# Migrations and fluvial habitat of salmonids: overview of current projects in Bergeron's lab

## Brook trout passage performance in culverts

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USGS science for a changing world

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### Introduction

Access to habitat is a fundamental metric of habitat quality. Culverts may act as partial or complete barriers to fish upstream movements, due to specific hydraulic or environmental conditions. Predicting the probability of passage success for a given fish is challenging.

### Methodology

1090 wild brook trout were tested during field passage trials in 13 culverts located in 3 watersheds of Québec. Attempts and passage success were monitored with fixe

Passive Integrated transponders systems (PIT-tags), installed in each culvert (fig. 1). Hydraulic conditions were measured before the trials, with a current meter.

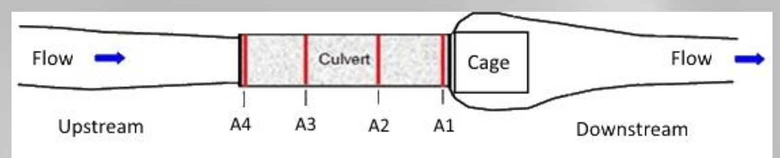


Figure 1: Experimental design

### Statistical analysis

A logistic regression was used to quantify the effect of various biological, environmental and hydraulic variables on passage success. Model selection was done by minimizing the Akaike information criterion.

The selected model (Δ AIC of 3.9 from closest competing model, *w* of 0.870) is presented in table 1.

### Model of passage success

The probability of successful passage is higher in corrugated culverts than in smooth ones, particularly among smaller fish (fig. 3, panels A-C). Fish < 175 mm may take advantage of the hydraulic complexity of corrugated culverts to increase their ascent distances (fig. 4). Passage success increases with water temperature, but this effect diminishes above 15°C (fig. 2, panel C). Success is lower in culverts with high flow velocities, steep slopes and deep downstream pools (fig.2, panels A; B).

Table 1: Selected model of passage success

| | | Variables in standard units | | | |
|---|---|---|---|---|---|
| | Parameters | $^*\beta$ | $\beta$ | ±SE | OR |
| β0 | Intercept | | -4.563 | 4.411 | |
| β1 | Water temperature | 2.744 | 1.436 | 0.722 | |
| β2 | Water temperature $^2$ | -2.022 | -0.048 | 0.026 | |
| β3 | Culvert type (rough v/s smooth) | 1.646 | 2.985 | 0.761 | |
| β4 | Culvert slope | -0.846 | -1.304 | 0.363 | 0.270 |
| β5 | Mean flow velocity | -0.581 | -2.985 | 0.625 | 0.050 |
| β6 | Depth of downstream pool | -0.845 | -8.159 | 1.376 | 0.000 |
| β7 | Trial duration | 0.395 | 0.078 | 0.022 | 1.080 |
| β8 | Culvert type * fish length | 0.869 | -0.012 | 0.005 | |

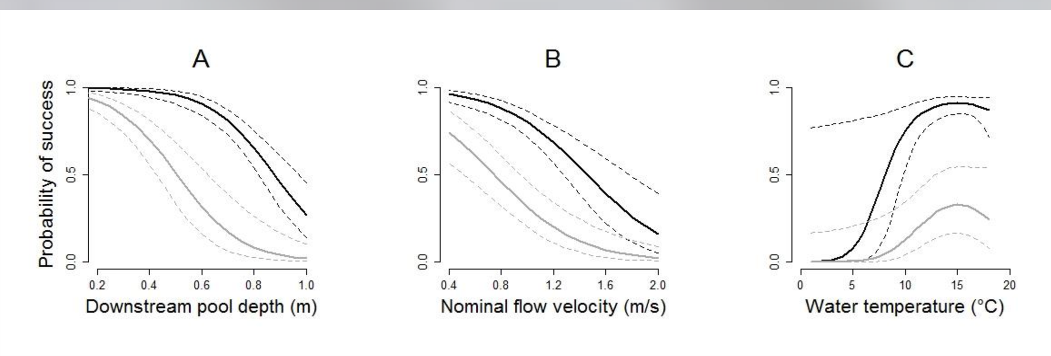


Figure 2: Probability of success with regards to downstream pool depth (A), flow velocity (B) and water temperature (C), in corrugated (black) and smooth (gray) culverts.

