Canada about trans-boundary water issues along the length of the US-Canada border that originated in the Great Lakes region and Niagara Falls Ontario. It became evident that there was a need for the development of guiding principles and rules to jointly manage issues related to cross border contamination and backing- up water into neighboring countries through the construction of dams.

These discussions resulted in the Boundary Waters Treaty of 1909 and the development of the International Joint Commission (IJC), an international committee organized to manage and resolve any trans-boundary water disputes. The Kootenay River system was one of the trans-boundary water bodies that was brought to the IJC for resolution. There were primarily two interested parties discussing projects and applications with the IJC during this time; the West Kootenay Power (WKP) and the agricultural community of Kootenay Flats near Creston.

West Kootenay Power (WKP), was interested in constructing a dam at the Corra Linn location to store water in the Kootenay Lake during fall and early winter and to excavate Grohman Narrows to increase the discharge from the lake. That latter was required to improve power production during low water.

The first application to the IJC by WKP to create the Kootenay Reservoir was in 1929, which was amended in 1932. This application resulted in public hearings in 1933. Concerns from farmers in the Kootenay Flats were voiced during the hearings. They felt the dam would raise the elevation of the lake for longer periods of time and affect farming operations. This conflict resulted in WKP withdrawing their application. The farmers at this time had already sought and received approval from the IJC to construct and improve dykes in the Kootenay Flats to reclaim flooded lands. This was the first form of river regulation in the system.

Through ongoing discussion, the agricultural community of Kootenay Flats began to see the benefits of the WKP application for control of the Kootenay Lake water levels and instead of opposing the development, they began to petition for the project to proceed

Figure 1: Aerial photo showing from top to bottom, the Corra Linn, Upper Bonnington, Lower Bonnington, South Slocan and Kootenay Canal Plants.

with regulations to lower the lake water levels during spring runoff and improve the control of evacuated flood waters.

The IJC revived the application and reconsidered the concerns of all US and Canadian stakeholders who agreed that the operation of the Corra Linn Dam would offer substantial and lasting benefits, and would lessen the damage caused by flooding. On Nov 11, 1938 the IJC order for Kootenay Lake was signed by both parties.

The IJC Order

The IJC Order for Kootenay Lake required WKP to enlarge the Grohman Narrows by removing 250,000 cubic yards of material to increase the discharge capabilities.
The IJC order also set rules related to storage and operations through the following:

- a maximum level rule curve outside of the freshet period during fall and early winter;
- a linear drawdown requirement between Jan to April;
- And a minimum lake level on or around April 1st each year and a requirement to evacuate as much water as possible during freshet to realize the benefit of the Grohman excavation

During freshet conditions, and often prior to freshet, Corra Linn is operated in a manner where it transfers the discharge flow regulation to Grohman Narrows by opening spill gates at Corra Linn. This operation is known as “freefall” and typically lasts from March until July.

The Grohman constriction is due mostly to a naturally high river bed level through the reach, with some narrowing of the river. During the period from the 1940’s until the late 1960’s Grohman Narrows and Corra Linn shared regulation of the discharge of Kootenay Lake during different parts of the year.

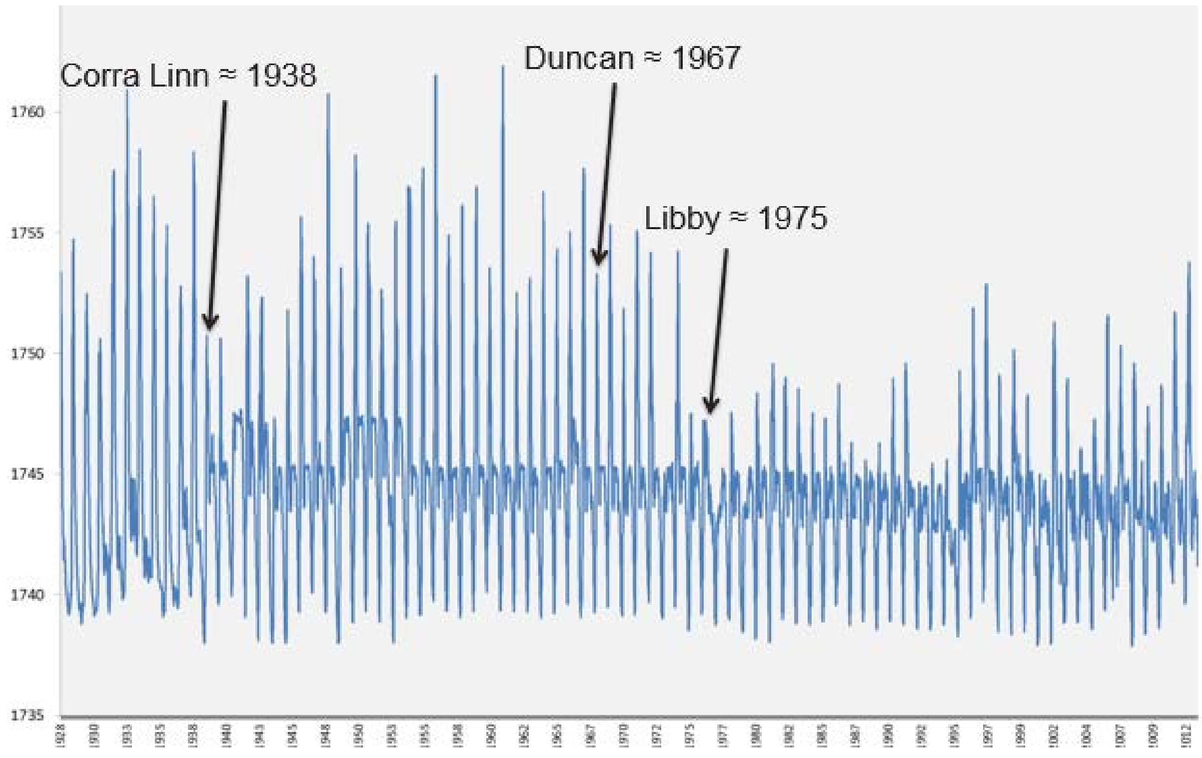
However, there was no regulation of the inflows at this time which meant that the natural inflows during the freshet period were very influential in determining the lake levels annually. For example, if there was a large weather event or a very rapid spring runoff the lake level would rise quickly due to the discharge constraints presented by the Grohman narrows. This continues to hold true today, but to a lesser extent because of the introduction into the system of the Columbia River Treaty (CRT) dams in the late 60’s to the mid 70’s.

Columbia River Treaty Dams

The CRT was ratified in 1964 and resulted in the construction of the Libby, Duncan and Hugh Keenlyside dams in BC and one in the Libby Dam in the USA for flood control and to increase the hydroelectric generation in both countries which were priorities at that time.

Two of the treaty dams introduced not only new regulation to the inflows into Kootenay Lake, but it also added a number of new stakeholders and increased the number of parties involved in coordinating overall operations. The two dams directly affecting Kootenay operations were BC Hydro's Duncan Dam at the north end of Kootenay Lake and US Army Corp of Engineer's (the Corp) Libby Dam in Montana.

As the holders of the IJC Order for Kootenay Lake FortisBC must communicate regularly with BCHydro and the Corp to ensure that the IJC Rule Curve is maintained. This adds complexity to the overall operation of the system, but the overall objectives of flood control and increased power production are met. Figure 2 demonstrates the flood control benefits that were realized by further regulation.



The most concerning recent flood peak on the Kootenay River was in 2012 at almost 1754 ft. (1753.78 early July), which caused damage to some structures and considerable concern and coordination. It was the highest level on the lake since 1974 when it slightly higher than 1954, and just around the time Libby was coming into operation. However, both these peaks are well below the historical and highest recorded peak which was about 8 feet higher in 1961 when it reached almost 1762 ft. (1761.92), prior to Libby and Duncan.

Canal Plant Agreement

This further regulation also allowed for the construction of the Kootenay canal plant by BCH to take full advantage of the CRT dams from a power production perspective. The Kootenay Canal diverts water around all four of FortisBC's Kootenay River plants, with the inlet of the canal at the forebay of Corra Linn and the discharge downstream of South Slocan. Construction of the project was completed in 1976.

This project drove the need for the Canal Plant Agreement between BC Hydro and those whose generation would be affected by the project, namely FortisBC among others on the Kootenay River. The overall operations are governed by the agreement and detailed in twenty-eight Operating Procedures that cover everything from the impact of maintenance outages, to the relationship between FortisBC and BC Hydro related to the IJC Order for Kootenay Lake. The CPA introduces more layers of regulation and coordination into the system.

The CPA has also shaped the operational relationship between BC Hydro, FortisBC and all the other operators on the system where the exchange information on real time operations is required many times a day between the two control centers and operating personnel.

Since the completion of the CRT and Canal Plant projects there have been no major projects that have further regulated the Kootenay River, however there are a number of parties and stakeholders connected by the river that can influence and impact operations on a very regular basis.

Libby Dam and VarQ

With the Libby Dam in the US, Kootenay River operations is impacted by U.S. regulatory influences in support of downstream fish species recover efforts. These interests influenced the development of the VarQ Flood Risk Management methodology in the late 90's, intended to more closely mimic the natural downstream flow patterns which is better for fish and wildlife habitat. It also maintains higher reservoir levels prior to spring than with standard flood control curves, which does have an impact on Kootenay Lake when forecast inflows do not meet actuals.

Another downstream impact due to US requirements were experimental “spill tests” from Libby during spring to potentially aid spawning sturgeon. These spill tests have since been discontinued since they did not achieve their intended purpose, but certainly did impact the Kootenay River system, by releasing additional discharge during freshet when inflows were already high.

Other coordination is required throughout the year which impacts operations related to balancing the needs for maintenance outages for the hydroelectric facilities versus the various stakeholder needs for farming activities and recreational use of Kootenay Lake.

Emerging Issues

The operation of a regulated river is one of constant change, influenced by the priorities and values of our society and of our time. This can be no better demonstrated than through a review of the emerging issues that impact the operation of the Kootenay system.

The management of fish-related impacts of regulated rivers is not new. For example there are operating orders that dictate the flow of water during spawning events and operating orders that dictate ramping rate to reduce fish stranding events. However, there are a few newer emerging initiatives that have the potential to influence Operations on the Kootenay system including the protection of Kootenay Lake shore spawning Kokanee, the protection of white sturgeon that spawn in the Kootenay River south of Creston and the proposed reintroduction of salmon to the Columbia River Basin. Dialogue on these issues is ongoing.

Another Environmental influence that FortisBC has been forced to reckon with is climate change. The operation of a regulated system is reliant on accurate forecasts. This includes the assessment of snow loads, precipitation, temperature and timing of all those factors impact the water management forecasts. The unpredictable weather patterns that have been prevalent in recent years require considerably more coordination and balancing of the system. From an operational perspective it makes forecasting very difficult and requires a need to re-examine historical models and adapt to the changes we are seeing.

Figure 3 summarizes how the priorities and impacts of various regulation actually impact the operations related to Kootenay Lake.
The black dashed line in Figure 3 represents the rule curve set by the IJC Order for Kootenay Lake and the blue line represents the actual lake levels. Ideally the blue line should always remain under the dashed rule curve. However, even with all the regulation previously discussed, it is not always possible, especially with the onset of

spring runoff and the discharge constraints presented by Grohman Narrows. Other deviations in lake levels compared to the rule curve can generally be explained due to the various other priorities such as environmental issues and stakeholder issues.

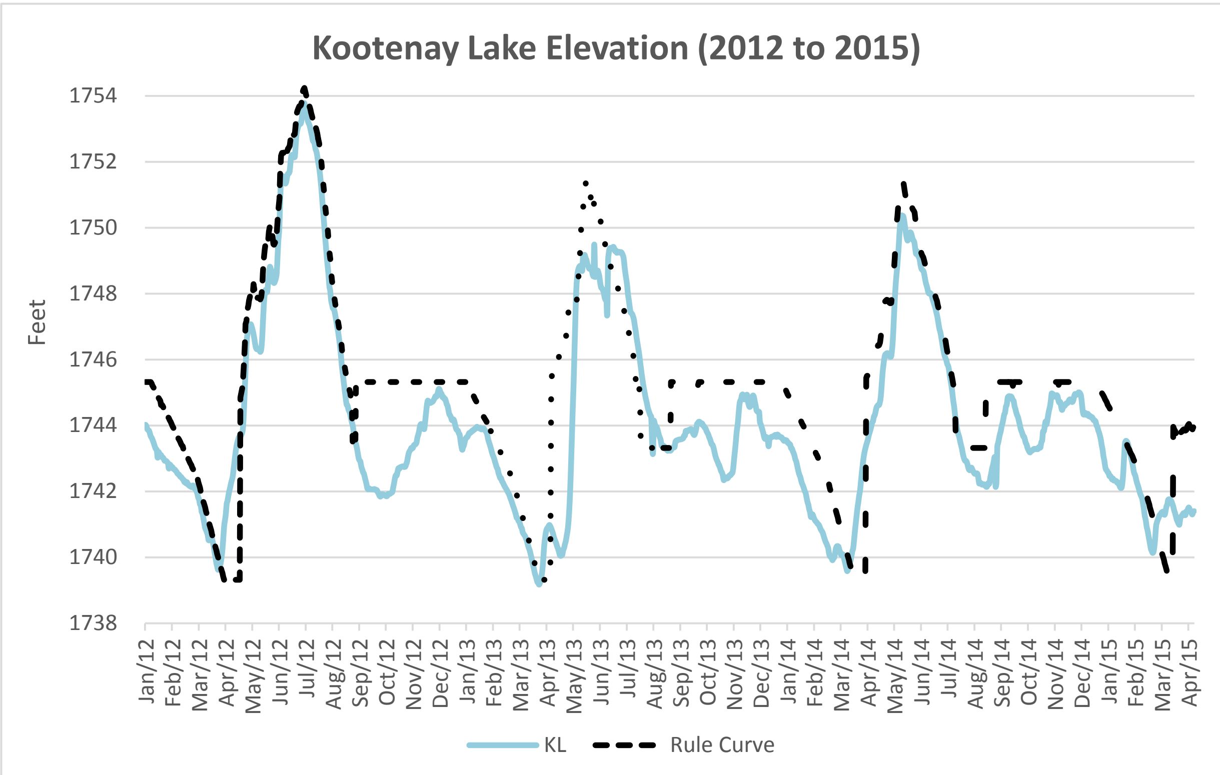


Figure 3: Summary of the impacts of other issues on the regulation

For example:

- Starting in 2012, due to abnormally high precipitation late in spring and into June – with record levels – which were way above what was forecasted - coordinated efforts between FortisBC, BCHydro and US Army Corp were not able to draw the lake down to the minimum level, due to earlier and higher discharges from Libby dam than expected, however these efforts did mitigate an even higher peak level on the lake in 2012

- Later in 2012, in Sept to October, the lake was drawn down to support the shoal spawning Kokanee to ensure that the eggs were not dewatered later in the year. This special operation proved to be very successful and something that may be included on a regular basis.

- From an operations perspective, 2012 was a challenging year but also very successful from a coordinated operations standpoint for managing peak lake levels and supporting fisheries initiatives, but there were also heard a number of concerns expressed from other stakeholders and landowners related to high lake levels during peak and then concerns for low lake levels later in the year for recreational interests.

- 2013 this was a predictable year, where the low level target for April 1st were met as per the IJC and there was also saw a much lower peak lake level, and therefore fewer stakeholder concerns.

- In 2014, weather events versus forecasted levels presented challenges around freshet and did not allow operations to meet the IJC low level target for the lake, and later in the year the lake levels had to be lowered to support maintenance outages.

- 2015 already has seen the mid-level snowpack runoff approximately 6 weeks earlier than normal, which resulted in crossing the IJC rule curve even with "freefall" operations at Corra Linn and maximum discharge thru Grohman Narrows. Now in May when the lake would typically rise dramatically it remains very flat for this time of year.

These examples demonstrate that even with all the regulation in place it is very challenging to meet all of the operational requirements and through the changing societal priorities it is impossible to meet all the various stakeholder requirements all of the time.

Back to Table of Contents

2. *Kootenai River floodplain ecosystem operational loss assessment*

Norm Merz
Kootenai Tribe of Idaho
PO Box 1269
Bonners Ferry, ID 83805
(208) 267-3620
merz@kootenai.org
http://restoringthekootenai.org/ResourcesKootenai/OnlineLibrary/wildlifelibrary/
Coauthors:

Paul Anders	Cramer Fish Sciences, Inc.
Rohan Benjankar	Center for Ecohydraulics, University of Idaho
Dwight Bergeron	Montana Fish, Wildlife and Parks
Brian Bieger	Inter-fluve, Inc.
Micheal Burke	Inter-fluve, Inc.
Gregory Egger	Umweltbüro Klagenfurt
Timothy D. Hatten	Invertebrate Ecology, Inc.
Charlie Holderman	Kootenai Tribe of Idaho
Stewart Rood	University of Lethbridge, AB
Bahman Shafii	Statistical Consulting Services
Scott Soults	Kootenai Tribe of Idaho
Philip Tanimoto	Conservation Imaging, Inc.
Alan Wood	Montana Fish, Wildlife and Parks
Elowyn Yager	Center for Ecohydraulics, University of Idaho

The full report can be found at:
http://restoringthekootenai.org/ResourcesKootenai/OnlineLibrary/wildlifelibrary/Phase 1: Kootenai River Floodplain Ecosystem Operational Loss Assessment Report.

Introduction:

Fish and wildlife resources in the Kootenai River drainage were historically abundant and used for cultural and subsistence purposes by the Ktunaxa or Kootenai Nation. The abundant natural resources that sustained the Kootenai people also were vital to the survival of early European traders and subsequent settlers to the Kootenai Valley. As Europeans settled in the Kootenai Valley, a shift in subsistence occurred from native food sources to livestock and agricultural crops. For this to occur, the fertile floodplain needed to be dried and separated from the river. By 1916, the first of sixteen diking district was established and many acres of floodplain were drained and under cultivation. In 1966, construction of Libby Dam was initiated to aid in flood control and to produce electricity for the region. Libby Dam became operational in 1972.

Dams and reservoirs impact the environment through their presence in the landscape and by altering natural hydrologic cycles. To assess the impacts of these alterations, a process-based hierarchy is effective for representing this succession of impacts, and provides a 'roadmap' for exploring and assessing the processes linking successive levels of impact throughout the ecosystem.

To produce a scientifically defensible, repeatable, comprehensive, and process-based assessment tool, Kootenai Tribe of Idaho assembled a team of skilled scientists in the fields of hydrology, hydraulics, geomorphology, ornithology, entomology, statistics, riparian and river ecology, among other expertise, known as the Research Design and Review Team (RDRT). To assess the ecological impacts experienced in the Kootenai River and on its associated floodplain, a series of multimetric indices were developed for each order of impacts and combined into an overall Index of Ecological Integrity (IEI) for the US portion of the Kootenai River floodplain and for each of the three unique geomorphic reaches of this river; the canyon, braided, and meander reaches.

Project area:

The Kootenai River Basin is an international watershed located primarily in the province of British Columbia, Canada (B.C.), with smaller portions of the basin in the states of Montana and Idaho. The Kootenai River is the second largest Columbia River tributary in terms of runoff volume (average annual discharge 454 cubic meters per second (m^3/s) (16,032 cfs) (USGS 1979), and the third largest in terms of watershed area, 35,490 km^2, (Knudson 1994). Historic pre-impoundment peak river discharges exceeded 2,832 m^3/s (100,011 cfs) (Paragamian et al. 1996). From headwaters in southeastern BC, the Kootenay River flows southward into northwestern Montana, where Libby Dam, forming Lake Koocanusa, impounds it. Downstream from Libby Dam, the river flows through Montana, into Idaho, and then turns north, entering BC and Kootenay Lake. The river exits the West Arm of Kootenay Lake and flows westward to its confluence with the Columbia River at Castlegar, B.C. (Anders et al. 2002) (Figure 1).

The Operational Loss assessment occurred on the US portion of the Kootenai River floodplain between Libby Dam and the international border. The project area downstream from Libby Dam can be generally described as having three distinct reaches based on gross geomorphologic characteristics, they are: the canyon reach, the braided reach, and meander reach (Snyder and Minshall 1996, 2005). These three distinct reaches make for an exceptional study area for assessing operational losses in a regional context, where each reach presents different issues, aquatic and terrestrial communities, geomorphology, hydrology and impacts.

Methods:

A process-based hierarchy is an effective means for representing a succession of operational impacts and providing a 'roadmap' for exploring and assessing the processes linking successive levels of impact. Jorde et al. (2008) proposed a hierarchy for considering operational impacts on floodplain ecosystems, adapted from a framework originally proposed by Petts (1984). We have adapted this hierarchy with minor revisions for this study (Figure 2). In this hierarchy, first-order impacts are changes to the primary physical drivers of the fluvial system: hydrology, water quality and sediment supply (Williams and Wolman 1984; Richter et al. 1996; Poff et al. 1997; Naiman et al. 2000; Grant et al. 2003). Changes in hydrology and sediment supply lead to second-order impacts of altered hydraulics, sediment transport, and channel and floodplain morphology (e.g., Gilbert 1917; Williams and Wolman 1984; Church 1995; Webb et al. 1999; Grant et al. 2003). Third-order and fourth order impacts represent the combined influence of first- and second-order impacts on biological functions in terms of vegetation and faunal communities respectively,

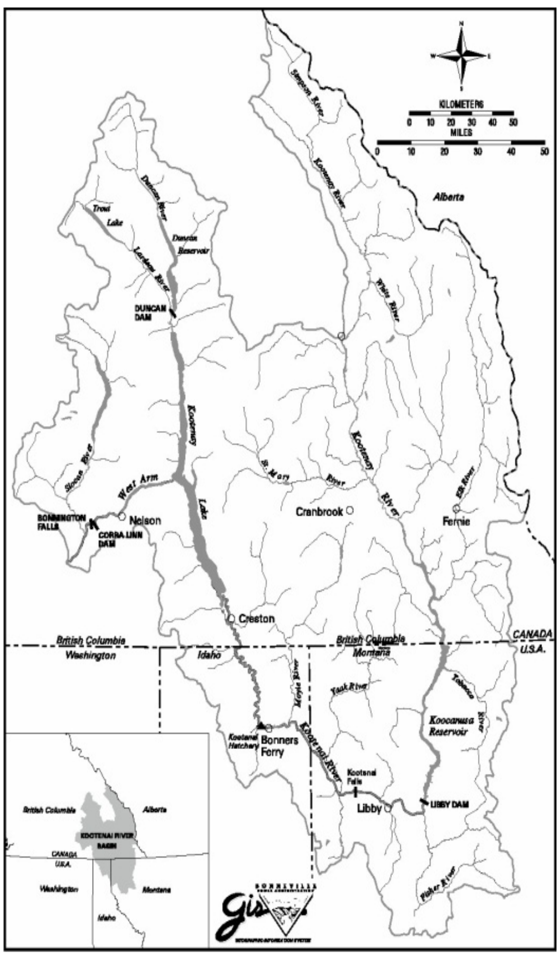


Figure 1. Location of the Kootenai River and its associated subbasin boundaries (KTOI and MFWP 2004).

through direct and indirect linkages (Ligon et al. 1995; Jorde and Bratrich 1998; Naiman et al. 2000; Rood et al. 2005). Fifth-order impacts describe feedback between biological responses and physical processes (Naiman et al. 2000; Rood et al. 2005). This cascade of impacts often results in compromised ecosystem integrity (Ward and Stanford 1983; Richter et al. 1996; Poff et al. 1997; Nilsson and Berggren 2000; Tockner and Stanford 2002; Naiman et al. 2005; Jorde et al. 2008). In particular, prior studies have shown that hydrology is a fundamental driver of riverine ecosystems and that ecosystem function may depend on the full suite of naturally occurring flows (Poff et al. 1997; Naiman et al. 2000). Hence, river management is frequently in conflict with ecosystem function, the preservation of which may depend on plasticity of riverine organisms to environmental changes and management compromises compatible with overall river management goals. Using a process-based hierarchical approach, KTOI project personnel and the RDRT developed ecological indices that quantified current levels of system functionality that we contrasted with similar measures back through time. The project focused on development of indices that described ecological integrity of Kootenai River flora and fauna. However, to understand the changes in the hydrologic functions that drive this system, abiotic factors such as hydrology, hydraulics, and geomorphology provided the underpinnings to those biotic components. It is the interaction between biotic and abiotic ecosystem components and the ecosystem processes that are responsible for creating and maintaining biodiversity. These interactions and processes are what constitute biological integrity, or an "(*eco*) system's wholeness" (Angermeier & Karr 1994).

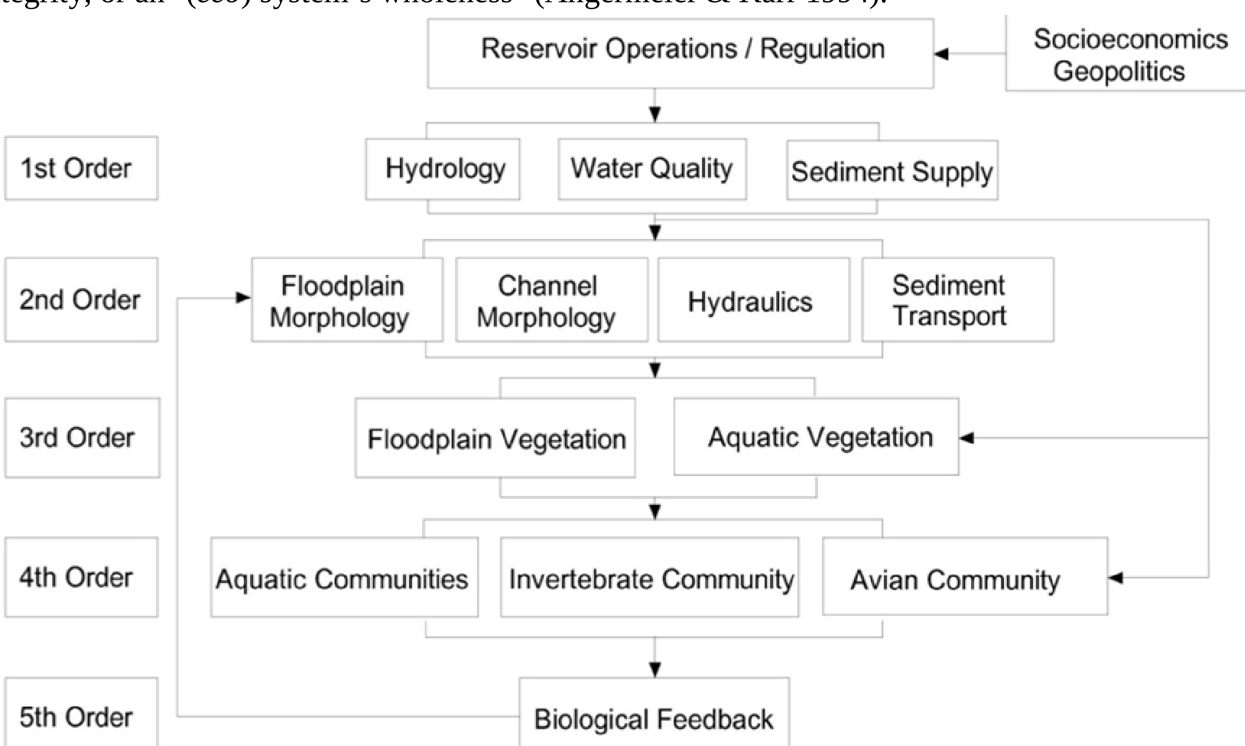


Figure 2. Conceptual model of the cascading effects that could result from dam related hydrological alterations. Modified from Petts (1984) and Jorde et al. (2008).

Ecological Integrity (or Index for Ecological Integrity– IEI) refers to the capability of supporting and maintaining "a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr and Dudley 1981). The ecological integrity concept provides a system-specific framework in which abiotic and biotic changes (as measured by indices) can be assessed, combined, and ranked on a qualitative scale.

To assess the ecological impacts experienced in the Kootenai River and on its associated floodplain, a series of multimetric indices were developed for each order of impact (Figure 3) and combined into an Index of Ecological Integrity (IEI). Since each geomorphic reach is unique due to geomorphology, landform, and land use patterns, we developed an IEI score for each major geomorphic reach (canyon, braided, meander). The overall score allows for comparison of the relative level of effects between reaches. Each index quantifies the level of effects at a specific abiotic (hydrology, hydraulics, sediment), terrestrial biotic (vegetation, wetlands, terrestrial invertebrate, and avian communities), or aquatic biotic (aquatic vegetation, algae, macroinvertebrates, and fish) level. The indices and their abbreviation used in this document are:

First Order Impacts:
- IHA – Index of Hydrologic Alteration
- ISSA – Index of Sediment Supply Alteration

Second Order Impacts:
- IFA – Index of Fluvial Alteration (in stream)
- IFFA – Index of Floodplain Fluvial Alteration

Third Order Impacts:
- IWFA – Index of Wetland Functional Alteration
- ILCCA – Index of Land Cover Classification Alteration

Fourth Order Impacts:
- RMI –Riverine Macroinvertebrate Index
- RFI – Riverine Fish Index
- I-IBI– Invertebrate Index of Biological Integrity
- A-IBI - Avian Index of Biological Integrity

Figure 3. Summary of the Operational Loss Assessment indices by order of impacts.

For each index, a thorough list of metrics that could be used to create the index was derived. The complete list of metrics was evaluated for temporal and spatial consistency and redundancy to limit the number of metrics within each index. In some cases, indices were chosen that included a pre-determined suite of metrics (e.g. RMI and RFI). Once metrics were selected, a process to measure the change in metrics was developed. Whenever appropriate and when data were available, the current metric value was compared to the historic metric value. Where historic metric values were not available, an index of biological integrity (Karr 1981, Karr and Dudley 1981, Karr and Chu 1997, Royer et al. 2001, Grafe 2002, Mebane et al. 2003) was used to assess impacts. The difference between the historic and contemporary metric values were compared and placed on a standardized scale ranging from 1 (drastic change) to 10 (limited change) to quantify the difference between the conditions. This value is referred to as the metric score. The metric scores were averaged together to represent the index. This average of metric scores is referred to as the index score. To calculate the IEI, all the index scores were averaged. This IEI value is referred to the IEI score (Figure 4).

To display and communicate the metric scores, index scores, and IEI scores, the radar chart type offered in Microsoft Excel Spreadsheet 2007 was used. A radar chart was developed for each index showing the metric scores that were used to represent the index score. On the radar chart, each ray is scaled from 0 to 10 radiating from a center point and represents a metric score. Similarly, an IEI radar chart was use to display each index scores that contributed to the overall IEI score. In this way, the ecological operational effects can be apportioned to each component, with the scale of the impact clearly displayed. By accounting for and displaying the metrics and indices in this way, not only can we document current impacts, but we can also identify mitigation/restoration opportunities and document responses to such management actions.

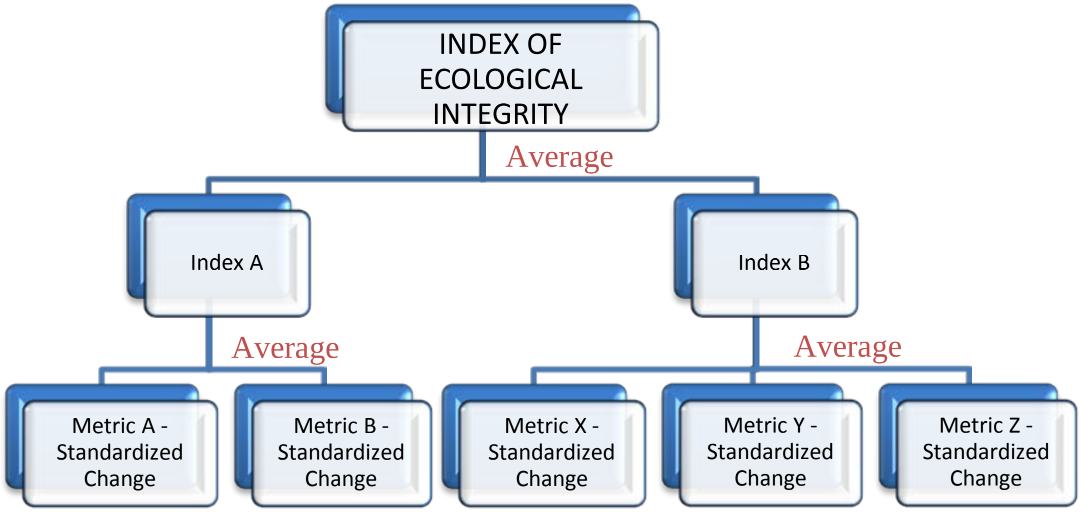


Figure 4. Schematic diagram for the calculation of the Index of Ecological **Integrity**

Results:

The overall IEI value for the Kootenai River floodplain is 4.9 out of 10. When the IEI is calculated at the reach scale, the canyon, braided, and meander reaches score 5.0, 5.3, and 4.5, respectively (Figure 5). The individual index scores range from 2.2 for the IFFA in the meander reach to 7.9 for the RFI in the canyon reach. These scores were calculated for the contemporary condition, which includes the operation of Libby and Corra Linn Dams, the presence of the levee system, the sturgeon augmentation flows, nutrient addition, and a host of past and present land use practices, such as human development, agriculture, floodplain drainage, and other alterations.

The reach scores indicated that ecological integrity in the braided reach was the least affected, while the meander reach was the most affected of the three reaches. The braided and meander reach scored similarly for most indices. However, they differed substantially in their fish and wildlife community index scores (RMI, RFI, I-IBI, A-IBI), with the meander reach scoring substantially lower in all fourth order indices. Conversely, the canyon reach scored similarly to the braided reach in fourth order indices, but lower than both reaches in the in-stream abiotic indices (IHA, ISSA, and IFA) order indices (Figure 5). It is important to note, that these scores are not static and will change over time due to activities that are occurring within the Kootenai River Valley, including any future changes in dam operations.

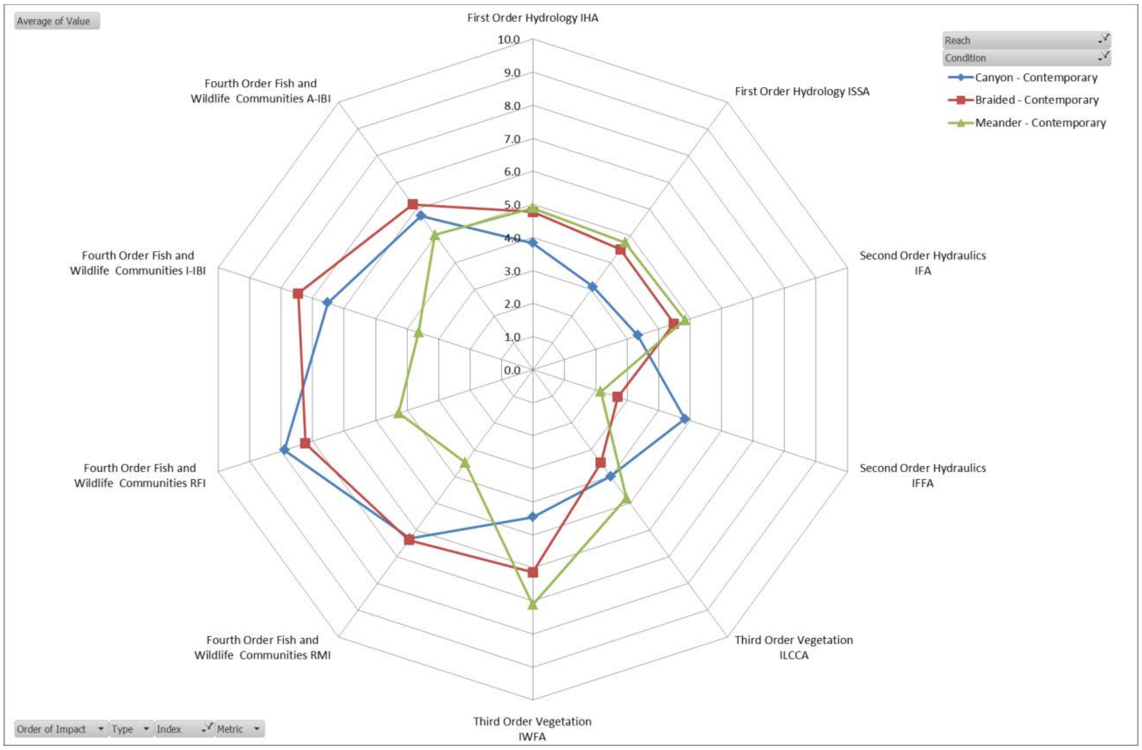


Figure 5. Radar charts showing the order of impact and individual index scores for each reach in the Kootenai River.

Discussion:

The IEI score that we developed for the Kootenai River Floodplain (4.9) along with the component scores for the canyon (5.0), braided (5.3), and meander (4.5) reaches appear accurate and consistent with current research. The index scores between each reach react similarly in most cases to broad system-wide changes resulting from actions like augmented sturgeon flows and nutrient addition.

However, the fourth order (biotic) differences in the meander reach (4.2) are quite different from the canyon (6.6) and the braided (6.8) reaches. The floodplain within the meander reach is heavily dominated by agricultural land uses. Additionally, sampling locations for the terrestrial Index of Biological Integrity (invertebrate and avian) focused on remnants of native vegetation and land classification cover types were not sampled in proportion to their availability (Chapter 7 and Appendix E). Since a majority of the natural vegetation in this reach has been converted to agricultural uses, it is likely that the landscape within this reach suffers from a lack of habitat diversity and the effects of habitat fragmentation which are detected in the terrestrial IBI scores.

Conversely, the first order (hydrologic alteration) effects are more pronounced in the canyon (3.7), than the braided (4.7) or meander (4.9) reaches. These effects are due to the proximity to the dam and the confined nature of the canyon. In this reach, the canyon walls constrain the ability of the water to spread out, therefore any changes in hydrology are readily detectable in the IHA.

The scoring variation among the indices within the different reaches points to ecological components that differ substantially between the reaches. These differences and their relative values to other indices within and between reaches show where mitigation actions could provide the greatest opportunity to improve the overall ecological condition of the reach.

The IEI method described in this assessment quantifies the amount of anthropogenic impacts on the Kootenai River and its associated floodplain. Additionally, several on-going mitigation actions were evaluated and quantified against the initial conditions following construction of Libby Dam. However, because of the aggregation method (i.e. averaging of index scores), and summarizing across an entire reach, these increases were somewhat muted. However, the results of these management actions were still detectable in the metrics and index scores, which documented improved ecological integrity at the reach scale, albeit to a small extent.

These IEI examples demonstrated that this methodology will allow managers to assess direct, indirect, and cumulative effects of management actions on an independent index or a combination of indices at multiple scales. Additionally, the IEI concept easily adapts to varying audiences from policy level decision makers that might be interested in the overall score, to a scientific audience that is interested in the details of metric scores and the ecological mechanisms underlying the overall assessment. Land managers and dam operators can also employ this technique to assess and prioritize ecosystem deficiencies and to monitor management actions. For these reasons, the proposed component indices in the IEI provide a useful method for defining and monitoring ecological losses caused by the operations of dams within the Columbia River Basin.

Another benefit of the IEI approach is that it can be adapted to each unique river system. The methodologies used in this assessment provide a framework from which to develop and/or adapt a site-specific IEI to other watersheds. If different metrics or additional indices are needed for a specific area, and suitable empirical data were available, a new index could be developed and inserted on a corresponding axis in the IEI radar chart. To suit individual situations, indices, and individual metrics within each index, could be added, modified, or removed from the IEI.

Managers can use the IEI and radar charts to focus on the indices that their mitigation actions would most directly affect. These metrics and indices form the basis of the monitoring strategy for documenting site-specific and large-scale changes in response to mitigation efforts. As the management action benefits cascade through the system, other index scores also should capture overall ecological changes. However, the indirect effects cascading through the system are typically more subtle, more difficult to measure, may involve a time lag, and may be confounded by other variables. For example, flow regime often drives vegetation succession within the floodplain. However, the results of these changes in the flow regime may take decades to be conclusively expressed on the landscape. Therefore, if a change in flow regime occurs, the IHA index would be directly and immediately affected. In contrast, the land cover alteration index might take decades to respond numerically. Nonetheless, evidence of plant succession could be easily confirmed by documenting reproduction of key community types.

It is important to understand the cascading nature of effects. When management actions improve or degrade conditions at the lower orders of impacts, those effects cascade through the system over time. For example, observations indicate that new cottonwood stands are establishing along the banks of the Kootenai River. It is hypothesized that the changes resulting from the augmented sturgeon flows may be improving woody riparian regeneration (pers. Comm; Dr. Stewart Rood, University of Lethbridge, AB. pers. Comm; Burke et al. 2009). This observation is supported by the IHA and IFA metric scores that document movement of metric scores upward toward a more natural condition. The change in flow management improved many of the IHA metrics along with the daily stage fluctuation and bed mobility patterns represented in the IFA. These variables have been associated with woody riparian recruitment and are consistent with the observations of increase riparian woody vegetation along the Kootenai River. These indications are being further studied and modeled as part of the Operation Loss Assessment Project.

While this methodology was successful at quantifying anthropogenic impacts on the Kootenai River and its floodplain, it is important to maintain a qualitative perspective on the magnitude of these ecological impacts. The overall IEI indicated that about half of the ecological integrity has been lost below Libby Dam within the 50-year floodplain, much of that over the last 40 years. These impacts will continue to cumulatively alter the riverine ecosystem into the future. In addition, our analysis did not even attempt to quantify impacts from the upper boundary of the 50-year floodplain on through the 500-year floodplain because it has been substantially isolated from the influence of the river, resulting in a near complete loss of floodplain dynamics in these portions of the floodplain. The ecological impacts to that portion of the ecosystem will continue to cause a decline in ecological integrity across that larger geographic area that is likely to cascade through the entire riverine system as long as Libby Dam continues to catch and hold flood waters for future power generation. Effective monitoring through time will be necessary to determine if positive mitigation actions can offset ongoing ecological declines within the broader floodplain system.

Future Tasks:

As an assessment tool, the IEI methodology documented many changes in the Kootenai River ecosystem at varying abiotic and biotic levels and over multiple scales. Many, but not all, of these changes can be tied back to the construction and operation of Libby Dam. With the completion of the IEI assessment, the Kootenai River Operational Loss Assessment, Protection, Mitigation, and Rehabilitation (OLA) project (BPA Project 200201100) has met the objectives of the project's first phase. Given these results, the project will now focus on developing and implementing a mitigation plan to identify and prioritize appropriate opportunities to rehabilitate significant ecological functions within the Kootenai River Valley. The plan will be aimed at protection, restoration, and mitigation of resources affected by the operation of Libby Dam. Additionally, project personnel will be available to provide information to other regional managers that might be interested in developing or implementing an IEI based assessment and/or monitoring protocol in their subbasins.

Once an Implementation Plan is completed, actions focused on mitigating the effects resulting from operation of Libby Dam will be proposed, evaluated, prioritized, implemented, and monitored. These projects singularly and cumulatively are expected to work towards mitigating the ecological effects related to the operation of Libby Dam for the benefit of Tribal members, local communities, and future generations.

Acknowledgements:

The authors would like to thank the Kootenai Tribe of Idaho for managing and coordinating the Operational Loss Project and the Bonneville Power Administration for provision of funding.

References:

Anders, P. J., D. L. Richards, M. S. Powell. 2002. The First Endangered White Sturgeon Population (*Acipenser transmontanus*): Repercussions in an Altered Large River-floodplain Ecosystem. Pages 67-82 *In*: W. Van Winkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, Management and Protection of North American Sturgeons. American Fisheries Society Symposium 28.

Angermeier, P .L. and J. R. Karr. 1994. Biological integrity versus biological diversity as policy directives. - BioScience 44: 690-697.

Bradford, D.F., S.E. Franson, A.C. Neale, D.T. Heggman, G.R. Miller, and G.E. Canterbury. 1998. Bird species assemblages as indicators of biological integrity in Great Basin rangeland. Environ. Manage. Assess.

Church, M., 1995. Geomorphic Response to River Flow Regulation: Case Studies and Time-Scales. Regulated Rivers: Research & Management 11, 3-11.

Gilbert, G.K. 1917. Hydraulic mining debris in the Sierra Nevada. U.S. Geol. Surv. Prof. Paper 105, 154 p.

Grafe, C.S. 2002. Idaho river ecological assessment framework: an integrated approach. Idaho Department of Environmental Quality, Boise, ID.

Jorde, K., Bratrich, C., 1998. River bed morphology and flow regulations in diverted streams: effects on bottom shear stress patterns and hydraulic habitat. Advances in River Bottom Ecology. Backhuys Publishers, Leiden, The Netherlands, pp. 47-63.

Jorde, K., Burke, M., Scheidt, N., Welcker, C., King, S., Borden, C., 2008. Reservoir operations, physical processes, and ecosystem losses. In: Habersack, H., Piégay, H., Rinaldi, M. (Eds.), Gravel-Bed Rivers VI: From Process Understanding to River Restoration. Elsevier, pp. 607-636.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21–27.

Karr, J. R. and D. R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5: 55-68.

Karr, J. R. and E. W. Chu. 1997. Biological monitoring and assessment: Using multimetric indexes effectively. EPA 235-R97-001. University of Washington, Seattle, WA.

Knudson, K. 1994. Water quality status report. Kootenay (Kootenai) River basin. British Columbia, Montana, and Idaho. Prepared for the Kootenai River Network. Ecological Resources Consulting. Helena, MT.

