Managing Response of resident rainbow trout to water diversion at run-of-river Projects

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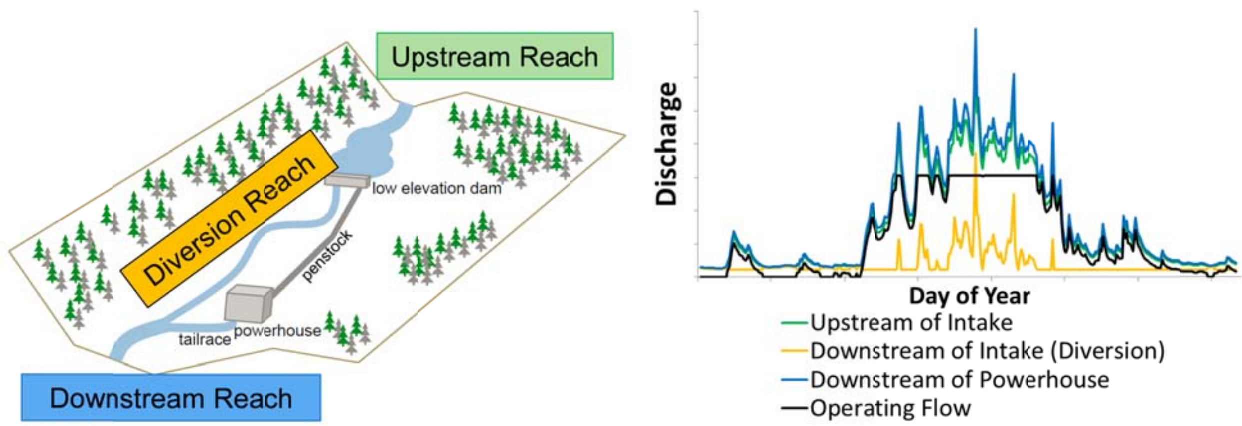
ABSTRACT

A surge in new run-of-river hydropower development in British Columbia in the 2000s, coupled with an absence of clear guidance on scientific requirements for long-term monitoring, led British Columbian and Canadian government agencies to develop monitoring protocols for these projects. These monitoring protocols require a minimum of two years of pre-project (baseline) data and five years of post-project (operational) data to assess project effects on the fish community. The recommended experimental design was based on a target power of 0.8 to detect a 50% decline in target fish species abundance or biomass. Here we present results of fish community monitoring for a group of four run-of-river projects operated by Innergex Renewable Energy. The four projects are located on streams in south-western British Columbia and have fish communities in the diversion and upstream reaches composed of only Rainbow Trout. The experimental design for fish community monitoring used a BACI design, with sampling conducted in the project diversion reaches (n=5 per stream) and upstream control sites (n=5 per stream). The primary sampling method was closed-site electrofishing. Data on water flow, temperature, chemistry, habitat, geomorphology, and invertebrate abundance were also collected. After five years of operational monitoring, increases in Rainbow Trout density and biomass were observed in the diversion reaches of all four streams, relative to control and baseline conditions, despite earlier environmental assessment predictions of habitat losses related to flow diversion. Integrated analysis of physical and biological metrics is ongoing and will facilitate better understanding of causal mechanisms.

Background

British Columbia's clean energy policy led to the development of a large number of independent power projects during the 2000s. The majority of these projects are run-of-river hydroelectric projects, which take advantage of the wet coastal climate, abundant snowpack, and large hydraulic head provided by the mountainous terrain. Run-of-river hydropower has the potential to create less environmental impact than traditional storage facilities, as no reservoir is created and the flow regime upstream of the water intake and downstream of the powerhouse remains unchanged (Figure 1). Nevertheless, potential remains for environmental impacts, particularly in the diversion reach, the section of the stream subject to reduced stream flow. Aquatic biota living in this reach may be affected (positively or negatively) by reduced streamflow, and fish species either within the diversion reach or downstream of the project may be directly or indirectly impacted by a project. The effects of run-of-river hydropower have not been well studied in British Columbia, and projects were permitted to proceed subject to monitoring of their environmental effects.