Kootenai Tribe of Idaho and Montana Fish, Wildlife, and Parks 2004. Kootenai River Subbasin Plan. http://www.nwcouncil.org/fw/subbasinplanning/kootenai/plan/

Ligon, F.K., Dietrich, W.E., Trush, W.J., 1995. Downstream Ecological Effects of Dams. Bioscience 45, 183-192.

Mebane, C.A., T.R. Maret, R.M. Hughes. 2003. An index of biological integrity for Pacific Northwest Rivers. Transactions of the American Fisheries Society 132: 239-261.

Naiman, R.J., Décamps, H., McClain, M.E., 2005. Riparia. Academic Press, San Diego.

Naiman, R.J., Elliot, S.R., Helfield, J.M., O'Keefe, T.C., 2000. Biophysical Interactions and the Structure and Dynamics of Riverine Ecosystems: The Importance of Biotic Feedbacks. Hydrobiologia 410, 79-86.

Paragamian, V., G. Kruse, and V. D. Wakkinen. 1996. Kootenai River fisheries investigations: stock status of burbot and rainbow trout and fisheries inventory. Idaho Department of Fish and Game, Annual Progress Report FY94, Project No. 88-65, Boise, ID.

Petts, G., 1984. Impounded Rivers: Perspective for Ecological Management. John Wiley & Sons, Chichester.

Richter, B.D., Baumgartner, J.F., Powell, J., Braun, D.P., 1996. A Method for Assessing Hydrologic Alterations within Ecosystems. Conservation Biology 10, 1163-1174.

Royer, T.V., C.T. Robinson, and G.W. Marshall. 2001. Development of macroinvertebrate-based index for bioassessment of Idaho Rivers. Environmental Mange. 27:627-636.

Snyder, E.B. and G.W. Minshall. 1996. Ecosystem metabolism and nutrient dynamics in the Kootenai River in relation to impoundment and flow enhancement for fisheries management. Final Report. Stream Ecology Center, Idaho State University, Pocatello, ID.

Williams, G.P., Wolman, M.G., 1984. Downstream Effects of Dams on Alluvial Rivers. United States Government Printing Office, U.S. Geological Survey Professional Paper 1286, 83 pp.

[Back to Table of Contents]

3. *Protecting our waters from invasive species: A collaborative approach in the Canadian Columbia Basin*

Juliet Craig
Silverwing Ecological Consulting
915 Vernon Street, Nelson, BC, V1L 4G7
julietcraig@uniserve.com
(250) 352-2260

The ecological, economic and social impacts of invasive species like zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena rostriformis*) are well documented. The economic impact of these species into BC has been predicted to cost $28 to $43 million with much of this cost being hydropower maintenance estimates. Given the highly suitable habitat for these mussels in the Columbia Basin, the number of boats travelling from mussel infested waters into BC, and the abundance of hydropower facilities, there is a growing concern about the potential introduction and impact of invasive mussels into the Columbia Basin. In fact, local citizens prioritized invasive species as one of the key ecosystem concerns during the Columbia Basin Trust (CBT) strategic planning process in 2013.

In 2014, a collaborative partnership was developed between the Columbia Basin Trust and the four regional invasive plant committees within the Columbia Basin (Central Kootenay Invasive Plant Committee, East Kootenay Invasive Plant Council, Columbia Shuswap Invasive Species Society and the Northwest Invasive Plant Council) to develop a strategic approach to Aquatic Invasive Species (AIS) prevention and management. The Program Framework includes goals and action items for five program areas including 1) Coordination and Collaboration; 2) Education and Outreach; 3) Watercraft Inspection and Decontamination; 4) Research and Monitoring; and 5) Response and Management.

The *Canadian Columbia Basin Regional Framework for an Aquatic Invasive Species Program 2015 – 2020* is available at:

http://ckiss.ca/wp-content/uploads/2015/04/FinalCBAIS_Regional_Program_Framework_1June2015.pdf

Back to Table of Contents

4. *Managing mountain whitefish (Prosopium williamsoni) egg loss through flow regulation in the Columbia River downstream of Arrow Lake*

James Baxter, BC Hydro, James.Baxter@bchydro.com, 250-365-4569, 601-18th Street, Castlegar, BC V1N 2N1

Co-authors: Brad Hildebrand, Golder Associates Ltd., Castlegar, BC
Sima Usvyatsov, Golder Associates Ltd., Castlegar, BC
Dana Schmidt, Golder Associates Ltd., Castlegar, BC
Josh Korman, Ecometric Research, Vancouver, BC
Guy Martel, BC Hydro, Burnaby, BC

The Columbia River downstream of Arrow Lakes is a regulated river that can be influenced by operations of dams on the Columbia River (Hugh Keenleyside Dam (HLK) and Arrow Lakes Generating Station(ALGS)) and lower Kootenay River (Brilliant Dam and Brilliant Expansion Project (BRD/X)). There is a substantial Mountain Whitefish (*Prosopium williamsoni*) population in this system that has the potential to be impacted by these operations. Flow reductions during the spawning period and egg incubation period can cause stranding of eggs in both river systems, and this has the potential to reduce the abundance of the population. During the winter of 1992/1993, it was identified that flow reductions had dewatered a significant number of incubating eggs, and it was estimated that roughly 60% of the eggs from that year were killed during that reduction. This caused concern both within BC Hydro and the regulatory agencies.

In an attempt to mitigate these impacts, a Whitefish Management Flow program (WMF) was initiated by BC Hydro in the winter of 1994/1995. The objective of this WMF was to reduce egg dewatering by minimizing the reductions in flow from HLK between spawning (Jan. 1-20) and incubation (Jan. 21 – Mar. 31) periods. BC Hydro has committed to try and negotiate these flows annually through discussions under the Columbia River Treaty, and in the fall of 2003 signed a letter to target accepted levels of egg mortality within a five year period after consultation with the Department of Fisheries and Oceans (Table 1).

Table 1. Mountain Whitefish egg mortality tier allocations.

Tier	Expected MWF Egg Mortality	Calculated 5-Year Frequency	Adjusted 5-Year Occurrence
1	0-20%	60%	3
2	20-40%	30%	2
3	40-60%	10%	0

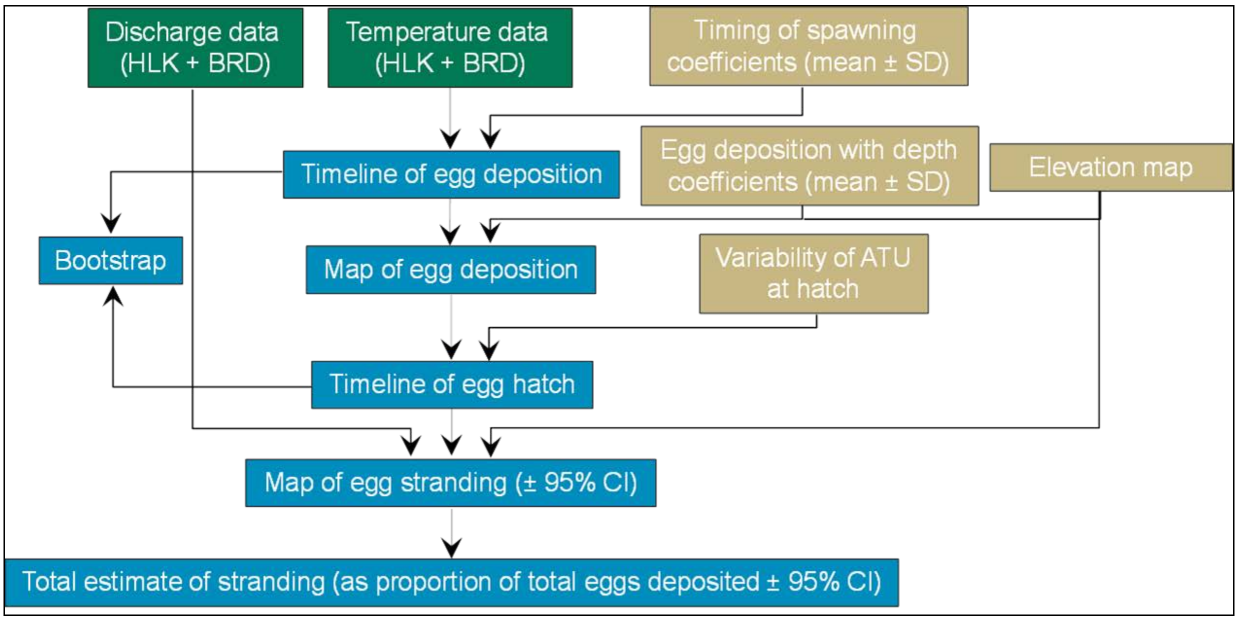
It was understood that the overall mortality targets (Table 1) were experimental in nature and not mandatory targets, but that BC Hydro would make reasonable efforts to achieve all targeted tiers. To do this a tool was needed to provide annual estimates of egg mortality, but also allow within season advice as to the level of flow reductions that could be made to achieve the desired tier of egg mortality. As such an initial Egg Loss Model (ELM) was developed in 2003 (Golder 2003), and the ELM predicted egg loss in four areas solely on depth based on a single HEC-RAS transect in four areas, and deterministic egg deposition timing curves, egg deposition with depth curves, and egg hatching timing curves. Egg loss was calculated in each of the four areas, and a weighted average from these four areas allowed a single estimate of egg mortality to be generated.

In the four years (starting in 2004/2005) following the signing of the letter with DFO, Tier 1 levels of egg mortality (see Table 1) were achieved each year (Table 2). This suggested that the WMF program was successful in meeting its target of keeping egg mortality at lower levels compared to prior to the implementation, and that the ability to use the ELM was allowing within season decisions to be made to keep egg mortality levels low. However in 2007 through the Columbia River Water Use Planning process, the consultative committee expressed concern about the reliability of the ELM for quantifying egg loss resulting from regulated flow changes (BC Hydro 2007), and it was identified that the low quality and quantity of topographic data was a key data gap (Golder 2014).

Table 2. Estimated Mountain Whitefish egg mortality from 2001/2002 to 2007/2008 using the egg loss model. Note 2004/2005 is the start of the estimates after agreed mortality levels with the Department of Fisheries and Oceans.

Operational Year[1]		**2001/2002**		**2002/2003**		**2003/2004**		**2004/2005**		**2005/2006**		**2006/2007**		**2007/2008**	
Pop. Indexing Mon.Year		**1**		**2**		**3**		**4**		**5**		**6**		**7**	
Tier	**Proportion Egg Loss**	**Egg Loss (%)[2]**	**Tier**	**Egg Loss (%)[2]**	**Tier**	**Egg Loss (%)[2]**	**Tier**	**Egg Loss (%)[2]**	**Tier**	**Egg Loss (%)[2]**	**Tier**	**Egg Loss (%)[2]**	**Tier**	**Egg Loss (%)[2]**	**Tier**
1	**0-20%**	3.1	X	17.3	X	17.0	X	12.3	X	14.0	X	10.7	X	7.6	X
2	**20-40%**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	**40-60%**	-	-	-	-	-	-	-	-	-	-	-	-	-	-

As such a process was put in place to develop an updated ELM that incorporated more comprehensive topographical and hydraulic data from multiple transects in the key spawning areas, as well as current egg depth deposition and timing data and developmental rates (Golder 2014). A new model was developed and delivered in 2014, and the only data that the user has to provide is water temperature and water discharge data for both the Kootenay (BRD/X) and Columbia (HLK and ALGS) rivers (Figure 1). The updated model provides maps of both egg deposition and egg stranding for a given model run for the two main spawning areas (CPR Island and Kootenay River; Figure 2), and generates a stranding estimates (with 95% CIs) for these two main areas as well.



*Green boxes designate input data required for every run, brown boxes designate model components developed for this study, and blue boxes designate steps in the model computation.

Figure 1. Flow chart of the components used in modelling Mountain Whitefish egg loss using the new model (see Golder 2014).

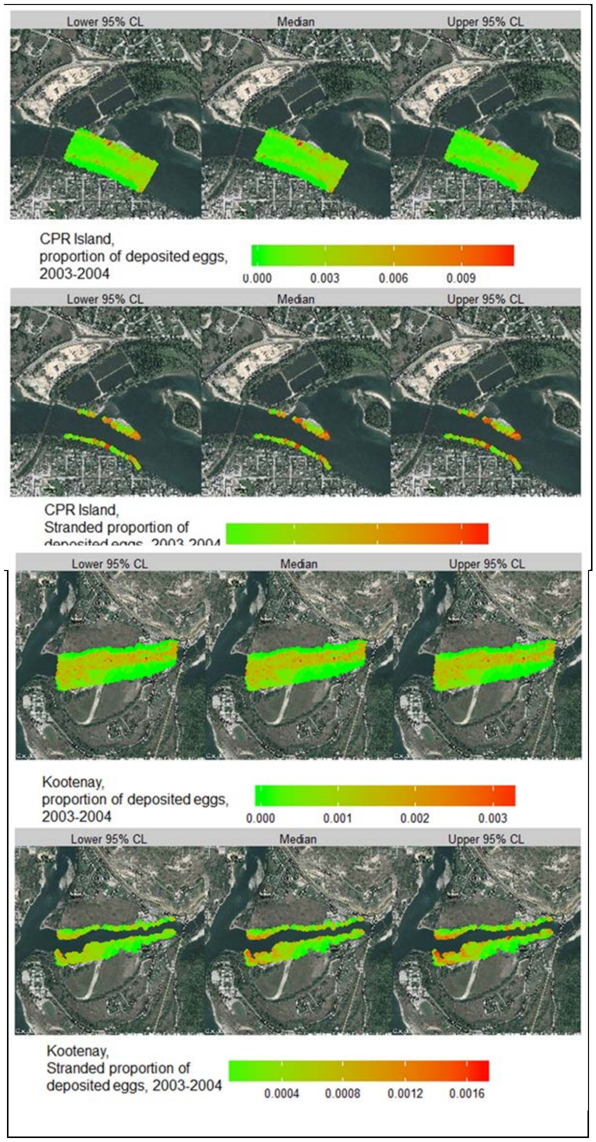


Figure 2. Maps of total egg deposition (upper panels) and proportion of stranded eggs out of those deposited (lower panels) at CPR Island and Kootenay River throughout the entire spawning and incubation period for 2003/2004 (November 1 to May 1). The maps are colour-coded based on deposition and standing levels (see Golder 2014).

The new model is a big improvement over the previous model, and incorporates more comprehensive habitat and Mountain Whitefish life-history data. This allows variability to be estimated around the total stranding calculation (Table 3). What is evident from a comparison of stranding estimates using the two models is that there are similarities in some years, and differences in others (Table 4). Despite this, the updated model will be the model used in the future to provide within season advice on flow requirements.

Table 3. Differences between previous and current ELMs (see Golder 2014).

	Previous model	Current model
Hydraulic data (depth)	Based on 4 HEC-RAS 1D transects	Based on 99 ADCP and topographic transects, and interpolation of 99 River2D model runs
Spatial scale	One-dimensional (depth)	Two-dimensional (depth and mean column velocity), spatially explicit, with egg deposition and stranding probabilities associated with each River2D node
Variability in egg deposition time	None; deterministic deposition curve with separate curves for Kootenay and Columbia River spawning areas	Based on six years of egg collections
Variability in egg deposition with depth	None; deterministic deposition curve	Based on six years of egg collections
Variability in egg hatching time	None; deterministic ATU to development	Based on distribution of developmental stages at different ATUs
Total stranding variability estimates	None; deterministic stranding estimates, provides a weighted average based on 1990's egg sampling data	Incorporation of bootstrapping allows estimation of variability around stranding estimates

Table 4. Comparisons of Mountain Whitefish egg mortality using the previous ELM and current ELM (see Golder 2014). The highlighted columns represent similar sites for the two models

Year	Original ELM Output					Updated ELM – CPR Island			Updated ELM – Kootenay River		
	Kootenay River	Kinnard Bridge Area	Lower Tin Cup Rapids	Upper Tin Cup Rapids	Weighted Average	Lower 95% CI	Median	Upper 95% CI	Lower 95% CI	Median	Upper 95% CI
2007	4.9%	12.2%	17.0%	10.3%	10.7%	13.3%	27.2%	46.1%	4.3%	11.4%	25.8%
2008	13.2%	25.5%	34.8%	64.2%	29.8%	23.1%	45.4%	67.5%	9.6%	30.5%	59.2%
2009	37.9%	#N/A	#N/A	18.1%	#N/A	14.6%	33.0%	55.3%	7.8%	32.7%	73.8%
2010	2.5%	6.8%	16.0%	21.4%	9.4%	10.9%	23.1%	44.0%	1.6%	4.3%	12.0%
2011	5.9%	9.4%	33.6%	27.5%	15.0%	14.6%	29.8%	52.1%	3.4%	8.7%	18.7%
2012	34.4%	27.5%	46.6%	52.1%	36.1%	23.9%	46.8%	70.1%	9.6%	33.7%	66.5%

So in terms of some general results and conclusions from the 20 years of work on Mountain Whitefish eggs what do we know?

1. Does flow regulation on the Columbia and Kootenay rivers impact developing Mountain Whitefish eggs? The answer is yes, and it probably has been since these dams were put in place. However, it's only been since we have started looking at what that impact was in the 1990's that the issue was raised. We do have a tool now to quantify that impact and the variability around it, and to provide within season advice on flow reductions.
2. Has the implementation of WMF reduced egg mortality? The estimated mortality for the two years prior to the implementation of WMF (1992 and 1993) were both the 40-60% level, whereas in the following years the majority of the estimates are in the 20-40% range (Table 5). The flows appear to have reduced egg mortality. Since 2003 we have had a tool to try and ensure we are in those lower levels of mortality and it has been successful.

3. Finally in a general sense has the implementation of these flows been of benefit to population? We know that implementation of these flows can result in lower egg mortality but does this translate to the adult population? We have had a stock recruitment analysis done using the egg loss data and the adult data that is generated under a separate project. The general conclusion from that work is that the effect of the WMF program on the population dynamics of Mountain Whitefish in the system is uncertain, but the average recruitment loss due to dewatering over the period of record ranges from 0-14% (see Korman 2015).

***Table 5. Estimated Mountain Whitefish egg mortality from 1992 to 2012 using the current ELM (see Korman 2015*).**

		Egg Loss Category			
Year	**Mean**	**0-20%**	**20-40%**	**40-60%**	**>60%**
1992	0.59	0.00	0.08	0.46	0.46
1993	0.44	0.02	0.34	0.56	0.09
1994	0.23	0.29	0.70	0.00	0.00
1995	0.48	0.01	0.25	0.59	0.15
1996	0.35	0.07	0.63	0.29	0.01
1997	0.23	0.33	0.67	0.00	0.00
1998	0.28	0.18	0.74	0.08	0.00
1999	0.34	0.08	0.63	0.28	0.01
2000	0.12	1.00	0.00	0.00	0.00
2001	0.12	0.99	0.01	0.00	0.00
2002	0.50	0.01	0.22	0.53	0.23
2003	0.25	0.22	0.76	0.01	0.00
2004	0.30	0.10	0.82	0.08	0.00
2005	0.28	0.15	0.80	0.05	0.00
2006	0.27	0.17	0.80	0.03	0.00
2007	0.27	0.18	0.77	0.04	0.00
2008	0.43	0.02	0.38	0.53	0.06
2009	0.32	0.09	0.72	0.19	0.00
2010	0.22	0.37	0.62	0.00	0.00
2011	0.29	0.13	0.78	0.09	0.00
2012	0.45	0.02	0.31	0.57	0.10

References

BC Hydro. 2007. CLBMON-47 Lower Columbia River Whitefish Spawning Ground Topographic Survey. Monitoring Program Terms of Reference, Columbia Water Use Plan.

Golder Associates Ltd. 2003. Estimates of Mountain Whitefish Egg Stranding Mortality for Potential Columbia River Flow Reductions in 2002-2003. Report prepared for BC Hydro, Castlegar, BC. Golder Report No. 02-28-057D: 12 p.

Golder Associates Ltd. 2014. Lower Columbia River Whitefish Spawning Ground Topography Survey: Year 3 Data Report. Report prepared for BC Hydro, Castlegar, BC. Golder Report No. 10-1492-0142F: 68 p. + 3 app.

Korman, J. 2015. Mountain Whitefish Flow Management Evaluation. Report prepared for BC Hydro, Burnaby and Castlegar, BC. 26 p.

Back to Table of Contents

5. *Flow management and trends for spawning rainbow trout in the lower Columbia River*

Robyn L. Irvine, robyn@poissonconsulting.ca, Poisson Consulting Ltd., Nelson, BC

Jeremy T.A. Baxter, jbaxter@redmtn.ca, Mountain Water Research, Silverton, BC
Joseph L. Thorley, joe@poissonconsulting.ca, Poisson Consulting Ltd., Nelson, BC
Guy Martel, Guy.Martel@bchydro.com, BC Hydro, Burnaby, BC

Background

Flow management to keep discharge from Hugh L. Keenleyside (HLK) Dam stable or increasing during the Rainbow Trout peak spawning and egg incubation periods in the Lower Columbia River were instituted in 1992. These Rainbow Trout Spawning Protection Flows were implemented to reduce redd dewatering and prevent potential population level effects. After a drop on April 1st, stable or increasing flows are maintained from HLK until June 30th.

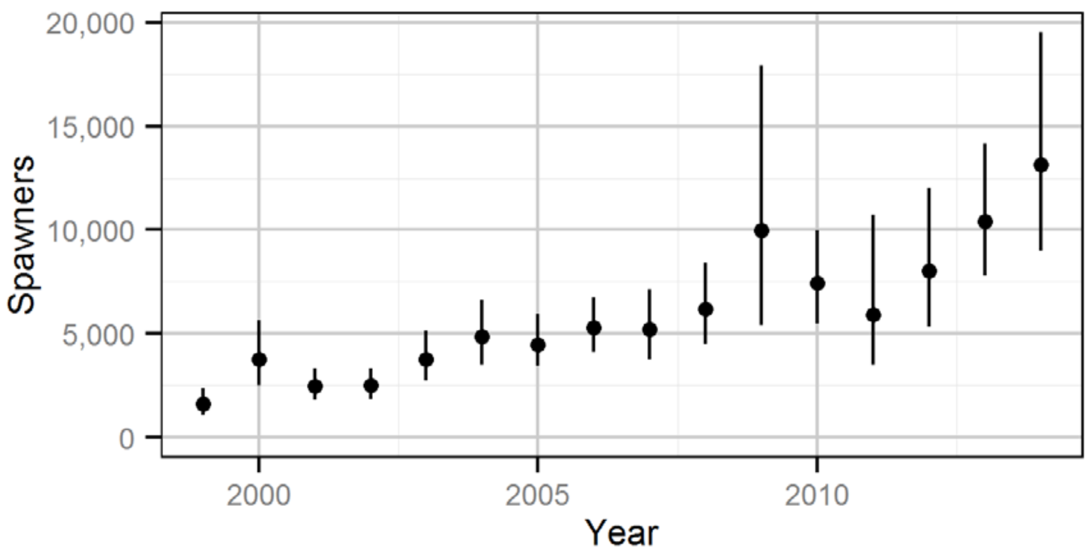
The purpose of the study program is 'to better understand the link between flow management strategy and population abundance.' There are three main management questions: the first question asks whether the protection flows have increased the spawner abundance of Rainbow Trout; the second asks if the spatial distribution and habitat use has increased as a result of the protection flows; and the third question asks if the majority of redds in the system are protected from dewatering by the protection flows. The population has been studied in the context of these management questions since 1999.

Methods

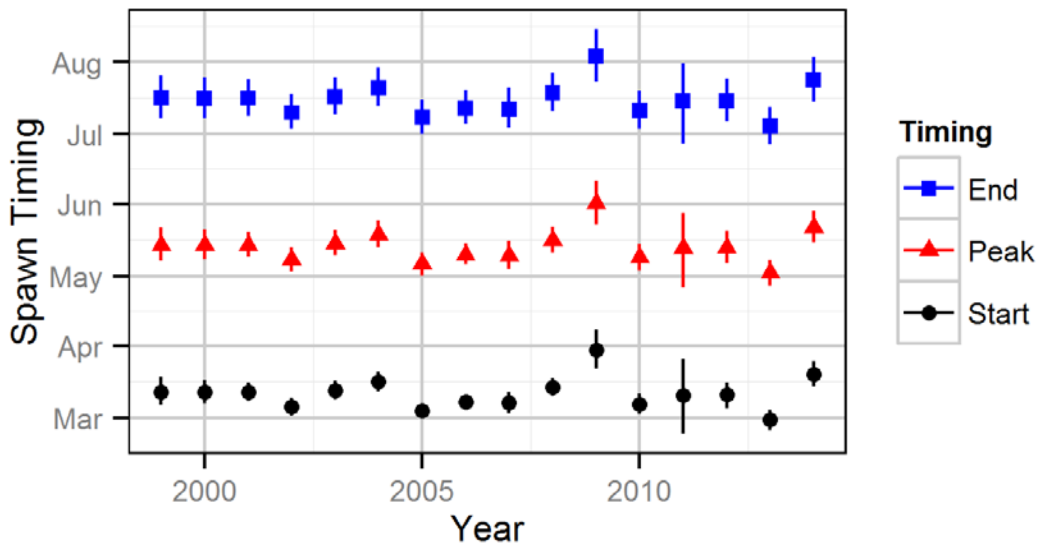
The adult Rainbow Trout spawner abundance and spatial distribution have been monitored with aerial counts of redds and fish. The redd dewatering levels and locations have been monitored with shallow redd counts and locational data carried out by boat survey immediately after the helicopter surveys. Count surveys typically span the March until May period, and are ceased when turbidity increases in spring prevent accurate enumeration of the redds and fish. In 2012, 20 fish were tagged with VEMCO tags and acoustic receivers were placed on the Norn's Creek fan in order to determine the residence time. Spawner and redd counts from helicopter surveys were analysed with Bayesian hierarchical models to determine timing of spawning and emergence and the abundance of spawners. The abundance was estimated with Area-Under-the-Curve modeling that uses both redd and spawner data to model arrival and departure curves with the incorporation of efficiency and residence time. The spatial distribution of spawners throughout the lower Columbia was assessed by calculating the Shannon Index

to look at the distribution of spawners at each site with a higher index indicating greater spatial distribution.
age-1 rainbow trout data were obtained from the BC Hydro Indexing program and combined with spawner data to carry out Beverton-Holt Stock Recruitment models.

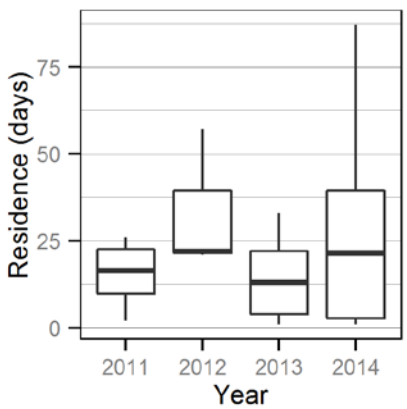
Results
The number of spawners has increased approximately 10-fold since the flows were instituted and was ~13,000 fish in 2014.



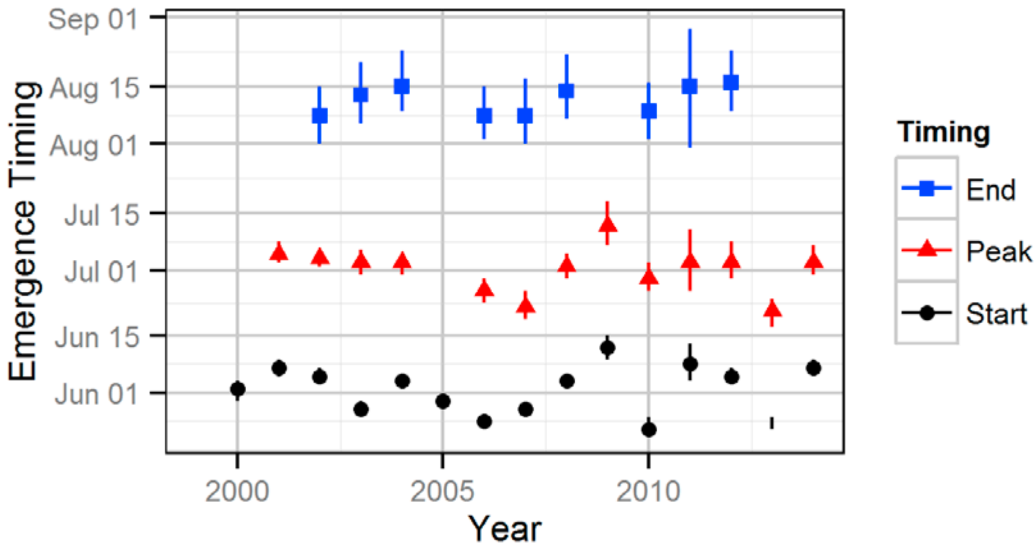
Three periods of spawning (start, peak, end) were delineated and estimates and 95% credibility intervals were derived for each period. Spawning in 2014 was estimated to commence on March 19, peak on May 21 and end on July 24 though spawners have been observed from January to July.



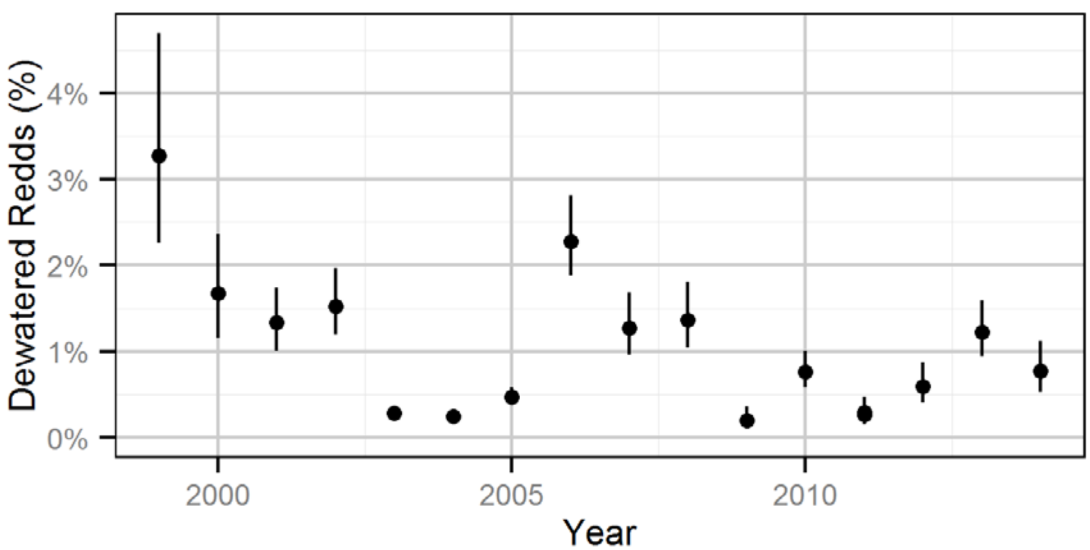
Residence time as determined from detections of radio-tagged fish was estimated to be 24.3 days. The mean estimate for peak fry emergence was July 3.



When predicting emergence timing, a similar approach was used as for determining the spawning timing with starting, peak and end points uses. The mean estimate of peak fry emergence for the 2014 spawn year was July 3 (95% CI June 30 – July 7). The mean estimate for the start of fry emergence was June 7 for 2014 (95% CI June 6- June 9). The end period of fry emergence mean estimate and the lower and upper credibility intervals could not be determined for some years due to missing temperature data. It is important to note that the last fry may not emerge until the second half of August.

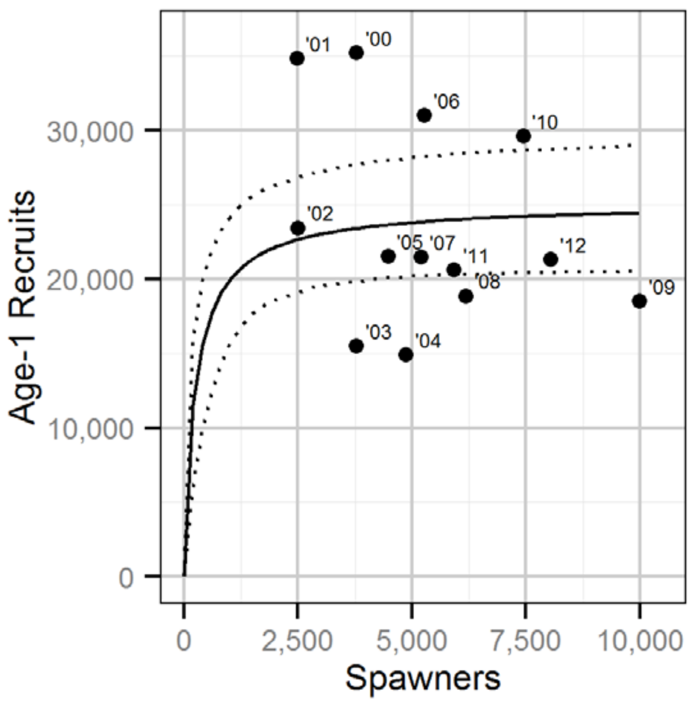


There were two years of study prior to protection flow implementation in 1992 where 50-75% of the redds at Norn's fan were dewatered. The lifespan of these data from 1999-2014 only cover protection flow years and overall, the percentage of dewatered redds by year is about 0.75% and ranges from almost zero to 3.3%. In the 2014 spawn year 77 redds were dewatered and this was estimated to be 0.78% of the total redds for the year

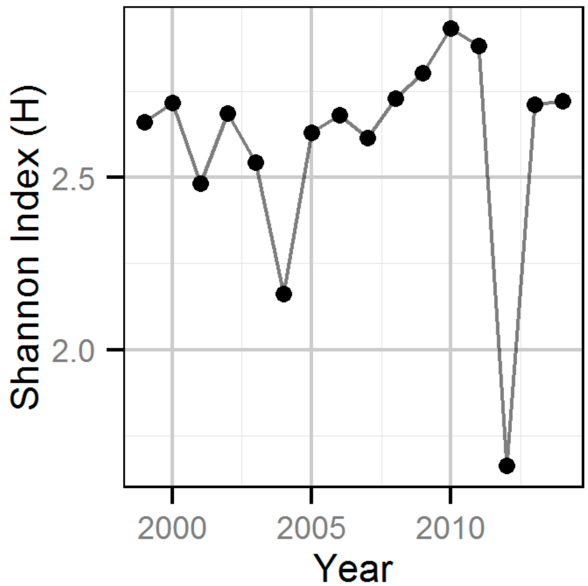


The Beverton-Holt stock recruitment model fitted to age-1 RB abundance vs. spawner abundance shows clear patterns of density dependent stock-recruitment dynamics. The abundance of age-1 Rainbow Trout at the index sites in the Lower Columbia River and Lower Kootenay River as estimated by the indexing program (Ford et al. 2013) is highest in the 2000, 2001, 2006 and 2010 spawn years. Those first two years in which both types of data were collected had the lowest combined redd / spawner abundance observed over the course of the study. This relationship between the age-1 fish and the spawner abundance is consistent with the density dependent curve. Also consistent with density dependence is the fact that the roughly quadrupled number of redds over the years are not strongly reflected in the numbers of age-1 recruits.

The relationship between age-1 RB and spawners suggests that recruitment of age-1 RB is unaffected (i.e., the curve does not drop off substantially) as long as a minimum of approximately 1,500 spawners are present in the system but the abundance has not fallen below that level to empirically test the minimum levels required



The spatial distribution has not changed significantly through time when estimated with the Shannon Index.



Discussion

The answer to whether the abundance has stabilized or increased due to protection flows is unanswered. From 1999 until 2014 the number of spawning rainbow trout has increased approximately 10 fold from 1600 to 13000. This could be a result of protection flows since they have been in place over the entire period or it could be due to other environmental factors. There are good data on the fish numbers consistently collected over the course of the study program, but there is little variation in the flows to test whether or not it is the flow protection that has been the major causal factor. The xecond management question of whether spatial distribution of spawners has increased due to flow protection also remains unanswered at this time. The distribution of spawning activity among the spawning sites was estimated and has not increased since 1999. The third management question pertaining to whether the protection flows have reduced the number of redds dewatered has been answered in the affirmative by this study program. The number of dewatered redds was not well documented prior to the advent of the protection flows, but estimates were that in 1990 and 1991, approximately 50-75% of the redds on Norn's fan were dewatered and now the percentage of dewatered redds is generally less than 1%.

Back to Table of Contents

6. *Is blue power green? Synthesis of the effects of run-of-river hydropower on salmonids**

Gibeau P.[1,2,†], B.M. Connors[3,4,] and W. J. Palen[1,2]
[1]Earth to Ocean Research Group, Simon Fraser University, Burnaby, BC, Canada
[2]Department of Biological Sciences, Simon Fraser University, Burnaby, BC, Canada
[3]ESSA Technologies, Vancouver, BC, Canada
[4]School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC, Canada
[†] pgibeau@sfu.ca, phone: 01-778-266-0142
*(in prep for peer-reviewed publication, Summer 2015)

Rivers are dynamic, disturbance-driven ecosystems, where flow plays a fundamental role in structuring aquatic and riparian communities (Resh et al. 1988, Poff et al. 1997, Murchie et al. 2008). The natural flow regime (NFR) of rivers is defined by the magnitude, frequency, duration, timing, and rate of change of flow events, all of which directly and indirectly affect stream-dwelling aquatic populations over evolutionary timescales (Poff et al. 1997, Bunn & Arthington 2002, Cowx et al. 2012). Many anthropogenic activities can alter the flow and disturbance regimes of streams, which in turn may affect the fitness and survival of native organisms (Poff & Ward 1990, Reice et al. 1990, Strayer & Dudgeon 2010). Impoundment of water by dams is one of the greatest anthropogenic drivers of change to NFRs. Small-scale hydropower production, consisting largely of Run-of-River hydropower (ROR), has emerged as an alternative to the creation of new large dams and reservoirs in recent decades because of their perceived lower economic, social, and environmental costs (Postel et al. 1996, Abbasi & Abbasi 2011, Anderson et al. 2014). As a consequence, the number of ROR hydropower projects has increased considerably over the last two decades in Canada (Cyr et al. 2011,Jaccard et al. 2011, Sopinka et al. 2013), and worldwide (e.g. Indian Himalaya: Grumbine & Pandit 2013; China: Wang et al. 2010). The adverse effects of flow alteration by ROR hydropower are often considered to be small and localized compared to large hydropower reservoirs. However, there is limited peer-reviewed research directed towards understanding how ROR hydropower influences individual stream-dwelling organisms or their populations. Based on an extensive peer-reviewed literature synthesis, we detail three hypothesized pathways of effects by which ROR hydropower has the potential to affect salmonids (Figure 1).

Pathway of effect 1: Presence of a dam

The presence of a dam as a physical barrier is not a unique feature of ROR hydropower, and the effects of ROR dams on fish populations are likely to be similar to some degree to those of larger reservoir-storage systems. Dams can affect fish populations via:

- Mortality associated with entrainment: similarly to reservoir-storage hydropower systems (Skalski et al. 2002), the intake structures of ROR hydropower projects may entrain fish in the penstock or turbines, often leading to injury and mortality. Entrainment, risks as noted in reservoir-storage systems, depend on the amount of water diverted, as well as fish species and season (Martins et al. 2013).
- Habitat fragmentation: The physical presence of a dam in a stream network also results in the disruption of the longitudinal connectivity of the river (Vannote et al. 1980) and dams often act as a barrier to fish movement and migration. Changes to gene flow may potentially increase genetic drift, alter potential for local adaptations, and increase extinction risk. The consequences of habitat fragmentation and potential for genetic drift may be enhanced by the fact that ROR dams are often built on relatively small, high gradient streams that tend to support smaller salmonid populations than the large order streams and rivers where large reservoirs are typically situated. The risk for the survival and fitness may be greater for these small populations because genetic drift may occur more rapidly than in large populations, leading to inbreeding and increased vulnerability to environmental stress (Altukhow et al. 2000, Heggenes & Roed 2006). The presence of dams may compromise the stability of rivers by decreasing connectivity and the diversity of processes contributing to portfolio effects and metapopulation resilience, especially in smaller watersheds that are typically more variable (Yeakel et al. 2014, Moore et al. 2015).
- Perturbation of the geomorphological processes that structure fish habitat: low-elevation dams can also act as discontinuities in the natural transport of sediment and organic matter in streams (Cushman 1985, Csiki & Rhoads 2010, Renofalt et al. 2010, Baker et al. 2011). High natural temporal and spatial variability in flow and sediment regimes combined with few studies on geomorphic impacts of ROR dams mean that there is little conclusive evidence of potential impacts (Csiki & Rhoads 2010, Baker et al. 2011). However, reduced water turbulence and velocity in diversion reaches has been associated in low-head dams with higher fine sediment accumulation and embeddedness of gravels (Baker et al. 2011).

Pathway of effect 2: Probabilistic Flow Fluctuations

Probabilistic flow fluctuations are another frequent outcome of production of hydroelectricity by ROR facilities, with potential consequences for salmonids. ROR hydropower operations create flow fluctuations by purposely increasing or decreasing the flow diverted to the turbines to match electricity demand, as well as for planned and emergency shutdowns. These operational procedures often result in more rapid changes in flow in the diversion and downstream reaches than would occur under natural conditions. As the amount of water needed to generate electricity changes over minutes or hours, the water not used for electricity generation is rapidly rerouted to the diversion reach, which can lead to sudden increases in flow in the diversion reach. The lag in time in takes water to travel the length of the diversion reach compared to through the penstock also creates a sudden, and sometimes substantial, drop of flow downstream of the powerhouse. Rapid increases in flow have been associated downstream of large reservoir-storage systems with the displacement or flushing of juvenile trout, increased energetic costs to fry foraging or holding, and scouring of redds (Harby & Halleraker 2001, Nislow & Armstrong 2012). Declines in flow in the downstream reaches lead to declines in water levels (stage) in the stream channel and concurrent declines in wetted width and depth. As noted in reservoir-storage systems, a rapid decline in water stage in a stream channel following fluctuations in flow can cause fish stranding, and high levels of stress, injury, and mortality, which in turn can lead to reduced population productivity (Bell et al. 2008, Nagrodski et al. 2012). Declining flows can also isolate fish in pools, leading to mortality as a result of increased predation, temperature shock, or lack of oxygen (Cushman 1985, Bradford 1997). Salmonid fry are more vulnerable to stranding or isolation in pools than other life stages because fry have limited swimming capacities and inhabit low-velocity, shallow habitats most susceptible to dewatering (Bonneau & Scarnecchia 1998, Bell et al. 2008, Korman et al. 2011). Several factors influence the risk of stranding for fry of resident and anadromous salmonids.

Pathway of effect 3: Flow diversion

The diversion of flow for the production of electricity by ROR hydropower is likely to alter the physical and geomorphic characteristics of the rivers in which it occurs. The diversion of flow by ROR hydropower can influence all reaches in a river:

- Upstream reach: impounds flow and modifies riverine habitat with subsequent impacts on macrophytes, invertebrates, and fish (Santucci et al. 2005, Mueller et al. 2011, Anderson et al. 2014).
- Downstream reach: may induce probabilistic flow fluctuations (see Pathway 2) or dissolved gas super-saturation (Weitkamp and Katz 1980), but does not affect NFR since all water is returned.
- Diversion reach: As observed in rainfall-runoff mountainous areas of China (Fig 2a) or northern snow-dominated watersheds of Canada (Figure 2b), most if not all flow is diverted to the turbines at low to moderate flows in systems with ROR facilities, which consequently changes the frequency, duration, timing, and magnitude of extreme low flows in the diversion reaches (Kibler & Tullos 2013). On the contrary, during high flows, discharges to the diversion reach follow more closely the natural timing and frequency of natural high flows because the headponds do not have much water storage capacity (Poff & Hart 2002). The potential changes to NFR due to ROR hydropower in the diversion reach is therefore best characterized by the accentuation of low flows and dry-season rather than by changes to the timing, magnitude and frequency of high flows that are common in systems regulated by storage-reservoirs dams (Kibler & Tullos 2013). Based on knowledge accumulated in natural and regulated rivers, we hypothesize that the changes in magnitude, timing, and frequency of low flow periods in the diversion reach of ROR systems may induce changes to habitat quantity, diversity, and quality mainly through changes in

water temperature, as well as declines in channel wetted width, depth, and water velocities (Kubečka et al. 1997, Baker et al. 2011, Nislow & Armstrong 2012).

Conclusion

ROR hydropower is an emerging component of renewable energy portfolios worldwide, largely because of its perceived lower economic, social, and environmental costs compared to traditional hydroelectricity production (Postel et al. 1996, Abbasi & Abbasi 2011, Kibler 2011, Anderson et al. 2014). We argue that there are two characteristics of ROR hydropower that are the primary differences in how they change NFR and may impact salmonids compared to large dams and reservoir-storage systems. First, ROR dams have the potential to accentuate the frequency, magnitude, and duration of low flow periods in the diversion reach, while not controlling much the incidence and characteristics of high flows. Second, compared to most large dams and reservoirs, ROR dams are typically located in small creeks hosting small salmonid populations that are likely to be more vulnerable to genetic drift and environmental perturbations. Our synthesis of the peer-reviewed literature also shows that, despite the limited amount of studies directed specifically at the environmental impacts of ROR hydropower (27 papers), we can expect most potential effects on salmonids to occur along the three main pathways of effects described above. Additionally, evidences from BC are mostly inconclusive, as illustrated by an extensive independent review of the monitoring reports that concluded that most pathways of effects were possibly affecting salmonids (at 70-90% of existing ROR in the province, Connors et al. 2014). All that highlights the need to conduct more research to substantiate the pathways describe here, and understand better how ROR hydropower may influence salmonids.

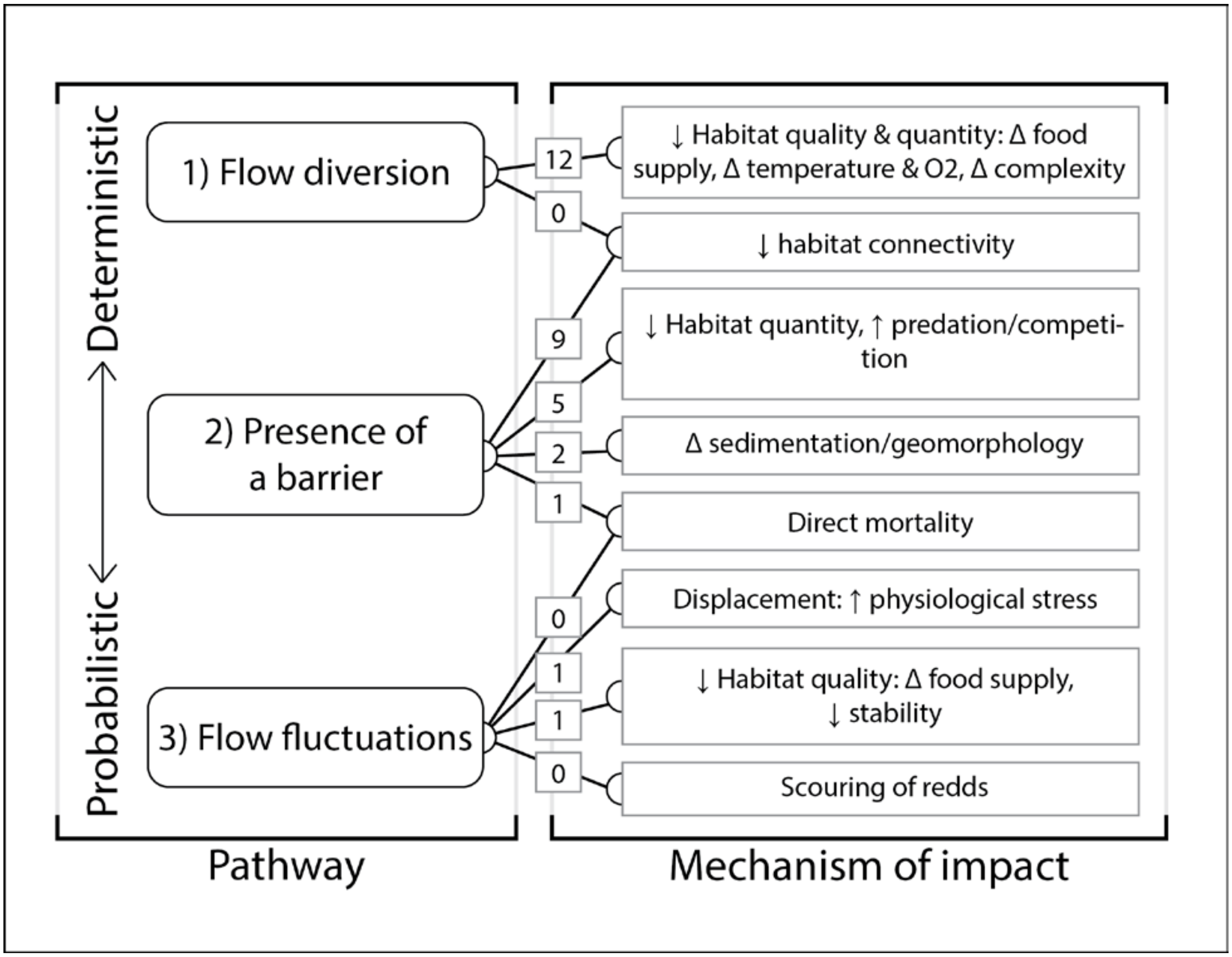


Figure 1:Conceptual model of the three main hypothesized pathways describing th potential ways in which ROR hydropower may influence salmonid growth, recruitment, abundance, and population productivity. The pathways are ordered along a deterministic to probabilistic gradient of occurrence. The specific mechanisms by which each pathway might ultimately affect growth, abundance, recruitment and productivity population productivity are noted in the middle boxes. Numbers along each link refer to the number of peer-reviewed papers specifically on ROR hydropower that supported directly or indirectly the mechanism.

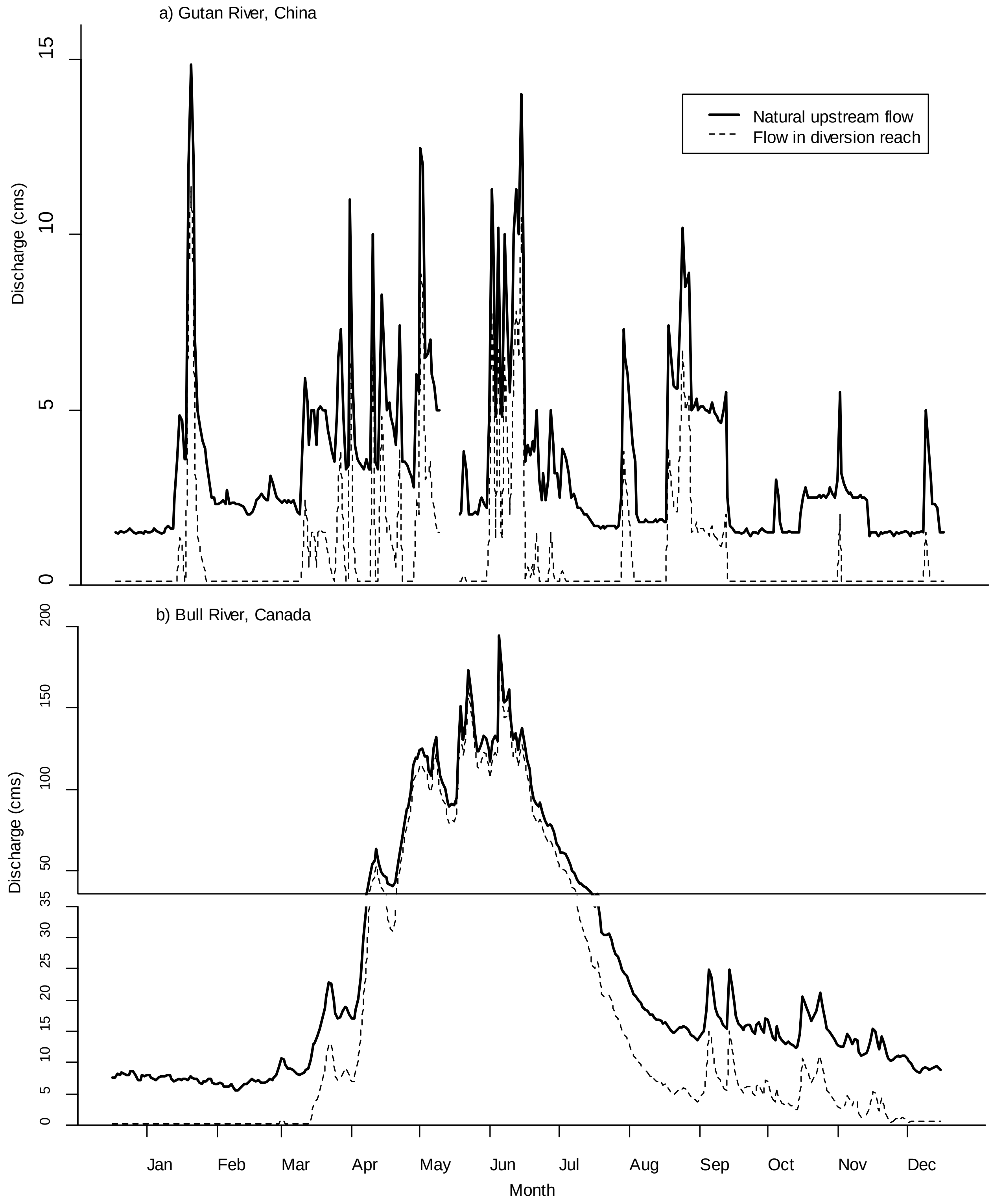


Figure 2:Modeled natural upstream flows (black line) and flows passing through the diversion reaches(dashed line) during an average runoff year below a RoR hydropower dam in a) Yunnan Province, China (rain-dominated Gutan River, Lushui County, adapted from Kibler and Tullos 2013), and b) south-eastern British Columbia,

Canada (snowmelt-dominated Bull River, natural flow averaged from 2010-2013, diverted flow modelled with a hypothetical turbine flow of 9.9 cms; www.bchydro.com). Flow alterations in the diversion reaches are more pronounced during low to moderate flows, when ROR hydropower operations remove the highest proportion of flow from the channel. The Bull River has a minimum flow requirement varying between 0.25 and 2.0 cms, depending on the season.

References

Abbasi, T. & Abbasi, S.A. (2011). Small hydro and the environmental implications of its extensive utilization. *Renew. Sustain. Energy Rev.*, 15, 2134–2143.

Altukhow, Y.P., Salmenkova, E.A. & Omelchenko, V.T. (2000). The theoretical principles of population genetics. In: *Salmon. Fishes Popul. Biol. Genet. Manag.* Blackwell, United Kingdom, pp. 1–32.

Anderson, D., Moggridge, H., Warren, P. & Shucksmith, J. (2014). The impacts of "run-of-river" hydropower on the physical and ecological condition of rivers. *Water Environ. J.*

Baker, D.W., Bledsoe, B.P., Albano, C.M. & Poff. (2011). Downstream effects of diversion dams on sediment and hydraulic conditions of Rocky Mountain streams. *River Res. Appl.*, 27, 388–401.

Bell, E., Kramer, S., Zajanc, D. & Aspittle, J. (2008). Salmonid fry stranding mortality associated with daily water level fluctuations in Trail Bridge Reservoir, Oregon. *North Am. J. Fish. Manag.*, 28, 1515–1528.

Bonneau, J.L. & Scarnecchia, D.L. (1998). Seasonal and diel changes in habitat use by juvenile bull trout (Salvelinus confluentus) and cutthroat trout (Oncorhynchus clarki) in a mountain stream. *Can. J. Zool.*, 76, 783–790.

Bradford, M.J. (1997). An experimental study of stranding of juvenile salmonids on gravel bars and in sidechannels during rapid flow decreases. *Regul. Rivers Resour. Manag.*, 13, 395–401.

Bunn, S.E. & Arthington, A.H. (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environ. Manage.*, 30, 492–507.

Connors, B.M., Marmorek, D.R., Olson, E., Hall, A.W., de la Cueva Bueno, P., Bensen, A., Bryan, K., Perrin, C., Parkinson, E., Abraham, D., Alexander, C., Murray, C., Smith, R., Grieg, L. & Farrell, G. (2014). Independent review of run-of-river hydroelectric projects and their impacts on salmonid species in British Columbia.

Cowx, I.G., Noble, R.A., Nunn, A.D., Bolland, J., Walton, S., Peirson, G. & Harvey, J.P. (2012). Flow requirements of non-salmonids. *Fish. Manag. Ecol.*, 19, 548–556.

Csiki, S. & Rhoads, B.L. (2010). Hydraulic and geomorphological effects of run-of-river dams. *Prog. Phys. Geogr.*, 34, 755–780.

Cushman, R.M. (1985). Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. *North Am. J. Fish. Manag.*, 5, 330–339.

Cyr, J.-F., Landry, M. & Gagnon, Y. (2011). Methodology for the large-scale assessment of small hydroelectric potential: application to the province of New Brunswick (Canada). *Renew. Eergy*, 36, 2940–2950.

Grumbine, R.E. & Pandit, M.K. (2013). Threats from India's Himalaya Dams. *Science*, 339, 36–37.

Harby, A. & Halleraker, J.H. (2001). Ecological impacts of hydropeaking in rivers. *Hydropower Dams*, 132–135.

Heggenes, J. & Roed, K.H. (2006). Do dams increase genetic diversity in brown trout (Salmo trutta)? Microgeographic differentiation in a fragmented river. *Ecol. Freshw. Fish*, 15, 366–375.

Jaccard, M., Melton, N. & Nyboer, J. (2011). Institutions and processes for scaling up renewables: Run-of-river hydropower in British Columbia. *Energy Policy*, 39, 4042–4050.

Kibler, K.M. (2011). *Development and decommissioning of small dams: analysis of impact and context* (Doctor of Philosophy (PhD)).

Kibler, K.M. & Tullos, D.D. (2013). Cumulative biophysical impact of small and large hydropower development in Nu River, China. *Water Resour. Res.*, 49, 3104–3118.

Korman, J., Walters, C.J., Martell, S.J.D., Pine III, W.E. & Dutterer, A. (2011). Effects of flow fluctuations on habitat use and survival of age-0 rainbow trout (Oncorhunchus mykiss) in a large, regulated river. *Can. J. Fish. Aquat. Sci.*, 68, 1097–1109.

Kubečka, J., Matěna, J. & Hartvich, P. (1997). Adverse ecological effects of small hydropower stations in the Czech Republic: 1. bypass plants. *Regul. Rivers Res. Manag.*, 13, 101–113.

Martins, E.G., Gutowsky, L.F.G., Harrison, P.M., Patterson, D.A., Power, M., Zhu, D.Z., Leake, A. & Cooke, S.J. (2013). Forebay use and entrainment rates of resident adult fish in a large hydropower reservoir. *Aquat. Biol.*, 19, 253–263.

Moore, J.W., Beakes, M.P., Nesbitt, H.K., Yeakel, J.D., Patterson, D.A., Thompson, L.A., Phillis, C.C., Braun, D.C., Favaro, C., Scott, D., Carr-Harris, C. & Atlas, W.I. (2015). Emergent stability in a large, free-flowing watershed. *Ecology*, 96, 340–347.

Mueller, M., Pander, J. & Geist, J. (2011). The effects of weirs on structural stream habitat and biological communities. *J. Appl. Ecol.*, 48, 1450–1461.

Murchie, K.J., Hair, K.P.E., Pullen, C.E., Redpath, T.D., Stephens, H.R. & Cooke, S.J. (2008). Fish response to modified flow regimes in regulated rivers: research methods, effects and opportunities. *River Res. Appl.*, 24, 197–217.

Nagrodski, A., Raby, G.D., Hasler, C.T., Taylor, M.K. & Cooke, S.J. (2012). Fish stranding in freshwater systems: sources, consequences, and mitigation. *J. Environ. Manage.*, 103, 133–141.

Nislow, K.H. & Armstrong, J.D. (2012). Towards a life-history-based management framework for the effects of flow on juvenile salmonids in streams and rivers. *Fish. Manag. Ecol.*, 19, 451–463.

Poff, N.L., Allan, D.J., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E. & Stromberg, J.C. (1997). The natural flow regime. *BioScience*, 47, 769–784.

Poff, N.L. & Hart, D.D. (2002). How dams vary and why it matters for the emerging science of dam removal. *BioScience*, 52, 659–668.

Poff, N.L. & Ward, J.V. (1990). Physical habitat template of lotic systems: recovery in the context of historical pattern of spatiotemporal heterogeneity. *Environ. Manage.*, 14, 629–645.

Postel, S., Daily, G.C. & Ehrlich, P.R. (1996). Human appropriation of renewable fresh water. *Science*, 271, 785–788.

Reice, S.R., Wissmar, R.C. & Naiman, R.J. (1990). Disturbance regimes, resilience, and recovery of animal communities and habitats in lotic ecosystems. *Environ. Manage.*, 14, 647–659.

Renofalt, B.M., Jansson, R. & Nilsson, C. (2010). Effects of hydropower generation and opportunities for environmental flow management in Swedish riverine ecosystems. *Freshw. Biol.*, 55, 49–67.

Resh, V.H., V., B., Arthur, Covich, Alan P., Gurtz, Martin E., Li, Hiram W., Minshall, G. Wayne, Reice, Seth R.; Wissmar, Robert C.; Naiman, Robert J., Sheldon, Andrew L., Wallace, J. Bruce & Wissmar, Robert C. (1988). The role of disturbance in stream ecology. *J. North Am. Benthol. Soc.*, 7, 433–455.

Santucci, V.J.J., Gephard, S.R. & Pescitelli, S.M. (2005). Effects of multiple low-head dams on fish, macroinvertebrates, habitat, and water quality in the Fox river, Illinois. *North Am. J. Fish. Manag.*, 25, 975–992.

Skalski, J.R., Mathur, D. & Heisey, P.G. (2002). Effects of turbine operating efficiency on smolt passage survival. *North Am. J. Fish. Manag.*, 22, 1193–1200.

Sopinka, A., van Kooten, G.C. & Wong, L. (2013). Reconciling self-sufficiency and renewable energy targets in a hydro dominated system: the view from British Columbia. *Energy Policy*, 61, 223–229.

Strayer, D.L. & Dudgeon, D. (2010). Freshwater biodiversity conservation: recent progress and future challenges. *J. North Am. Benthol. Soc.*, 29, 344–358.

Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R. & Cushing, C.E. (1980). The River Continuum Concept. *Can. J. Fish. Aquat. Sci.*, 37, 130–137.

Wang, G., Fang, Q., Zhang, L., Chen, W., Chen, Z. & Hong, H. (2010). Valuing the effects of hydropower development on watershed ecosystem services: case studies in the Jiulong river watershed, Fujian Province, China. *Estuar. Coast. Shelf Sci.*, 86, 363–368.

Yeakel, J.D., Moore, J.W., Guimaraes Jr., P.R. & de Aguiar, M.A.M. (2014). Synchronisation and stability in river metapopulation networks. *Ecol. Lett.*, 17, 273–283.

Back to Table of Contents

7. BC Hydro Water Use Planning – Investigations of mountain whitefish (*Prosopium williamsoni*) spawning and life history programs in the lower Columbia River

These programs were funded by BC Hydro and conducted by Golder Associates Ltd. in partnership with the Okanagan Nation Alliance Fisheries Department.
Brad Hildebrand, Golder Associates Ltd. bhildebrand@golder.com, 250-365-0344. 201 Columbia Ave, Castlegar, BC. V0G 1X0.

The BC Hydro Water Use Plan encompasses management plans throughout many regions in the province. This presentation is on the Lower Columbia River Fish Management Plan, which is an adaptive management plan to address fish stranding impacts and protect spawning and rearing of Mountain Whitefish and Rainbow Trout populations in the Lower Columbia River. It includes several monitoring programs to assess the effectiveness of flow decisions on fish populations. This presentation will focus on the CLBMON-47 Lower Columbia River Whitefish Spawning Ground Topography Survey and the CLBMON-48 Lower Columbia River Whitefish Life History and Egg Collection Mat Programs that are part of the Lower Columbia River Fish Management Plan (Figure 1).

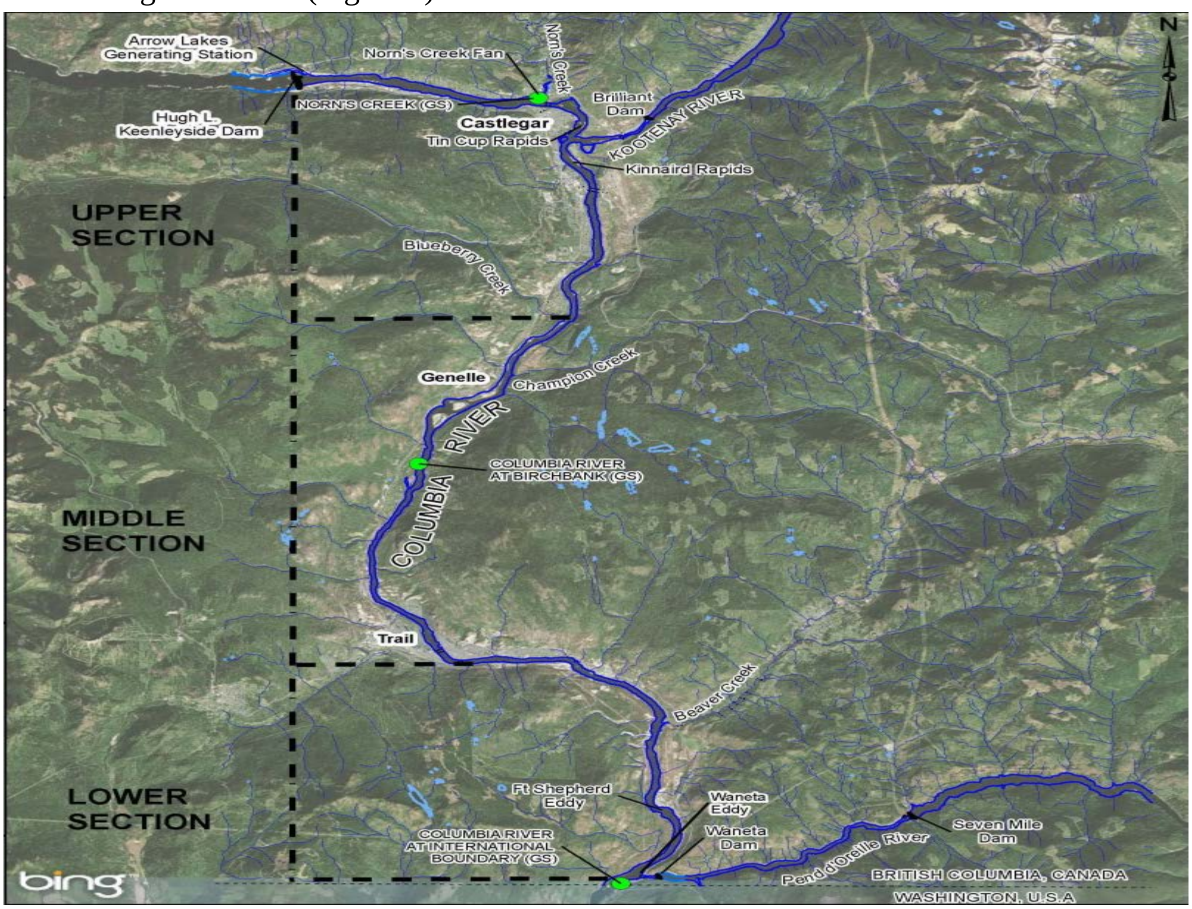


Figure 1: CLBMON-47 and CLBMON-48 Overall Study Area

The CLBMON-48 program was five years in duration, and included six management questions and study hypotheses. Sampling was conducted for all Mountain Whitefish life stages, utilizing multiple sampling techniques (Golder 2014).

Results from the adult telemetry program indicated that female dual-tagged Mountain Whitefish exhibited higher overall total and net movements than males (Table 1). Female movements were slightly greater, but differences in total and net movements between sexes were not statistically significant (*p* values of 0.15 and 0.24, respectively; Golder 2009).

Table 1: Summary of total and net movements of dual-tagged Mountain Whitefish detected in the study area, October 2008 to March 2009.

Category	***n***	**Total Movement (km)a**				**Net Movement (km)a**			
		Mean	**Min.**	**Max.**	**St. Dev.**	**Mean**	**Min.**	**Max.**	**St. Dev.**
Female	28	48.4	2.4	105.3	30.7	24.2	1.4	55.9	16.8
Male	20	36.0	2.0	91.8	25.1	19.0	1.1	45.3	12.0
All	**48**	**43.2**	**2.0**	**105.3**	**28.9**	**22.0**	**1.1**	**55.9**	**15.1**

[a] Total Movement = sum of all detected movements; Net Movement = difference between furthest upstream and downstream detections.

The habitat characteristics documented at key Mountain Whitefish spawning areas in the present study are very similar to those recorded in the 1990s (R.L.&L. 2001). Spawning in both areas occurred over predominantly cobble-boulder substrate (greater than 65 mm diameter). In previous studies, documented egg deposition areas were located in 0.5 to 9.0 m water depth with surface velocities from 0.1 to 3.4 m/s and upstream from riffles or rapids (R.L.& L. 1997, 1999, 2000, 2001).

In order to determine the depth at which the majority of Mountain Whitefish egg deposition occurred within the key spawning areas, the egg deposition probability (EDP) was modelled based on data collected during egg mat sampling (Figure 2). At CPR Island, EDP peaked at 1.7-1.8 m depth in 2009 and 2011. In 1997, EDP peaked at 2.6 m over a narrower range of depths than other study years. In 2010, egg deposition occurred over a wide range of depths with a slight peak at 4.0 m. In the Kootenay River, the EDP peaked between 2.7 m and 4.4 m in all study years, with the widest depth ranges in 2010 and 2012 (Figure 2).

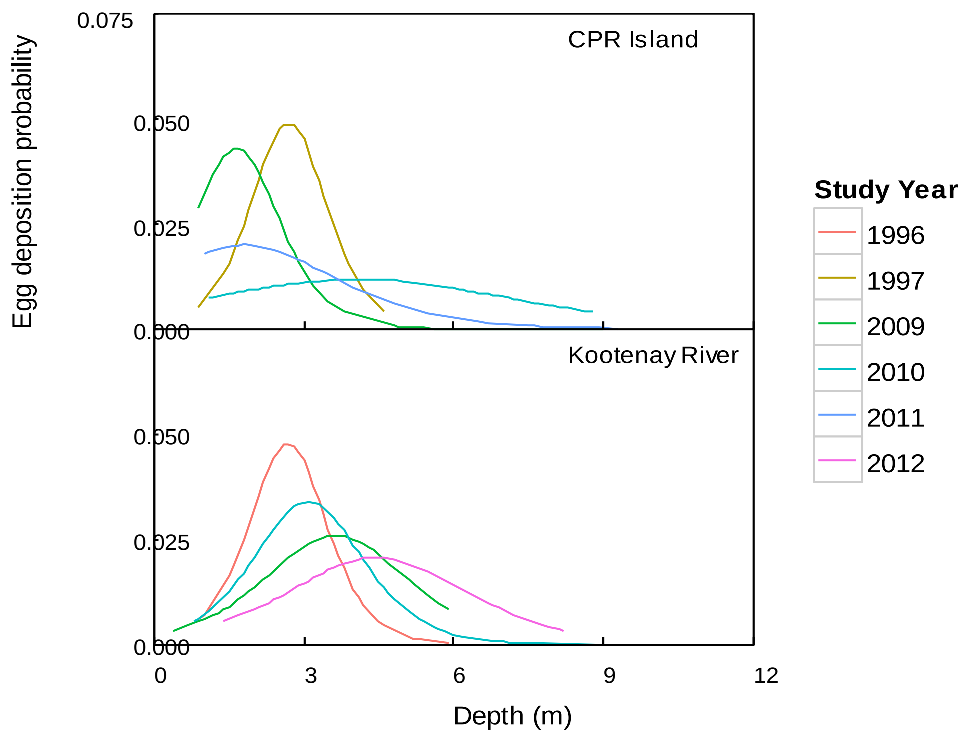


Figure 2: Egg deposition probability at the key spawning areas as a function of depth (m), modeled separately for each year and river.

The EDP was also modelled using the mean column velocities interpolated from the River 2D models created as part of the CLBMON-47 program (Figure 3). At CPR Island in 1997, the peak EDP occurred at a mean column velocity of approximately 0.4 m/s, compared to 0.8 m/s in 2011, and 1.1 m/s in 2009 and 1.3 m/s in 2010. Egg deposition occurred over a wider range of velocities in 2009, 2010, and 2011 compared to 1997. In the Kootenay River, the EDP patterns and ranges were similar for 1996 and 2012 and for 2009 and 2010 (Figure 3). Peak EDP occurred between 0.8 m/s and 1.4 m/s in all years studied although egg deposition occurred over a narrower range of velocities in 1996 and 2012 than in 2009 and 2010.

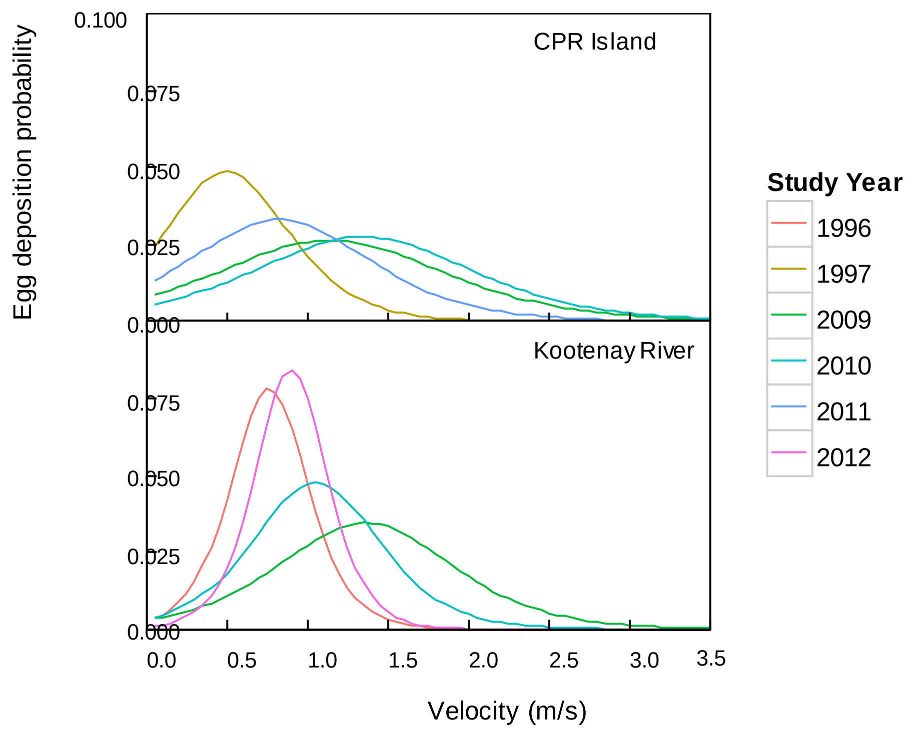


Figure 3: Egg deposition probability at the key spawning areas as a function of mean column velocity (m/s), modeled separately for each year and river. Velocities were derived values interpolated using the CLBMON-47 River2D models.

For both larval and juvenile Mountain Whitefish, the highest numbers were consistently recorded in the upper section of the study area within low relief, gently sloping habitat types with fine substrates. Low encounters in the middle and lower sections of the study area precluded an in-depth look at habitat utilization. While data have been collected on nighttime habitat use of age-0 and age-1 juvenile Mountain Whitefish, little is known about habitats used by these age-classes in the daytime. Due to the difficulties of capturing juveniles during the day (Golder 2009) and poor survival rates of juveniles during acoustic tag implantation in Years 2 and 3 (Golder 2010 and 2011), it is currently unknown if this cohort occupies deeper habitats during the day where they are not susceptible to sampling by conventional methods, or whether they are present in the same habitats as used at night but are able to avoid capture. The high use of shallow, low velocity habitat by young-of-the-year Mountain Whitefish documented in this study is consistent with the results from the studies conducted on the Lower Columbia River in the 1990s (R.L.&L. 2001).

The CLBMON-47 program was three years in duration, and included three management questions. There were no study hypotheses associated with the program, as the main objectives were to update the existing 1D HEC RAS hydraulic model and the Mountain

Whitefish egg loss model (ELM). Refined hydraulic modelling was chosen as the primary tool to both assess habitat use by spawning Mountain Whitefish and determine project areas being dewatered during regulated flow changes in the Kootenay and Columbia rivers. Golder updated the existing HEC-RAS model for the Columbia River below HLK and the Kootenay River below BRD using the topographic survey data collected in 2011.

Individual River2D hydraulic models were calibrated for the two key Mountain Whitefish spawning areas. The developed Columbia Reach River2D Hydraulic Model adequately represents the river hydraulic situations of the CPR Island spawning area (Figure 3). The results of the sensitivity analysis for this reach showed that the simulated water levels are not sensitive to variations in *Ks* (the effective roughness height, a bed resistance parameter). In the Kootenay Reach, the hydraulic situation is influenced by the water levels in the Columbia River at the confluence. High water levels in the Columbia River will cause backwater effects in the Kootenay River. During development and testing of the Kootenay River2D model, inconsistencies were found that were related to the hydraulic effects of the confluence. To address these inconsistencies, the model was expanded to incorporate the confluence in addition to the Kootenay River area. To facilitate the expansion of the Kootenay spawning area River2D model, a total of 30 ADCP cross sections were conducted in the confluence area of the Columbia and Kootenay rivers (Figure 4). After expansion, sensitivity analysis testing was conducted on the roughness height *Ks*. As in the Columbia Reach, it was shown that the simulated water levels are not sensitive to *Ks* variations along the Kootenay River Reach.

For the purpose of egg loss analysis, the area modeled using the River2D model was restricted to the extent of the Mountain Whitefish spawning areas to reduce computational time of the egg loss model. Because every point in the modeled area is propagated throughout the entire study period (Nov 1 to May 1), the reduction of sampled points dramatically streamlined the analysis and trimmed the processing time. The original Mountain Whitefish ELM includes HEC-RAS transects from Kinnaird and Tin Cup Rapids. These areas were not selected for topographic or ADCP surveys based on the relatively low numbers of stranded eggs found in these areas during previous studies. The original Mountain Whitefish ELM solely predicted the depth at which eggs are deposited, which could potentially constrain the predictive ability of the ELM as flow regulation alters both depth and velocity, and both have been shown to be highly correlated with spawning site selection in salmonids. The updated ELM includes data from the River2D models, updated bathymetry data, as well as data collected during Mountain Whitefish spawn monitoring as part of the CLBMON-48.

The use of the statistical environment R for developing the updated version of the ELM allows for great flexibility in the resulting model. The updated version includes the entire River2D-modeled surface of both spawning areas, rather than individual transects, which allows incorporation of a variety of environmental effects on the timing and location of egg deposition and the timing of egg hatching. R also supports error propagation to provide confidence intervals around the final estimate of stranding levels, and provides a flexible and powerful graphic platform, allowing the inclusion of a variety of plots as the output from the model. Such plots include time series of discharge, temperature, and stranding, and maps of egg deposition and stranding at both spawning sites. In addition, the modular nature of the R scripts allows straightforward incorporation of future findings related to Mountain Whitefish spawning and incubation ecology, as well as modifications to desired output.

The River2D models allowed quantification of the fluctuations in river stage (water elevation) in the key spawning areas as a function of BRD and HLK discharges. River stage within these spawning areas was also shown to depend on the particular discharge levels of HLK and BRD that comprised the total discharge. At CPR Island, predicted water elevations and wetted area were higher if discharge from HLK made up the larger portion of combined discharge. This pattern was also observed in the Kootenay River if BRD discharge accounted for the larger portion of the combined discharge. As HLK discharge increased, the influence of BRD on wetted area at CPR Island decreased dramatically. On the other hand, HLK discharge had a large effect on Kootenay River wetted area under all examined BRD discharges, albeit this effect was somewhat smaller at high BRD discharge. Increases in water elevation resulted in a nonlinear increase in wetted area at both areas. Over the range of discharge documented in this study, the wetted area in the Kootenay River spawning area was typically 3 to 5 times higher than at CPR Island.

Under the current operating regime for both the HLK and BRD facilities during the Mountain Whitefish spawning period, daily flow changes are most likely to occur at BRD as load factoring. The extent of wetted area loss at both spawning sites due to load factoring at BRD decreased with increasing HLK discharge, although Kootenay River lost wetted area was greatest at intermediate HLK discharges. HLK discharge not only affects the amount of channel dewatering during load factoring, but also dictates specific habitat dewatering. If HLK discharge remains stable, the area dewatered during load factoring at BRD is consistent.

References

Golder Associates Ltd. 2009. Lower Columbia River whitefish life history and egg mat monitoring program: 2008 - 2009 investigations data report. Report prepared for BC Hydro, Castlegar, BC Golder Report No. 08-1480-0054F: 42 p. + 6 app.

Golder Associates Ltd. 2010. Lower Columbia River whitefish life history and egg mat monitoring program: 2009 - 2010 investigations data report. Report prepared for BC Hydro, Castlegar, BC Golder Report No. 08-1480-0054F: 59 p. + 7 app.

Golder Associates Ltd. 2011. Lower Columbia River whitefish life history and egg mat monitoring program: Year 3 data report. Report prepared for BC Hydro, Castlegar, BC. Golder Report No. 10-1492-0111F: 50 p. + 5 app.

Golder Associates Ltd. 2014. Lower Columbia River Whitefish Life History and Egg Mat Monitoring Program: Year 5 Interpretive Report. Report prepared for BC Hydro, Castlegar, BC Golder Report No. 11-1492-0111F: 102 p. + 5 app.

R.L.&L. Environmental Services Ltd. 1997. Lower Columbia River whitefish monitoring program, 1996-1997 investigations, Data Report. Draft report prepared for BC Hydro. R.L.&L. Report No. 574D: 21 p. + 6 app.

R.L.&L. Environmental Services Ltd. 1999. Lower Columbia River whitefish monitoring program. 1997-1998 investigations, data report. Report prepared for BC Hydro. R.L.&L. Report No. 608F: 21 p. + 5 app.

R.L.&L. Environmental Services Ltd. 2000. Lower Columbia River whitefish monitoring program, 1998-1999 investigations, data report. Report prepared for BC Hydro, Kootenay Power Supply/Power Facilities, Castlegar, B.C. R.L.&L. Report No.694F: 16p.+5app.

R.L.&L. Environmental Services Ltd. 2001. Lower Columbia River Mountain Whitefish monitoring program: 1994-1996 investigations. Final Report prepared for BC Hydro, Kootenay PS/PF. R.L.&L. Report No. 514F: 101 p + 8 app.

Back to Table of Contents

8. *Fishway entrance efficiency for Pacific lamprey under two head differential treatments at Wells Dam.*

David Robichaud, LGL Limited, Environmental Research Associates
drobichaud@lgl.com

This presentation was based on a published study ***Lamprey passage and enumeration study report*** found here:

http://www.douglaspud.org/ASWG%20Documents/2014_09_09%20Douglas%20-%202013%20Lamprey%20Passage%20and%20Enumeration%20Study%20Report%20(Final%209-08-14).pdf

Back to Table of Contents

9. Quantifying the impact of reservoir operations on nesting birds

Harry van Oort[1] and John M. Cooper[2]
[1]Cooper Beauchesne and Associates Ltd.
#308-1123 West 2nd Street
Box 2508, Revelstoke, BC
V0E 2S0 CANADA
Tel: 250.837.3550
hvanoort@cooperbeauchesne.com

Introduction

The regulation and impoundment of river basins causes considerable impact to riparian and wetland wildlife, initially through habitat destruction, and continually via the ongoing regulation of water flow (Nilsson and Dynesius 1994). More than half of the world's large river systems are regulated by the construction of an estimated 16.7 million impoundments (Nilsson et al. 2005, Lehner et al. 2011), with ~ 50, 000 of these being major reservoirs, behind dams > 15 m in height (Berga et al. 2006). The Columbia River is one of the most modified and regulated large rivers in North America (Nilsson et al. 2005), with multiple dam projects existing in both the USA and British Columbia portions of the basin. Water storage reservoirs along the primary course of the Columbia River in BC include the Kinbasket Reservoir (KIN), Lake Revelstoke and the Arrow Lakes Reservoir (ALR), positioned sequentially along the river's course. The footprint impact of these, and several other reservoir projects has been estimated to cause a loss of 26% of the wetlands, 21% of riparian cottonwood, and 31% of shallow water and ponds in the BC Columbia basin (Utzig and Schmidt 2011). In place of these and other natural habitats that were lost, are the substantial drawdown zones of these reservoirs, typically comprised of steep, barren shorelines, with negligible value as habitat for wildlife.

In some parts of the reservoir drawdown zones in BC, important wildlife habitats remain, with particular significance as nesting habitat for a variety of birds. In particular, the upper 4 m of the drawdown zone in Revelstoke Reach (RR) at the north end of ALR is highly vegetated and known to be used by a diversity birds during the breeding season (Boulanger 2005, CBA 2013). The drawdown zones at Canoe Reach (CR) and Bush Arm (BA), both in KIN, also contain several vegetated areas suitable as nesting habitat (CBA 2013). Because these remnant breeding habitats are located in reservoir drawdown zones, the operation of ALR and KIN may have significant impacts on the productivity of resident bird populations (CBA 2013). It is possible that some nesting habitats within the reservoir act as ecological traps (Schlaepfer et al. 2002, Robertson and Hutto 2006, Anteau et al. 2012a), and/or that some drawdown zone populations act as population sinks (Pulliam 1988).

During the Columbia River Water Use Planning process (BC Hydro 2007), nest mortality caused by reservoir operations was identified as a critical issue. The primary concern was that the operations of ALR and KIN may reduce the productivity of breeding bird communities due to flooding of active nests. This concern arose from earlier studies in Revelstoke Reach that documented a high diversity of birds using drawdown habitats during the breeding season (Boulanger 2005), and pilot surveys that documented nest mortality resulting from reservoir operations (Jarvis 2003, 2006). Furthermore, the discovery of a pair of Short-eared Owl (*Asio flammeus*) nesting within the drawdown zone in 2002 (Jarvis 2003) highlighted the potential for reservoir operations to have negative impacts to threatened species. Under the direction of the Columbia River Water Use Plan, and as one of their Water Licence Requirements (WLR), BC Hydro initiated CLBMON-36, a 10-year program designed to determine the effects of reservoir operations (water level management) on breeding success of birds nesting in the drawdown zone of KIN and ALR, and to provide feedback and guidance on the efficacy of methods used to enhance breeding habitats for birds in reservoir drawdown zones (habitat management and wildlife physical works).

In this paper, we review the small body of existing literature regarding nest flooding in reservoirs, and we review the most recent understanding of nest morality issues in KIN and ALR. Through considering nest flooding in an ecological context, rather than an isolated process, we show that nest flooding impacts should be reconsidered in some cases, and this alternate view allows a more strategic approach to mitigating and preventing negative impacts.

Drawdown zones, nesting habitat, and nest flooding

Reservoir drawdown zones are defined as the perimeter topography of the impounded basins that lie between the minimum and maximum water elevations. It is common that large regions of reservoir drawdown zones are exposed to extremely arid conditions during some part of the year, and inundated under fathoms of water at other parts of the year. The nature of this oscillation depends on the elevation within the drawdown zone, and the nature of the reservoir's operation. The extreme environmental fluctuation cannot be tolerated by most plant species, and soils are often lost as a result, making drawdown zones even less habitable (Figure 1). Terrestrial vegetation can be retained in parts of some drawdown zones, or become established in parts of the drawdown zone that are inundated less frequently; aquatic vegetation may persist in permanently impounded pools. It is therefore common to see drawdown zones become more vegetated at higher elevations, and in areas where there are natural seepages or pools. Reservoirs that have irregular water surface elevations among years may have drawdown zones that become more vegetated during drought years when the impoundment water elevations remain low (Hatten et al. 2010).

In some cases, reservoir drawdown zones may provide a diverse and complex vegetated habitat (e.g., within the top two meters below the full pool), especially if soils have been retained, and near drawdown zone wetlands. Drawdown zones that are more highly vegetated, can provide nesting habitat for a higher diversity of bird species (e.g., Boulanger 2005, CBA 2013).

Figure 1. A view of the drawdown zone habitat in the Bush Arm of Kinbasket Reservoir (photo Harry van Oort).

Given the degree to which river systems around the world have been impounded, there has been remarkably little work conducted on the nest flooding issue. In a recent review of human-related mortality factors of Canadian bird populations, data were conspicuously lacking with respect to nest flooding in reservoirs (Calvert et al. 2013). There is probably an unappreciated body of information that has been presented (and forgotten) in numerous grey literature reports. In general, it is challenging to find information about nest flooding.

Most information about reservoir nest flooding has previously considered ground-nesting birds. One of the earliest studies examined the impacts of reservoir operations at two impoundments in northern Utah (Cutler Reservoir and Newton Reservoir; Wolf 1955). This paper made a strong initial case that a diversity of species are highly impacted by reservoir operations. For example, 50% of Mallard (*Anas platyrhynchos*) nests were destroyed by water in the Cutler Reservoir study plot. Redhead (*Aythya americana*) encountered fluctuating water more frequently (90% of nests) but the species showed some ability to deal with the problem by building up their nests, resulting in 'only' 39% of the nests suffering negative impacts.

Nest flooding of the threatened Piping Plovers (*Charadrius melodus*) has been the focus of two different studies. Piping Plover nesting habitat in reservoir drawdown zones has been described as < 15% vegetated, flat, gravelly, and typically lower in elevation compared with random sites, therefore exposing them to nest flooding (Anteau et al. 2012b). Such habitats are not uncommon in drawdown zones. The species' are adapted to nesting in natural sandy 'drawdown zones' for example alkali lakes, rivers margins, and sand spits (Elliott-Smith and Haig 2004), which, like the Redhead mentioned above, is reflected in their behaviour. When water levels increase during the nesting period, they have been observed to move the clutches to higher elevations (Wiltermuth et al. 2009). Despite their adaptations, Piping Plovers do not appear to be able to prevent nest flooding when faced with the unnaturally large water level fluctuations in reservoirs. Nest flooding was determined to be a major limitation of Piping Plover productivity at two large reservoirs. Lake Diefenbaker is a bifurcation lake in Saskatchewan impounded in 1967 by the Gardener Dam on the South Saskatchewan River and the Qu'Appelle River Dam on the Qu'Appelle River. Lake Sakakawea, North Dakota, is the third largest man made impoundment in the US, and has a maximum depth of 55 m, behind the Garrison Dam on the Missouri River. Nest survival in both reservoirs was highly impacted by nest flooding (Espie et al. 1998, Anteau et al. 2012a). In Lake Diefenbaker, Espie et al (1998) determined that reservoir operations would cause nesting to be inadequate, as a result of nest flooding, in 24 out of the previous 30 years. On Lake Sakakawea, Anteau et al (2012a) concluded that the drawdown zones habitat constituted an ecological trap.