Figure 1. Configuration (adapted from Connors et al. 2014) and flow regime of a run-of-river hydroelectric facility

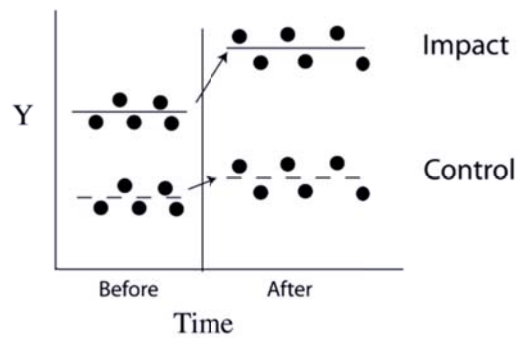


Environmental Monitoring

The rapid increase in run-of-river development led the provincial and federal governments to develop instream flow and environmental assessment methodologies (e.g., Hatfield *et al*. 2003, Lewis *et al*. 2004), and monitoring protocols that recommend specific study designs and data collection methods (e.g., Hatfield *et al.* 2007, Lewis *et al.* 2013). The monitoring protocols recommend a study design that is expected to detect a 50% decline in fish with statistical power of 0.8. To achieve this objective, a minimum of two years pre-project (baseline) and five years post-project (operational) data are required with five sites sampled in the diversion reach (impact) and upstream reach (control). The data collected in these studies are analysed using a before-after control-impact (BACI) statistical design, which corrects for the effects of natural environmental variability (Figure 2).

The primary purpose of data collection through this standardized monitoring is to determine if impacts to the fish community have occurred. When collected according to standardized approaches, monitoring data also provides general knowledge regarding the effects of run-of-river facilities that can be considered in future water management decisions throughout the province and more widely.

Figure 2. Before-After Control-Impact study design (Schwarz 2015)



Kwalsa Projects

The Kwalsa group of run-of-river projects, operated by Innergex Renewable Energy Inc., were among the first run-of-river facilities in British Columbia monitored according to the environmental monitoring protocol described above. The Kwalsa group consists of four run-of-river facilities located near the north end of Harrison Lake, northeast of Vancouver, British Columbia; these facilities are located on Douglas Creek, Fire Creek, Stokke Creek, and Tipella Creek (Figure 3). These streams have similar physical characteristics (Table 1) and Rainbow Trout are present throughout the diversion and upstream reaches of all projects.