Other ground-nesting species, have also been shown to suffer from reservoir operations. At Whatshan Lake Reservoir, located in the Monashee Mountains of BC, the Common Loon (*Gavia immer*) was shown to be highly vulnerable to nest flooding (van Oort and Kellner 2006, Kellner and van Oort 2011). Common Loons typically nest in vegetated shorelines, but will also nest in barren shorelines (Figure 2), which was an issue, given that the reservoir was filling during the nesting period. Over three years of monitoring, only two out of fourteen nests were successful; 44% of observed nest failures were caused nest flooding (Kellner and van Oort 2011).

Figure 2. A Common Loon nest in the Whatshan Lake Reservoir (photo Mandy Kellner).

At a very basic level, the potential for nest flooding in reservoirs depends on two factors: (1) the presence of nesting birds, and (2) the potential for reservoir's hydrograph (timing of water surface elevations) to disrupt nesting. The former depends on habitat complexity in drawdown zones, with more vegetated drawdown zones attracting a greater diversity and density of nesting activity. For example, 60 species have been observed nesting in the ALR drawdown zone, which is extensively vegetated, compared with the KIN drawdown zone where less than 30 species have been observed (CBA 2015).

Once it is known where and when birds are nesting, it is a simple matter of examining reservoir operation hydrographs to study the potential for nest flooding. Reservoir operations vary tremendously among reservoirs. KIN, for example, is operated to reach full pool late in the summer, and nest flooding is uncommon (CBA 2013). By comparison, the ALR reaches full pool in mid-summer, and nest flooding occurs almost annually (CBA 2013). The differences between KIN and ALR operations is exemplified in Figure 3.

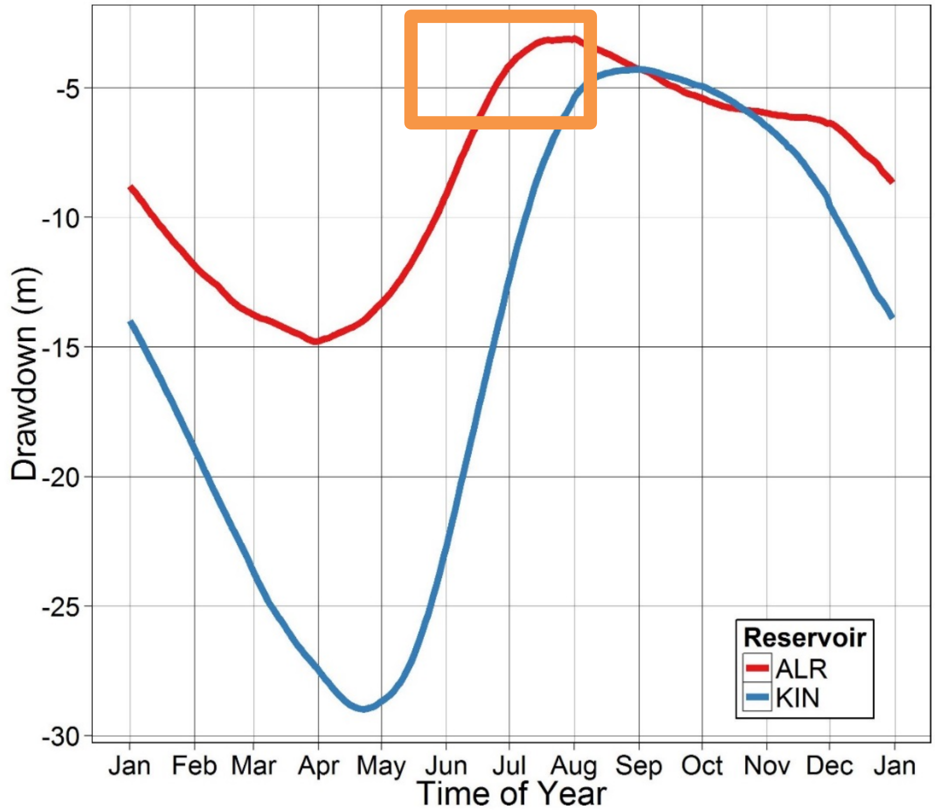


Figure 3. Comparison of reservoir hydrographs of Kinbasket Reservoir (KIN) and Arrow Lakes Reservoir (ALR). The drawdown is measured as the mean surface elevation subtracted from the historic maximum surface elevation. The orange box symbolizes approximately when and where most bird nesting activity occurs.

Reservoir operations and nest flooding at ALR – a simple empirical model

In the ALR, early pilot surveys documented high potential for nest flooding in the Revelstoke Reach area including a diversity of species nesting on the ground, in wetlands, and in shrubs (Jarvis 2003, 2006). These surveys highlighted the need for improved information; in particular, a model of nest flooding was needed.

After considering the geographic distribution of the nesting community, the nest heights and the timing of nesting, a model of nest flooding was produced providing the first empirically derive model of nest flooding for this reservoir (CBA 2013; Figure 4). Models like these can be very informative with respect to predicting nest flooding. The model was applied to predict how severe the annual reservoir operation was with respect to the degree to which nests were flooded. This ranking was a strongly correlated with the observed proportion of nests that were flooded from 2008 through 2014 (Figure 4).

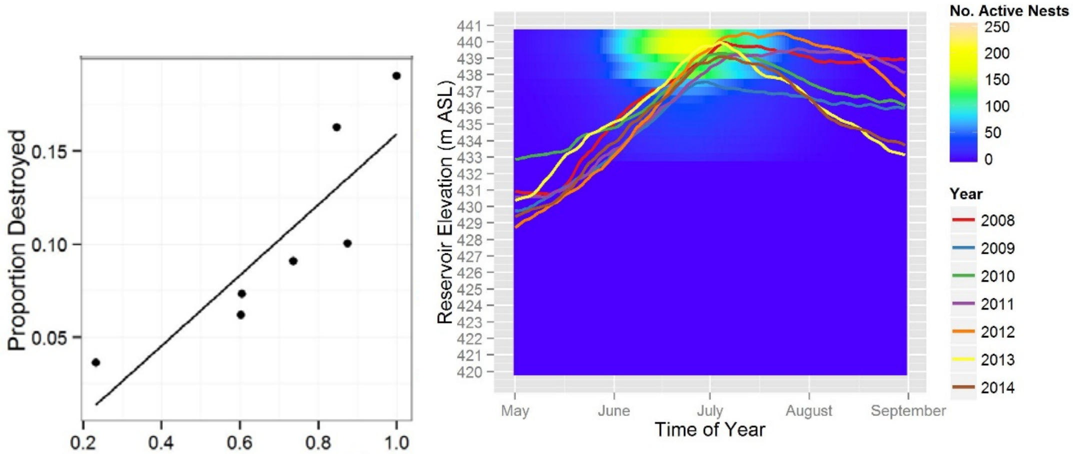


Figure 4. (L) Model of nesting in Revelstoke Reach of the Arrow Lakes Reservoir, showing reservoir elevations from 2008-2014. (R) Correlations between predicted potential for nest flooding and the observed proportion of nests flooded from 2008 through 2014 (reproduced from CBA 2014).

Impacts of flooding varies across species – differences and solutions

Grouping all birds in a single model may be informative with respect to nest flooding rates, but such models provide poor measures of true impact, because the impact will differ across species, and will depend on species' nesting ecology. Drawdown zone nests – those that are located within drawdown zone habitat – can be assigned to one of two basic groups: those at risk of being flooded, and those not at risk of being flooded. Here, we draw this distinction entirely based on nest elevation, with all nests that are elevated in shrubs or trees above the historic maximum reservoir elevation being safe from the threat of flooding. Among those nests that are at risk, the risk will vary according to the nesting elevations and the timing. For example, Willow Flycatchers (*Empidonax traillii*) nests lower and later than Yellow Warblers (*Setophaga petechia*) in the ALR, and had almost double the rate of nest flooding (van Oort et al. 2015). Some species in the ALR, such as the Short-eared Owl (*Asio flammeus*) or the Savannah Sparrow (*Passerculus sandwichensis*) nest at much lower elevations in the ALR grasslands, and have a very low chance of nest survival. Future modelling should attempt to build flood-risk models for individual species nesting in drawdown zones, so that impacts can be assessed for each species, for example, those that are listed as threatened or endangered.

Nest flooding is but one impact that will occur when reservoir water elevations overtop nesting habitat. In a recent analysis we showed that the survivorship of nests positioned off the ground in shrubs was not affected by habitat inundation, despite considerable occurrences of nest flooding (van Oort et al. 2015). This counter-intuitive outcome can be explained by the effect that water has on nest predation rates. It is widely observed that nest predation is reduced in aquatic habitats, or when nests are positioned over water

(Picman et al. 1993, Picman and Schriml 1994, Cain et al. 2003, Hoover 2006, Roy Nielsen and Gates 2007, Cocimano et al. 2011, Robertson and Olsen 2015). As such, it was concluded that there is significant compensation for nest flooding by a reduction in nest predation, for birds that nest above the ground in shrubs and trees. This is significant, because over 50% of nest flooding observed during empirical study were of shrub nesting species (CBA 2015). As such, approximately half of the birds that experience nest flooding, nest in shrubs, and experience some level of compensation, and perhaps very little impact to productivity as a result of nest flooding (CBA 2015, van Oort et al. 2015).

The advantage of nesting over water is indeed exploited by many species, and explains the propensity for birds to nest in marshes at high densities (Picman et al. 1993, Picman and Schriml 1994, Robertson and Olsen 2015). To some degree, some bird species that nest in marshes, such as the Redhead and the Sora (*Poranza carolina*) are adapted to fluctuating water levels, exhibiting the behaviour of building up nests as water levels rise (Wolf 1955, Robertson and Olsen 2015). However, in the ALR, approximately 20% of nest flooding is observed in species that nested in emergent vegetation in wetlands, and for some of these birds, it was the leading cause of nest failure (CBA 2015). It is therefore highly likely that for there is no upside to habitat flooding for species nesting in emergent vegetation of wetlands.

Because there is a high density of nests in wetlands that suffer when water overtops their habitat, and because these habitats are typically smaller contained features in the landscape, wetlands make prime targets for physical works projects aimed at protecting nesting habitat from reservoir inundation (e.g., dykes, weirs, and pump stations). Such projects would protect a large number of nests that would gain a large benefit. In the ALR, such a project designed to protect a single wetland – the Airport Marsh, would protect as many as one quarter of all nests that currently get flooding in the Revelstoke Reach area (CBA 2015).

Ground-nesting species clearly experience no positive impacts when reservoir waters flood their nesting habitats. This group can include endangered species (Espie et al. 1998, Anteau et al. 2012a, CBA 2015). Unlike in wetlands, ground nesting occurs in low densities over a larger area. Habitat cannot easily be managed for these birds as they often use gravel, or grass-dominated nest sites. Slight manipulations to reservoir operations may allow impacts to be reduced effectively. For example, allowing the reservoir to fill to full pool each year may keep vole populations in check, and discourage Northern Harriers (*Circus cyaneus*), Short-eared Owls and Long-eared Owls (*Asio otus*) from nesting (Long-eared Owls are known to nest in trees, but nest on the ground in the ALR). Also, it may be possible to slightly advance filling of major parts of the ALR drawdown zone so that large nesting habitat areas are no longer available, prior to the nesting season. Future work should attempt to model ground nesting in the ALR so that this latter option can be explored quantitatively.

Conclusions

It has been estimated that there are as many as 16.7 million impoundments globally, with 55, 000 of these being behind dams greater than 15 m high (Berga et al. 2006, Lehner et al. 2011). It is surprising that there is such a poor understanding of the effects that reservoir operations have on nesting birds (Calvert et al. 2013). We are aware of just four peer-reviewed papers that quantify the effects (Wolf 1955, Espie et al. 1998, Anteau et al. 2012a, van Oort et al. 2015). Clearly more work is warranted.

Impacts of nest flooding need to be assessed in the context of the ecology of the species; clearly the impacts differ, depending on where a species nests, with those low in the drawdown zone being at much greater risk, and those nesting in shrubs being compensated with reduced predation when their habitats become flooded. It makes very little sense to expect that reservoirs should not be operated as they were intended, but subtle changes to their operations could make their operational impacts considerably better without crippling their intended function. Wetland breeding areas should be targeted by projects aimed to mitigate negative impacts; water control structures should be used to isolate these habitats from reservoir impoundment.

Acknowledgements

We thank BC Hydro Water Licence Requirements for funding our work. We are grateful to support at BC Hydro given by Margo Dennis, Jason Watson, and particularly Susan Pinkus. Thanks to the CMI for organizing and hosting the Regulated Rivers conference, and giving us the opportunity to share ideas and learn from others. CBA partnered with the Okanagan Nation Alliance, the Splatsin First Nation, and the Ktunaha. We thank Al Peatt, Bruce Weaver, Len Edwards, Stuart Lee, and all field technicians who have contributed to the project.

References

Anteau, M., T. L. Shaffer, M. Sherfy, M. Sovada, J. Stucker, and M. Wiltermuth. 2012a. Nest survival of Piping Plovers at a dynamic reservoir indicates an ecological trap for a threatened population. Oecologia 170:1167–1179 pp.

Anteau, M., M. Sherfy, and M. Wiltermuth. 2012b. Selection Indicates Preference in Diverse Habitats: A Ground-Nesting Bird (Charadrius melodus) Using Reservoir Shoreline. PloS ONE 7:e30347 pp.

Berga, L., J. Buil, E. Bofill, J. De Cea, J. Garcia Perez, G. Mañueco, J. Polimon, A. Soriano, and J. Yagüe (Eds.). 2006. Dams and Reservoirs, Societies and Environment in the 21st Century. Proceedings of the International Symposium on Dams in Societies of the 21st Century, Taylor and Francis Group, London, UK.

Boulanger, J. 2005. Land birds in a high human use riparian zone: Revelstoke Reach wetlands, Columbia Basin Fish and Wildlife Compensation Program, Nelson, BC.

Cain, J., M. L. Morrison, and H. Bombay. 2003. Predator activity and nest success of willow flycatchers and yellow warblers. Journal of Wildlife Management 67:600–610 pp.

Calvert, A. M., C. A. Bishop, R. D. Elliot, E. A. Krebs, T. M. Kydd, C. S. Machtans, and G. J. Robertson. 2013. A synthesis of human-related avian mortality in Canada. Avian Conservation and Ecology 8 pp, doi: 10.5751/ACE-00581-080211.

Cocimano, M., M. L. Morrison, H. Mathewson, and L. Vormwald. 2011. The influence of meadow moisture levels on activity of small mammal nest predators in the Sierra Nevada, California. Northwestern Naturalist 92:50–56 pp.

Cooper Beauchesne and Associates Ltd (CBA). 2013. CLBMON-36: Kinbasket and Arrow Lakes Reservoirs: Nest Mortality of Migratory Birds Due to Reservoir Operations. 5 Year Interim Review Report: 2008-2012, BC Hydro Water Licence Requirements, Burnaby, BC.

Cooper Beauchesne and Associates Ltd (CBA). 2015. CLBMON 36: Kinbasket and Arrow Lakes Reservoirs, nest mortality of migratory birds due to reservoir operations, Year 7, 2014, BC Hydro Water Licence Requirements, Castlegar, BC.

Elliott-Smith, E., and S. Haig. 2004. Piping Plover (*Charadrius melodus*). The Birds of North America Online pp, doi: 10.2173/bna.25.

Espie, R., P. James, and R. M. Brigham. 1998. The effects of flooding on Piping Plover Charadrius melodus reproductive success at Lake Diefenbaker, Saskatchewan,Canada. Biological Conservation 86:215–222 pp.

Hatten, J., E. Paxton, and M. Sogge. 2010. Modeling the dynamic habitat and breeding population of Southwestern Willow Flycatcher. Ecological Modelling 221:1674–1686 pp.

Hoover, J. 2006. Water depth influence nest predation for a wetland-dependent bird in fragmented bottomland forests. Biological Conservation 127:37–45 pp.

Jarvis, J. 2003. Preliminary evaluation of the impact of reservoir operations on nesting birds in the Revelstoke Reach, Upper Arrow Lakes Reservoir, Revelstoke, British Columbia, Canada, BC Hydro, Burnaby, B.C.

Jarvis, J. 2006. Impact of reservoir operations on nesting birds in the Revelstoke Reach, BC Hydro, Burnaby, B.C.

Kellner, M., and H. van Oort. 2011. Whatshan Water Use Plan Monitoring Program: Wildlife Monitoring. Study period: 2008-2010, Kingbird Biological Consultants Ltd., Revelstoke, BC.

Lehner, B., C. Reidy Liermann, C. Ravenga, C. Vörösmarty, B. Fekete, P. Crouzet, P. Döll, M. Endejan, K. Frenken, J. Magome, C. Nilsson, J. Robertson, R. Rödel, N. Sindorf, and D. Wisser. 2011. High-resolution mapping of the world's reservoirs and dams for sustainable river-flow management. Fronteers in Ecology and the Environment 9:494–502 pp.

Nilsson, C., and M. Dynesius. 1994. Ecological effects of river regulation on mammals and birds: a review. Regulated Rivers: Research and Management 9:45–53 pp.

Nilsson, C., C. A. Reidy, M. Dynesius, and C. Ravenga. 2005. Fragmentation and flow regulation of the world's large river systems. Science 308:405–408 pp.

Picman, J., M. Milks, and M. Leptich. 1993. Patterns of predation on passerine nests in marshes: effects of water depth and distance from edge. The Auk 110:89–94 pp.

Picman, J., and L. Schriml. 1994. A camera study of temporal patterns of nest predation in different habitats. Wilson Bulletin 106:456–465 pp.

Pulliam, H. 1988. Sources, sinks, and population regulation. American Naturalist 132:652–661 pp.

Robertson, B. A., and R. L. Hutto. 2006. A framework for understanding ecological traps and an evaluation of existing evidence. Ecology 87:1075–1085 pp.

Robertson, E., and B. Olsen. 2015. Behavioral plasticity in nest building increases fecundity in marsh birds. The Auk: Ornithological Advances 132:37–45 pp.
Roy Nielsen, C., and R. Gates. 2007. Reduced nest predation of cavity-nesting Wood Ducks during flooding in bottomland hardwood forest. The Condor 109:210–215 pp.

Schlaepfer, M. A., M. C. Runge, and P. W. Sherman. 2002. Ecological and evolutionary traps. Trends in Ecology and Evolution 17:474–480 pp.

Utzig, G., and D. Schmidt. 2011. Dam footprint impact summary; BC Hydro dams in the Columbia Basin, Fish and Wildlife Compensation Program, Columbia Basin, Nelson, B.C.

van Oort, H., D. J. Green, M. Hepp, and J. M. Cooper. 2015. Do rising water levels alter nest survivorship in reservoir drawdown zone shrubs? The Condor: Ornithological Applications: *in press*.
van Oort, H., and M. Kellner. 2006. Whatshan Water Use Plan Monitoring Program: Wildlife Monitoring, BC Hydro.

Wiltermuth, M., M. Anteau, M. Sherfy, and T. L. Shaffer. 2009. Nest Movement by Piping Plovers in Response to Changing Habitat Conditions. Condor 111:550–555 pp.

Wolf, K. 1955. Some effects of fluctuating water and falling water levels on waterfowl production. Journal of Wildlife Management 19:13–23 pp.

Back to Table of Contents

10. The effects of river regulation on productivity in the varial zones of large rivers

Jason Schleppe, M.Sc., R.P.Bio
Ecoscape Environmental Consultants Ltd.
102-450 Neave Crt
Kelowna, BC
V1W 2M2
Email: jschleppe@ecoscapeltd.com
Phone: 250-491-7337 x. 202 (o) // 250-808-3474 (c)
Contributing Authors:
Mary Ann Olson Russello, M.Sc., R.P.Bio
Heather Larratt, R.P.Bio
Kyle Hawes, R.P.Bio

Introduction

The Columbia River system is highly regulated along many sections, both within Canada and the United States. River regulation affects many aspects of riverine ecosystems including physical parameters such as velocity and light, and biological parameters such as periphyton and invertebrate production. Understanding the habitat related effects of regulation is extremely complicated due to the dynamic nature of biological systems that interact with the effects of regulation. On the Middle Columbia River (MCR), flows from the Revelstoke Dam vary hourly and result in water levels that typically fluctuate 3 to 4 vertical m within a 24 hr period. On the Peace and Lower Columbia Rivers (LCR), variation in hourly flow is less extreme with monthly and yearly changes being quite dramatic. The varying patterns in river water elevations, creates wetted histories that can be investigated to understand river productivity. On each river, data has been collected from three key zones, noting the specific data collected varies by system. The areas include: 1) areas that are permanently submerged (LCR/MCR/Peace); 2) varial zone areas that alter between wet and dry due to frequent fluctuation in flow (MCR); and 3) flood plain areas that are wetted infrequently and contribute little to productivity (MCR). In permanently submerged areas, physical parameters such as velocity, substrate type and size, light via depth, and water quality such as turbidity, are the most important determinants of productivity and vary with season and weather. In varial zone areas, productivity is almost entirely a function of time spent submerged in the water, with the effects of other factors, such as season and weather less important. A simplistic predictive model has been developed to facilitate our understanding of impacts of dam regulation on certain habitats/segments of a river or for a river as a whole. The basis for this model is that total production is the sum of food for fish (i.e., periphyton or invertebrates) in permanently submerged and varial zone areas during recent wetted periods (i.e., the last 60 to 90 days). The model is simplistic in that it only accounts for growth and death of periphyton and benthic invertebrates based on submergence and desiccation times, and does not consider physical factors which are known to directly affect productivity. Data suggests that newly wetted habitats tend to grow for a period of time before stabilizing at a peak. When habitats are exposed, both invertebrates and periphtyon start to desiccate and die, with the rate of death directly linked to key factors such as rain and air temperature (with death increasing as temperatures approach extremes). Growth and death rates developed for this model use multi- year/season LCR data and data from the literature. Although the rates could be refined with further data collection (i.e., the model sacrifices accuracy for utility), the model is effective at determining large scale levels of productivity for planning pruposes. Further, it is useful for flow managers because it only utilizes riverine flows as an input (i.e., flow determines submergence) rather than complicated predictive algorithms for numerous site specific physical parameters. For these reasons, the model is useful to evaluate how changes in flow regulation alter levels of productivity within a river.

Data Collection and River Overview

The sampling apparatus used to collect field data to build the spatial model of productivity was very similar between each different region sampled. The general artificial sampler design is presented in Figure 1 below, and consists of a heavy anchor to hold in the apparatus in place during high flows, associated sampler lines connected using snap hooks, a large metal frame with Styrofoam mounted on treated plywood with a temperature / light logger for sampling periphyton, and a benthic invertebrate rock basket. Our works have assumed that the artificial sampling substrates do not exert any bias on sampling. However, we do have data to suggest that this is not necessarily true and investigations of the potential biases are discussed in Schleppe et al (2015) and Olson et al (2015).

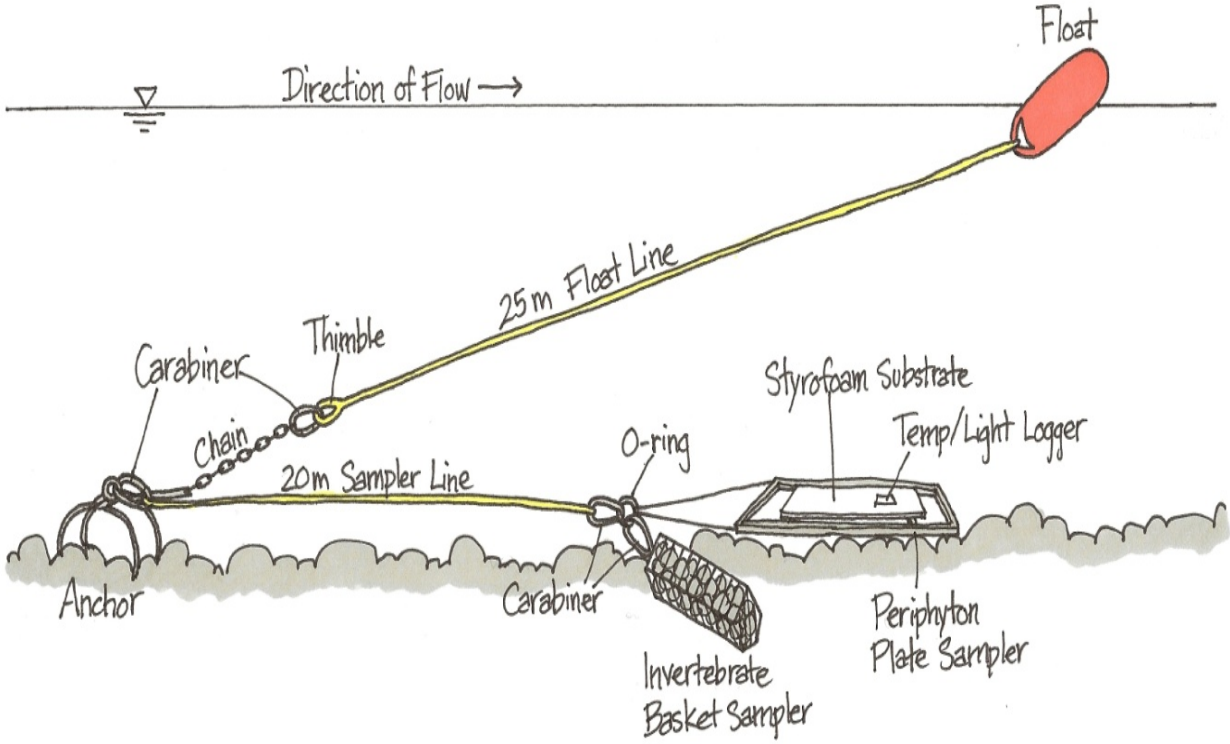


Figure 1: An example of the sampling apparatus used to collect periphyton and invertebrate samples from the Columbia River.

During operational cycles, river habitats are wetted depending upon whether more or less water is released. The concept is nearly identical to opening or closing a valve. This operation creates an area of the river called the varial zone, which is basically the area between high and low water. Within the varial zone, the area that has been submerged or exposed in the last 60 to 90 days is the area that is under direct influence of the regulatory regime.

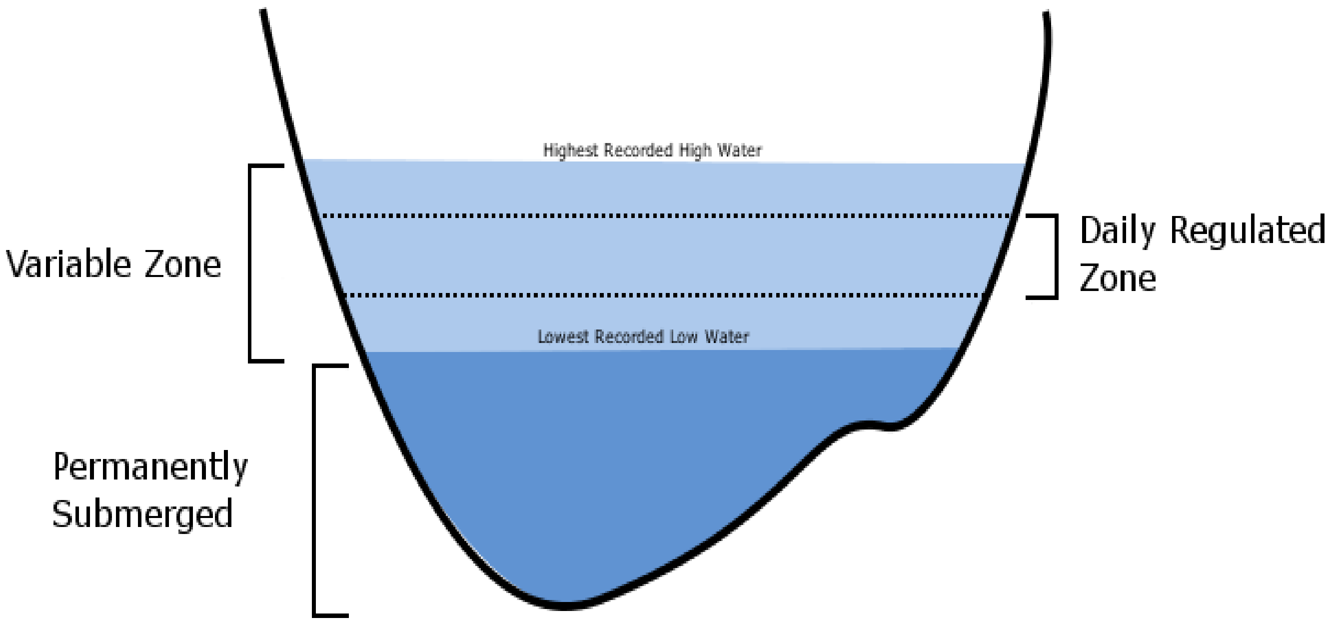


Figure 2: An example of the varial zone areas affected by a regulated river regime.

Permanently Submerged Areas

In permanently submerged areas, the primary factors that affect production within the river are related to physical factors such as substrate size, light intensity, and velocity. The list of physical factors that are potentially influential is quite long, noting that regulation can have a direct or indirect effect on many of them. To generalize, we general expect productivity to increase with increasing substrate size largely because stable substrates experience less abrasion due to the larger sizes and elevation above the bed of the river, and these areas typically experience less deposition (Figure 2). The effects of velocity are generally negative, with decreasing productivity as velocity increases, noting however, that this trend is more complicated than this simple generalization and the local channel morphology can also interact with the effects of velocity. For factors such as light intensity, it is also complicated. However, our data generally indicate that as light intensity increases, so does productivity, noting again that light intensity is not the only parameter and complex interactions ultimately determine productivity at any permanently submerged location.

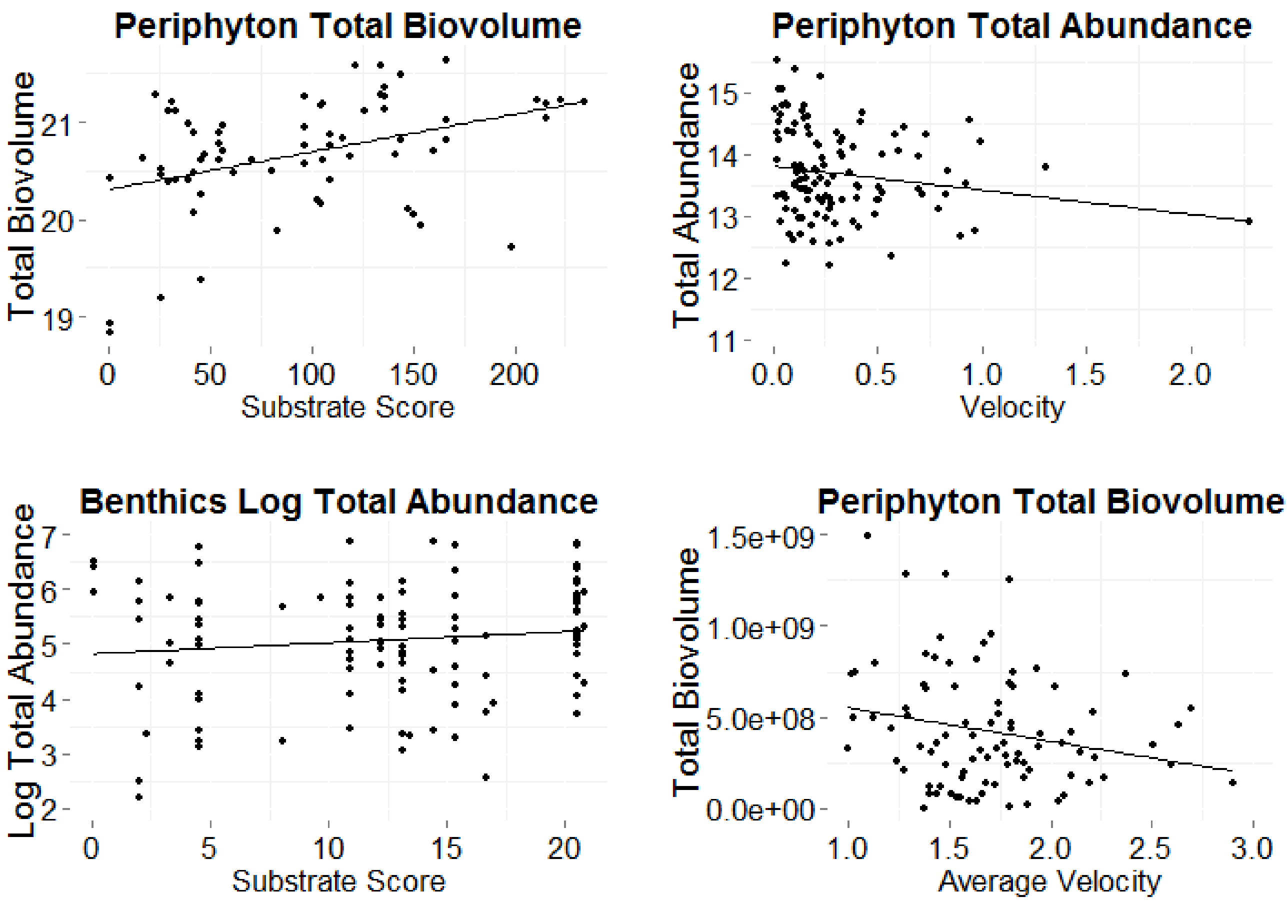


***Figure 3: Primary factors, including substrate size and velocity that affect periphyton and invertebrate production. As substrate score increases, so does substrate size*.**

Varial Zone Areas

In varial zone areas, the most important factor that affects production is submergence. Submergence is a direct function of flow regulation in combination with channel morphology where any increases in flow create larger vertical elevation changes in narrow confined channels when compared to wider, more open channels. Although physical factors are potentially influential, these effects are less important than the submergence time spent within the water. We have modelled this data using numerous different variables that describe submergence, including total submergence time, total time spent in the water during the day, frequency of 9 and 12 hour submergence events and many others. In each case, the most important predictor of productivity for invertebrate abundance and biomass and periphyton abundance and biovolume was submergence when compared to any physical parameter such as light, substrate size, or velocity. Since submergence is the most important factor affecting productivity, it is highly useful to develop spatial models of productivity because it can easily be determined for most riverbed areas and is a direct function of flow.

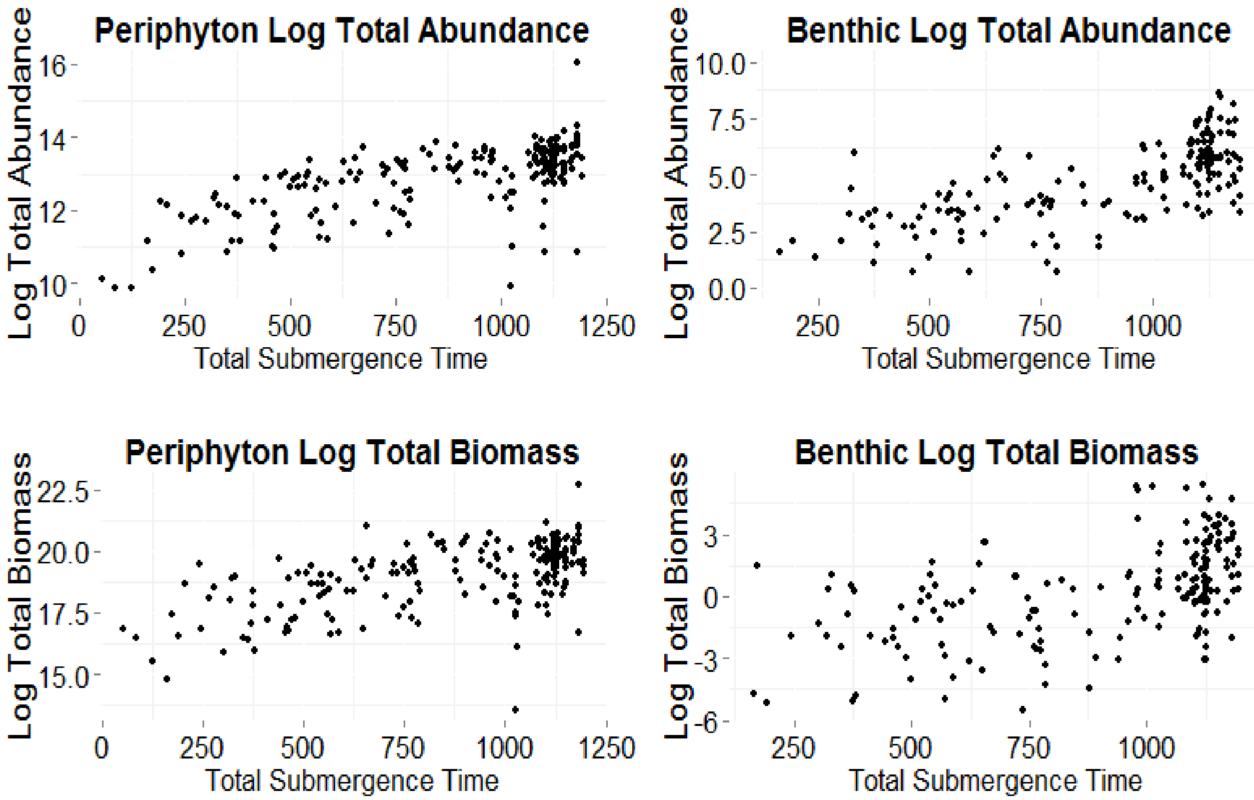


Figure 4: The effects of total submergence time on benthic abundance and biomass, and on periphyton abundance and biovolume in the Mid Columbia River.

Growth Curves

Since submergence is a key factor in varial zone areas, to use it in a spatial model, a growth curve is needed to determine how fast newly submerged areas will achieve peak biomass. Growth curves have been developed for both the Lower Columbia River and Mid Columbia River, and in each of these cases, the curves developed varied by season. Since the spatial model has been developed for the Lower Columbia River, only these have been presented. It is important to note that many factors affect these growth curves, including patterns of submergence and the time spent in a state of variable daily submergence (see Schleppe et al, 2015; Schleppe et al., 2014) However, since these patterns have not been fully investigated or are fully understood, growth functions from permanently submerged areas have been utilized as they are a close proxy and more easily developed than accounting for many small factors that tend to influence a variable submergence regime.

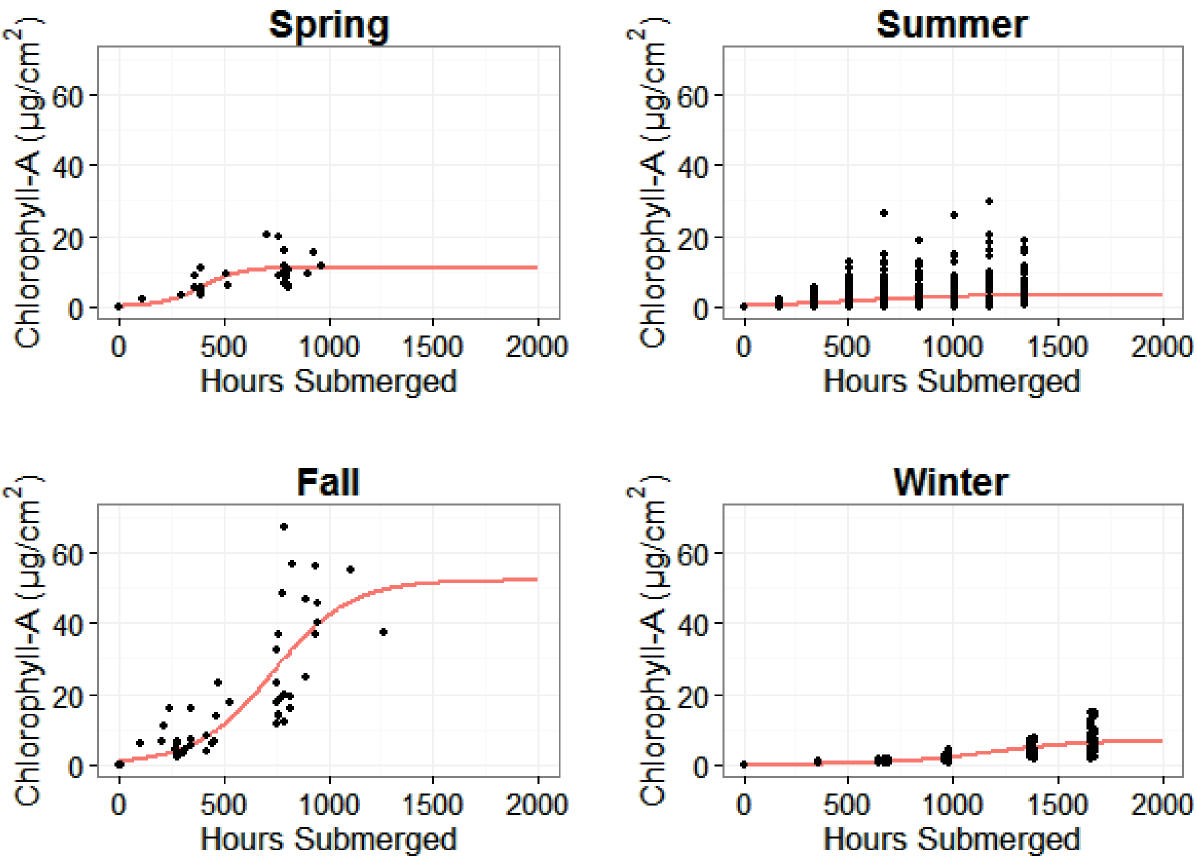


Figure 5: Periphyton chlorophyll A growth curves in the Lower Columbia River in the spring, fall, summer and winter.

Death Curves

Since submergence is a key factor in varial zone areas, to use it in a spatial model, a death or exposure curve is needed to address consequences of the riverbed drying during a period of exposure. Data for death curves is less abundant for the Columbia system, and we have used existing data published by Stanley et al (2004) for periphyton, some assumptions based upon literature reviews, and field exposure data collected to develop theoretical death curves. For invertebrates, some simple exposure experiments have been conducted, but do not address the highly variable field conditions that exists. We acknowledge that we have developed death curves that represent potential consequences across a broad array of species, and have not developed species specific death response curves which are likely important factors. Again however, the need to simplify scenarios to develop a large spatial model necessitated reducing potential exposure related scenarios to only one.

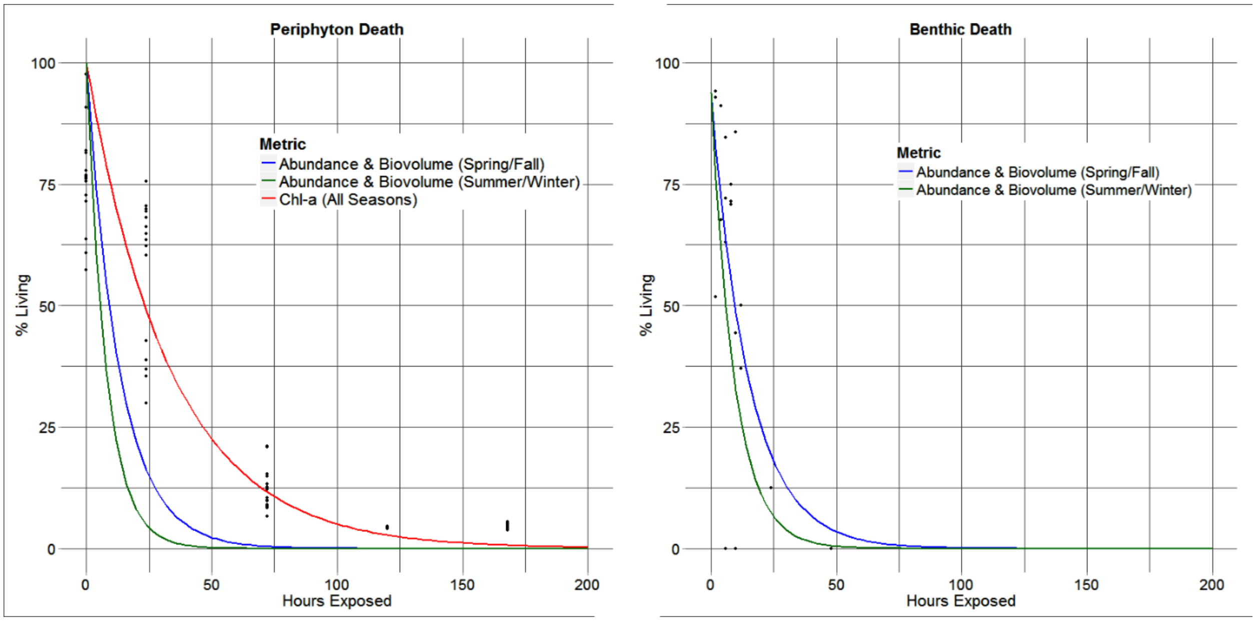


Figure 6: Periphyton and invertebrate death curves. Note that the periphyton death curve is reproduced from Stanley et al (2004).