Figure 3. Location of Kwalsa Projects

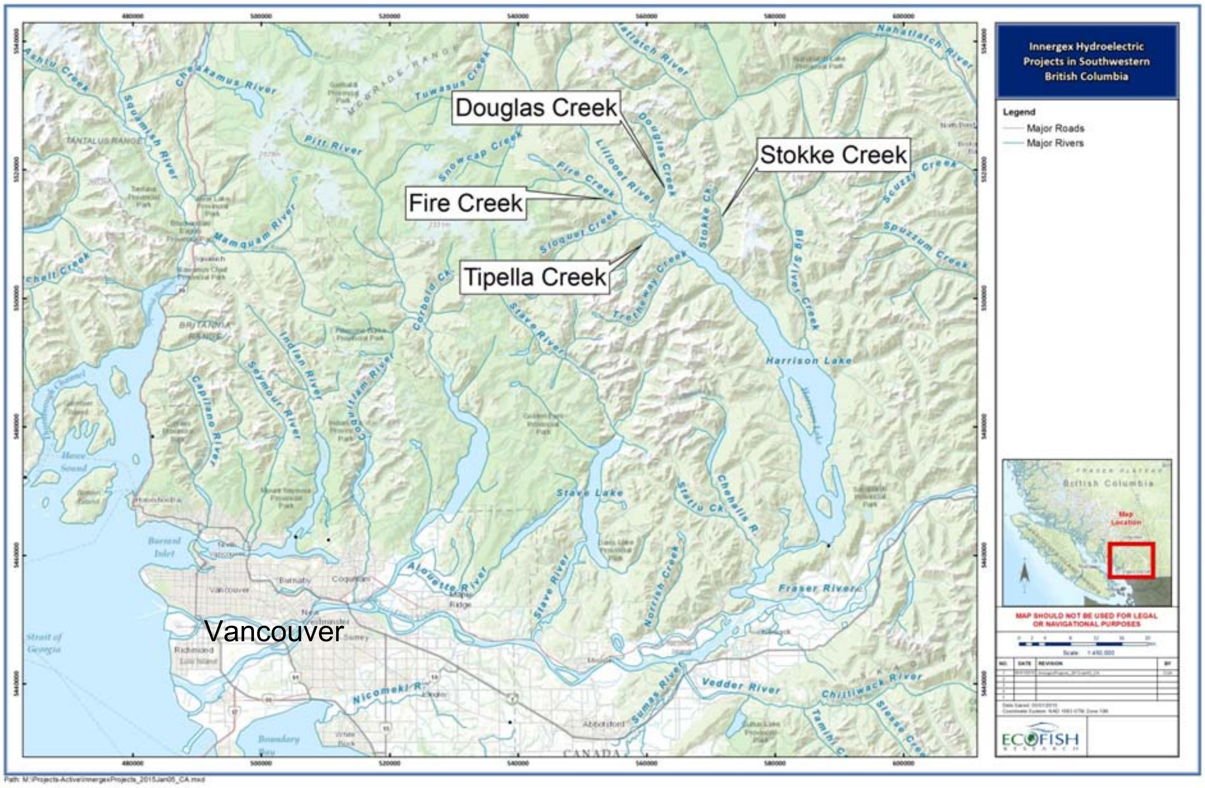


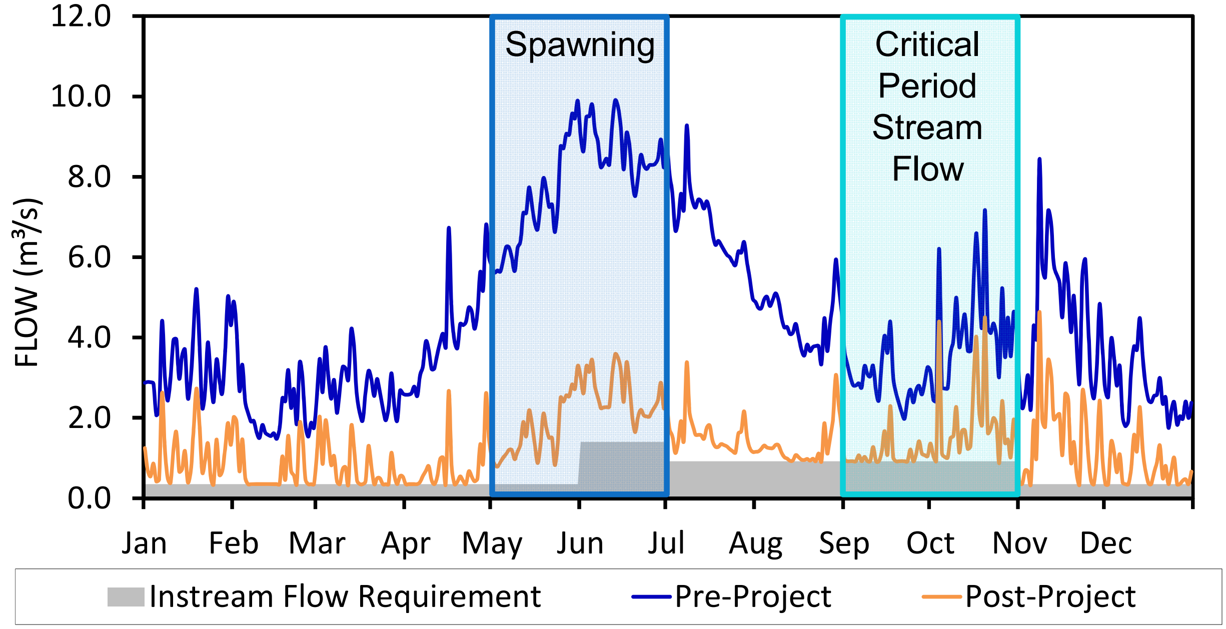
Table 1. Summary of Kwalsa Projects characteristics

Project	Stream Order	Stream Length (km)	Gradient (%)	Water Temp. Range (°C)	MAD at Intake (m^3/s)	Fish Species
Douglas Creek	3	22.0	10	0-15	6.5	Rainbow Trout
Fire Creek	3	13.8	7	0-14	5.2	Rainbow Trout
Stokke Creek	3	13.5	12	0-18	4.9	Rainbow Trout
Tipella Creek	3	14.0	14	0-13	4.5	Rainbow Trout