Spatial Model Development and Utility

The spatial model that was developed general consisted of six steps, as follows:

1. Develop a river 2D model to determine water elevation for any given flow
2. Determine a "reasonable" patch or polygon size
3. Determine the elevation of each patch or polygon
4. Determine the water elevation for *every* hour you wish to consider
5. Match the elevation of the water and the elevation of water for each hour for each polygon
6. Call the seasonal growth or death functions depending upon submergence for each hour, where:
    a) Submergence = growth (Water Elevation > Polygon Elevation)
    b) Exposure = Death (Water Elevation < Polygon Elevation)

Although the model is very simple, there is a lot of utility both in the approach and the subsequent data that is derived. The following provides a brief summary of the utility of the model:

1. A functional river 2D model allows all disciplines to relate river patches or polygons to submergence
2. Allows different operational scenarios to be considered equally and subsequently be tested using field methods
3. Allows different disciplines to "pass" data for river polygons. For example:
    a) Fish Food (aka Productivity) to Fish Indexing works

b) Fish Food to Fish Density
c) Fish Food to Rainbow Trout Spawning

References

Olson-Russello, M.A., J. Schleppe, H. Larratt, K. Hawes, 2015. Monitoring Study No. CLBMON-44 (Year 7) Lower Columbia River Physical Habitat and Ecological Productivity, Study Period: 2014. Report Prepared for BC Hydro, Castlegar, British Columbia. 99 p. Report Prepared by: Ecoscape Environmental Consultants Ltd. Draft

Schleppe, J., H. Larratt., N. Swain and C. Whitney, 2014. CLBMON-15b Middle Columbia River Ecological Productivity Monitoring, Annual Report 2007-201. Okanagan Nation Alliance in association with Ecoscape Environmental Consultants Ltd. & Larratt Aquatic Consulting Ltd..

Schleppe, J., and H. Larratt., 2015. CLBMON-15b Middle Columbia River Ecological Productivity Monitoring, Annual Report 2015. Okanagan Nation Alliance with Ecoscape Environmental Consultants Ltd. & Larratt Aquatic Consulting Ltd. 99pp. Draft

Stanley, E.H., Fisher, S.G. & Jones Jr., J.B. (2004). Effects of water loss on primary production: A landscape-scale model. *Aquatic Sciences*. 66: 130-138

Back to Table of Contents

11. Effects of damming and flow stabilization on riparian processes and black cottonwoods along the Kootenay River.

Dr. Mary Louise Polzin, VAST Resource Solutions Inc.

MaryLouise.Polzin@vastresource.com

This presentation is based on the following published paper:

Polzin M.L., and S.B. Rood. 2000. Effects of Damming and Flow Stabilization on Riparian Processes and Black Cottonwoods along the Kootenay River. Rivers: 221-232

Found here:
http://people.uleth.ca/~rood/PolzinRivers%28Kootenay%29.pdf

Back to Table of Contents

12. Cottonwood and beaver interactions under two flow regimes: comparing the free-flowing Lardeau River and the regulated lower Duncan River, in southeastern British Columbia.

Brenda Herbison, Argenta B.C. bjhnkcs@gmail.com, and
Stewart B. Roodrood@uleth.ca , University of Lethbridge, Alta.

This study investigated the influence of river regulation on two keystone species - beavers and cottonwood trees - and on their interactions by contrasting the free-flowing Lardeau River and the regulated lower Duncan River in a paired comparison. The annual timing and discharge of the Lardeau River has remained nearly unchanged since the early 1900s, whereas the seasonal hydrograph pattern along the lower Duncan River has been altered since dam construction (1967), and peak discharges have been reduced by around one-half of historic flows. To investigate subsequent impacts on riparian woodlands field methods included random sampling of black cottonwoods (*Populus trichocarpa*), alders and willows, and of beaver cutting, and an inventory of beaver colonies through counts of winter dens and food–caches.

Our analyses suggest that river regulation by Duncan Dam has reduced cottonwood recruitment, and that it may have exacerbated both the intensity and extent of beaver cutting. Both of these could be linked to changes in the seasonal flow (stage height) patterns and channel narrowing and stabilization. Beaver dams, canals, ponds and small wetlands were common, occurring along most medium and smaller side channels, back channels and distributaries of both rivers, particularly in association with fine-textured sediments, These ponds and wetlands appeared to be extensively used by other species, and this function is likely to become even more important in a regionally warmer and drier climate that may occur in the future. Practical solutions to maintaining both of these keystone species along regulated rivers need to be further explored.

Back to Table of Contents

13. Dams: A global review of environmental, economic and social impacts as we understand them today.

Dr. Catherine Reidy Liermann, University of Wisconsin, Center for Limnology.
cathyrl@uw.edu

Dr. Liermann's presentation is a synthesis of the following published articles:

For global implications of dams:

Reidy Liermann, C.A., C. Nilsson, J. Robertson and R. Ng.2012. Implications of dam obstruction for global freshwater fish diversity. *BioScience*, 62 (6): 539-548. http://bioscience.oxfordjournals.org/content/62/6/539.short

Lehner, B., C.A. Reidy Liermann, C. Revenga, B. Fekete, C.J. Vörösmarty, P. Crouzet, P. Döll, M. Endejan, K. Frenken, J. Magome, C. Nilsson, J. Robertson, R. Rödel, N. Sindorf, and D. Wisser. 2011. High resolution mapping of the world's reservoirs and dams to assess the degree of global river regulation. *Frontiers in Ecology and the Environment*, doi:10.1890/100125.
http://www.esajournals.org/doi/abs/10.1890/100125

Vörösmarty, C.J. and P. McIntyre, M. Gessner, D. Dudgeon, A. Proussevitch, P. Green, S. Glidden, S. Bunn, C. Sullivan, C.A. Reidy Liermann and P. Davies. 2010. Global Threats to Human Water Security and River Biodiversity. *Nature*, 467: 555-561.
http://www.nature.com/nature/journal/v467/n7315/full/nature09440.html%3Fref%3Dnf

For regional work related to flow management and ELOHA:

Reidy Liermann, C.A., J.D. Olden, T. Beechie, M. Kennard, P. Skidmore, C. Konrad and H. Imaki. 2011. Hydrogeomorphic classification of Washington State rivers to support emerging environmental flow management strategies. *River Research and Applications*, doi: 10.1002/rra.1541.
http://onlinelibrary.wiley.com/doi/10.1002/rra.1541/abstract

Back to Table of Contents

14. An overview of the statistical challenges to understanding the ecology and management of regulated rivers

Dr. Joe Thorley, Poisson Consulting Ltd.
Email: joe@poissonconsulting.ca
Phone: +1 (250) 551 2194
Address: 4216 Shasheen Road, Nelson, BC
Web: http://www.poissonconsulting.ca

Introduction

The statistical challenges associated with understanding the environment, ecology and management of regulated rivers are *numerous*. The challenges can be divided into **data** and **analytic** challenges. This document briefly defines and illustrates each of the challenges and provides recommendations for overcoming them. The challenges are illustrated using examples involving fish and discharge.

Data Challenges

There are at least seven types of data challenge:

1. insufficient data
2. missing data
3. biased data
4. erroneous data
5. messy data
6. undocumented data
7. lost data

To understand the data challenges consider the following example fish and discharge dataset (Table 1) and simple (overly so!) linear regression model (Figure 1).

Date	Discharge	Fish
2010-01-01	1.10	0
2010-01-02	1.50	2
2010-01-03	3.00	5
2010-01-04	1.25	3
2010-01-05	1.05	1
2010-01-06	1.00	0
2010-01-07	1.30	0
2010-01-08	2.40	3
2010-01-09	1.20	1
2010-01-10	1.00	0

Table 1. Example data.

The linear regression yields the following significant (p = 0.001) result where the intercept is -1.74 and the slope 2.19 (Figure 1).

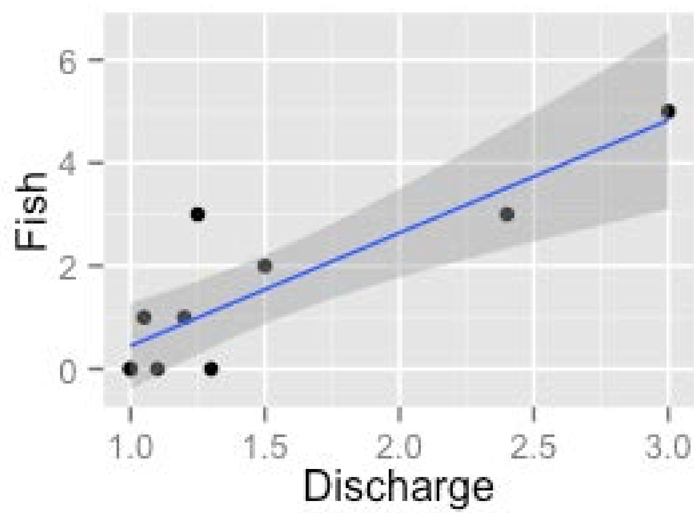


Figure 1. Example data analysis.

Insufficient Data
The challenge of **insufficient** data occurs when not enough data was collected to answer the question of interest (Table 2).

Date	Discharge	Fish
2010-01-01	1.1	0
2010-01-02	1.5	2
2010-01-03	3.0	5

Table 2. Example insufficient data.

In the example the result is no longer significant ($p = 0.1$; Figure 2). Reasons for insufficient data include a lack of appreciation of the variation in the data.

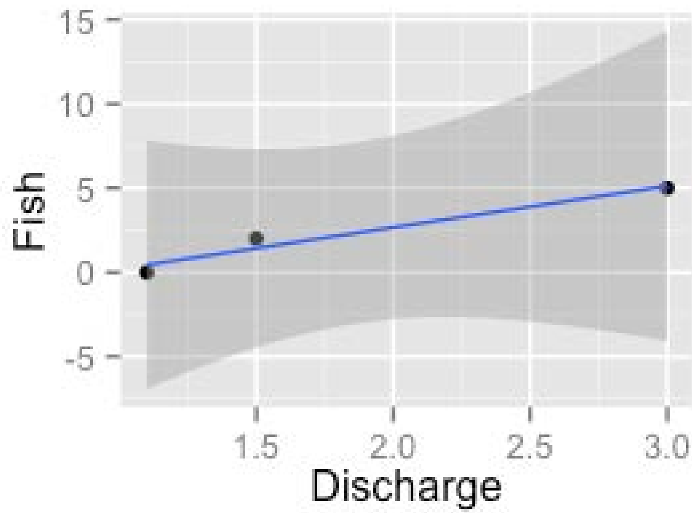


Figure 2. Example insufficient data analysis.

Missing Data

Although it can also result in a failure to answer the question of interest, **missing** data is different from insufficient data in the sense that it should have been collected but wasn't (Table 3; Figure 3). The presence of missing data often requires special analytic techniques. Reasons for missing data include equipment failure and crew inattention.

Date	Discharge	Fish
2010-01-01	1.10	0
2010-01-02	1.50	2
2010-01-03	NA	NA
2010-01-04	1.25	3
2010-01-05	1.05	1
2010-01-06	1.00	NA
2010-01-07	1.30	0
2010-01-08	2.40	3
2010-01-09	1.20	1
2010-01-10	NA	0

***Table 3. Example missing data*.**

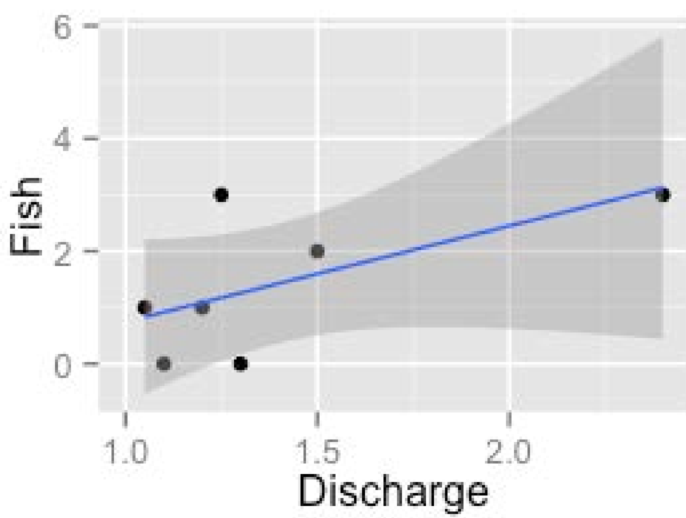


***Figure 3. Example missing data analysis*.**

Biased Data

Although **biased** data also results from non-collection of data it is different from missing data in that the sense that the gaps are systematic (Table 4).

	Date	Discharge	Fish
2	2010-01-02	1.50	2
3	2010-01-03	3.00	5
4	2010-01-04	1.25	3
5	2010-01-05	1.05	1
8	2010-01-08	2.40	3
9	2010-01-09	1.20	1

Table 4. Example biased data.

As well as presenting the same challenges as missing data, biased data can also result in incorrect estimates even though the data points are themselves correct. Thus the regression model now estimates the slope to be 1.68 (Figure 4).
Biased data can result from non-random subsampling decisions.

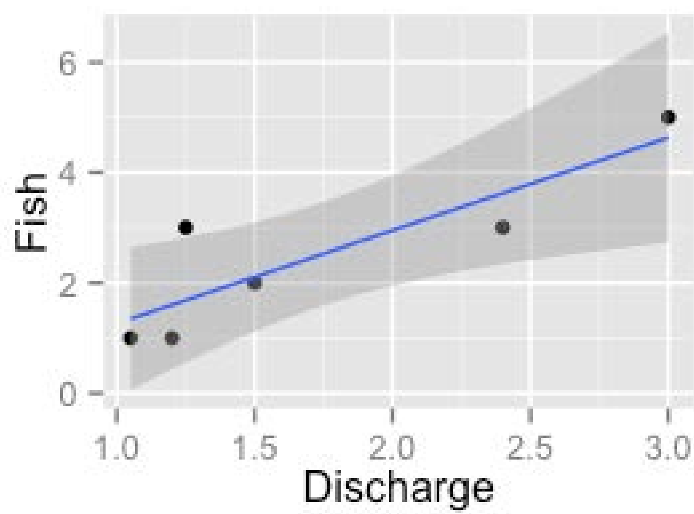


Figure 4. Example biased data analysis.

Erroneous Data

Like biased data, **erroneous** data can result in incorrect estimates although the problem is due to invalid data points as opposed to systematic gaps (Table 5). Equipment malfunction and crew inexperience are common causes of erroneous data. In the current example the slope is now estimated to be -2.19 (Figure 5)!

Date	Discharge	Fish
2010-01-01	-1.10	0
2010-01-02	-1.50	2
2010-01-03	-3.00	5
2010-01-04	-1.25	3
2010-01-05	-1.05	1
2010-01-06	-1.00	0
2010-01-07	-1.30	0
2010-01-08	-2.40	3
2010-01-09	-1.20	1
2010-01-10	-1.00	0

***Table 5. Example erroneous data*.**

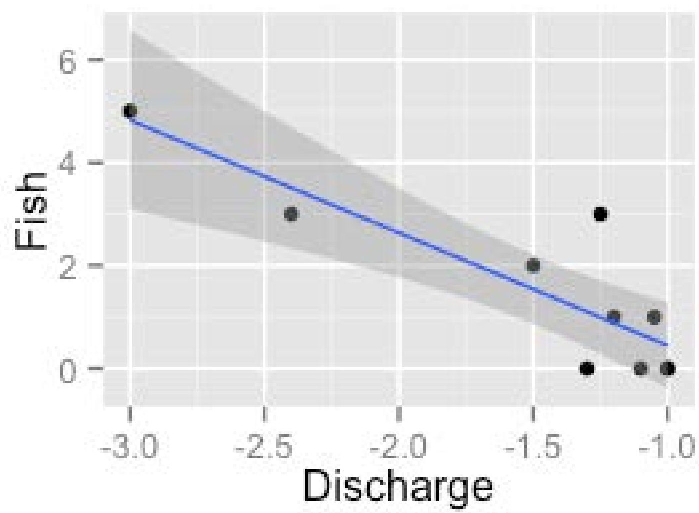


***Figure 5. Example erroneous data analysis*.**

Messy Data

Wickham (2014) formally defined *tidy data* to be that for which:

1. Each variable forms a column.
2. Each observation forms a row.
3. Each type of observational unit forms a table.

Messy data is by definition any other arrangement of the data (Table 6). Tidy data is easy to manipulate, model and visualize. Messy data must first be tidied.

Day	1	2	3	4	5	6	7	8	9	10
Discharge	1.1	1.5	3	1.25	1.05	1	1.3	2.4	1.2	1
Fish	0.0	2.0	5	3.00	1.00	0	0.0	3.0	1.0	0

Table 6. Example messy data.

Undocumented Data

Undocumented data is that for which no metadata exists (Table 7). The absence of metadata can prevent any sort of analysis or worse yet result in an inappropriate analysis being performed (Figure 6).

Date	Q	F
2010-01-01	1.10	0
2010-01-02	1.50	2
2010-01-03	3.00	5
2010-01-04	1.25	3
2010-01-05	1.05	1
2010-01-06	1.00	0
2010-01-07	1.30	0
2010-01-08	2.40	3
2010-01-09	1.20	1
2010-01-10	1.00	0

Table 7. Example undocumented data.

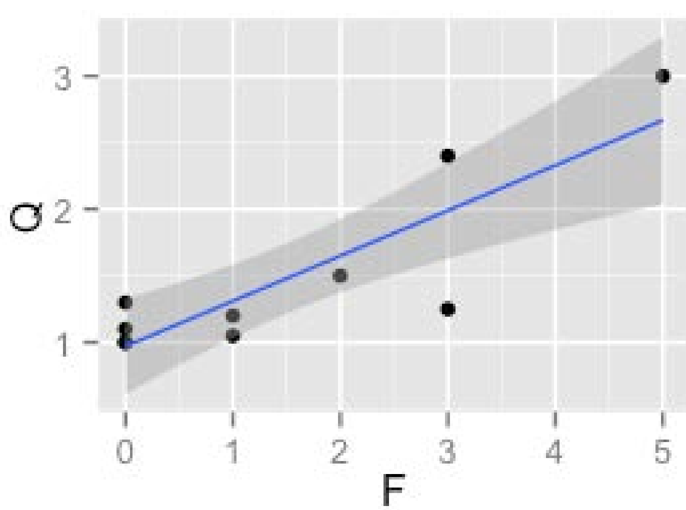


Figure 6. Example undocumented data analysis.

Lost Data

Lost data can be defined as data that was collected but no longer exists in paper or electronic form (Table 8).

Date	Discharge	Fish
NA	NA	NA

Table 8. Example lost data.

Data Solutions

Fortunately most of these data-related challenges can be overcome through recognition of the potential problems and a *study design* that includes where necessary a **pilot study** to identify all the data challenges; **power analyses** to ensure sufficient data are collected; **equipment redundancy** and specialized data collection and data entry **forms** so that the data are complete; **field protocols** that ensure unbiased subsampling; **crew training** and equipment redundancy so the data points are valid; a **relational database** so that the information is documented and tidy; and **long-term data curation** budgets so the information is archived for future use.

Analytic Challenges

There at least six types of analytic challenge

1. vague questions
2. hidden assumptions
3. derived indices
4. pseudo-replication
5. over-reliance on significance testing
6. researcher degrees of freedom

Vague Questions

An example of a **vague question** is

Does discharge affect fish abundance?

The question is obviously vague because it does not specify the species, life-stage or location (population). However nor does it specify the aspect of the hydrograph of interest (Olden and Poff (2003) identified 171 discharge metrics!) or the period of concern. It is also vague because it doesn't specify how much of an effect is to be considered important.

Hidden Assumptions

Hidden assumptions are those that reseachers are not aware they are making. An example would be to collect fish abundance data at *index* sites and then use it to draw river-wide conclusions. The hidden assumption is that changes in fish density at the index sites are representative of changes at the other sites. Often this is not the case.

Once recognised hidden assumptions sometimes become *heroic assumptions*: assumptions that are unlikely to be true but which are necessary in order to draw any meaningful conclusions.

Derived Indices

Derived indices are values which are calculated from other values without consideration of the underlying sampling distributions. For example the catch-per-unit-effort (CPUE) is

$$\text{CPUE} = \frac{\text{Catch}}{\text{Effort}}$$

However, analysing CPUE (as opposed to Catch and Effort) precludes

1. use of a readily interpretable distribution, i.e., Poisson for Catch
2. accounting for reduced uncertainty when lower effort
3. testing for catch depletion

Pseudo-replication

Pseudo-replication occurs when replicates are not statistically independent, which is almost all the time in ecological studies! When determining the effect of discharge on fish abundance non-independence can occur due to repeated measures, individual longevity, recruitment, aggregations, invasive species, downstream effects and climatic effects on fish abundance and discharge.

Over-Reliance on Significance Testing

Often an effect is judged solely on its significance. However significance alone is a poor criterion because significant and insignificant effects can be large or small (Figure 7). A large insignificant effect is potentially much more important than a small significant one.

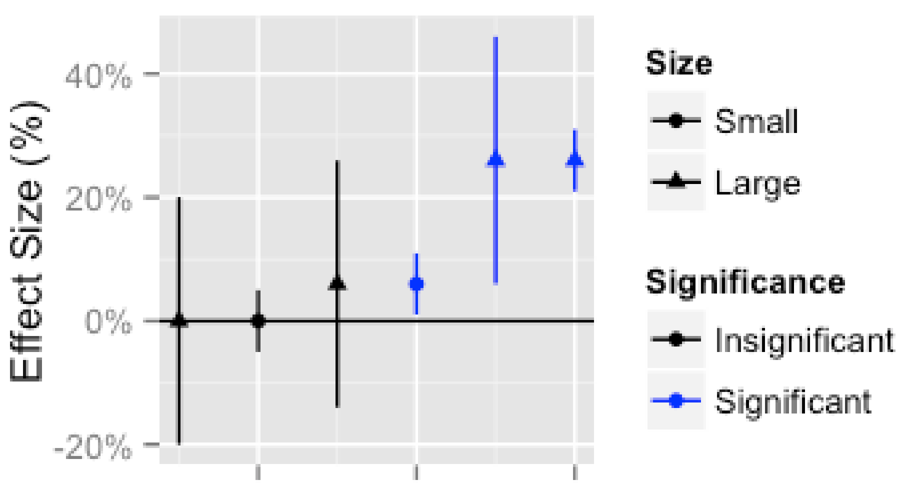


Figure 7. Various effect sizes.

Researcher Degrees of Freedom

Researcher degrees of freedom is an umbrella term for all the data-processing and analytical choices researchers make after seeing the data. A classic example is when researchers are tasked with identifying the environmental predictor variable(s) responsible for changes in the response. In the case of discharge and fish abundance the number of predictors can stretch into the tens or even hundreds. If 20 time series are considered the expectation is that one will predict the response by chance.

If researchers decisions are undocumented then the extent to which the probability of getting a false positive has been inflated cannot be assessed.

Analytic Solutions

Most of the analysis-related challenges can be overcome through hierarchical (account for non-independence), Bayesian scientific (explicitly describe observational and biological processes) models that allow the estimation of secondary parameters (answers to specific questions) with credible intervals (effect sizes) and the release of version-controlled code (researcher decisions).

References

Olden, Julian D., and N. L. Poff. 2003. “Redundancy and the Choice of Hydrologic Indices for Characterizing Streamflow Regimes.” *River Research and Applications* 19 (2): 101–21. doi:10.1002/rra.700.

Wickham, Hadley. 2014. “Tidy Data.” *Journal of Statistical Software* 59 (10): 1–22. http://www.jstatsoft.org/v59/i10.

Back to Table of Contents

15. Accounting for imperfect detection and uncertainty in abundance when monitoring biodiversity: a case study of the fish community in the Columbia River downstream of Revelstoke Dam

David Roscoe, Golder Associates Ltd., david_roscoe@golder.com
Joe Thorley, Poisson Consulting Ltd., joe@poissonconsulting.ca
Dustin Ford, Golder Associates Ltd., dustin_ford@golder.com
Larry Hildebrand, Golder Associates Ltd., larry_hildebrand@golder.com

Introduction

Detecting changes in the diversity of aquatic organisms is often a key objective of monitoring programs in regulated rivers and other ecosystems. Although a wide array of methods exists to quantify and describe biological diversity, all aspects of the diversity cannot be reduced to a single number or metric (Magurran 2004). Certain metrics can, however, be useful for comparing diversity across space or time, where the most appropriate measure depends on the aspect of biodiversity of interest and the objectives of the study (Purvis and Hector 2000). Traditional measures of diversity, such as species richness and indices of diversity, use presence/absence data or counts of organisms to calculate diversity metrics. These traditional indices of diversity are widely used in ecology, are simple to calculate, and are easily understood by stakeholders, policy makers and other investigators (Lamb et al. 2009). Two common limitations of traditional diversity indices are: 1) the assumption of 100% detectability of organisms during the survey; and, 2) lack of any quantification of uncertainty in the estimates. Failure to account for these limitations could limit the ability to detect trends over time, or result in trends that are due to random chance or changes in detectability, which could lead to inappropriate management decisions. In this study, boat electrofishing data from the Columbia River below Revelstoke Dam from 2001 to 2014 were used to calculate diversity metrics that include estimates of uncertainty and account for imperfect detection using hierarchical Bayesian models.

Revelstoke Dam is located on the Columbia River near Revelstoke, BC. This hydroelectric dam operates as a hydro-peaking facility where discharge is increased during periods of high energy demand, and discharge is reduced during periods of low demand. A minimum flow release of 142 m^3/s from Revelstoke Dam was implemented in December 2010 as part of BC Hydro’s Water Use Plan for the Columbia River. The key environmental objective of the minimum flow release is to increase the abundance and diversity of fish populations in the middle Columbia River (MCR). Fish populations have been monitored by BC Hydro annually since 2001. One of the objectives of the study is to investigate and document changes in species richness or species diversity in the MCR in response to the minimum flow release. Using fisheries data from boat electrofishing surveys, diversity metrics were calculated to assess changes over time and differences before and after the implementation of minimum flows in the MCR.

Methods

The study area encompassed the 12 km portion of the Columbia River between Revelstoke Dam and the Illecillewaet River confluence. Fishes were sampled by boat electrofishing at night within nearshore habitats. All captured fishes were measured for fork length and weighed. Select species were implanted with a Passive Integrated Transponder (PIT) tag for individual identification. Between three and five boat electrofishing sessions were conducted each year as part of a mark-recapture survey used to estimate abundance, growth, body condition, and biodiversity of fishes in the MCR. Sampling was conducted mainly in the fall but spring sampling was also conducted in 2011, 2012 and 2013.

Species richness and Shannon's index of diversity and evenness were chosen as metrics to assess trends in diversity because they are commonly used and easy to understand for managers and stakeholders. Hierarchical Bayesian models were used to estimate species occupancy, fish counts, species richness, and Shannon's diversity index, which accounted for varying detectability and allowed credible intervals (the Bayesian analogue of confidence intervals) to be calculated. Statistical analyses are summarized below and further details, including model specifications and code, are available in ONA, Golder and Poisson (2014).

Occupancy, which is the probability that a particular species was present at a site, was estimated from the temporal replication of detection data from electrofishing surveys. The model was equivalent to a generalized linear mixed model where observed presence was described by a Bernoulli distribution, site and year were included as random factors, and season (spring/fall) and minimum flow (before/after) were included as fixed effects. Species richness was estimated by summing the estimated occupancies for all species that had estimates of occupancy that varied through time.

Counts of each species were obtained by summing all fish captured or observed at a particular site and sampling session. Count data were analyzed using an overdispersed Poisson model. The model was equivalent to a generalized linear mixed model with a gamma distribution to describe the extra Poisson variation, site and year as random factors, and season (spring/fall) and minimum flow (before/after) as fixed effects.
The Shannon index of species diversity (H) was calculated using the following formula (Shannon and Weaver 1949; Krebs 1999):

$$H = -\sum_{i=1}^{S} (p_i \log(p_i))$$

Where S is the number of species and p_i is the proportion of the total number of individuals belonging to the i^{th} species, which is often referred to as the proportional abundance. Shannon's Index of evenness (E) was calculated using the formula (Pielou 1966):

$$E = H/\ln(S)$$

Shannon's diversity depends on the total number of species, as well as the evenness in the proportional abundances. By dividing Shannon's diversity by the natural logarithm of the number of species, Shannon's evenness is a measure of how even abundances are among species. In this study, Shannon's diversity was calculated by using the estimated counts from the Bayesian model to calculate the proportional abundance of each species.

In the MCR, the total number of species present in the study area likely does not vary from year to year, although uncommon species may or may not be detected in a given site or year. For the hierarchical Bayesian model for count data, the estimated count density of uncommon species was low but was never zero, even if the species was not detected in a certain year or site. This likely provides a more realistic representation of fish populations in the study area compared to an analysis that assumes densities of zero at sites or years where a species was not observed. However, this approach also means that the number of species, S, was the same for all years and sites when calculating Shannon's diversity. Therefore, the estimates of diversity among sites and years primarily reflect evenness, as the number of species is constant. Because S is constant, the denominator in the equation for evenness becomes a scaling constant that results in values between 0 and 1. Thus, for the purposes of comparing trends over time in the MCR, evenness and diversity are equivalent. For this reason, only evenness is presented.

Species richness and Shannon's evenness were also calculated using traditional methods to compare to the values obtained using the Bayesian models. Species richness was calculated as the total number of species captured or observed across all sampling sessions each year. Shannon's index was calculated using total counts of captured and observed fish across all sampling sessions each year.

Results

Species richness increased between 2001 and 2008, and decreased from 2010 to 2014 (Figure 1; left panel). Richness generally increased with decreasing river kilometre, with lower richness near Revelstoke Dam (Rkm 238) and greater richness at the downstream end of the study area (Rkm 227), which was closer to Arrow Lakes Reservoir (Figure 1; right panel). Higher species richness downstream is likely a reflection of this portion of the study area serving as a transition zone between the flowing section of the Columbia

River and Arrow Lakes Reservoir. Species evenness increased gradually from 19% in 2001 to 27% in 2007, although credible intervals overlapped for all years (Figure 2; left panel). Evenness was greatest at sites furthest downstream, which were closest to Arrow Lakes Reservoir (Figure 2; right panel). The increase in species richness from 2001 to 2008 was attributed to increases in the probability of occupancy of several species during the same time period including Burbot, Lake Whitefish, Northern Pikeminnow, Rainbow Trout, Redside Shiner, and Sculpin species (Figure 3).

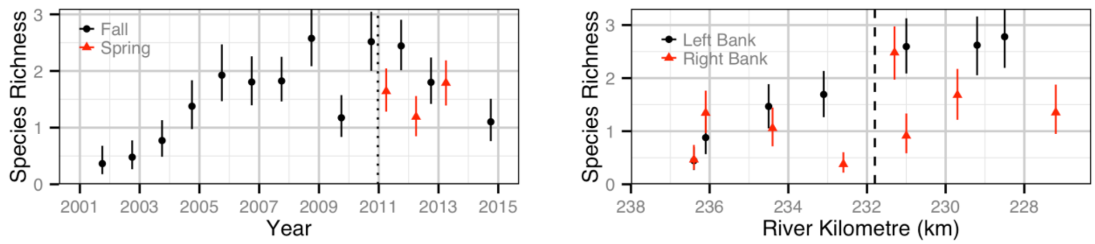


Figure 1. Species richness estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for the middle Columbia River study area, 2001 to 2014. The dotted line (left panel) represents the implementation of the minimum flow release from Revelstoke Dam.

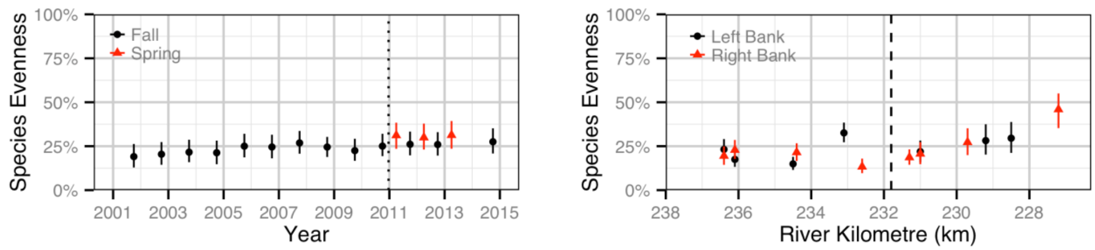


Figure 2. Species evenness estimates (with 95% credible intervals) by year and season (left panel) and site (right panel) for the middle Columbia River study area, 2001 to 2014. The dotted line (left panel) represents the implementation of the minimum flow release from Revelstoke Dam.

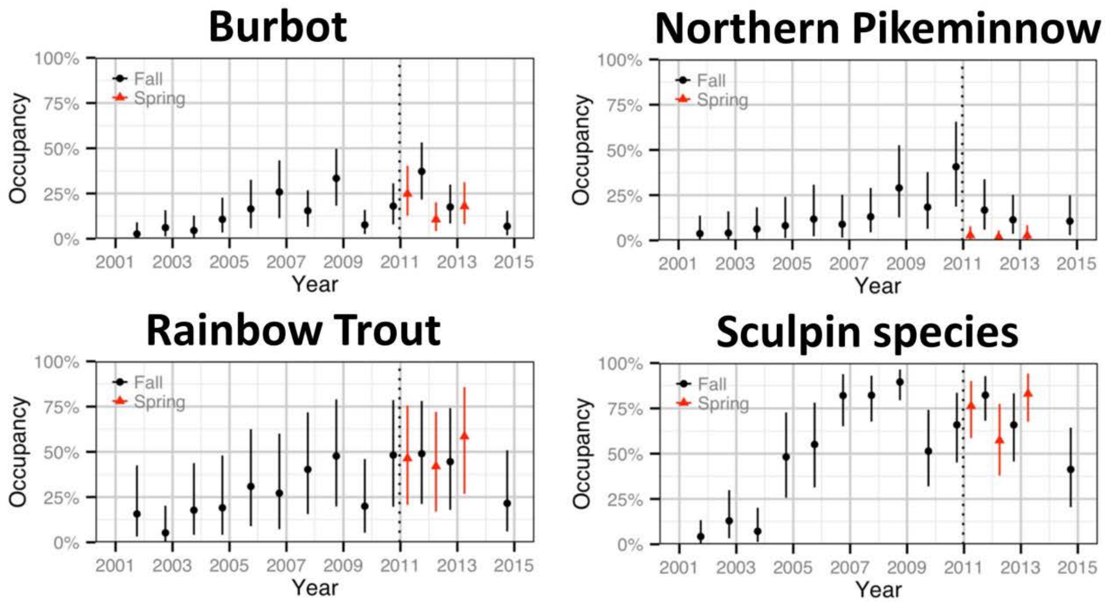


Figure 3. Occupancy estimates (with 95% credible intervals) by year for four of the less common fish species in the Middle Columbia River study area, 2001 to 2014. The dotted line represents the implementation of the minimum flow release from Revelstoke Dam.

In comparison, traditional estimates of species richness also showed an increase between 2001 and 2008 (Figure 4), although the change was not as large as the trend in richness based on occupancy estimates (Figure 1). Trends in Shannon's evenness were similar using the traditional calculation and the method using Bayesian estimates from count data. However, the method using Bayesian occupancy estimates included credible intervals to describe the uncertainty around the estimates, whereas confidence intervals could not be calculated for the traditional method.

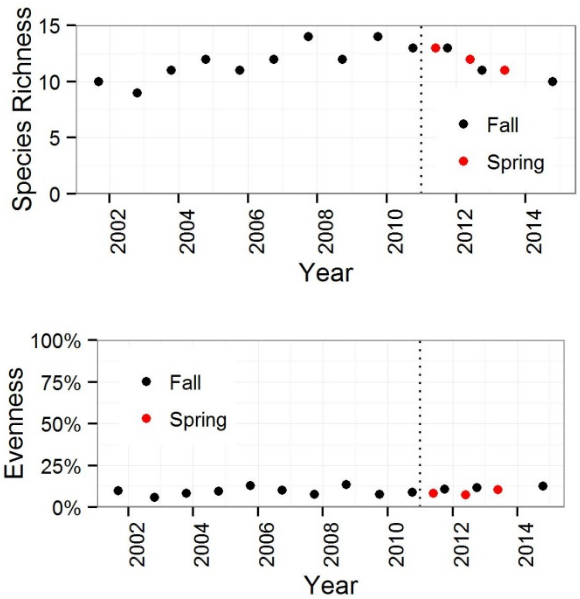


Figure 4. Species richness and Shannon's evenness calculated using traditional methods for the middle Columbia River study area, 2001 to 2014. The dotted line represents the implementation of the minimum flow release from Revelstoke Dam.

Discussion

The traditional measure of species richness calculated as the number of species observed is based on the unrealistic assumptions that detection probability of each species is 100% and that detection probability does not change over time (Boulinier et al. 1998; Gotelli and Colwell 2001). Therefore, the number of species may not be a reliable indicator of richness over time, because it may fluctuate due to changes in detection probability or chance encounters with rare species. The method used in this study takes into account varying detection probabilities over time. Although the method used resulted in lower estimates of richness (compared to the number of species), results were a robust index of richness that can be compared over time. As species introductions or extirpations likely did not occur in the study area during the monitoring period, this method provides a more reliable means of evaluating changes in species richness in the fish community in the study area. Similar methods of using estimates of species occupancy to calculate species richness have previously been used to model richness of plant communities (Gelfand et al. 2005) and birds (Kery and Royle 2008). The estimates of species richness in this study should not be interpreted as the total number of species present in the study area, but can be considered an indicator of changes in the number of species at typical sites in the study area over time.

The results suggested increases in species richness and evenness between 2001 and 2008, which were attributed to increasing occupancy and abundance of several less common species including Burbot, Lake Whitefish, Northern Pikeminnow, Rainbow Trout, Redside Shiner, and Sculpin species. Following the implementation of minimum flows, species richness decreased whereas evenness remained relatively constant. Overall, the results indicated a substantial change in the fish community between 2001 and 2008 but did not suggest an effect of minimum flows on fish diversity in the MCR.

Acknowledgements
BC Hydro funded this study and provided valuable input on study design. Numerous individuals at Golder Associates Ltd. and Okanagan Nation Alliance assisted with planning, field work, and administrative support. Poisson Consulting Ltd. conducted the modelling.

References
Boulinier, T., J.D. Nichols, J.R. Sauer, J.E. Hines, and K.H. Pollock. 1998. Estimating species richness: the importance of heterogeneity in species detectability. Ecology 79: 1018-1028.

Gelfand, A.E., A.M. Schmidt, S. Wu, J.A Silander, A. Latimer, A.G. Rebelo. 2005. Modelling species diversity through species level hierarchical modelling. Journal of the Royal Statistical Society - Series C - Applied Statistics 54: 1-20.

Gotelli N.J. and R.K. Colwell. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4: 379-391.

Kery, M. and J.A. Royle. 2008. Hierarchical Bayes estimation of species richness and occupancy in spatially replicated surveys. Journal of Applied Ecology 45: 589-598.
Krebs, C.J. 1999. Ecological Methodology. Addison Wesley, Longman, Menlo Park, California.

Lamb, E. G., E. Bayne, G. Holloway, J. Schieck, S. Boutin, J. Herbers, J., and D.L. Haughland. 2009. Indices for monitoring biodiversity change: Are some more effective than others? Ecological Indicators 9: 432-444.

Magurran, A.E. 2004. Measuring Biological Diversity. Blackwell, Oxford.

Okanagan Nation Alliance (ONA), Golder Associates Ltd., and Poisson Consulting Ltd. 2014.CLBMON-16 Middle Columbia River Fish Population Indexing Survey. Report prepared for BC Hydro Generation, Water License Requirements, Revelstoke, BC.

Pielou, E.C., 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13: 131-144.

Purvis, A. and A. Hector, A. 2000. Getting the measure of biodiversity. Nature 405: 212-219.

Shannon, C.E. and W. Weaver. 1949. The mathematical theory of communication. The University of Illinois Press, Urbana. 177pp.

Back to Table of Contents

16. A quantitative approach in comparing rivers and their whitewaters: a proven tool in promoting a balance between river regulation and conservation in northern Québec.

Yann Troutet, M.Env., Association Eaux-Vives Minganie
yanntroutet@yahoo.com

Co-author: Lorie Ouellet, M.A., Professor, Laboratoire d'expertise et de recherche en plein-air, Université du Québec à Chicoutimi, QC.
lorie_ouellet@uqac.ca

Introduction

As a hydrological feature, whitewater has important ecological functions in river systems (Allan and Castillo 2007). To humankind, whitewater also procures valued esthetic, recreational and cultural landmarks. From an economic standpoint, however, such social values are difficult to frame in terms of "exchange value", and are hence often neglected in the decision-making that underpins the management of fluvial systems.

The loss of whitewater features is a common impact of the hydroelectric development of rivers. This cost is generally impossible to compensate for. To ensure a balanced approach in land management at a regional scale, measures must be taken to better assess this impact. In this paper, we describe a method that offers quantitative means of comparing rivers on the basis of their whitewater character. Relying on the detailed information provided by recreational river-running maps, the method has proven to be a valuable tool in assessing broad hydrological characteristics of river systems, in turn helping to inform land-use planning in the face of continued river regulation in northern Québec.

Figure 1: ***Gorge on the Magpie River, Québec. The whitewater features of a river possess an undeniable attractiveness. This confers social value to the rapids, cascades and falls of large, free-flowing rivers. Sites like these are where lies most of the potential for future hydroelectric development in Québec. Most often, the social value of whitewater is not factored-in when rivers are slated for industrial development. Finding objective ways to describe the whitewater character of rivers can help promote practices balancing social, ecological and economical values in the decision-making processes that support land-use planning.***

Geographical and historical context
Québec's geography has allowed the province to leverage hydroelectricity as one of the main drivers of its socio-economic development (Lanoue and Hafsi 2010; Bernard 2014), ranking it among the early world leaders in the development, production, and export of hydroelectricity (Morin 2014; Aaron and Vine 2015).

The topography of the Québec-Labrador peninsula is dominated by a vast plateau, the heights of which mark the border between Québec and Labrador (figure 2). Forming the headwaters of most of the Québec's largest watersheds (figure 3), this plateau also gives for high elevation differentials. Accordingly, the rivers that drain the *Labrador Plateau* are the key to Québec's exceptional hydroelectric potential.

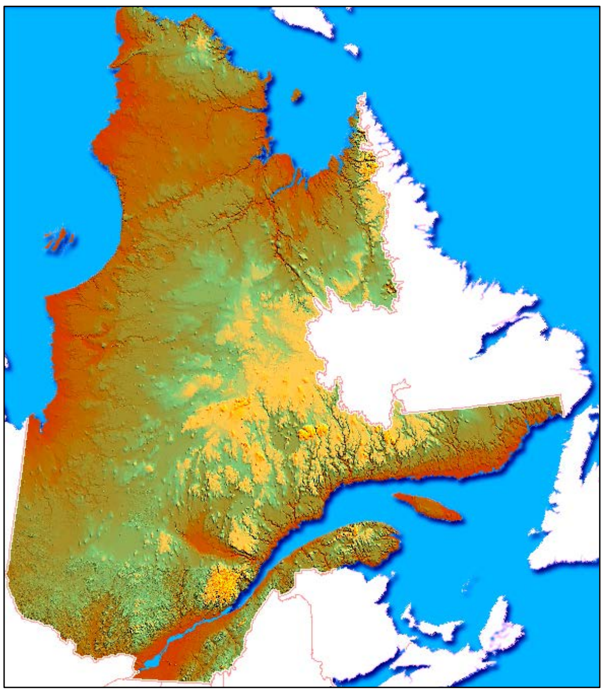


Figure 2: The topography of Québec.

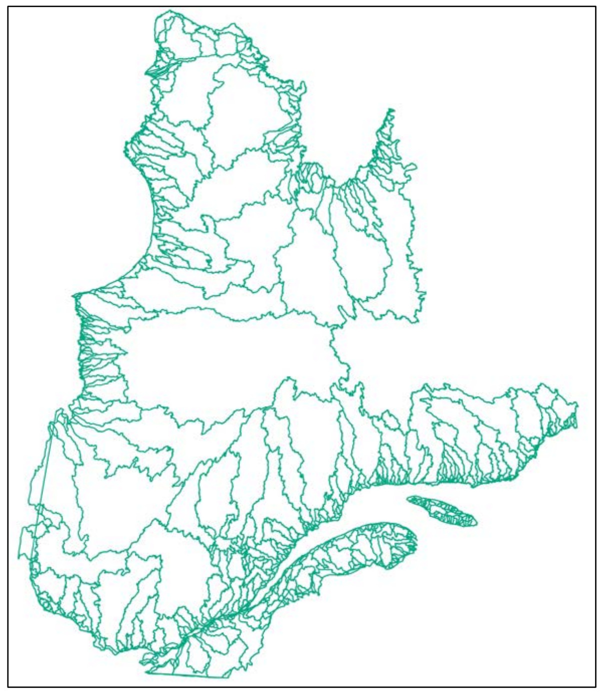


Figure 3: Québec's Level-1 watersheds.

By the mid 20th century, all the larger watersheds in the southern reaches of the province had been regulated. In the 1950's and 1960's, Hydro-Québec pioneered the long-distance transport of electricity, expanding its network of installations to the rivers flowing down from the Labrador Plateau, to the North-Shore of the St. Lawrence. Culminating with the Manicouagan/Outardes complex, this phase of development was soon followed by the construction of what was to become the largest hydroelectric complex in the world, which involved the impoundments and diversion of several rivers flowing to the James Bay and Ungava Bay, the flow of which were redirected toward a network of hydro-electric plants on the *La Grande* River.

Following the completion of the *La Grande* complex in the 1980's, the pace of hydroelectric development decelerated markedly in Québec. Concurrently, concerns were being voiced regarding the environmental impacts of such large-scale projects. In 1996, the province released a comprehensive energy policy, following a vast consultation effort. One of the "major initiatives" in this policy was the commitment to classify the province's rivers, recognizing that this process embodied a "consensus emanating from the public debate on energy" in Québec (Québec 1996). Despite this consensus, the government never followed through on its commitment (Bureau d'audiences publiques sur l'environnement 2009). Rather than that, Québec's current energy strategy, released in 2006, calls for an acceleration in the development of the province's hydroelectric potential, and makes no mention of protecting rivers.

By 2008, the acceleration of hydroelectric development was to become the centerpiece of the provincial government's plan for Northern Québec. According to the *Plan Nord*, 8000 megawatts of new hydroelectric capacity is to be built by 2035 in northern Québec (Québec 2006, Québec 2011a). Along with this, the plan also promises to protect 50% of all provincial lands north of the 49^{th} parallel, in an attempt to "balance industrial development and conservation" (Québec 2011b).

To obtain high levels of hydroelectric capacity, dam construction must target rivers that have relatively large catchment basins at high elevation. It is this combination of factors that make the Labrador Plateau so conducive to hydroelectric development: large amounts of water collect on the elevated plateau, forming rivers that proceed to cascade several hundreds of meters down to the ocean.

By the early 2000's, the last remaining watercourses flowing freely off the Labrador Plateau were the mid-sized rivers that cascade steeply down to the central part of the Gulf of St. Lawrence's North-Shore (figure 4). It is no surprise that the first river to be slated for hydroelectric development under the Plan Nord, the Romaine River, is situated in this part of the province, known as *Minganie*. With a capacity of 1550 MW, the Romaine River complex was presented by Hydro-Québec's CEO as only "the beginning of large-scale hydroelectric development in Minganie".

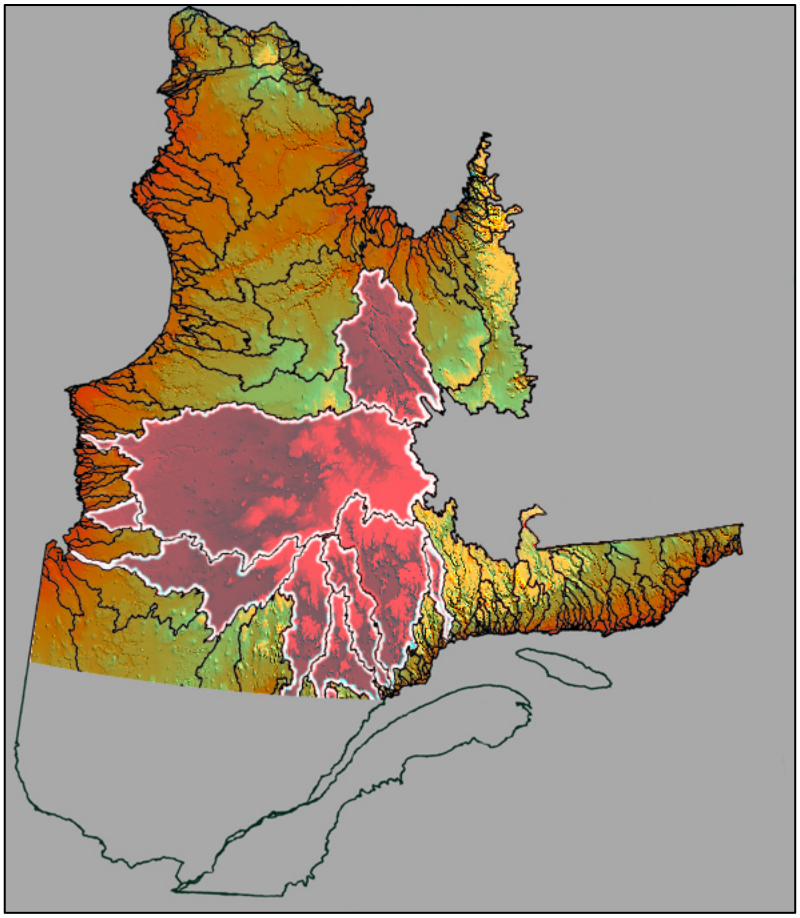


Figure 4: ***The topography and watersheds of the territory targeted by Québec's Plan Nord. Highlighted are the watersheds that have already been regulated or diverted for hydroelectric production. The last rivers flowing freely from the heights of the Labrador Plateau are all located in a part of Québec's North-Shore region known as Minganie. Flowing through glacier-carved valleys, these large, steep rivers are punctuated by numerous whitewater sections, and possess remarkable scenic and recreational value. However, this is also where lies most of the remaining hydroelectric potential in the province, and where most of Québec's future hydroelectric developments are proposed.***

As a large industrial project, the Romaine River complex was subject to an environmental review both under provincial and federal law. A joint Federal-Provincial Review Panel help public hearings as part of its analysis of the project. In this context, efforts were made to attempt to capture and communicate the exceptional character of the North-Shore's rivers, with a particular emphasis on characteristics that make these rivers especially distinctive: the exceptionally high number, size and density of their whitewater features.

As is apparent on figures 2 and 4, the Labrador Plateau is offset to the south-east in relation to the geographical center of the Québec-Labrador peninsula. As a result, the rivers flowing down to the North-Shore of the St. Lawrence have a comparatively steep gradient. By virtue of this, and given the relatively large size of their watersheds, these rivers are able to generate sizeable whitewater features, in rapid succession, along their entire length. Their course is also dictated by the large U-shaped valleys that were created by south-bound glaciers of the last glaciations, which adds to the distinctive character of the North-Shore rivers. And while these factors all contribute to the obvious hydroelectric potential of these rivers, they also explain why they have the reputation of being world-class destinations for extended whitewater expeditions.

Indeed, several rivers of the North-Shore are renowned whitewater runs. The Moisie River is often referred to as the “Nahanni of the East” (Wikipedia contributors 2015a). The Magpie River was voted #2 on National Geographic’s list of the world’s best rivers for whitewater rafting expeditions (National Geographic 2007). The Petit-Mecatina river is known as one of the most remote and difficult rivers to paddle in North-America. For its part, the Romaine River is said to have “the best, most runnable, whitewater of the rivers on the North Coast. Better than the Petit Mecatina, and better than the Magpie.” (Coriell 2009)

Such statements underscore quite vividly the remarkable character of these rivers, and go a long way toward illustrating the need to consider the value of protecting some of these rivers. Such anecdotal evidence, however, does little to inform a formal environmental review, which requires more from factual, systematic and verifiable data. For river conservation advocacy, the challenge, hence, was to find ways by which to capture, describe and compare the whitewater character of Québec’s rivers on the basis of recognized and objective data.

Capturing the whitewater character of rivers – the approach

In order to inform the Joint Review Panel on the Romaine River Complex, a method was devised to reveal the exceptionally high number, size and density of whitewater features that were present on this river. Relying on the detailed maps that are used by recreational paddlers, this method calls upon some of the most standardised and scrutinised information available pertaining to the whitewater features of rivers in Québec. These maps are published by a centralised organisation, the *Fédération québécoise du canot et du kayak (FQCK)* on the basis on a recognized scale of rapid classification (Wikipedia contributors 2015b).

Among the details provided by FQCK rivers maps, the length and class of each rapid are standard information (figure 5). Based on a scale of 6, the rapid class gives an appreciation of the level of difficulty of the obstacle in the context of a river run. This is most often closely related to the size of the waves and whitewater features that the rapid presents: class-1 rapids will have small features, while class-6 rapids have very big ones. By multiplying the length and class of each rapid, a "Whitewater Index" can be obtained, summarizing the whitewater content of each given obstacle (table 1). With these units, various statistics can in turn be calculated, enabling us to characterise and compare different rivers or section of rivers on the basis of their whitewater.
The total length of rapids is obtained by simply summing the length of all individual rapids. In the example given by figure 5, this adds up to 4195 meters of whitewater. Likewise, the Whitewater Index of this section of the river is obtained by adding together the indexes calculated for each rapid (table 1). Here, we obtain 11 935 "whitewater units". The average difficulty level of this section of river can be summarized by dividing the Whitewater Index by the total length of the rapids. In this case: 11 935 / 4195 = 2.85. The Whitewater Index can also be averaged on a per-kilometer basis. For the example given in Figure 5, the Whitewater Index of 11 935 is averaged over the 11 kilometers of this section of river, for an average index of 1085 "whitewater units" per kilometer.

The Whitewater Index does not consider the contribution of falls. Generally considered impassable, falls often require that the boats be portaged. In certain cases, portages can be arduous, and their presence could arguably be perceived as a negative factor. On the other hand, falls often give rise to very scenic sites, which may well make-up for the effort, and constitute a valued feature in a given river run. Moreover, the technical evolution of whitewater sports has been such that, today, many falls are routinely paddled as integral part of river runs. Overall, sections of falls add unequivocally to the challenge and character presented by a river. To capture this, a distinct index, the Overall Index, is also calculated, where the reputedly impassable obstacles are given a "class 6" rating.

Table 1 :
The class, length and Whitewater (WW) Index of the whitewater features (R = rapids, S = ledges) located between km 55 and km 44 of the Lower Magpie River.

Rapid Class	Length (m)	WW Index
3.5	800	2800
1	220	220
2	75	150
2	130	260
1	200	200
2	300	600
4	30	120
3	170	510
3.5	150	525
1	100	100
4	300	1200
1	200	200
4.5	100	450
4	400	1600
1	30	30
3	50	150
4	100	400
2	350	700
3	30	90
4	250	1000
5	100	500
2	5	10
4	30	120
Falls (6)	*75*	*450*
Length		4195 m
Whitewater Index		11 935
Average class		2.85
WW Index/km		1085
Overall Index		12 385

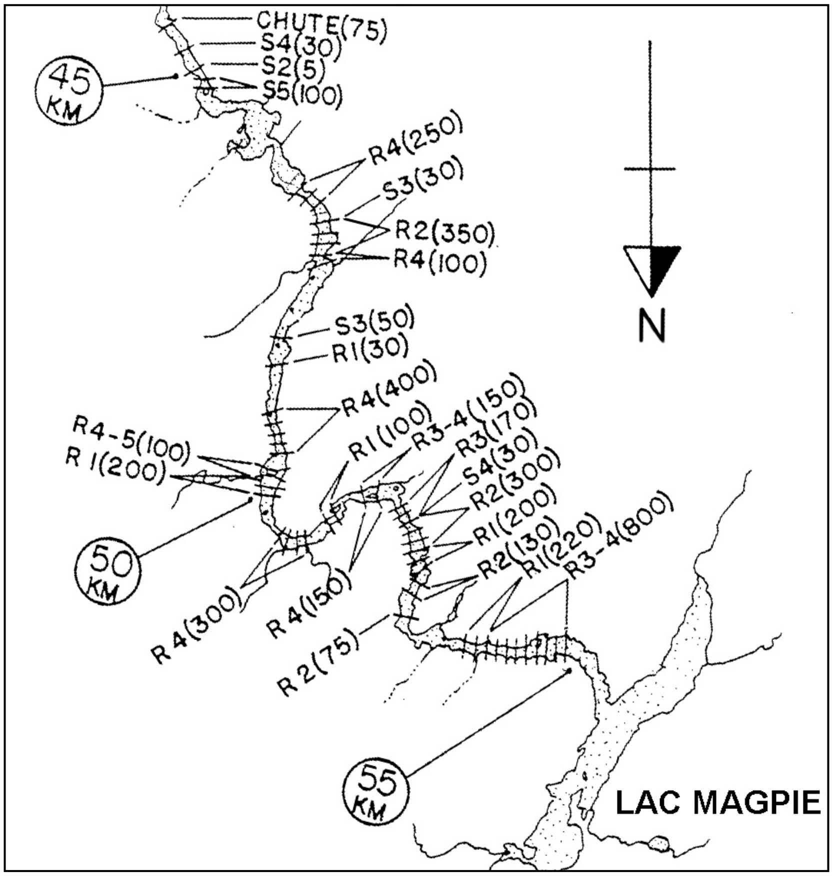


Figure 5 ***Excerpt from a standard FQCK map (no. 07-35-10-00), presenting the class and length (in meters) of the whitewater features (R = rapids, S = ledges) located between km 55 and km 44 of the Lower Magpie River.***

Results
Using the Whitewater Index calculations described above, we can begin to compare various rivers on the basis of their broad whitewater characteristics, with quantitative reference information. Troutet and Charest (2008) demonstrate that the steepest of Québec's larger watersheds are found in the Minganie and hence, only rivers in this region can rival the Romaine in terms of whitewater character. In addition to the Romaine, these include the Magpie River, the St-Jean River, the Aguanish River and the Natashquan River, which were all analysed (table 2). For the purpose of comparing these rivers with better known and more commonly paddled rivers in Québec, two prominent rivers were added to the comparison: the neighbouring Moisie River, and the Dumoine River, located in south-western Québec. Both these rivers have also been granted interim protection status and have often been presented as success-stories for river conservation by the province's government (Troutet 2011).

Table 2 Whitewater Index and related metrics for the Dumoine, Moisie, Magpie, St-Jean, Romaine, Aguanish and Natashquan rivers.

	DUMOINE	MOISIE	MAGPIE	ST-JEAN	ROMAINE COMPLEX*	AGUANISH	NATASHQUAN
Length(km)	144	420	277	210	235	270	300
Gradient (‰)	1,4	1,2	2,1	2,7	1,9	2,0	0,7
Whitewater (m)	14 800	26 387	41 465	20 665	44 385	32 895	21 120
Whitewater Index	26 325	52 647	103 648	33 553	81 070	42 183	23 068
Average class	2,14	2,09	3,07	2,46	2,37	2,02	1,14
Whitewater Index/km	183	125	374	98	345	156	77
Overall Index	31 725	55 047	127 378	50 923	105 070	66 543	24 088

* : the data considers only the portion of river directly affected by the hydro complex (km 51 to km 286)

According to the data summarized in table 2, the most striking result is that, in itself, the portion of the Romaine River that is targeted by the hydro complex project has more whitewater than all but one of the rivers considered, this exception being the Magpie River. Despite their reputation and their poster-child status, neither the Moisie, nor the Dumoine come close to having a comparable amount and density of whitewater.

The Romaine River complex is the first project to embody Québec's Plan Nord, which promises both large-scale industrial development and large-scale land protection in northern Québec. On the basis of its public hearing efforts, and considering the above results, the Joint Review Panel on the project, voiced the following opinion:

"The panel is of the opinion that harnessing rivers for hydroelectric purposes on the North Shore should be accompanied by the protection, in the region, of a natural heritage that is qualitatively and quantitatively equivalent in terms of ecosystem, landscape and recreational richness."

The panel added that:

"The Romaine River, because of its whitewater, has undeniable valued qualities that contribute to the landscape and recreational heritage of North Shore rivers. The panel is therefore of the opinion that if the project goes ahead, a similar river in the region offering comparable aesthetic and recreational features according to recognized criteria in this area should be protected." (Bureau d'audiences publiques sur l'environnement 2009)

These strongly-worded opinions can arguably be presented as a direct result of the compelling application of the Whitewater Index. The echo that these opinions found in the media (see Chartrand 2009; Corbeil 2009) was a more indirect but none the less validating result of this approach.

Following the early successes brought about by the application of the Whitewater Index, Association Eaux-Vives Minganie was able to partner with the Canadian Parks and Wilderness Society (CPAWS), who was convinced by these initial results that the Magpie River warranted national attention, and deserved to become the focus of one of CPAWS' campaigns. This partnership led to a study that, among other things, examined the Magpie River as it compares with world-renowned rafting expedition destinations. Conducted at *Université du Québec à Chicoutimi*, this work focused on rivers that support substantial tourism operations and have available detailed river maps: the Middle Fork of the Salmon River, in Idaho (USA); the Nahanni, in Canada's Northwest Territories; the Colorado, in Grand Canyon National Park (USA) and the Futaleufú, in Chile's Patagonia (Ouellet 2013). The study examines various facets of each one of these selected destinations as they pertain to the appeal of each river for whitewater expeditions. Among these parameters is the Whitewater Index and its related metrics (Table 3).

Table 3 Whitewater Index and related metrics for the Magpie, Middle Fork of the Salmon, Nahanni, Colorado and Futaleufú rivers.

	MAGPIE	Middle Fork of the SALMON	NAHANNI	COLORADO	FUTALEUFU
Section	Lac Éric - St-Lawrence	Boundary Creek -Cache Bar	Moose Pond - Blackstone	Lee's Ferry - Diamond Creek	Palena - Lake Yelcho
Length (km)	277	156	600	364	46
Gradient (%)	0,21	0,53	0,07 - 0,17	0,17	0,17
Whitewater length (m)	41 465	5 395	56 175	16 794	11 895
Whitewater Index	103 648	15 055	117 475	41 491	41 495
Average class	3,07	2,8	2,08	2	3,4
Whitewater index /km	374	96	196	114	902
Overall Index	127 378	15 055	119 935	41 491	41 495

Once again, the application of the whitewater Index was instrumental in summarizing some of the broad hydrological characteristics of these exceptional, yet very different whitewater river destinations. For instance, these numbers explain why the Nahanni is best known for the long canoe-tripping opportunities that it offers. Indeed, it is the longest of the rivers considered by Ouellet (2013), with an average rapid class that is well-suited to this type of travel. On the other hand, this analysis illustrates why the Futaleufú is first and foremost a rafting destination: its average rapid class and whitewater index per kilometer are the highest of the group. For their part, the Colorado and the Middle Fork of Salmon prove to be more modest whitewater rivers, suggesting that their notoriety and popularity may have to do with factors such as their greater accessibility, scenic values or protection status, all of which also contribute to the overall appeal of a whitewater river destination.

Conclusion

Whitewater is a valued component of fluvial systems. One of the most unavoidable impacts of hydroelectric development is the loss of whitewater features on impounded watercourses. In the absence of a systematic process of river classification and in the face of continued river regulation in Québec, novel approaches are warranted to underscore the exceptional characters of some of the province's most remarkable whitewater rivers. Based on the detailed and standardised information provided by recreational river maps, a Whitewater Index and various related metrics can be obtained. These allow for quantitative and objective comparisons of rivers from the particular perspective of their whitewater character. Québec's *Plan Nord* calls for both an acceleration of large-scale hydroelectric development and the protection of 50% of the province's North. In this context, the application of the Whitewater Index has been instrumental in prompting authorities to consider the protection of important whitewater rivers. It has also served as a springboard for environmental advocacy and helped lay the foundation for more in-depth academic studies. The application of this method has revealed that, from a whitewater perspective, the Magpie River is likely the only remaining river in Québec that is commensurate with the Romaine River, which has been dedicated to hydroelectric development. Moreover, the use of the Whitewater Index reveals that the Magpie River can justifiably be presented as a world-class destination for whitewater endeavours, in turn helping inform and balance the decision-making that is currently changing the face of Northern Québec.

References

Allan, J. D. and M. M. Castillo. 2007. Stream Ecology: Structure and function of running waters, Second Edition. Springer, Dordrecht, Netherlands. 436p.

Bernard, J.-T. 2014. Electricity Pricing Was Not Part of the Debate Leading to Electricity Nationalization by the Québec Government in 1962. Center for Research on the economics of the Environment, Agri-food, Transports and Energy. Working Paper 2014-3. 14 p.

Bureau d'audiences publiques sur l'environnement. 2009. Romaine River Hydroelectric Complex Development Project Investigation and Public Hearing Report. Report no. 256. Online. Ottawa: Canadian Environmental Assessment Agency. 243 p. http://www.ceaa-acee.gc.ca/050/documents/34664/34664E.pdf Accessed June 16, 2015

Chartrand, Y. 2009. Magpie: une autre déclaration de guerre d'Hydro-Québec. Ex Rue Frontenac. August 1 2009. Online. http://www.exruefrontenac.com/nouvelles-generales/117-vu-de-la-colline/8848-riviere-magpie-hydro-quebec-vu-de-la-colline. Accessed June 16 2015.

Corbeil, M. 2009. Les rivières en péril à cause d'Hydro, clame Eaux-Vives Minganie. Le Soleil. December 16 2009. Online. http://www.cyberpresse.ca/le-soleil/actualites/environnement/200912/15/01-931400-les-rivieres-en-peril-a-cause-dhydro-clame-eaux-vives-minganie.php. Accessed June 16 2015.

Coriell, F. 2009. Romaine River. Web blog post. Riversenses : Rainsing Awareness of the threatened rivers of Québec's Cote-Nord. 29 May 2009. http://riversenses.blogspot.ca/2008/09/romaine-river.html Accessed June 16, 2015.

Lanoue, R. and T. Hafsi. 2010. Société d'État? Pourquoi pas? Concilier performance et politique, les secrets de la réussite d'Hydro-Québec. Québec, Presses de l'Université du Québec. 194 p.

National Geographic. 2007. Journeys of a Lifetime: 500 of the World's Greatest Trips. 400 p.
Retreived from http://travel.nationalgeographic.com/travel/top-10/white-water-rafting/ Accessed June 16 2015.

Ouellet, L. 2013. *La rivière Magpie : Une rivière de classe mondiale à protéger. Caractérisation comparée des grandes rivières d'eau vive d'Amérique et de la rivière Magpie pour leur potentiel de pratique des activités d'eau vive.* Laboratoire d'expertise et de recherche en plein air. Université du Québec à Chicoutimi. 105 p.

Québec. Ministère des Ressources naturelles. Direction des relations publiques. 1996. *L'énergie au service du Québec : Une perspective de développement durable.* Online. Charlesbourg : Ministère des Ressources naturelles. Direction des relations publiques. Publication no. RN96-4014. 108 p. http://www.politiqueenergetique.gouv.qc.ca/wp-content/uploads/2014/12/Strategie-Energie-1996.pdf. Accessed June 16, 2015

Québec. Ministère des Ressources naturelles et de la Faune. 2011a. *Le Plan Nord : faire du Québec une puissance mondiale de l'énergie renouvelable.* Fiche - Énergie renouvelable. Québec : Ministère des Ressources naturelles et de la Faune. 2 p.

Québec. Ministère du Développement durable, de l'Environnement et des Parcs. Centre d'information. 2011b. *Plan Nord. Document de consultation. Engagement gouvernemental visant à consacrer 50 % de la superficie du territoire du Plan Nord à la protection de l'environnement, au maintien de la biodiversité, à la mise en valeur du patrimoine naturel et à divers types de développement qui ne font pas appel à des activités industrielles : Pour un équilibre entre les types de développement et les formes de conservation dans une perspective de développement durable.* Centre d'information du ministère du Développement durable, de l'Environnement et des Parcs. 56 p.

Québec. Ministère des Ressources naturelles et de la Faune. 2006. Using Energy to Build the Québec of Tomorrow: Québec Energy Strategy 2006-2015. Online. Québec: Ministère des Ressources naturelles et de la Faune. Distribution code: 2006-4002. 111 p. http://www.mern.gouv.qc.ca/english/publications/energy/strategy/energy-strategy-2006-2015.pdf. Accessed June 16, 2015

Troutet, Y. and A. Charest. 2008. *Rivière d'Eau Romaine, rivière d'eau vive.* Submission presented to the Joint Review Panel on the Romaine River Hydroelectric Complex Development Project. 22 p. + addenda
http://www.bibliotheque.assnat.qc.ca/DepotNumerique_v2/AffichageNotice.aspx?idn=22202 Accessed June 16 2015.

Troutet, Y. 2011. *Pour un équilibre entre le développement hydroélectrique et la conservation des rivières : Mémoire concernant l'engagement gouvernemental de consacrer 50 % de la superficie du territoire du Plan Nord à la protection de l'environnement, présenté au Ministre du développement durable, de l'environnement et des parcs.* Association Eaux-Vives Minganie. 35 p.

http://www.bibliotheque.assnat.qc.ca/DepotNumerique_v2/AffichageNotice.aspx?idn=21983
Accessed June 16 2015.

Wikipedia contributors. 2015a. *Moisie River.* Wikipedia, The Free Encyclopedia. June 11, 2015, 11:26 UTC. Available at: https://en.wikipedia.org/w/index.php?title=Moisie_River&oldid=666471355 Accessed June 16, 2015.

Wikipedia contributors. 2015b. *International Scale of River Difficulty.* Wikipedia, The Free Encyclopedia. January 14, 2015, 19:27 UTC Available at: http://en.wikipedia.org/wiki/International_Scale_of_River_Difficulty Accessed June 16, 2015.

Back to Table of Contents

17. Shallow fish habitat utilization assessments in reservoirs.

Elmar Plate, Ph.D
LGL Limited
9768 Second Street
Sidney, BC, V8L 3Y8
E-mail: eplate@lgl.com
Phone: 250-656-0127
Website: http://lgl.com/

Abstract

Typically population estimates in reservoirs are limited to the assessment of fish larger than 120 mm in the pelagic zone. Consequently, early recruitment trends often remain undetected and in general, younger age classes are underestimated in the pelagic zone. At the same time, invasive presence and absence measures such as, minnow trap deployment, beach seining or electrofishing can provide fish species composition but are less suited for population estimates in the shallow littoral zone. Therefore, the focus of our research was the development of measures that can optimize the spatial resolution and coverage during hydroacoustic surveys in the pelagic zone and suggest the use of Dual-Frequency Identification Sonar or DIDSON to assess the shallow littoral zone during day and night. The combination of both techniques throughout the diel cycle also reveals non-invasive diurnal versus nocturnal differences in habitat utilization in the shallow littoral versus the pelagic zone. In addition, the use of DIDSON can differentiate between fish activities that are carried out in the shallow littoral zone. For example, behaviours such as preying, spawning and holding can be easily told apart. Nevertheless, invasive fish sampling method, such as beach seining must still be used to determine species composition, albeit at a much reduced frequency. Power analysis can determine the DIDSON sample size to obtain reasonable shallow littoral zone population estimates in the typically quite uniform habitats of a reservoir draw down zone. In this context, the dreaded simplicity and homogeneity of draw-down zones can drastically reduce the number of DIDSON sample locations to achieve acceptable confidence levels for population estimates. Although none of the aforementioned techniques is new, their optimization and use in combination and in reservoirs offers a better option to especially assess reservoir fish populations and their behaviours.

Back to Table of Contents

18. Rocky Reach Reservoir white sturgeon indexing and monitoring program, 2011-2014.

Lance Keller,
Public Utility District No. 1 of Chelan County
327 North Wenatchee Avenue, Wenatchee, Washington 98801
Email: lance.keller@chelanpud.org
Phone: 509-661-4299
and
David Robichaud
LGL Limited
9768 Second Street, Sidney, BC V8L 3Y8
Email: drobichaud@lgl.com
Phone: 250-656-0127
and
Corey Wright
Blue Leaf Environmental
2301 W Dolarway Rd STE 3
Ellensburg, WA 98926
Email: cwright@blueleafenviro.com
Phone: 509-210-7423

Abstract
Chelan County Public Utility District has initiated a white sturgeon (*Acipenser transmontanus*) hatchery supplementation program in order to bring the population level up to carrying capacity of the Rocky Reach Reservoir by 2039. Since 2011, a total of 19,450 hatchery-reared, PIT-tagged juvenile sturgeon have been released into the Reservoir, including 169 that are also acoustic-tagged. Tracking, using a network of 16 acoustic receivers, has shown that fish movement has been predominantly in the upstream direction, and mostly within the first six months post release. The rate of emigration into areas downstream of the reservoir was 4.7%. We are in year 2 of a 3-year indexing survey, which, to date, has shown that catch rates vary spatially, temporally and among years. Catch rates also appear to be somewhat higher in areas of lower velocity, higher DO, and over fine-sized substrates in range of depths from 10-30 m and below 40 m. Growth rates were calculated from recaptured fish, and averaged 153-176 mm/yr within the first half year at large, and slowed thereafter to 62-93 mm/yr. Weight gain averaged 141-143 g/yr within the first half year at large, 96-157 g/yr in the next 365 days, and increased to 272-457 g/yr thereafter. PIT-tag mark recapture data were fit to Cormack-Jolly-Seber survival models, which showed that survival in the first 6 months post-release ranged from 36.7% (SE=2.6%) to 67.9% (SE=10.9%), depending on the cohort (i.e., the year of release). Model results suggested that, within a cohort,

subsequent survival rates did not vary among years. There is evidence for differences in survival rates among rearing and release locations. Indexing and acoustic-tracking will continue into 2015.

Back to Table of Contents

19. Use of underwater videography to quantify fish abundance downstream of a hydroelectric facility

Sima Usvyatsov[1]*, **Paul Grutter[1]**, Peter Johnson[2], and Larry Hildebrand[1]
[1]Golder Associates Ltd., 201 Columbia Avenue, Castlegar, British Columbia, Canada V1N 1A8 Email: Paul_Grutter@golder.com
[2]LGL Ltd., PO Box 225 North Bonneville, Washington, United States, 9863
*Email: susvyatsov@golder.com

Introduction

Underwater videography has been used extensively as a low-impact technique for studying aquatic systems (Caimi et al. 2010). In environments where visibility is restricted, acoustic cameras, such as a Dual-frequency Identification Sonar (DIDSON, SoundMetrics Corp.), are often used instead (e.g., Moursund et al. 2003). The two systems may be viewed as complementary (Frias-Torres & Luo 2009). While acoustic systems can quantify fish abundance and size (Boswell et al. 2008, Price et al. 2013) regardless of turbidity or light levels (Becker et al. 2011), underwater video can provide supplemental information on such parameters as species composition and substrate condition.

The goal of this study was to develop an underwater videography technique to obtain data on densities of potential predators on White Sturgeon (*Acipenser transmontanus*) eggs in a large riverine system. The Upper Columbia River population of White Sturgeon, listed under Schedule A of the Species At Risk Act (SARA), spawns annually downstream of Waneta Dam, at the confluence of the Columbia and Pend d'Oreille rivers (Hildebrand & Parsley 2013). Data were collected using a combination of an underwater substrate-viewing camera (MatCam) and a DIDSON, deployed at the White Sturgeon spawning site downstream of Waneta Dam.

Methods

Study site

The Upper Columbia River is defined as the Columbia River drainage upstream from Grand Coulee Dam in Washington State, USA to the Canadian headwaters in British Columbia, excluding the Kootenay River upstream of Bonnington Falls. The Canadian subpopulation of White Sturgeon in the Upper Columbia River resides within the ~56 km reach between the Canada-United States border and Hugh L. Keenleyside (HLK) Dam and within the ~3 km reach of the Kootenay River between the confluence of the Columbia and Kootenay rivers and Brilliant Dam (Fig 1). Based on egg collection data from previous work in the area, White Sturgeon eggs spawned within the Waneta spawning area settle and adhere to the cobble-boulder riverbed along the left downstream bank of the Columbia River.

The MatCam and DIDSON system was deployed in 2011 and 2012 downstream of Waneta Dam at the confluence of the Columbia and Pend d'Oreille rivers, along the left downstream bank (Fig 1). In 2011, high sustained flows delayed deployment until mid-

August, after the White Sturgeon spawning period. In 2012, MatCam sampling was performed in July, during White Sturgeon spawning.

Physical Parameters
Water temperature and underwater light intensity were recorded hourly within the Waneta area using two Onset Hobo® Pendant temperature and light loggers. Pend d'Oreille River mean hourly discharge data were provided by FortisBC, the operators of Waneta Dam. Mean hourly Columbia River discharge measurements were obtained from Environment Canada Water Office as recorded at the Birchbank gauge station (http://www.wateroffice.ec.gc.ca/graph/graph_e.html?stn=08NE049).

MatCam
The MatCam consisted of an egg-collecting mat, with a mounted steel frame on top (Fig 2). From the top of the frame, a time-lapse camera (Wingscapes BirdCam™ 2.0 in 2011, GoPro Hero2™ in 2012) was suspended over the egg mat. The MatCam was used to image an entire egg mat's surface throughout the diel cycle in summer 2011 and 2012. The 2011 pilot study of MatCam sampling was performed on July 29, August 2-4, August 4-6, and August 17-22, to develop and test the MatCam design. In 2012, MatCam sampling was performed from July 17 to July 19, from July 22 to July 24, and from July 25 to August 3.

DIDSON
The DIDSON system consisted of the sonar head, 61 m long DIDSON cable, topside control box, Ethernet cable and laptop computer loaded with DIDSON Data Acquisition software. The DIDSON sampled a 10 m long window that started 2.92 m from the sonar head and resulted in a 43 m^3 sample volume. DIDSON sampling was performed during August 17-21, 2011, and July 14-24, 2012.

DIDSON data were collected at a rate of seven frames per second in successive 10 minute files. Data were randomly sub-sampled; for each hour of data, two 10-minute files were randomly chosen to estimate densities of potential egg predators. All static background was removed using the DIDSON software. Within each 10-minute file, the number of fish within the sample volume was estimated every 30 seconds. Fish lengths were estimated using the DIDSON software sizing tool, and fish were classified as small (<25 cm total length) or large (>25 cm). The hourly means of number of fish > 25 cm were estimated based on the 40 within-hour interval estimates (20 estimates for each of the two 10-minute file). To assess patterns in hourly predator densities, DIDSON effort was standardized by dividing the total number of hourly predator events by the hourly number of samples. The 95% confidence interval around each hourly mean value was estimated using the within-hour number of estimates and standard deviation of fish counts, and the z-score for the 97.5 percentile (approximate value of 1.96).

Results

Physical Parameters
In 2011, hourly discharge of the Pend d'Oreille River measured below Waneta Dam during the study period (August 8-22, 2011) ranged between 23 m^3/s and 875 m^3/s

(hourly mean of 488 m^3/s). Waneta discharge fluctuated daily, reflecting the daily cycle of electricity demand (Fig 3).

During the 2012 monitored spawning period (July 14 to August 3), hourly discharge of the Pend d'Oreille River ranged between 23 m^3/s and 1507 m^3/s (hourly mean of 845 m^3/s). Due to record rainfall, daily fluctuations in Waneta Dam discharge were less apparent in 2012 than in 2011. Columbia River flow, which was substantially higher than the Pend d'Oreille in both sampling years, ranged between 2611 m^3/s and 2980 m^3/s in 2011, and between 4294 m^3/s and 6065 m^3/s in 2012 (mean hourly discharge of 2736 and 5499 m^3/s in 2011 and 2012, respectively).

MatCam

During the 2011 MatCam pilot deployment, 698 time-lapse images recorded, of which three showed Smallmouth Bass (*Micropterus dolomieu*). These were recorded during daylight hours, at 0830, 1826, and 1651 h. In 2012, over 13,600 time-lapse images were collected, of which 48 recorded images of fish: 1 sucker (*Catostomus* sp.), 3 unidentified fish, 6 sculpin (*Cottus* spp.), 9 Smallmouth Bass, and 29 Walleye (*Sander vitreus*). Walleye were only observed at night (2000 to 0200 h), with most (27 of 29 fish) observed between 2000 and 2200 h. The increased detection of Walleye coincided with reduced daylight and the activation of the external LED light that was used to illuminate the camera's field of view at night. Daytime detections of fish in 2012 consisted of 10 Smallmouth Bass and 1 sucker. Smallmouth Bass were only recorded during daylight hours (0700-1400 h), similar to the diel timing of Smallmouth Bass recordings in 2011.

DIDSON

In total, 115 and 199 hours of DIDSON data were collected in 2011 and 2012, respectively. In 2011, DIDSON estimates of egg predator density revealed a strong diel pattern with higher densities during day than night; the non-overlapping confidence intervals indicated a significant difference ($\alpha \leq 0.05$; Fig 3). Whether these diel distribution patterns of potential egg predators were due to light levels, discharge, or other factors is unknown.

In 2012, significant differences ($\alpha \leq 0.05$) were observed between hourly predator densities, however both MatCam and DIDSON results indicated increased predator density at night, as opposed to the day, as was observed in 2011. Another discrepancy between the two sampling years was in the estimates of fish abundance. While in 2011 daily densities typically peaked at approximately 8-10 potential egg predators per sample volume, in 2012 the daily peaks typically consisted of 2-3 fish per sample volume. All days in which data were collected showed similar patterns of hourly densities, and most of the days exhibited similar values of fish abundance.

Discussion

This study demonstrates the effectiveness of a DIDSON camera for collecting fish density data. Hourly density estimates based on DIDSON recordings allowed quantification (with confidence intervals) of potential egg predator density in the spawning area. Complementing the DIDSON density estimates, underwater video images recorded by the MatCam were used to identify fish species.

The observed patterns of fish densities, such as the distinct and statistically significant diel changes in egg predator abundance, and the discrepancies between the 2011 and 2012 results, i.e., the timing of peak fish presence and the difference in fish abundances, are still to be studied. The relationships between predator abundance and environmental parameters (mainly flow and light levels) are complicated by the correlated patterns of Waneta discharge that are driven by higher electricity demand during daytime.
Fish behaviour must be taken into account when deploying equipment similar to the combined DIDSON-MatCam system. Sampling under low light conditions may require a light source, potentially attracting or repelling the sampled fish, thereby biasing counts. The presence of the MatCam structure itself may attract fish by acting as a small-scale fish aggregating device (Gascon & Miller 1981). The effect may increase with structure size (Bohnsack et al. 1994) and length of deployment (Gascon & Miller 1981), and may be especially strong in relatively homogenous and low-complexity habitat (Speight & Henderson 2010).

The MatCam-DIDSON combined observation system may provide an effective tool for egg predator density quantification. This approach may be used to expand results in studies focused on demersal egg predation, e.g. (Caroffino et al. 2010) and (Forsythe et al. 2013) in order to provide information on the effect of specific predators. Future increase in image resolution will allow precise recording of egg deposition and consumption, leading to better understanding of early life stage mortality in White Sturgeon. Additional future changes include deploying the MatCam within the DIDSON sampling window to provide species identification of fish recorded by the DIDSON, adding a red filter to the external LED light to reduce fish attraction, and reducing camera height to increase stability and resolution.

Acknowledgements
Special acknowledgement is due to Mr. Ron Giles for the design and fabrication of the MatCam. Data used in this study were obtained through work on White Sturgeon funded by BC Hydro and Columbia Power Corporation (CPC).

References
Becker, A.; Whitfield, A..; Cowley, P.D.; Järnegren, J.; Naesje, T.F., 2011: An assessment of the size structure, distribution and behaviour of fish populations within a temporarily closed estuary using dual frequency identification sonar (DIDSON). J. Fish Biol. 79, 761–75.

Bohnsack, J.A.; Harper, D.E.; Mcclellan, D.B.; Hulsbeck, M., 1994: Effects of reef size on colonization and assemblage 55, 796–823.

Boswell, K.M.; Wilson, M.P.; Cowan, J.H., 2008: A semiautomated approach to estimating fish size, abundance, and behavior from Dual-Frequency Identification Sonar (DIDSON) data. North Am. J. Fish. Manag. 28, 799–807.

Caimi, F.M.; Kocak, D.M.; Dalgleish, F.; Watson, J., 2010: Underwater imaging and optics : recent advances. IEEE Ocean. Eng. Soc. Newsl. 21–29.

Caroffino, D.C.; Sutton, T.M.; Elliott, R.F.; Donofrio, M.C., 2010: Predation on early life stages of Lake Sturgeon in the Peshtigo River, Wisconsin. Trans. Am. Fish. Soc. 139, 1846–1856.

Forsythe, P.S.; Scribner, K.T.; Crossman, J.A.; Ragavendran, A.; Baker, E.A., 2013: Experimental assessment of the magnitude and sources of Lake Sturgeon egg mortality. Trans. Am. Fish. Soc. 142, 1005–1011.

Frias-Torres, S.; Luo, J., 2009: Using dual-frequency sonar to detect juvenile goliath grouper <i>Epinephelus itajara<\i> in mangrove habitat. Endanger. Species Res. 7, 237–242.

Gascon, D.; Miller, R.A., 1981: Colonization by nearshore fish on small artificial reefs in Barkley Sound, British Columbia. Can. J. Zool. 59, 1635–1646.

Hildebrand, L.R.; Parsley, M., 2013: Upper Columbia White Sturgeon Recovery Plan - 2012 revision. Prepared for the Upper Columbia White Sturgeon Recovery Initiative.

Moursund, R.A.; Carlson, T.J.; Peters, R.D., 2003: A fisheries application of a dual-frequency identification sonar acoustic camera. ICES J. Mar. Sci. 60, 678–683.
Price, V.E.; Auster, P.J.; Kracker, L., 2013: Use of high-resolution DIDSON sonar to quantify attributes of predation at ecologically relevant space and time scales. Mar. Technol. Soc. J. 47, 33–46.

Speight, M.; Henderson, P., 2010: Marine ecology: concepts and applications. Wiley-Blackwell, Chichester, UK.

Figures

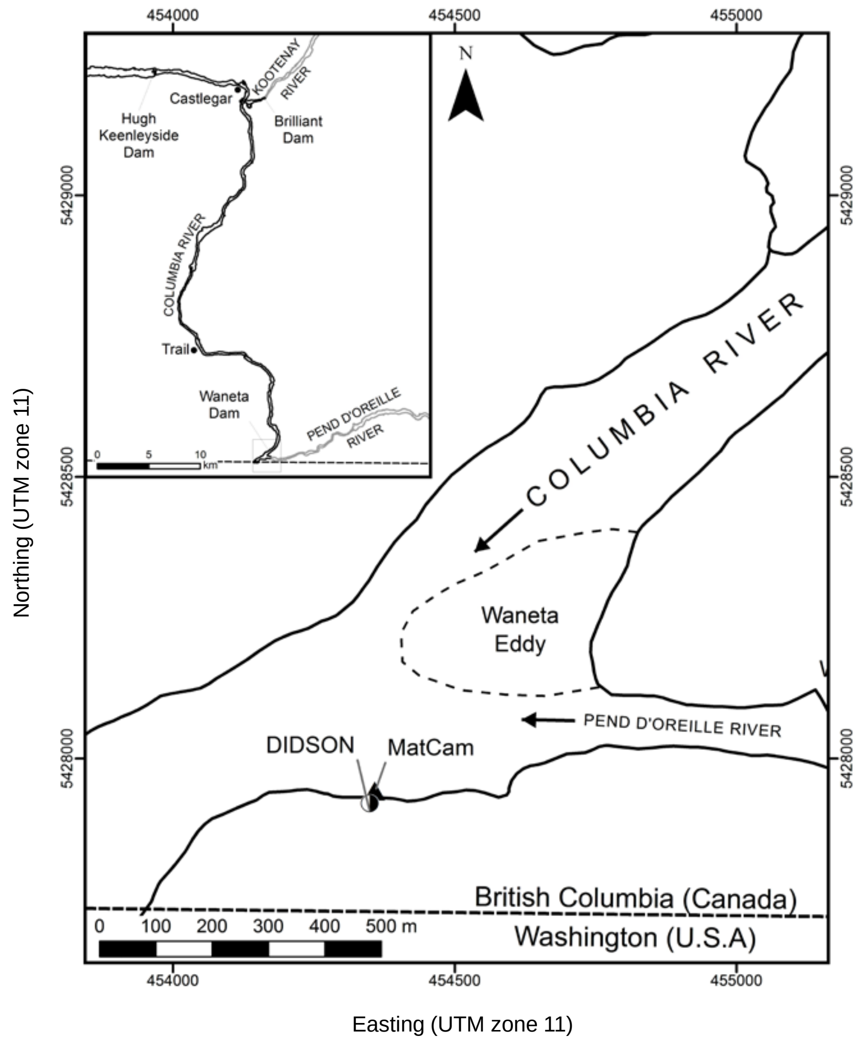


Figure 1. The study area, showing the confluence between Columbia and Pend d'Oreille rivers, and the location of the MatCam and the DIDSON. The inset shows the Upper Columbia River extending from the Canada-U.S. border upstream to Hugh Keenleyside Dam, with a rectangle around the study area just north of the border.

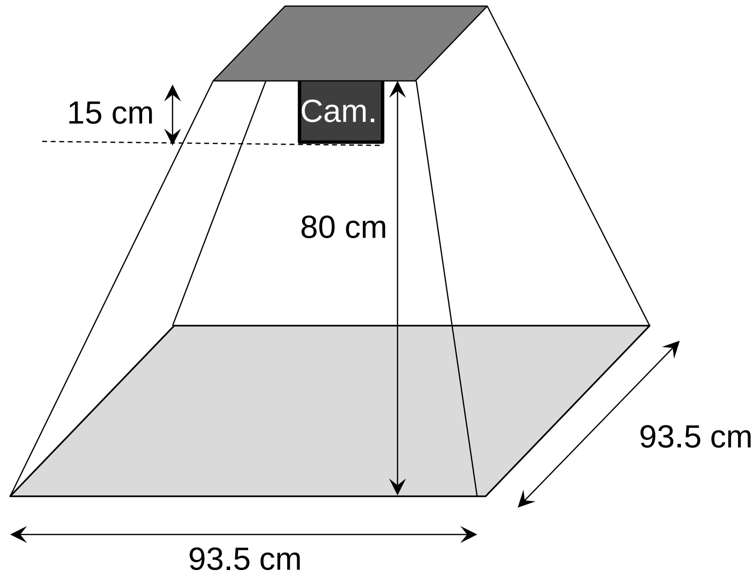


Figure 2. The structure of the MatCam. The position of the mounted camera ("Cam.") and all measurements are provided on the schematic.