Predicted Flow-Related Effects

Environmental impact assessments were completed for the Kwalsa projects prior to regulatory approval. During this process, instream flow regimes were designed to mitigate the effects of flow diversion on Rainbow Trout during important periods for these fish (e.g. Figure 4). These flow regimes prescribe minimum instream flow requirements that are to be maintained throughout the year. Nevertheless, negative effects on Rainbow Trout rearing habitat (ranging from 1% to 57% habitat loss) were predicted during September and October, the lowest flow months in the growing season that are assumed critical for fish production based on competition for foraging habitat and density dependent constraints. The environmental monitoring program for the Kwalsa projects was designed to detect changes in fish abundance that were expected to accompany the predicted habitat losses.

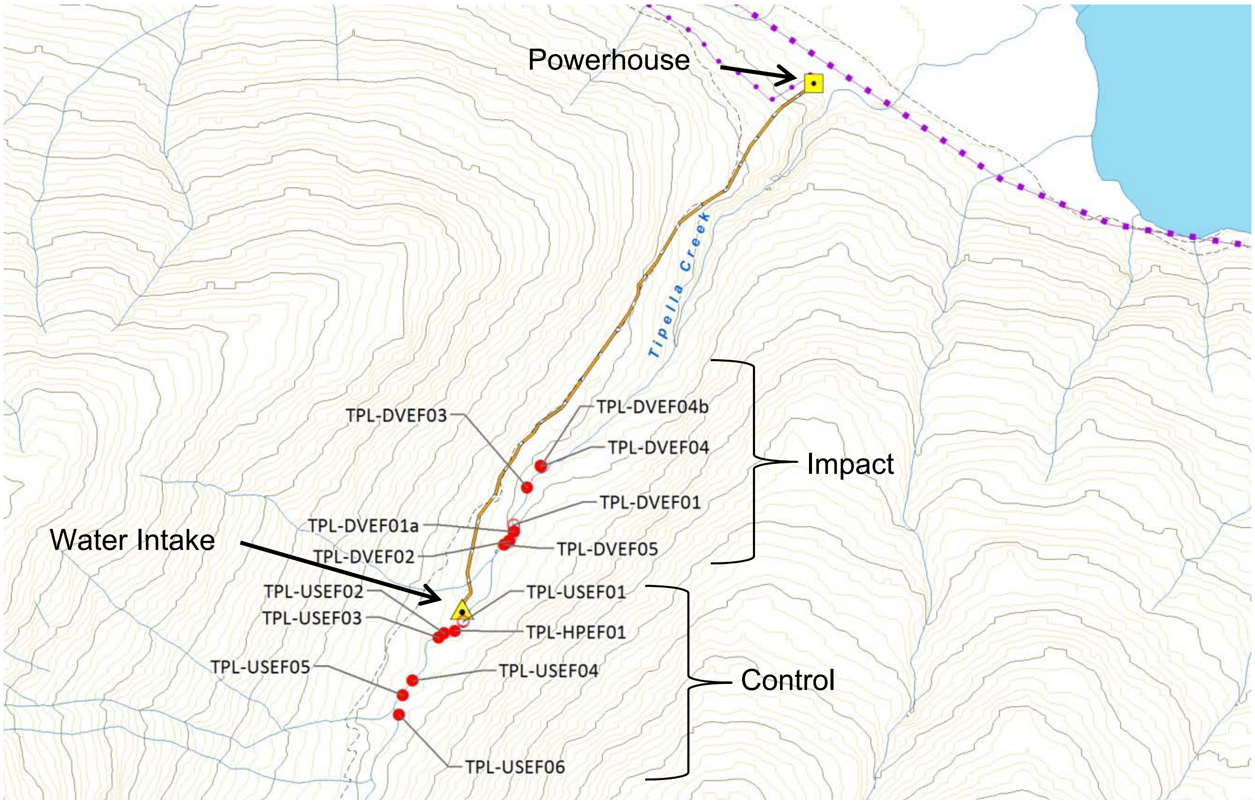
Figure 4. Flow regime at the Tipella Creek project. Pre-project flow is shown in blue, post-project flow is shown in orange, and the minimum instream flow requirement is shown in grey.