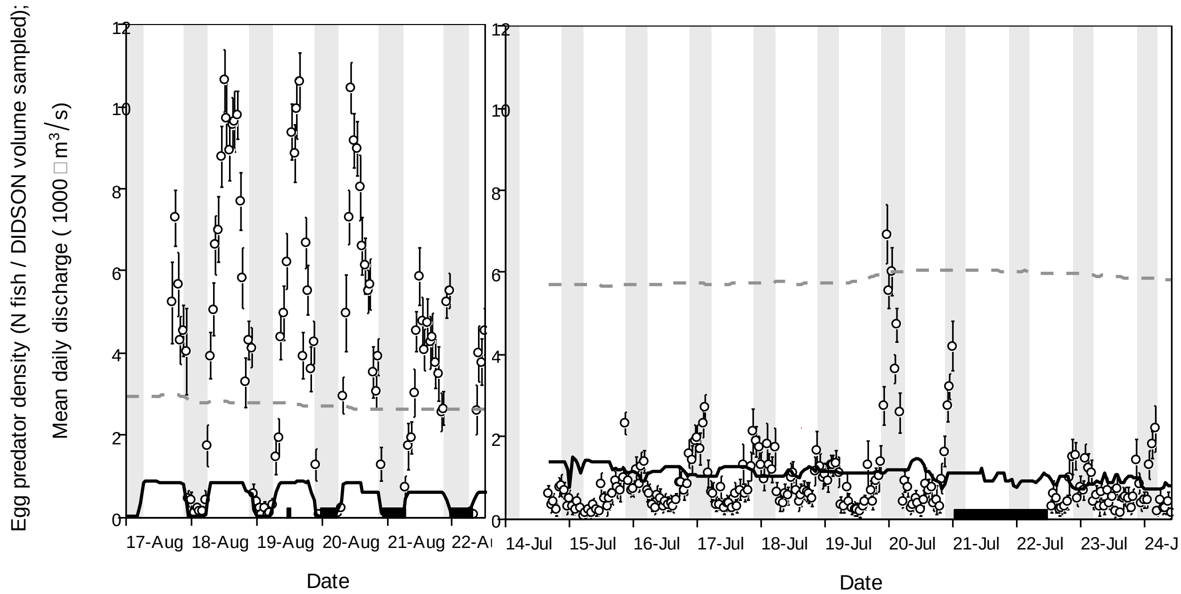


Figure 3. Hourly estimates of potential egg predator densities recorded using a DIDSON camera in the Waneta area during the 2011 feasibility study (left) and 2012 White Sturgeon spawning season (right). Error bars represent 95% confidence limits. Black horizontal bars represent times of no recording.

.

[Back to Table of Contents]

20. Overwinter site selection of a northern population of western painted turtles (Chrysemys picta bellii) in a hydroelectric reservoir environment

Amy Duncan, *Thompson Rivers University, amy-leeming@mytru.ca, 250-551-9449 900 McGill Road, Kamloops, BC V2C 0C8;* Dr. Karl Larsen, Professor, *Thompson Rivers University; klarsen@tru.ca*

Introduction

In 2007, BC Hydro's Columbia River Water Use Plan (WUP) identified the Western Painted Turtle (*Chrysemys picta bellii*, WPT hereafter) as a species that may be vulnerable to fluctuations in water levels as a result of hydroelectric operations (BC Hydro 2007). Beginning in 2010, Basaraba (2014) conducted a two-year pilot study investigating two subpopulations of WPT inhabiting the reservoir south of Revelstoke, BC. Her work provided a foundation for my work in terms of habitat use, seasonal movement, nesting success and demographics. Basaraba observed a change in basking substrates as water level rose, but she did not determine any adverse effects from the fluctuating water table (reservoir operations) on this population. Although a small number of turtles were monitored over winter, this was not a main focus of her research. However, she detected variations in the spatial display of overwintering sites used by reservoir subpopulations; in one location (Montana Slough) turtles congregated in a floating mass of vegetation to overwinter, and in a separate location (Airport Marsh) turtles overwintered scattered across a large area.

Following on this, the specific goals of my research were to (1) document more closely the variation in overwintering tactics occurring across the different subpopulations of turtles in this area, (2) determine if the turtles in the different subpopulations are experiencing and/or selecting different conditions during hibernation, and (3) determine if changes in reservoir levels during winter elicit a response in the turtles, and if so, see if the relationship contributes to the use of different tactics within this area.

In keeping with the Basaraba study, I focused my work on the two main subpopulations of turtles in the reservoir (Airport Marsh and Montana Slough - see Figure 1). To provide comparative data, I also focused on Turtle Pond (TP), a small upland body of water (approximately 2.74 ha in size and 1 km from the reservoir) that supports a relatively large number of turtles (>100 turtles, Tarswell 2013, personal communication) (Figure 1). The Airport Marsh and Montana Slough sites are both easily influenced by changes in water elevation, whereas Turtle Pond is an isolated, upland pond that is unaffected by changes in the reservoir. Cartier Bay is an additional location within the reservoir (Figure 1) where Basaraba detected a small number of turtles (6 sightings) during the summer months. To date, there is no evidence of animals overwintering in this water body and it was therefore excluded from my study.

Figure 1: Study site south of Revelstoke, BC, showing specific turtle subpopulation locations.

Overwintering Ecology

Painted Turtles are well-known to possess a suite of characteristics that enable them to survive in northern environments (Ultsch and Jackson 1982, Ultsch *et al.* 1999, Reese *et al.* 2000, review by Ultsch 1989). Three main physiological strategies are utilized by Painted Turtles to survive overwintering within an anoxic environment: (1) a depression in metabolic processes, (2) mobilization of buffering ions from the shell and skeleton to neutralize lactic acid accumulation in the blood, and (3) the lactic acid “sink” effect of the turtles’ shell and bones (Jackson 2002). All species of Painted Turtle have shown the ability to survive in normoxic (oxygenated) conditions for up to 150 days of submergence (Reese *et al*. 2004). When overwintering in normoxic environments, Western Painted Turtles have the ability to utilize both anaerobiosis and aerobiosis which further helps reduce plasma lactate concentrations (Ultsch *et al*. 1985; Reese *et al*. 2004). The ecology and behaviour of hibernating Painted Turtles in their natural environment is a subject less investigated compared to identifying their physiological abilities. However, studies have reported the animals overwintering in ponds and small lakes at shallow depths (20-100 cm) and either nestled within the bottom substrates to a depth as low as 45 cm (Ernst 1972, Peterson 1987, Taylor and Nol 1989) or lying atop the substrate within the oxygenated water column (St. Clair and Gregory 1990, Crocker *et al.* 2000, Rollinson *et al.* 2008). Use of specific habitat characteristics for overwintering sites has also been documented in other species of northern freshwater turtles (Greaves and Litzgus 2008). Certain freshwater turtles may possess the ability to select overwinter sites based on pre-hibernation habitat conditions; Rollinson *et al.* (2008) found that female Western Painted Turtles in Algonquin Park, Ontario hibernating in oxygenated waters used sites based on dissolved oxygen (DO) concentrations, whereas those using anoxic conditions selected sites based on temperatures. Edge *et al.* (2009) found variation in hibernacula site selection based on oxygen availability as a result of ice cover in a northern population of Blanding's Turtles (*Emydiodea blandingii*). These trends indicate that northern freshwater turtles can be specific in their overwinter habitat use, though can display behavioural plasticity in overwinter site used based on the characteristics of their environment prior to hibernation. However, most studies have looked at turtles inhabiting natural environments; few have investigated the effects of a fluctuating water table on turtles during winter.

Communal hibernation has been documented in similar studies of freshwater turtles at their northern extent (Brown and Brooks 1994, Litzgus *et al*. 1999, Crocker *et al.* 2000, Edge *et al*. 2009, Newton and Herman 2009). Researchers have speculated turtles may overwinter communally to optimize mating opportunities prior to or following hibernation (Gregory 1982, Ultsch 1989). Communal hibernation may also indicate a lack of suitable overwintering sites (Gregory 1982, Ultsch 1989, Newton and Herman 2009, Edge *et al*. 2009). This can be inferred by high levels of site fidelity (Gregory 1982); if an animal returns to the same spot in consecutive years, it may be out of necessity rather than selection. However, Brown and Brooks (1994) suggested that high frequency and accuracy of site fidelity by freshwater turtles indicates sites are not chosen at random.

Definitions

Various terms have been used to refer to the evolution of animal behaviours; however some of these terms have come to be used almost synonymously in animal ecology, including the terms strategy and tactic. A clear understanding of the meaning and application of these terms is critical to the advancement of the field. A strategy is defined as "a set of (behavioural, morphological, physiological) traits that optimize (the) success of an individual under given local conditions" (Nakadera and Koene 2013). Methods of foraging and reproduction are commonly recognized strategies within the ecological literature. The term strategy is commonly confused with tactic, which is "a trait or set of traits serving a particular function" (Oliveira *et al.* 2008). A tactic can be behavioural, morphological or physiological traits that aid in creating different phenotypes within a species (Oliveira *et al*. 2008). Essentially, a strategy is an evolved response to a given variable with a desired end result, and a tactic is an action used to conduct a strategy. For example, recent work has shown intraspecific differences in the mating strategies of melanistic and non-melanistic male Pond Sliders (*Trachemys scripta*) (Thomas 2002). This work showed that larger melanistic males utilized different tactics such as such as biting and chasing, whereas smaller non-melanistic males displayed titillation tactics (Thomas 2002). Thus, the end goal of the strategy is successful mating, and the tactics are the methods used to accomplish the goal. I use the term "tactic" to describe the spatial arrangement of overwintering turtles that I observed.

Methods

In spring (May 2013/2014) and late summer (August-October 2013) I captured adult turtles using hoop traps baited with sardines and/or cat food. Traps were checked at a minimum every 12 hours. I also incorporated 19 adult turtles still carrying transmitters from the Basaraba (2014) study, where necessary recapturing these animals to remove and replace aging transmitters. I targeted equal numbers of male and female adult turtles for telemetry using secondary sexual characteristics (Harless and Morlock 1979). Turtles were selected to ensure the radio-transmitters (models SI-2FT, SB-2F, or AI-2FT from Holohil Systems Ltd., Ontario CA) and all attachment material did not exceed 5% of body weight. Forty-one of 44 transmitters used were temperature sensitive (pulse rate proportional to temperature, Models SI-2FT and AI-2FT), and I affixed them to the turtles by drilling small holes at the posterior of the carapace and securing them using stainless steel wire (Grayson and Dorcas 2004, Basaraba 2014) to reduce potential loss due to shedding of the scutes (CCAC *n.d*., Grayson and Dorcas 2004). Marine epoxy (Amazing GOOP® Marine Epoxy Paste, eclecticproducts.com) was placed around the wire to prevent snagging and unwinding.

During the winters of 2012-13 and 2013-14 I collected data on each turtles' location using a wide-band radio receiver (Lotek Biotracker) and yagi three-prong antenna and recorded using a hand-held GPS instrument. While conditions did not allow safe travel over ice, I estimated turtle locations from safe points using triangulation. Once ice cover permitted safe travel, I was able to pinpoint the exact location of each telemetered turtle and collect associated habitat data.

Once a turtle was located the ambient temperature of the turtle's location was determined using the pulse-rate of the radio transmitter. Using an ice auger (Kovacs Enterprises Inc.), a 5 cm hole was made through the ice, enabling me to measure ice depth (cm), water depth (cm), dissolved oxygen (mg/L), water temperature (°C) (using a YSI Model 85 Handheld Oxygen, Conductivity, Salinity and Temperature System). I also obtained data on reservoir elevation (MASL), precipitation (mm) and local air temperature (°C). Air temperature and precipitation data were retrieved from Environment Canada's 'Revelstoke Airport Auto British Columbia' weather station (located at 50.5729 N, 118.1034 W, Environment Canada 2014). Reservoir elevation data (MASL) was recorded at the Fauquier hydromet station provided by BC Hydro (located at 49.5220 N, 118.0448 W, BC Hydro 2013-14).

Results
Underway.

Conclusion
The results of this work will contribute to species and land-based management plans including reservoir operations at the upstream Revelstoke Dam. This work will also contribute to the knowledge of overwinter site selection for this blue-listed species at the periphery of its northern extant, and also to the remarkable overwintering ecology of this species. In addition, this study may support the argument that anthropogenic activities and landscape alteration can create new challenges for a species, which can result in plasticity in behaviours or adaptation.

References

Basaraba, N. 2014. The Ecology of Western Painted Turtles (*Chrysemys picta bellii*) in a Northern Canadian Reservoir. MSc Thesis. Thompson Rivers University. 110 p

BC Hydro. 2007. Columbia River Project Water Use Plan. Revised for Acceptance by the Comptroller of Water Rights. BC Hydro Power Corporation. Burnaby, BC. 65 p.

Brown, G.P. and Brooks, R.J. 1994. Characteristics of and fidelity to hibernacula in a northern population of Snapping Turtles, *Chelydra serpentine*. Copeia. 1994(1): 222-226.

Canadian Council of Animal Care. *n.d*. CCAC species-specific recommendations on: Amphibians and Reptile. Ottawa, Ontario. [Web accessed; June 2014. http://www.ccac.ca/Documents/Standards/Guidelines/Add_PDFs/Wildlife_Amphibians_Reptiles.pdf].

Crocker, C.E., Feldman, R.A., Ultsch, G.R. and Jackson, D.C. 2000. Overwintering behaviour and physiology of eastern painted turtles (*Chrysemys picta picta*) in Rhode Island. Canadian Journal of Zoology. 78(6): 936-942.

Edge, C.B., Steinberg, B.E., Brooks, R.J. and Litzgus, J.D. 2009. Temperature and site selection by Blanding's Turtles (*Emydoidea blandingii*) during hibernation near the species' northern range limit. Canadian Journal of Zoology. 87: 825-834.

Environment Canada. 2014. Canadian Climate Normals Station Data 1971-2000. [Web accessed June 2014. http://climate.weather.gc.ca/climate_normals/results_e.html?stnID=1372&prov=&lang=e&dCode=4&dispBack=1&StationName=revelstoke&SearchType=Contains&province=ALL&provBut=&month1=0&month2=12].

Ernst, C.H. 1972. Temperature-activity relationship in the Painted Turtle, *Chrysemys picta*. Copeia. 1972(2): 217-222.

Grayson, K.L., and Dorcas, M.E. 2004. Seasonal temperature variation in the painted turtle (*Chrysemys picta*). Herpetologica. 60(3): 325-336.

Greaves, W.F. and Litzgus, J.D. 2007. Overwintering ecology of wood turtles (*Glyptemys insculpta*) at the species' northern range limit. Journal of Herpetology. 41(1): 32-40.

Gregory, P. T. 1982. Reptilian hibernation. Pages 53–154 in C.Gans & F. H. Pough (eds). Biology of the Reptilia. Volume 13. Academic Press, London.

Greaves, W.F. and Litzgus, J.D. 2007. Overwintering ecology of wood turtles (*Glyptemys insculpta*) at the species' northern range limit. Journal of Herpetology. 41(1): 32-40.

Harless, M., and Morlock, H. 1979. Turtles: Perspectives and Research. John Wiley & Sons, Inc. New York, USA.

Jackson, D.C. 2002. Hibernating without oxygen: physiological adaptation of the painted turtle. Journal of Physiology. 543(3): 731-737.

Litzgus, J.E., Costanzo, J.P., Brooks, R.J., Lee, R.E. 1999. Phenology and ecology of hibernation in spotted turtles (*Clemmys guttata*) near the northern limit of their range. Journal of Zoology. 77(9): 1348-1357.

Nakadera, U., and Koene, J.M. 2013. Reproductive strategies in hermaphroditic gastropods: conceptual and empirical approaches. Canadian Journal of Zoology. 91(6): 367-381.

Newton, E.J. and Herman, T.B. 2009. Habitat, movements and behaviour of overwintering Blanding's turtles (*Emydiodea blandingii*) in Nova Scotia. Canadian Journal of Zoology. 87: 299-309.

Oliveira, R.F. and Taborsky, M. 2008. Alternative Reproductive Tactics: an integrative approach. Cambridge University Press. 507 p.

Peterson, C.C. 1987. Thermal relations of hibernating Painted Turtles, Chrysemys picta. Journal of Herpetology. 21(1): 16-20.

Reese, S.A., Crocker, C.E., Jackson, D.C. and Ultsch, G.R. 2000. The physiological of hibernation among painted turtles: the midland painted turtle (*Chrysemys picta marginata*). Respiration Physiology. 124(2000): 43-50.

Reese, S.A., Stewart, E.R., Crocker, C.E., Jackson, D.C. and Ultsch, G.R. 2004. Geographic variation of the physiological response to overwintering in the painted turtle (*Chrysemys picta*). Physiological and Biological Zoology. 77(4): 619-630.

Rollinson, N., Tatersall, G.J., and Brooks, R.J. 2008. Overwintering habits of a northern population of painted turtles (*Chrysemys picta*): winter temperature selection and dissolved oxygen concentrations. Journal of Herpetology. 42(2): 312-321.

St. Clair, R.C., and Gregory, P.T. 1990. Factors affecting the northern range limit of Painted Turtles (*Chrysemys picta*): Winter acidosis or freezing? Copeia 1990(4): 1083-1089.

Taylor, G.M., and Nol, E. 1988. Movements and hibernation sites of overwintering painted turtles in southern Ontario. Canadian Journal of Zoology. 67: 1877-1881.

Thomas, R.B. 2002. Conditional Mating Strategy in a Long-Lived Vertebrate: Ontogenetic Shifts in the Mating Tactics of Male Slider Turtles (*Trachemys scripta*). Copeia. 2:456-461.

Ultsch, G.R. and Jackson, D.C. 1982. Long-term submergence at 3°C of the turtle, *Chrysemys picta belli*, in normoxic and severely hypoxic water. Journal of Experimental Biology. 96: 11-28.

Ultsch, G.R. 1989. Ecology and physiology of hibernation and overwintering among freshwater fishes, turtles and snakes. Biological Review. 1989(64): 435-516..

Ultsch, G.R., Carwile, M.E., Crocker, C.E. and Jackson, D.C. 1999. The physiology of hibernation among painted turtles: the eastern painted turtle *Chrysemys picta picta*. Physiological and Biochemical Zoology. 72(4): 493-501.

Ultsch, G. R., Hanley, R. W., and Bauman, T. R. 1985. Responses to anoxia during simulated hibernation in northern and southern painted turtles. Ecology. 66(2): 388-395

Acknowledgements

First and foremost, I'd like to thank my advisor, Dr. Karl Larsen, for his support, guidance, and advice. Special thanks to Virgil Hawkes from LGL Limited, for partnering with me on this project and providing support, both advisory and financial. The Okanagan Nation Alliance also was a terrific organization to work with on this project, especially Dixon Terbasket, Natasha Audy and Al Peatt. Thanks as well to Doug Adama from LGL for his field time and expertise and to Janean Sharkey from LGL for volunteering on her day off. Thank you to my committee members, Dr. Brian Heise, Dr. Leigh Anne Isaac from VAST Resource Solutions, as well as Virgil Hawkes from LGL, I very much appreciate your time and encouragement.

Thanks to Dr. Guy Martel at BC Hydro for making this project possible. This research could not have been completed without the support from the Natural Sciences and Engineering Research Council of Canada. This work was completed in accordance with Thompson Rivers University Animal Care Committee Permit # 100451 and BC Ministry of Forests, Lands and Natural Resource Operations Wildlife Act Permit CB10-60676.

Back to Table of Contents

21. Reach-scale movements of bull trout (Salvelinus confluentus) relative to hydropeaking operations in the Columbia River, Canada.

Bronwen A. Lewis
C/O Golder Associates Ltd.
201 Columbia Ave. Castlegar, B.C. V1N 1A2
Email: blewis@golder.com
Phone: 250-365-0344

This presentation is based on a published paper found in:

Ecohydrology
Volume 7, Issue 4 pages 1079-1086. August, 2014

(wileyonlinelibrary.com): http://onlinelibrary.wiley.com/doi/10.1002/eco.1429/abstract

Back to Table of Contents

22. Spawning morphology and timing of Umatilla dace in an unregulated river with comparisons to a regulated river system.

Crystal Lawrence, BSc, RPBio
Amec Foster Wheeler, Environment & Infrastructure, Suite 601E, 601 Front St., Nelson, B.C., V1L 4B6, 250-354-1600
crystal.lawrence@amecfw.com

Co-Author: Louise Porto, MSc, RPBio
Amec Foster Wheeler, Environment & Infrastructure
louise.porto@amecfw.com

Introduction

Umatilla Dace (*Rhinichthys umatilla*) are endemic to the Columbia River basin. In Canada, this species is federally listed as "Special Concern" under the Species at Risk Act because they have a spotty distribution, are in low abundance, prone to local extinction and their range is fragmented by hydropower dams (Harvey and Brown 2011). The Canadian distribution includes the northern extent of their range and the species occurs in the lower Columbia, lower Kootenay, Slocan, lower Pend d'Oreille, Similkameen and Kettle rivers (McPhail 2007). Little is known about their life history especially with respect to spawning in the wild. As for many dace species, Umatilla Dace are sexually mature at age 2 and spawning occurs in summer (Haas 2001; McPhail 2007). However, eggs have not been located in the wild and adult spawning characteristics within a natural setting have not been described The objectives of this study were to describe life history traits of Umatilla Dace in the wild and compare observations from populations that exist in the upper Columbia River below Hugh L. Keenleyside (HLK) Dam (Castlegar, BC) to natural occurring populations in the Slocan River (unregulated). Information reported here was part of a larger study conducted for BC Hydro with multiple objectives (AMEC 2014).

Methods

Study areas included sample sites on two river systems: the lower Columbia River downstream of HLK Dam including the confluence with the lower Kootenay River and the unregulated Slocan River (Figure 1). Three index sites were established on each river system based on the review of historical data and presence of Umatilla Dace during preliminary surveys. Index study sites were approximately 100 m in length and varied in width depending on seasonal flows. Sampling was conducted over a 3 year period (2011, 2012, 2013) on the Columbia and Slocan rivers. Sample timing focused on the projected spawning and larval rearing period for Umatilla Dace (biweekly: July through September; McPhail 2007). Index study sites were repeatedly sampled using a combination of standard backpack electrofishing and minnow trapping techniques. Habitat information including depth, velocity and substrate was collected at point of capture and fish were assigned a life stage and level of maturity. Spawn timing was estimated based on the presence/capture of sexually mature fish, the presence of young of the year Umatilla Dace and the reported laboratory incubation periods for Umatilla Dace (McPhail 2007, Haas 2001).

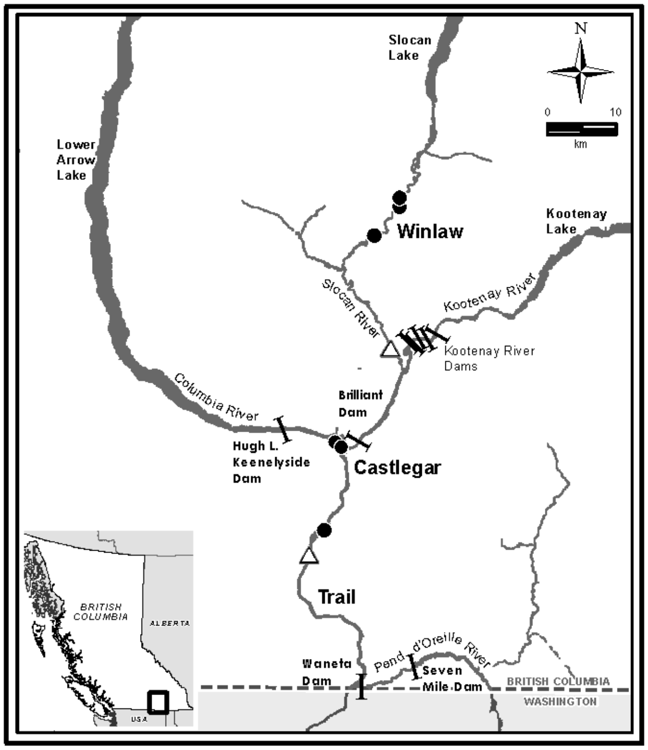


Figure 1:Overview of the Columbia and Slocan River systems depicting major tributaries and hydroelectric facilities. Circles identify sample locations and triangles identify Water Survey of Canada discharge and/or water temperature monitoring locations.

Results

A total of 39 mature Umatilla Dace were captured by minnow trapping (n=38) and backpack electrofishing (n=1) in the Slocan River during this study. Mature Umatilla Dace were not observed in the Columbia River even though similar minnow trapping effort and three times the backpack electrofishing effort were expended during the spawning season.

Spawning Morphology

External characteristics for ripe females expressing eggs included red colouration on lips, pelvic and pectoral fin insertions (Figure 2). Some females also had tubercles on dorsal scales above the lateral line. Expressed eggs were of two distinct varieties: either opaque and 1 mm in diameter or yellow and 1.3 - 1.5 mm in diameter. Spent females were captured in mid-August and early September and had soft, hollow abdomens and swollen urogenital pores. Ripe males that expressed milt had orange colour on their lips and/or operculum as well as pectoral, pelvic and/or anal fins and fin insertions (Figure 2). In addition to these traits, some mature males also had tubercles on scales above the lateral line on their dorsal surface. Mature fish captured in the Slocan River ranged from 55 to 110 mm fork length. Ripe females ranged from 88 to 110 mm fork length (n=8) and males ranged from 70 to 93 mm FL (n=9). Fertilized eggs were not observed during this study.

Figure 2:Sexually mature Umatilla Dace observed on the Slocan River. Female with red pigment on lips and snout (white arrow) observed on August 9, 2011 (left) and male with orange pigment on lips, pectoral fin insertions, operculum, and tubercles on dorsal surface observed on June 14, 2013 (right; black arrows).

Spawning Habitat
Mature Umatilla Dace were captured at depths between 0.2 and 1.2 m, average column velocities between 0 and 0.3 m/s over silt substrates associated with aquatic macrophytes and flooded terrestrial vegetation; fish were also captured over silt and cobble substrates without vegetation, but to a lesser degree.

Spawn Timing
The Umatilla Dace spawning and incubation period in the Slocan River occurs between mid-July and mid-September when water levels are declining following freshet and peak water temperature is observed. Diel surveys suggested more mature Umatilla Dace used nearshore areas during dusk than at night but use during other times of the day were similar.

Discussion
To our knowledge this is the first time that Umatilla Dace have been captured in spawning condition and observed with external spawning colouration and tubercles in the wild in Canada. Although we did not directly observe spawning or find fertilized eggs, spawning likely begins soon after the peak of freshet during the descending limb of the hydrograph over the period of annual maximum water temperature based on the presence of ripe individuals.

Ripe individuals and fish >70 mm fork length were not captured in the Columbia River despite conducting extensive sampling during the period when these fish were found on the Slocan River. It is assumed that a spawning population of Umatilla Dace exists in the Columbia River based on the capture of Umatilla Dace young of the year throughout the study area. Mature adults may have been in Columbia River habitats that were too difficult to sample despite targeting slow, shallow nearshore habitats with flooded terrestrial vegetation that were similar to those used by mature Umatilla Dace on the Slocan River. However, habitats on the Columbia River differ from the Slocan River because limited inundation of riparian areas was observed during the spring/summer high-water period. Umatilla Dace stranding risk may be higher during the spawning, incubation and early rearing period between July and September than other seasons because adults are potentially spawning and young-of-the-year are rearing in nearshore areas.

The Information obtained during this study has added to our limited understanding of the life history of Umatilla Dace, a species that is often misidentified and assumed to be similar to the more common Longnose Dace (*Rhinichthys cataractae)*. Results of this study will aid in the recovery and management of this species in British Columbia.

Acknowledgements
Financial and scientific support for this research came from BC Hydro Water Licensing Requirements (CLBMON-43 Lower Columbia River Sculpin and Dace Life History Assessment). Dr. Don McPhail (University of British Columbia) provided taxonomic guidance. Field assistance was provided by fisheries technicians from the Canadian Columbia Inter-tribal Fisheries Commission (Cranbrook, BC), the Ministry of Environment and Forest, Lands and Natural Resource Operations (Nelson, BC), Clint Tarala, Jimmy Robbins and Katy Fraser. Rachel Keeler (AMEC) and Guy Martel (BC Hydro) provided review comments that helped improve this presentation. Additional project reports are found here:
http://www.bchydro.com/about/sustainability/conservation/water_use_planning/southern interior/columbia_river/lower-columbia-fish.html

References

AMEC. 2014. Lower Columbia River Sculpin and Dace Life History Assessment (CLBMON-43). Year 5 Technical Report. Report Prepared for: BC Hydro, Burnaby, BC. Prepared by: AMEC Environment & Infrastructure Ltd. 117 pp + 8 App.

Haas, G. R. 2001. The evolution through natural hybridizations of the Umatilla dace (Pisces: Rhinichthys umatilla), and their associated ecology and systematics. PhD Thesis. University of British Columbia, Vancouver, BC.

Harvey, B. and T. Brown. 2011. Recovery potential assessment for the Umatilla Dace (*Rhinichthys umatilla*). DFO Can. Sci. Advis. Sec. Res. Doc. 2011/107.

McPhail, J. D. 2007. The Freshwater Fishes of British Columbia. The University of Alberta Press. Edmonton, AB.

Back to Table of Contents

23. How do fluctuating reservoir levels influence waterfowl use of wetlands?

Ryan Gill[1]* and Harry van Oort[1]
1. Cooper Beauchesne and Associates Ltd., Revelstoke, BC, Canada
* Corresponding author/presenter: rgill@cooperbeauchesne.com

Introduction

The Columbia River is a highly regulated system with impoundments distributed along its entirety between the United States and Canada. From its source in the Rocky Mountain trench, to the Canada/US border, the Columbia river passes through three, serially placed hydroelectric or flood-control dams (Mica, Revelstoke and Hugh Keenlyside dams) (BC Hydro 2005). Reservoirs impounded by these dams are regulated annually, and this seasonal inundation of terrestrial habitat has had long term impacts to the valley bottom habitat (Utzig and Schmidt 2011).

Due to the annual inundation of these reservoirs, habitat along the perimeter can be characterized as being largely modified ecosystems with little remnant terrestrial habitat (Utzig and Schmidt 2011). Valley bottom, wetland ecosystems have suffered the largest impact with losses of 26% of their original area having been modified, or lost completely (Utzig and Schmidt 2011). Few, intact riparian ecosystems remain between Valemount and the Canada/US border at Trail, BC with the most extensive wetland and riparian forests occurring in the Revelstoke reach of the Upper Arrow lakes reservoir.

Wetlands in the Revelstoke Reach are situated between 434m and 438m ASL and are differentially impacted by reservoir operations during the spring and fall migrations (Figure 4).

The operation of the Upper Arrow lakes reservoir (ALR) has been shown to have an effect on the distribution of waterbirds throughout the available habitat in Revelstoke reach, but not on the abundance or diversity of waterfowl (Cooper Beauchesne and Associates Ltd (CBA) 2013).

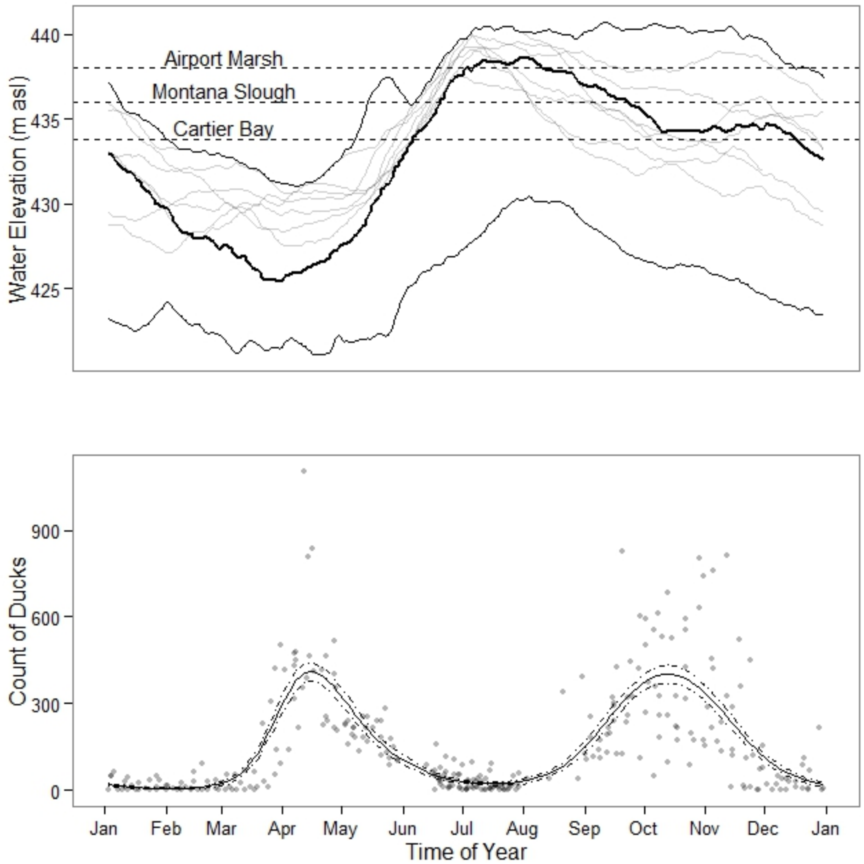


Figure 4: Wetland elevations within the Revelstoke Reach and peaks of waterfowl migration

The wetlands primarily used during waterfowl migration, listed in order of their importance to waterfowl are: Cartier Bay, Airport Marsh, Locks Creek Outflow, and Montana Bay. Cartier Bay sees the highest use during migration of all the wetlands, but only when it is not impacted by reservoir operations. Cartier Bay and Airport Marsh are predominantly aquatic habitats with large areas of emergent and submergent vegetation and varying water depths. Locks Creek and Montana Bay are predominantly terrestrial habitats with large expanses of open grassland.

Habitat use by waterfowl is partially dependent on water depth at foraging sites (Colwell and Taft 2000). Foraging efficiency constraints dabbling duck habitat selection to shallow water where they are able to access aquatic vegetation without diving. Thus, water depths used by dabbling waterfowl are dependent on morphological characteristics, specifically, body and neck length (Bolduc and Afton 2008).

Using at the first five years of data from monitoring waterfowl migration, from 2008-2012, we explored how water levels influence the selection of habitat within a hydroelectric reservoir. Waterfowl migration was monitored using two methods – land-based surveys and aerial surveys. Between 2008 and 2012 we conducted 84 land-based, and 44 aerial surveys during migration. Counts of birds were 57,881 (land-based) and 55,290 (aerial).

From these data we determined that wetlands are preferentially selected by waterfowl for using during migration, but the degree to which each wetland is used is influenced by the condition of each wetland – specifically, whether or not a wetland is flooded dictates its level of use. Waterfowl use of wetlands is highest when wetlands are not affected by reservoir operations. As these wetlands become inundated by the reservoir, water depth increases and ducks begin to leave these habitats (Figure 5).

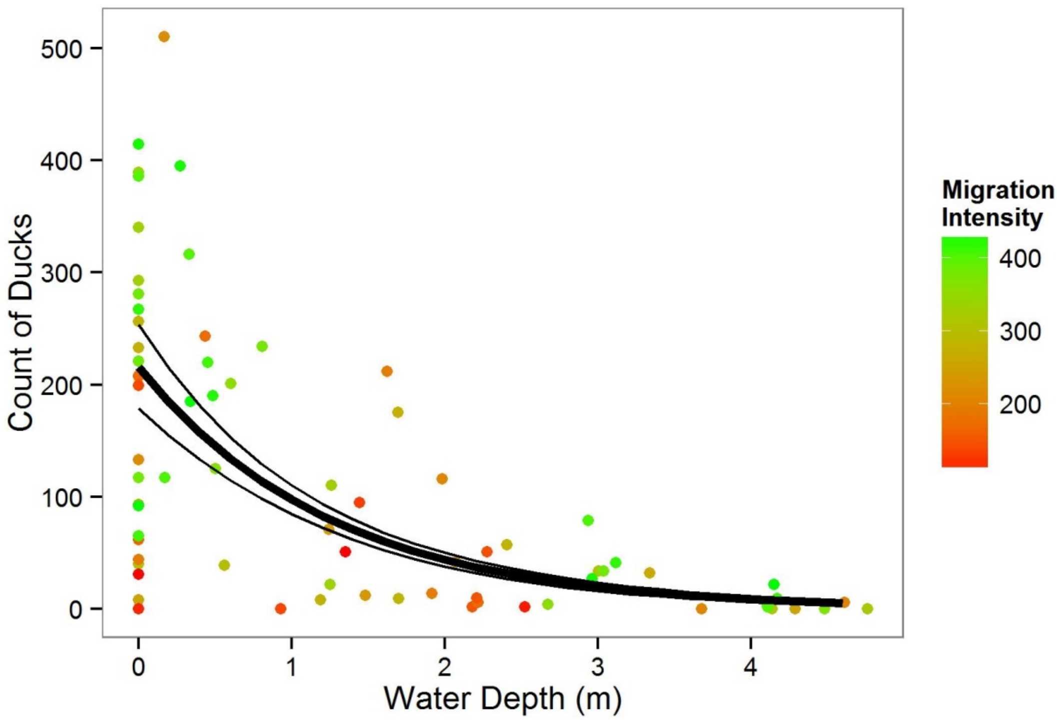


Figure 5: Model of relationship between depth of inundation of wetlands and count of ducks for Cartier Bay.

As water levels rise, terrestrial habitats become available for aquatic foraging at certain levels, while established wetlands become too deeply inundated to provide foraging opportunities. Figure 3 illustrates how the total counts of ducks in each of the wetlands changes with inundation. In unflooded conditions, the wetlands which are dominated by aquatic habitats (Airport Marsh, Cartier Bay) see the highest use. However, as these wetlands become inundated, their use diminishes and the opposite trend is seen for the wetlands with a large component of terrestrial grassland habitat (Locks Creek and Montana Bay).

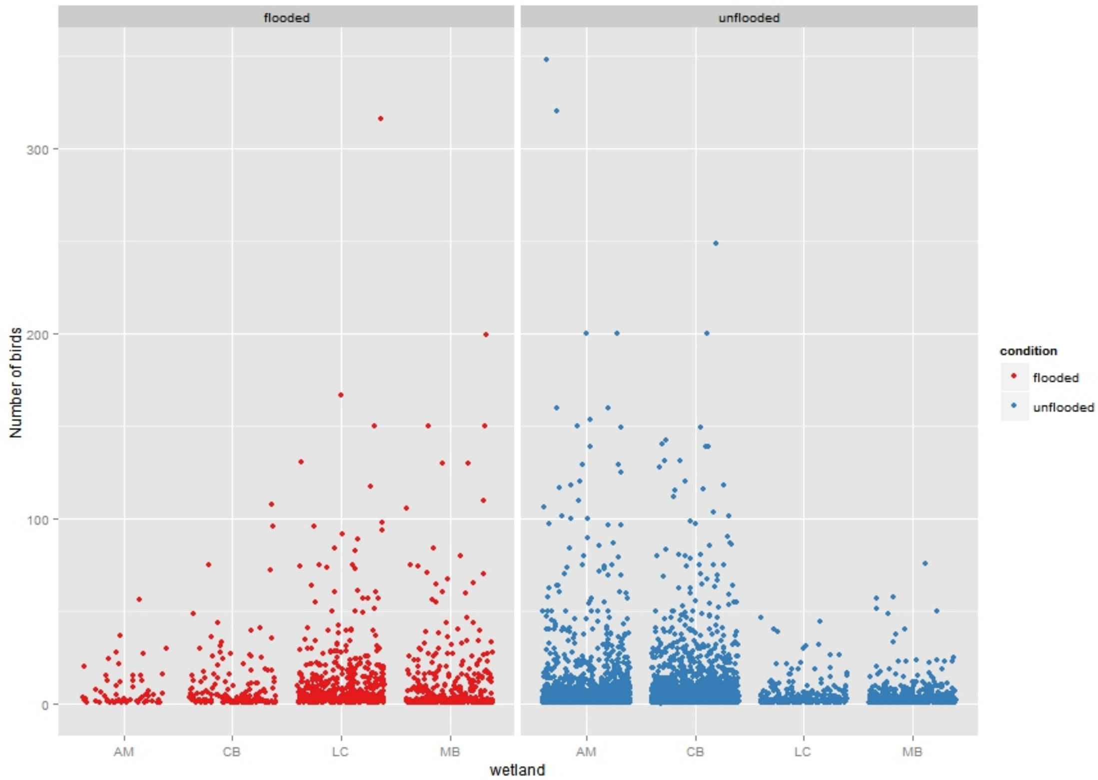


Figure 6: Waterfowl counts in each wetland in flooded and unflooded conditions. Each dot represents a survey where waterfowl were detected. Wetlands listed along the bottom of the figure are: Airport marsh, Cartier Bay, Locks Creek and Montana Bay.

Expanding on these results, the aerial survey data shows a similar trend throughout the reach. As flooding in wetland habitats precludes their use, grassland habitats become available for foraging (Figure 7).

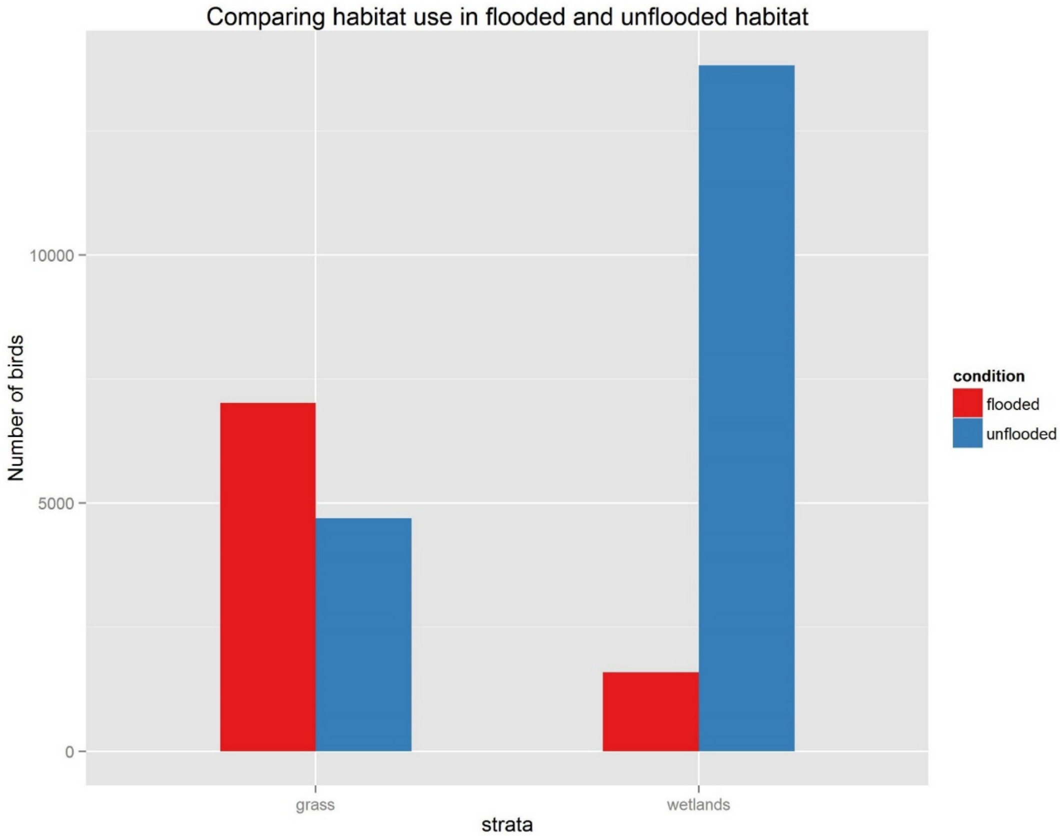


Figure 7: Aerial survey results showing the trend of waterfowl leaving flooded wetlands and using flooded grasslands as reservoir level rises.

Modeling the results from the aerial data indicates that as birds leave the inundated wetlands, they move into the shallowly flooded grassland habitat (Figure 8). However, as the middle panel of Figure 8 indicates, use of this flooded terrestrial habitat is ephemeral. Use of flooded grassland habitat increases with shallow flooding, but as inundation becomes greater, use begins to subside until depth is again too great for birds to forage efficiently. Once again birds move away from these deeply flooded habitats and seek out shallow habitat; likely the higher elevation, more densely vegetated habitats within the reservoir where detection becomes more difficult.

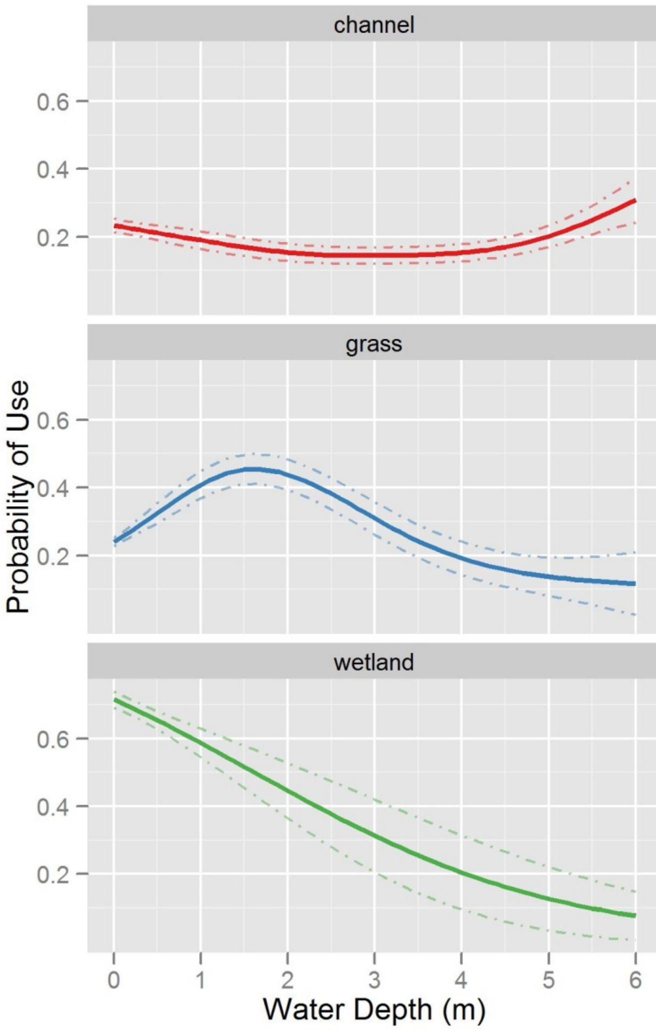


Figure 8: Aerial survey results showing modeled use of three types of strata: Channel, Grassland and Wetlands. The trend of birds leaving wetlands as they become inundated, and using terrestrial grasslands is clear.

Use of this flooded grassland suggests that vegetation composition is not the only driver of habitat use. Topography of flooded areas is also an important habitat characteristic for waterfowl, and along with depth as has been shown to be a strong predictor of waterfowl diversity in wetlands (Colwell and Taft 2000, Ma et al. 2010). Increasing water depth heterogeneity increases the habitat available to the different guilds of waterfowl. Smaller ducks, such as teal species, prefer the shallowest depths of aquatic habitat, often foraging along margins of wetlands in sparse vegetation. Larger dabblers can utilize depths of up to ~45cm, while diving ducks can forage at depths of many meters.

The availability of habitat in impounded wetlands is dependent on water control regimes, as water levels rise, habitat accessible to a broad guild of waterfowl is compromised. However, impounded wetlands provide a unique opportunity to provide this array of water depths during migration, and balancing water use objectives with wildlife habitat objectives should not be considered an irreconcilable problem (Taft et al. 2002, Parsons 2002). Providing water depth and topographic heterogeneity is a relatively easily improved habitat feature with reservoir drawdown zones, and is a physical works project which should be considered by managers wishing to improve habitat.

References

BC Hydro. 2005. Consultative Committee report: Columbia River Water Use Plan, Volumes 1 & 2. BC Hydro, Burnaby, BC.

Bolduc, F., and A. D. Afton. 2008. Monitoring waterbird abundance in wetlands: The importance of controlling results for variation in water depth. Ecological Modelling 216:402–408 pp.

Colwell, M. A., and O. W. Taft. 2000. Waterbird communities in managed wetlands of varying water depth. Waterbirds 23:45–55 pp.

Cooper Beauchesne and Associates Ltd (CBA). 2013. CLBMON-40: Arrow Lakes Reservoir shorebird and waterbird monitoring program. 5 Year Interim Review Report: 2008-2012. BC Hydro Water Licence Requirements, Burnaby, BC.

Ma, Z., Y. Cai, B. Li, and J. Chen. 2010. Managing Wetland Habitats for Waterbirds: An International Perspective. Wetlands 30:15–27 pp.

Parsons, K. C. 2002. Integrated management of waterbird habitats at impounded wetlands in Delaware Bay, U.S.A. Waterbirds 25:24–41 pp.

Taft, O. W., M. A. Colwell, C. R. Isola, and R. J. Safran. 2002. Waterbird responses to experimental drawdown: implications for the multispecies management of wetland mosaics. Journal of Applied Ecology 39:987–1001 pp.

Utzig, G., and D. Schmidt. 2011. Dam footprint impact summary; BC Hydro dams in the Columbia Basin. Fish and Wildlife Compensation Program, Columbia Basin, Nelson, B.C.

Back to Table of Contents

24. The Airport Marsh and a case for habitat enhancement

Corey Bird, Wildlife Biologist, Cooper Beauchesne and Associates Ltd.
cbird@cooperbeauchense.com

Harry van Oort, Wildlife Biologist, Cooper Beauchesne and Associates Ltd.
hvanoort@cooperbeauchesne.com

There are few true marshes which occur within the impounded portion of the Canadian Columbia River. The Airport Marsh is one such wetland which occurs within the City Limits of Revelstoke, British Columbia. Once farmland, this wetland was created through the development of the Revelstoke Airport in combination with the Arrow Lakes Reservoir resulting from development of the Hugh Keenleyside damn. Today this wetland, positioned as low as 2 m below the reservoir full pool elevation, provides breeding habitat for a myriad of bird species and is locally and regionally significant as a breeding ground for bird species that are rare within the impounded portion of the Columbia River Basin. Cooper Beauchesne and Associates Ltd. has been monitoring bird populations within this marsh since 2008 and in 2014 performed an inventory specifically designed to determine the number of breeding Pied-billed Grebe, Virginia Rail, American Bittern, and Sora in this wetland. These studies confirm the importance of this wetland, but also highlight that this wetland has a very high occurrence of nest submersions, indicating that productivity may be compromised by the operations of the Arrow Lakes Reservoir. Additionally, monitoring at the Airport Marsh has indicated that the water levels in this marsh fluctuate among years for reasons unrelated to reservoir operations, and that these inconsistencies likely impact the population size of the rare species which breed in this wetland. As such water level fluctuations, be they caused by the reservoir or not, appear to limit the productivity of this important marsh.
Under the Water Licence Requirements program, BC Hydro has outlined an objective to identify Wildlife Physical Works projects designed to mitigate adverse impacts of reservoir operations on wildlife, including bird nest submersions, and enhance productivity of the drawdown zone. We outlined how regulating water levels of the Airport Marsh would accomplish these goals. We reviewed the biodiversity of this unique marsh and its regional significance, review the productivity monitoring data for all birds in this area (and the factors that limit productivity). Using a model we estimate that as much as 25% of the nest submersions in Revelstoke Reach could be avoided by regulating water levels in the Airport Marsh, and that represents only 2.6% of the Revelstoke Reach drawdown zone area.


Aerial photograph of the Airport Marsh

[Back to Table of Contents]

25. Natural Process and Restoration Techniques in Drawdown Zones of Regulated Rivers

David F. Polster, M.Sc. R.P. Bio.
Polster Environmental Services Ltd.
and
Carrie L. Nadeau, R.P.Bio., NSNP Cert.
Summit Environmental Consultants Inc.

Introduction

British Columbia Hydro and Power Authority operate hydroelectric facilities throughout British Columbia. Most of these include dams or water diversion structures and reservoirs. Four large dams and resulting reservoirs were established with the ratification of the Columbia River Treaty in 1964. Other dams in other parts of the Province have also created impacts. Flooding of valley bottom lands displaced towns and residents and significantly modified valley bottom habitats. Impacts associated with dams and reservoirs have been keenly felt by local people as well as the native biota. Requirements by the Comptroller of Water Rights to ameliorate the impacts of reservoir operations have resulted in a variety of programs and studies. Some of the early work to ameliorate drawdown area dust has been successful; however, some works resulted in unanticipated impacts while other work has failed at its intended purpose. Refinements of impact mitigation approaches are being considered.

This study was established to assess and if necessary, improve previous techniques that have been applied to mitigate impacts. The approach is based on the natural processes system of ecosystem restoration that has been proposed by Polster (2009). Natural processes operate to establish a vegetation cover in a variety of ways. For instance, seed distribution timing of balsam poplar (*Populus balsamifera* L., cottonwood) coincides with receding water levels in order to best colonize the wet muddy margin s along the edges of waterbodies as the water is dropping (Braatne and Rood 1998). Although the seeds are small and do not have energy reserves to carry them for long periods, the growth of seedlings is timed for the roots to follow the falling hydrograph. In most cases, the hydrology of reservoir operation does not allow this to happen and there are relatively few balsam poplar stands establishing along the shores of reservoirs, but in some cases, balsam poplar has established high in the reservoir from root suckering. In other situations, balsam poplar trees have established on high elevation areas within the drawdown zone that have been constructed to protect boat launches and mooring sites. Understanding how these processes occur allows restoration treatments to be designed to build on these natural processes.

The establishment of pioneering species such as willows and balsam poplar can create conditions that modify the movement and storage of sediments. Establishment of willows on river gravel bars can cause a slowing of flow velocities allowing sediment to be deposited. This builds up the surface of the gravel bar, allowing other species that are not as tolerant of flooding to establish. Following these natural processes can assist in the development of restoration treatments that utilize these natural systems of ecosystem recovery.

This paper explores the identification of filters that are preventing recovery and how natural processes can be used to overcome these filters Currently, these treatments have not been extensively tested in the reservoir and an adaptive management approach should be taken towards implementation. If the treatments are found to work effectively, further implementation could be undertaken in the future. These treatment recommendations are based on the use of locally available materials that are appropriate in a reservoir setting. Treatments can make use of materials that are currently seen as wastes with living components that are collected locally.

Methods

Documents pertaining to the natural vegetation communities found on reservoirs and the various programs designed to revegetate the reservoir areas were reviewed. The Kinbasket, Arrow, Duncan and Carpenter reservoirs were inspected to identify filters that are impacting vegetation establishment and to observe any natural recovery processes that are influencing vegetation growth in the reservoir drawdown zone areas. Inspections of the drawdown zone included slope and aspect, assessments of substrates, substrate movement patterns, wind and wave action, erosion and erosion processes and natural examples of successful recovery. The current conditions of field restoration trials were briefly inspected.

Results and Discussion

Natural recovery process effectiveness was observed to be affected by the ongoing disturbance of reservoir operations. The uncertainty of maximum reservoir fill levels creates a shifting zone where recovery occurs. This provides opportunities to see the reaction of recovery processes to the various levels of reservoir fill. The operation of beaver dams over a number of years is analogous to this condition (Photograph 1). Pioneering species such as balsam poplar and willows colonize the bare ground that is left when the beaver dam is breached. These grow to the point where beaver once again find the habitat suitable with subsequent dam construction and flooding. This kills the flooded forest due to the anaerobic conditions that are associated with the flooding. Dead trees populate the upper reservoir area as a result of anaerobic substrate conditions (Photograph 2). These established during a prolonged period of low reservoir fills and then were killed during a few years when high water persisted. Understanding the filters that operate in reservoir areas can provide insights into the design of recovery options that address the goals of the restoration program.

Photograph 1 & 2. Beaver dams (left) display a recovery / disturbance system that is analogous to the conditions found in reservoirs. Balsam Poplars establish in the upper reservoir area (right) during periods of low water only to be flooded and die during high water years.

The general failure of woody species planting low in the reservoir areas appears to be due to the anaerobic conditions associated with the substrates in some areas of the reservoir. This suggests that attempts to establish trees in reservoir areas will only be successful when reservoirs are kept below full pool elevations or when the flooding of the stems is not so prolonged that anaerobic conditions result in death of the woody species. Non-woody species that have adapted to growth in anaerobic substrates may persist at low elevations in reservoirs. Observing site where woody species continue to persist within reservoirs provides insights into options for assisting the establishment of vegetation in reservoirs. Photographs 3 and 4 show vegetated areas within reservoirs.

Photograph 3 & 4. A floating peat island (left) keeps the vegetation above the anoxic zone of the Kinbasket Reservoir. Stumps have collected around the peat island that protects the island from wave erosion. A constructed mound (to protect boats) allows vegetation to establish within the Duncan Reservoir.

Building mounds with woody debris (a waste material found in reservoirs) could provide a way of establishing pioneering species along the shores of reservoirs. Programs of woody debris removal are currently conducted at many reservoirs to reduce the hazard to boaters. Excavators are used to collect the woody debris during low water periods. Piles of woody debris are then burned with the resulting ash and gravels that were inadvertently collected with the woody debris spread on the reservoir floor. Mounds could be built with a mixture of large woody debris and substrates to encourage woody species establishment. Large woody debris could be used around the outside to protect the mound from wave erosion with smaller debris and substrates placed in the centre of the mound to serve as a rooting zone for pioneering species. Live staking could be used in the mound area to get pioneering species established. The roots of willows, red-osier dogwood and balsam poplar will grow into the rotting wood in search of moisture, helping to lock it in place while replacing the erosion protection function of the woody debris over time. Creating habitat structures that make use of a waste material and can be constructed at little additional cost (above current woody debris removal costs) could provide a significant benefit on reservoir shorelines. Figure 1 shows a conceptual design for mounds that might be used in reservoirs to create wildlife habitat and enhance biodiversity.

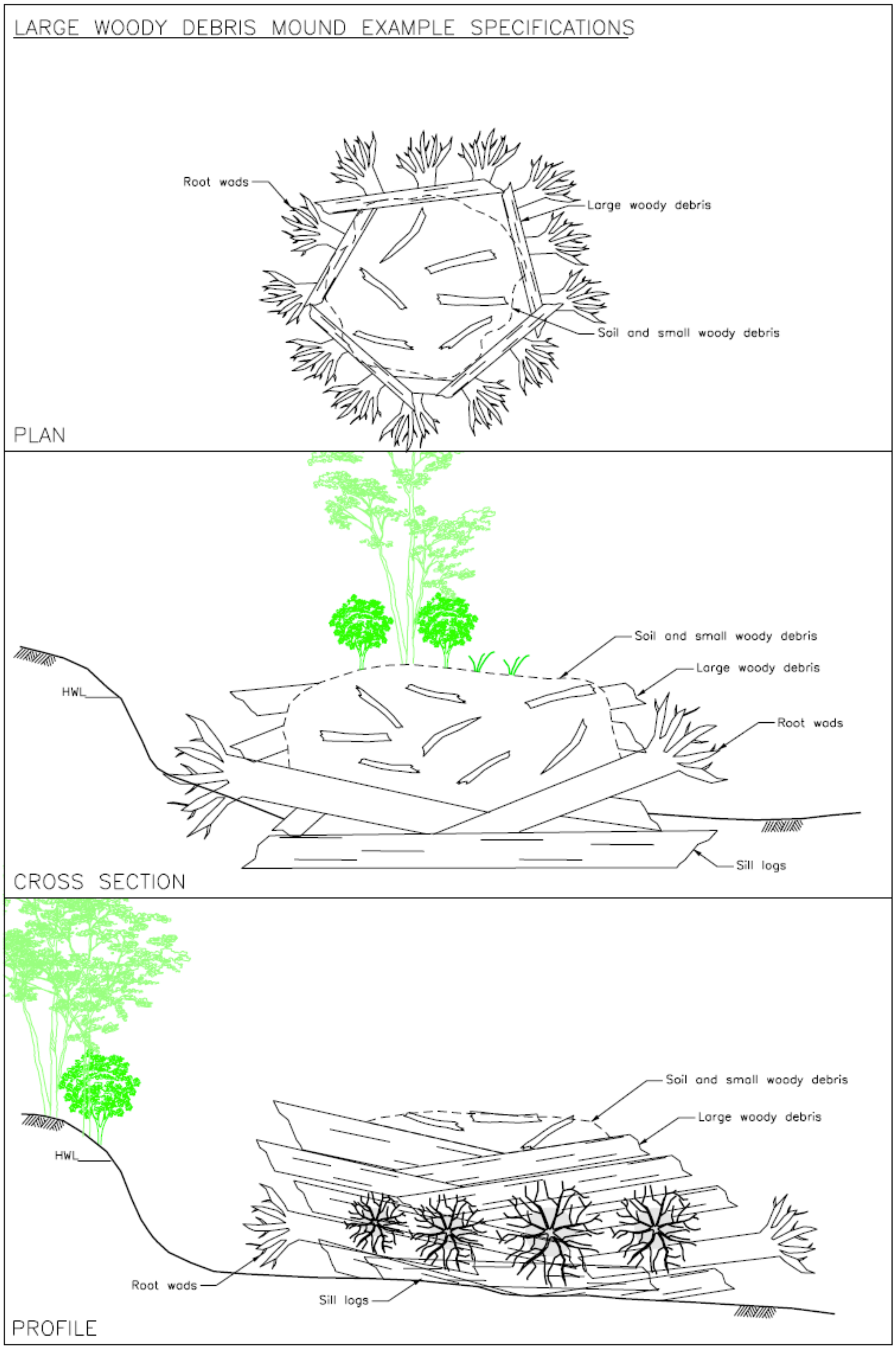


Figure 1. Mounds constructed of woody debris with associated sediments could provide a solution to soil anoxia. Note: this drawing is not to scale and is for conceptual purposes only.

Creating topographic heterogeneity (Larkin et al. 2008) within reservoir areas might also be used to reduce dust generation problems and shoreline erosion problems. Islands might provide opportunities for additional colonization (MacArthur and Wilson 1967) of reservoir areas by changing the sediment dynamics or other factors of the reservoir shoreline ecology.

Conclusions

Natural processes have operated to revegetate natural disturbances for millions of years. Finding natural analogues to reservoir ecology / operation is difficult. The activities of beavers on the landscape provide similar, albeit on a reduced scale, disturbance regime. Standing dead trees within beaver pond areas are similar to the standing dead trees found along the margins of reservoirs. The death of woody vegetation in both beaver ponds and reservoirs appears to be caused by anoxic conditions associated with flooding of the substrates. Beaver lodges provide habitat for the growth of woody species above the ponds that are not impacted by anoxia. Creating islands from woody debris within the margins of reservoirs might address the issues of anoxia in the reservoirs. These islands may create additional benefits such as dust control and serving as nuclei for additional vegetation establishment.

References

Braatne, J.H. and S.B. Rood. 1998. Strategies for promoting natural recruitment and restoration of riparian cottonwoods and willows. Paper presented at Ecosystem Restoration: Turning the Tide. Society for Ecological Restoration Northwest Chapter Conference and Annual Meeting. Tacoma, Washington.

Larkin, Daniel J., Sharook P. Madon, Janelle M. West, and Joy B. Zedler. 2008. Topographic heterogeneity influences fish use of an experimentally restored tidal marsh. Ecological Applications 18:483 – 496.

MacArthur, R. H. and Wilson, E. O. 1967. The Theory of Island Biogeography. Princeton, N.J.: Princeton University Press. 224 pp.

Polster, D.F. 2009. Natural Processes: The Application of Natural Systems for the Reclamation of Drastically Disturbed Sites. paper presented at the B.C. Technical and Research Committee on Reclamation, BC Mine Reclamation Symposium. Cranbrook, B.C. September 14-17, 2009.

SERI, 2004. The SER Primer on Ecological Restoration. Version 2. October, 2004. Science and Policy Working Group, October, 2004. Society for Ecological Restoration

International. Washington DC. accessed on January 12, 2015 (http://www.ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration).

Back to Table of Contents

26. The Okanganan Sockeye salmon restoration program and future salmon reintroduction to the Columbia River transboundary reach

Michael Zimmer
Fisheries Biologist, Columbia Region, Okanagan Nation Alliance.
mzimmer@syilx.org, 250-304-7341

Abstract
Anadromous fishes are important dietary constituents to Columbia Basin First Nations, and are considered one of four First Foods. None other is more important than salmon. Similarly, the cultural significance of healthy runs of salmon cannot not be overstated. Prior to the onset of industrialization and dam construction on the Columbia, millions of salmon used to make their way through the transboundary reach and into Canada to complete their life cycle. Those salmon are now extirpated. Okanagan Nation Alliance restoration efforts have been in place on the Okanagan River Since 2003 with numerous barrier access mitigation and habitat enhancement projects having been completed. Sockeye escapement response to the Okanagan River since that time has seen remarkable increases. 2014 escapement to Osoyoos Lake was in the order of 300,000 sockeye, the highest return since the start of modern record keeping in the 1930s. Returns in the last few years have been high enough for sustainable First Nations food fish and commercial harvest. Projections for 2015 run size looks to continue to improve. Commissioning of an ONA sockeye hatchery in Penticton in fall 2014 will support further restoration efforts with 2.5 Million sockeye eggs from 2014 brood collections, currently incubating. The success of the Okanagan River sockeye reintroduction program will help guide concurrent, bi-national, First Nation, Tribes and Indian Band collaborative efforts in restoring salmon and other anadromous Columbia River fishes throughout their historic range, past numerous large, high-head dams.

Back to Table of Contents

27. Lower Cascade Creek: Fisheries management in a regulated river within Banff National Park

Jeff Nitychoruk, BIT
Summit Environmental Consultants Inc.
200 – 2800 29th Street, Vernon, B.C.
Email: jn@summit-environmental.com
Phone: 250.545.3672

Abstract

The lower portion of the Cascade River is a system in Banff National Park that has a long history of hydroelectric regulation. Many other drainages inside and outside Canada's national parks have long histories of accidental or intentional introductions of non-native species. In recent times, hydroelectric activities and these unwanted introductions have been interrelated in the Cascade River, and Parks Canada has made concerted efforts to restore the original ecology of the aquatic environment by removing invasive fish species. In June of 2013, heavy precipitation caused flooding and widespread damage to public and private property across western Alberta, particularly in the Bow Valley. Rising water levels in the Minnewanka Reservoir, just outside the Banff town site, triggered emergency release of water as a means of protecting public safety and limiting damage to the power-generating infrastructure associated with the reservoir. Water was released into the original channel of the Cascade River, a watercourse that had not experienced flows of that volume in over 70 years. After the emergency spilling ceased, Parks Canada, numerous consulting firms, and TransAlta Corporation (the owner and operator of the Cascade hydroelectric plant) undertook a massive, three-tiered effort to salvage and relocate stranded fish from 13.5 km of the Cascade River channel. This presentation will provide a brief history of invasive fish species in Banff National Park, and will discuss recent efforts to remove those species from the Cascade River, the flood impacts to that work in 2013, and the subsequent effort to salvage fish after the unanticipated emergency spill.

Back to Table of Contents

Posters & Displays

1. Investigating impacts of run-of-river hydropower on American dippers and the river food webs of coastal British Columbia.

Veronica Norbury, MSc Candidate, University of Saskatchewan/Environment Canada, veronica.norbury@usask.ca, 1-306-850-5445, 628 7th Ave North, Saskatoon, SK, S7K 2V1

Co-authors:

1. Dr. Christy Morrissey, University of Saskatchewan, christy.morrissey@usask.ca
2. Dr. Christine Bishop, Environment Canada,[CAB.Bishop@ec.gc.ca]

Run-of-river dams, a form of small-scale hydro known synonymously as river diversions, are an increasingly common alternate energy source. Despite reductions in dam size and greenhouse gas emissions compared to conventional impoundments, run-of-river hydro may have ecological impacts through disruption of the natural flow regime and associated infrastructure. The American Dipper (*Cinclus mexicanus*) is a high trophic level river bird potentially affected by these developments, since their habitat overlaps with the placement of run-of-river dams on coastal mountain streams of British Columbia. Dippers are also known indicators of stream health; thus, they are an ideal species to study potential impacts of run-of-river hydropower. The objectives of this study are to 1) identify American Dipper habitat use upstream and downstream of regulated and unregulated streams in southwest BC; 2) characterize the food web at these sites using stable isotope analysis; and 3) evaluate the mercury biomagnification potential at these sites. Food webs were sampled at six regulated and five unregulated streams using a paired design a) upstream and downstream of each dam and b) between regulated and unregulated streams. Isotopic signatures ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$) and MeHg levels will be analyzed for the following samples: a) blood from dippers captured by mist-netting and b) periphyton and benthic macroinvertebrates sampled along a longitudinal gradient at regulated and unregulated streams. Dippers have been observed congregating immediately upstream and downstream of several RoR dams in coastal BC. This has led to the hypothesis that reduced flow associated with these small dams creates a novel habitat in which dippers may forage more efficiently. Analyses of the stream food webs will reveal whether this modified habitat contains higher levels of MeHg than upstream of the dam or nearby unregulated streams. This study is an opportunity to examine the effects of reduced and stabilized flow on lotic food webs and improve our understanding of mercury biomagnification in rivers. Further, this research will allow us to apply novel biomonitoring techniques to improve sustainable energy development, including the application of stable isotopes.

Back to Table of Contents

2. *Augmented flow may restrict the movement potential and habitat availability of the threatened western silvery minnow (Hybognathus argyritis) in a prairie river.*

Kenton Neufeld
University of Alberta
kenton@ualberta.ca

Co-authors: Mark Poesch, University of Alberta, poesch@ualberta.ca
Keith Tierney, University of Alberta, ktierney@ualberta.ca
Doug Watkinson, Fisheries and Oceans Canada, doug.watkinson@dfo-mpo.gc.ca

Hydrologic alterations are widespread in streams in the Great Plains region of North America, with impacts on their fish communities and habitats widely documented. In the Milk River of southern Alberta, flow augmentation for the purposes of downstream irrigation has led to a drastically altered flow regime with summer discharge much higher than natural levels. The Milk River contains the most northernly population of Western Silvery Minnow (*Hybognathus argyritis*), a species listed as threatened both provincially and federally. Using habitat preference and swim performance data we investigated the impacts of hydrologic alteration on Western Silvery Minnow habitat availability and movement potential in the Milk River. We found that during augmented flow periods the amount of preferred habitat was drastically reduced. We also found that increased water velocity associated with higher discharge may restrict the movement of individuals through much the river, especially young-of-the-year.

Back to Table of Contents

3. *Influence of reservoir operating regimes on the establishment and persistence of shoreline vegetation communities in the Kinbasket Reservoir*

Michael T. Miller
PhD Biology University of Victoria
Vegetation Ecologist, LGL Limited environmental research associates www.lgl.com
9768 Second Street Sidney, B.C., Canada V8L3Y8.
250.545.0904 mmiller@lgl.com
Co-authors: Virgil C. Hawkes, LGL Limited vhawkes@lgl.com
Pascale Gibeau, Ripple Environmental ripple.environmental@gmail.com

A 10-year vegetation study of the Kinbasket Reservoir foreshore (CLBMON-10: Kinbasket Reservoir Inventory of Vegetation Resources) was initiated in 2007. The primary objectives of the study are to monitor vegetation responses in the drawdown zone (DDZ) to ongoing reservoir operations (i.e., timing, duration, and depth of inundation) and to determine if changes to the current operating regime may be required to maintain/enhance the existing shoreline vegetation and the ecosystems it supports. To date, 19 different community types have been delineated, mapped, and monitored biennially within the vegetated portions of the DDZ (741-754 masl elevation band) using both aerial photography and belt transects. The lower limits of this elevation band tend to be occupied by pioneering and early seral communities, while more successionally advanced communities such as willow shrublands are generally limited to mid and upper DDZ elevations. Aerial photo monitoring indicates that since 2007, the extent and distribution of most communities has remained relatively stable at the landscape scale. However, over this same time there have been notable reductions in species richness and diversity for many communities, especially ones occurring at higher elevations (i.e., ≥750 m ASL). One-way ANOVAs found significant differences among years for the Clover-Oxeye Daisy ($F=30.6$, $p=0.0001$), Marsh Cudweed – Annual Hairgrass ($F=18.3$, $p=0.004$), and Kellogg's Sedge ($F=4.6$, $p=0.006$) communities. Other communities such as Willow-Sedge wetlands also show reduced diversity. The decreases are attributed in part to a reduction in available growing degree days (GDD) during the prime growing months (June-August) as a result of recent, successive full pool events, beginning with the filling or near filling of the reservoir in 2007 and 2011, followed by reservoir surcharge (exceedance of full pool) in both 2012 and 2013 and a subsequent near filling in 2014. Associated with these repeated high water events is a general die-back of less inundation-tolerant plants such as woody shrubs that likely became established in the upper drawdown zone during the decade of relatively low water levels that preceded 2007. Local vegetation changes resulting from reservoir operations could eventually manifest into larger, landscape level changes that may only become apparent after several more years of monitoring.

Back to Table of Contents

4. *The opposite river: Assessment of an environmental flow regime along the Duncan River, British Columbia*

Mary Louise Polzin, Brenda Herbison, Mike Miles, Alf Leake, Eva-Maria Boehringer, and Stewart B. Rood VAST Resource Soln., Cranbrook; N. Kootenay Consulting; M.Miles & Assoc. Ltd.; BC Hydro (AL & EMB); Univ. Lethbridge, AB
(contact: MaryLouise.Polzin@vastresource.com or rood@uleth.ca)

The Duncan River flows into Kootenay Lake and was dammed in 1967 as part of the transboundary Columbia River Treaty. The Duncan Dam has no hydroelectric facility and provides flexibility for downstream flow management. Subsequently, a new environmental flow regime was implemented in 2008 under Alternative 73 (Alt73) that was intended to benefit black cottonwood (*Populus trichocarpa*) and riparian woodlands, as well as Gerrard rainbow trout and Kokanee salmon. To assess responses to river damming and flow manipulation (Alt 73), we reviewed historical air photos and undertook field studies from 2009 through 2014 to investigate channel and riparian responses. We applied a paired-comparison design to contrast hydrology, channel pattern, bank pattern and profile, surface sediment and vegetation along the regulated reach of the lower Duncan River with the unregulated Lardeau River, which joins the Duncan River downstream of Duncan Dam.

Post-damming, substantial accumulation of cobbles, gravels, sands, and large woody debris has occurred along the lower Duncan River. This disparity in physical processes below most dams, where sediment and woody debris supply are typically non-existent, is due to sediment and woody debris inputs that persist from the free-flowing Lardeau River; notwithstanding notable differences, the attenuation of high flows from the upper Duncan River has diminished transport capacity below the Duncan Dam and downstream to Kootenay Lake.

To monitor effects of the altered flow regime (Alt73) on colonization dynamics of riparian vegetation, we established belt transects with sequential quadrats to assess plant occurrence and abundance, with an emphasis on the response of cottonwood seedlings and saplings. Changes were extensive in most years and seasonal patterns were strongly influenced by higher rainfall when compared to observations along other rivers in drier regions. We observed that seedling survival was strongly impacted by sediment deposition and scour, emphasizing the importance of fluvial geomorphic processes. Moreover, there was a strong relationship between alluvial groundwater and river stage demonstrating a high degree of connectivity within the riparian colonization zones. From these analyses we are refining hydrogeomorphic models that seek to provide the mechanism between river flow regime, sediment dynamics, and colonization and persistence of riparian vegetation. The Duncan River study provides useful insights towards development of environmental flow regimes for other regulated rivers of the North American Pacific Northwest.

[Back to Table of Contents](#)

5. *Floating nest platforms buoy up Common Loon nesting success in a reservoir*

Mandy Kellner
Kingbird Biological Consultants Ltd.
Box 8617, Revelstoke, BC, V0E 2S2
250-837-0820
mandy.kellner@gmail.com

Common Loons (*Gavia immer*) are large, piscivorous birds that nest on the shoreline of lakes, immediately adjacent to the water. At Whatshan Reservoir in southeastern British Columbia, construction of a dam and flooding of original wetland and riparian habitats has likely led to the reduction of suitable nesting habitat. Further affecting the productivity of loons at Whatshan, are disturbance from human development and recreation on the reservoir, and the flooding of nests through reservoir operations. Floating nest platforms have been used successfully to increase loon reproductive success in other lakes and reservoirs, and could help mitigate negative impacts of reservoir operations and encourage the loons to nest away from areas prone to human disturbance. In response to a low rate of reproductive success and very late hatch dates documented during previous work, we installed five floating artificial nest platforms in 2011. The platforms were planted with graminoids, emergent plants, and shrubs, which grew vigorously and by mid-summer, they were vegetated enough to appear as riparian habitat, adding diversity to the reservoir and potentially offering resting, foraging, or cover habitats to wildlife. Monitoring for use by loons continued through 2014, during which time we also documented the durability of platforms and anchor systems and developed recommendations for future installations. Although no loons nested on the platforms in the year of instalment, use has steadily increased over time. In the 2012 nesting season, water levels were 3-4 m below norm in spring (mid- to late-May) and loons could not access the stranded platforms during the start of the nesting period. However, a platform was used for a late re-nesting attempt. In 2013, three pairs used platforms, two of which successfully nested and raised young. In 2014, four of five nesting pairs used platforms, including in one territory where the pair has not been recorded attempting to nest before. One of these nests was successful. Perhaps equally as important, the successful young were hatched much earlier than hatch dates of successful nests in the past. We expect increased use of the platforms in subsequent years, with obvious benefits to nesting success of this iconic species.

Back to Table of Contents

6. *Long-term Wildlife Effectiveness Monitoring in Arrow Lake Reservoir: a look back and a step forward.*

Janean Sharkey, B.Sc, LGL Limited
9768 Second Street, Sidney, BC, V8L 3Y8
E-mail: jsharkey@lgl.com, Phone: 250-656-0127, Website: http://lgl.com/

Arrow Lakes Reservoir is an approximately 230 km long section of the Columbia River drainage between Revelstoke and Castlegar, B.C. that was created following the completion of the Hugh Keenleyside Dam in 1968. In an effort to mitigate the impact of habitat loss from reservoir operations on Arrow Lakes Reservoir and to fulfill BC Hydro water licence requirements, revegetation of nearly 106 ha occurred between 434 and 44 m ASL from 2007-2011 with the goal to enhance vegetation in the drawdown zone. In 2009, an 11-year monitoring program was initiated to study the efficacy of the revegetation treatments and effects of reservoir operations on wildlife and wildlife habitat. The overall scope of the study was to address whether the revegetation efforts were effective in enhancing wildlife habitat. This was accomplished through adaptive management and selecting the appropriate biological indicators and response variables. An effectiveness monitoring program was designed that focused on monitoring terrestrial arthropods, songbirds and mammal use of the revegetated areas, surrounding drawdown zone and adjacent upland habitat. Specific taxa within those groups were then selected by examining sensitivity of the taxa to change, ease of data collection and distribution of species. The seasonal inundation of the drawdown zone creates a successional environment that favours pioneering species. Terrestrial arthropods are ideal taxa to monitor change in revegetation efficacy due to their known associations with vegetation and vegetation communities, short lifecycle, life history and importance in the trophic food web. Focus will be given to how terrestrial arthropod species were monitored as a tool to assess the efficacy of revegetation prescriptions. Challenges in study design and analysis included limited establishment of revegetated areas, lack of replication of treatments, lack of baseline data and small scale of treatments. Despite these challenges, the use of terrestrial arthropod species as indicators of change in modified landscapes is appropriate and is discussed in the context of effectiveness monitoring and reservoir ecology.

Back to Table of Contents

7. Do rising water levels alter nest survivorship in reservoir drawdown zone shrubs?

Harry van Oort[1]*, David J. Green[2], Matthew Hepp[2], and John M. Cooper[3]

1. Cooper Beauchesne and Associates Ltd., Revelstoke, BC, Canada
2. Department of Biological Sciences, Simon Fraser University, Burnaby, BC, Canada
3. Cooper Beauchesne and Associates Ltd., Qualicum Beach, BC, Canada

* Corresponding author: hvanoort@cooperbeauchesne.com

Birds frequently nest in reservoir drawdown zones, but these habitats may represent ecological traps, because rising water levels are known to submerge active nests. But for species that nest above the ground in shrubs, nest submergence is unlikely to be the only impact caused by habitat inundation; the net impact of habitat flooding is therefore unclear. We calculated daily nest survival (DSR) for two shrub-nesting species with differing exposure to nest submergence in the Arrow Lakes Reservoir, British Columbia. Yellow Warbler (*Setophaga petechia*; YWAR) and Willow Flycatcher (*Empidonax traillii*; WIFL) nested over a similar range of geographic elevations in the drawdown zone, but YWAR built nests higher above the ground and initiated their clutches earlier than WIFL, causing spatiotemporal partitioning in nesting activity, with WIFL having greater exposure to nest submergence. In addition to nesting in the shrubby portions of the drawdown zone, both species were observed nesting on a floating island of bog habitat, where rates of nest submergence were greatly reduced. There was a minor reduction in YWAR DSR when their nest habitat was inundated, but this reduction was possibly explained by a seasonal decline of nest DSR. Despite higher rates of nest submergence, habitat flooding did not impact DSR of WIFL nests. WIFL nest DSR was enhanced considerably when nesting in the floating habitat. These results suggest that nest submergence caused by reservoir operations does not necessarily translate into reduced nest DSR of shrub nests, likely, we speculate, because of a reduction in nest predation rates when nesting habitat becomes flooded. Our results also indicate that floating habitat islands can be productive, and may hold potential as a way to enhance productivity of reservoir drawdown zones.

Back to Table of Contents

8. Restoring the river's sediment balance, dams, salmon and sediment

Giles Shearing
UBC / SEC Shearing Environmental Consultants
gilesshearing@live.ca

Important to dam operators and environmental regulators is how to restore sediment transport processes to regulated rivers without harmfully impacting downstream ecological processes. Without a means to convey transported sediment, dams placed on alluvial rivers can alter the morphology of the riverbed as a result of aggradation (upstream sediment accumulation) and degradation (downstream coarsening and channel incising). As sediment accumulates year after year in the dam forebay and backwaters, the magnitude of the problem grows. Determining a longterm solution poses many challenges. At Wilsey Dam, located on the Middle Shuswap River near Lumby, B.C., data was collected over a 2 year period to assess the impact of the dam on the river's sediment transport processes and modelling was undertaken to determine a way to reintroduce sediment without impacting important life stages of anadromous salmon, specifically coho and chinook. The poster will present findings on downstream fining trends observed throughout the 27 km study area, sediment transport modelling results showing different test scenarios and results from an experimental dredging project undertaken at Aberfeldie Dam in 2014.

Back to Table of Contents

9. *Okanagan River habitat water management and fish habitat enhancement initiatives.*

Michael Zimmer Fisheries Biologist,
Columbia Region, Okanagan Nation Alliance.
mzimmer@syilx.org, 250-304-7341

The Okanagan basin is managed via a series of dams to balance between flooding, agriculture and urban water supply, fisheries, and other interests. The challenges faced by water and fisheries managers include: variation in seasonal flow, competing objectives and communication barriers. The Okanagan Fish-Water Management Tool (FWMT) is an online, decision-support tool used by fisheries and water managers to balance competing water resource use, which utilizes six linked biophysical models (water supply, water management rules, water temperature, kokanee egg-to-fry emergence, Rocky Mountain ridged Mussel, and sockeye submodels) to predict the outcomes of water management scenarios (weekly releases). The predictions and the potential impacts of scenarios are then discussed by water and fisheries managers, and implemented by the regulating agency in balancing the competing uses of the limited water supply of the Okanagan basin. In particular, fish-friendly lake levels and flows reduce negative impacts to fish populations. The Okanagan River Restoration Initiative (ORRI) is an ongoing program concurrent with the FWMT which focuses on site-specific habitat restoration activities. To date ORRI projects include: reconnecting fragmented habitats, off-channel and riparian habitat improvements, and fish access mitigation.

Back to Table of Contents

10. Aquatic Invasive Species

Khaylish Fraser, Central Kootenay Invasive Plant Committee (CKIPC),
kfraser@ckipc.ca, 1.844.352.1160 ext. 207,
4559 Bain Rd, Beasley, BC, v1l 4b7,
www.ckipc.ca

The Central Kootenay Invasive Plant Committee (CKIPC) is a non-profit society comprised of concerned local citizens, land managers, government and non-government agencies who are working to improve the way we manage non-native invasive species in the Central Kootenay region.

Invasive species have been introduced to Canada intentionally and accidentally, and can have impacts socially, economically and environmentally. These introduced, non-native species establish and spread successfully due to a lack of natural predators and other controls. Invasive species are highly competitive and have the ability to outcompete native plant and animal species, impacting fragile native species and ecosystems. CKIPC program activities include education and awareness; prevention and early detection of new species introductions; coordinated and collaborative management; inventory, control and containment of invasive plants; and applied research. Recently, the Columbia Basin Trust and the four regional invasive species committees operating in the Canadian Columbia Basin have developed a program for regional committees and their partners to promote a proactive, strategic, collaborative and coordinated approach to AIS prevention and management

Back to Table of Contents

11. Osprey Productivity and Nest Provisioning in Revelstoke Reach

Catherine Craig, Cooper Beauchesne and Associates Ltd.
ccraig@cooperbeauchesne.com
Harry van Oort (hvanoort@cooperbeauchesne.com), Ryan Gill (rgill@cooperbeauchesne.com), Corey Bird (cbird@cooperbeauchesne.com), and John M.Cooper(jcooper@cooperbeauchesne.com)

Impoundments along the Columbia River have altered the abundance and quality of the wetlands within Revelstoke Reach of the Arrow Lakes Reservoir (ALR). We present preliminary results from nest monitoring of Osprey, a wetland raptor whose breeding success declined during the study. Osprey productivity was correlated with total June precipitation and the annual maximum elevation of the ALR. In 2014, we began monitoring nestling feeding rates to determine if lower productivity could be caused by reduced foraging efficiency.

Back to Table of Contents

Summary of conference evaluation forms

There were 103 people at the conference, and 21 evaluation forms were returned. Not all forms had a response for each question.

1. ***How well did the conference meet your expectation?***

   Exceeded Expectations: 10 People
   Fully met expectations: 10 people
   Met most expectations: 1 person
   Met only a few expectations: 0
   Did not meet any expectations: 0

2. ***Suggest two or three key things you learned at this conference, and list anything that you will now do differently in the future.***

- Global perspectives of hydropower. Many tradeoffs
- Mensuration problems well described (4)
- Small fish species biology
- Think differently about hydro dam infrastructure
- Recreational value of rivers: canoeing and kayaking and method for describing river characteristics
- Make an effort to keep abreast of other research happening around our Columbia Basin projects
- Huge variety of work being done in the region.
- Reclamation through “woody islands” in the Kinbasket.
- Other consultants facing similar challenges with different taxa
- Fish monitoring techniques
- Nest flooding in the Kinbasket is not as much of an issue as in Arrow.
- Debris mounds have been built in the Williston
- Global Regulated Rivers context was very interesting.
- Ultrasound system to count fish
- The pace of hydro development globally was pretty astounding and the costs of all types.
- Conclusion from several WUP projects.
- Great to have international speakers as well as locals.
- Excellent keynotes. Learned about ELOHA and NCC software from Cathy (3).
- Wildlife vs. Fish topics clustered on the agenda
- Weight of hydro reservoirs could alter planetary rotation of the earth.

- Flooding of waterfowl and passerine nests in the drawdown zones. Ephemeral wetland habitat. There are opportunities for restoration of these novel environments. I will be searching for this in my run-of the river site headponds.
- Use of hydraulics for live stake planting from discussion with Norm Merz. I will definitely look into this. Quantitative approach for comparing rivers and their white water habitat and recreation. Great conversations between and after presentations addressing specific areas of concern.
- Examples of how dam operation at load peaking plants have been modified
- Learned about restoration techniques in the drawdown zone
- More information on the extent of dam impacts worldwide
- More detail on ONA Sockeye plans (3)
- Presence of Umatilla dace
- Rainbow trout redds can be seen aerially!
- Always a trade-off: eg. Birds nesting over water have lower predation but higher flooding rates (3)

3. If we run a sequel to this conference what topics would you like to see included/be addressed?

- Examples of how dam operations at load peaking plants have been modified to mitigate downstream impacts
- Run-of –river dam research and findings (3)
- Expansion of topics outside of the Columbia River system (as there were some redundancies) . Would be great to hear more about what is being done elsewhere
- More looking to adaptive management in the face of climate change, shifting social values, water scarcity, invasive species etc.
- More studies from abroad so we can learn from other areas.
- More about the political aspects of regulated rivers.
- How local citizens can “advise/inform/plead with government to change policy on development of dams (without having to create an adversarial situation)
- Columbia River Treaty Renewal
- Please run a sequel!
- How do we test for the utility of restoration?
- Follow-up on the pilot projects that were introduced at this conference
- More on FN’s salmon reintroduction story (2)
- Flow regime modelling and how to apply this to assess ecological impacts
- Dam removal, pros and cons
- Wider variety of wildlife impacted by regulated rivers

- More terrestrial topics! Larger geographic scope of projects. Maybe expand to impacts from renewable energy projects (tidal, wind, solar etc.)
- Reservoir draw down restoration "prescriptions" for human made structures to initiate biological re-establishment both vegetative and wildlife ie: Island structures in the draw down zone and costs of operational plan, installation
- Water quality analysis
- Mitigation, cost benefit analysis and related intrinsic and extrinsic values
- TGP
- GIS modelling of hydrology/velocity
- Address the issue of climate change on landscape level hydraulic function of regulated rivers
- How can we coordinate efforts and share data
- How can we model hydrology for the Columbia River?
- Dam removal options for the Columbia
- Have the gaps "identified" been addressed? Or at least started to be addressed?
- The role politics plays in addressing these issues
- More student presentations from across the province
- Effects of global warming on regulated and free flowing rivers. How to sample/analyze effects of global climate change.

4. ***General comments concerning the conference?***

- Was very worthwhile (2)
- Would like to see this as a biannual event
- Did you make an attempt to invite municipal councillors/regional directors to attend this conference? They need to be educated!
- Awesome! It was great to hear about other projects in the area and results from other disciplines (2)
- Very valuable opportunity as a student! However, $160 for a student is unaffordable! I could only have come as a volunteer (2)
- Great diversity of talks (3).
- 15 minutes + 5 minutes for questions was a great length to maximize attendee interest and minimize fatigue
- Better lunch options/Coffee breaks were great
- Really enjoyed the keynote global focus! Cathy was excellent
- Well organized!
- Perhaps another one in a few years
- More advertisement in the US to get other basin biologists.
- Fantastic! Thank you

- People wanted to chat, give more time for this
- Please include abstracts with titles in synopsis
- Great poster session (well-attended) (2)
- Nice mix of local and non-local research
- Good mix of academic and industry based talks (2)
- Great conference!
- Well organized! (2)
- Would have been good to have a more facilitated discussion, not just standing around the coffee table! Could have split into groups and have 20 minute discussions

5. ***The Columbia Mountains Institute is always looking for suggestions for courses and workshops. Our niche is offering continuing education for ecologists, foresters, biologists, and resource managers. Do you have any suggestions for courses or events you like us to organize?***

- Reclamation
- Intro to Statistics course
- Host another Regulated Rivers conference when the current Columbia River WUP has concluded
- Use of smartphone technology in the field
- Wetland courses-reference sites/types. Classification of disturbed sites.
- Riparian restoration
- PEM (predictive ecosystem mapping)
- Climate change conference
- Course on TEM mapping for ecosystems
- Management requirements for listed species
- Bird 10 workshops
- Soil workshops
- Communicating science to affect policy
- Stats and GIS courses

Back to Table of Contents