Fish Abundance Monitoring Methods

The fish abundance monitoring study was designed according to the BACI approach described above. For each study stream, five control sites were selected in the reach upstream of the water intake, and five impact sites were selected in the diversion reach of the project (e.g., Figure 5). Baseline (before) sampling was conducted in 2006 and 2008, and operational (after) sampling was conducted between 2010 and 2014. Sampling was conducted using closed-site electrofishing using the multipass-removal method during the critical period stream flow.

Figure 5. Tipella Creek monitoring sites

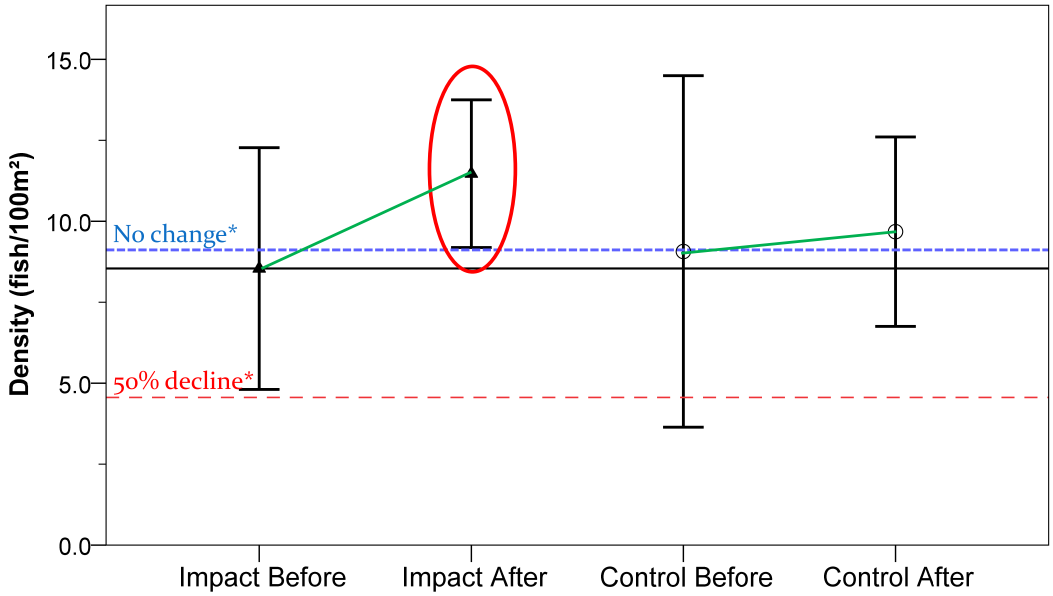


Fish Abundance Monitoring Results

Statistical analysis of the fish abundance data did not reveal negative effects on fish abundance for any of the Kwalsa project streams, despite the environmental assessment predictions of decreased habitat availability in the critical period stream flow. Instead, total Rainbow Trout abundance in the impact reaches increased post-Project relative to the control sites in all streams (e.g. Figure 6). In fact, a combined streams analysis revealed statistically significant increases in Rainbow Trout abundance for all life stages with the exception of fry (Figure 7).

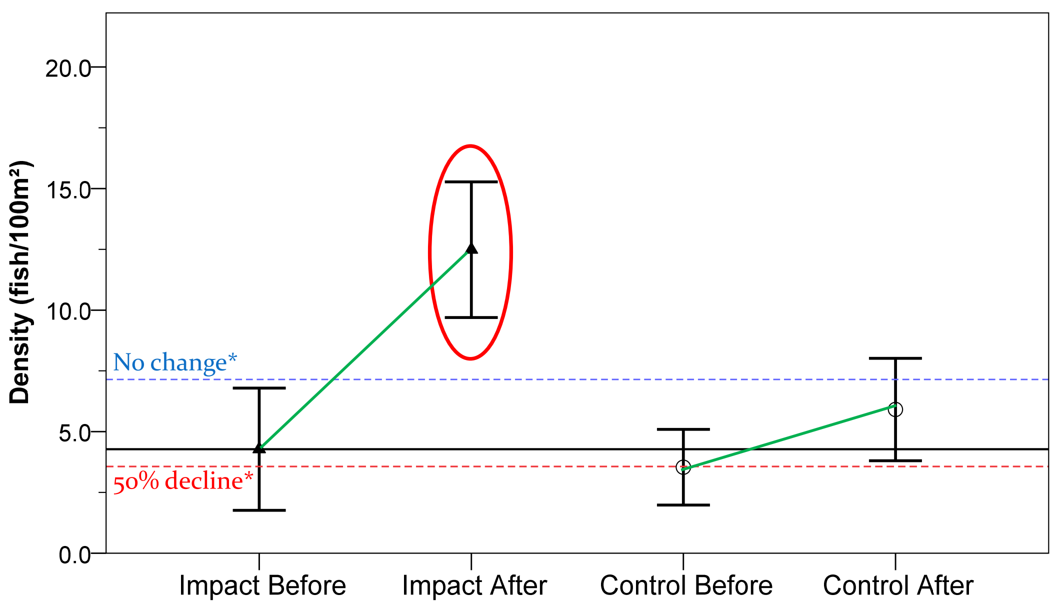
Figure 6. **Changes in Rainbow Trout density in a) Tipella Creek, and b) Douglas Creek**

a) Tipella Creek



*adjusted by before-after difference in Control reach

b) Douglas Creek



*adjusted by before-after difference in Control reach

Figure 7. Change in fish abundance by age class, over all streams. Light green represents an increase of less than 50%, dark green represents an increase greater than 50%, and asterisk (*) denote statistically significant results. Fit using linear model: Y = Stream + Reach + Period + Reach x Period.

Age Class	Δ Density
All	*
≥1+	*
0+	
1+	*
2+	*
≥3+	*

(dark green)	Increase ≥50%
(light green)	Increase <50%
*	Period x Reach $p < 0.05$

Management Lessons

The monitoring data collected in the Kwalsa streams can be used to improve management decisions at run-of-river hydroelectric facilities in BC. These data demonstrate that useful, statistically significant results can be obtained from the monitoring design specified in the protocols developed for the provincial and federal regulators. The data also revealed that reductions in fish habitat predicted in environmental assessments do not necessarily translate to reductions in fish abundance. Finally, the findings reveal that in some cases, flow diversion may result in greater fish abundance than under natural conditions.

The success of the monitoring program design, alongside the finding that less water does not necessarily lead to less fish, may provide scientists and regulators the confidence to recommend less conservative flow regimes. This result is reflected in the recent acceptance of adaptive management of stream flow at some facilities, whereby an initial instream flow regime is trialled, with specific adjustments made if negative effects exceed a set threshold.

Authors

Andrew Harwood, Ph.D., R.P. Bio. is a Senior Fisheries Biologist at Ecofish Research Ltd. and was co-author of the long-term monitoring protocols for new and upgraded hydropower facilities developed for Canada's federal Department of Fisheries and Oceans. In the past three years he has interpreted the results of instream flow and temperature modelling to assess the impacts of flow diversion on aquatic invertebrates and fish in six BC streams.

Adam Lewis, M.Sc. R.P. Bio. is a Fisheries Biologist and Principal at Ecofish Research Ltd. Adam developed the guidelines on instream flow assessment in BC, working with Todd Hatfield to create the standard approach to flow setting, assessment, and monitoring for the province that has gained international recognition. These guidelines have been applied to dozens of new hydroelectric facilities in BC to avoid impacts to fish habitat. A decade of monitoring has confirmed their effectiveness.

Sean Faulkner, M.Sc. R.P. Bio. is a Senior Fisheries Biologist at Ecofish Research Ltd. Over the past nine years he has conducted environmental assessments and long term monitoring on a number of run-of-river hydropower projects in British Columbia to assess the impacts of flow diversion on fish and aquatic habitat.

Todd Hatfield, Ph.D. R.P. Bio. is a biological consultant, focussing on development and application of rigorous scientific methods and decision-making techniques to resolve natural resource management issues and environmental conflicts. He has worked on numerous projects related to water management, fisheries conservation, and impact assessment, and has developed management plans and guidelines for industry and government. He has consulted on the assessment, permitting, construction and management of hydropower, oil and gas pipelines, and mining-related work.

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