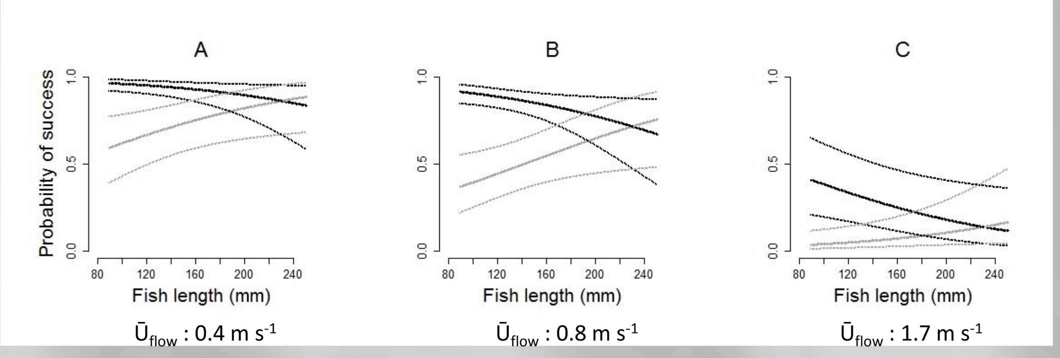


Figure 3: Probability of success with regards to fish length for 3 flow conditions, in corrugated (black) and smooth (gray) culverts.

Figure 4: Small brook trout taking rest in the lee of a corrugation.

## Analysis of brook trout spatial behaviour in a corrugated culvert using near-infrared video recordings

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### OBJECTIVES

1. Document spatial behaviour of brook trout individuals while ascending a corrugated (rough) culvert using video recordings and document low flow velocity zones to see if it can promote fish passage success, as seen in a previous study[1].
2. Document trout personality, i.e. consistent individual behavioural differences over time and across situations[2], and test if it can be related to their spatial behaviour while ascending culvert and passage success.

### METHODOLOGY

Spatial behaviour of brook trout individuals ($n$=23) while ascending a rough culvert (34 m x 2.2 m) was documented using 12 near-infrared ($\lambda \approx 850$ nm) illuminated video cameras (Figure 1). Passive integrated transponder (PIT) antennas equally distributed along the culvert allowed individual identification of fish on video images (Figure 2)

**Figure 1**. One of the 12 IR video cameras installed on the ceiling of the culvert. Infrared illumination allowed day and night recordings.

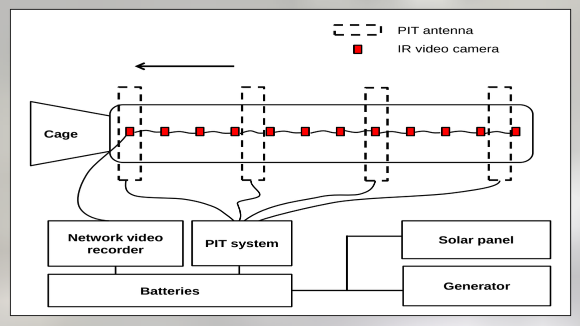


**Figure 2**. Schematic representation of the culvert equipped with IR video cameras, PIT antennas and all auxiliary systems. Arrow indicates flow direction in the downstream direction.

Three groups of 30 trout (FL: 80 - 250 mm) where PIT tagged and released in a cage connected to the downstream end of the culvert. Each group of trout was respectively assigned to hydraulic conditions of increasing intensity ($\bar{Q}$: $0.08 - 0.41\ m^3 \cdot s^{-1}$ and $\bar{U}$: $0.58 - 1.39\ m \cdot s^{-1}$).

Position of fish's nose on video images, was digitized every 0.33 second using a custom script in a numerical environment[3], allowing calculation of various spatial behaviour metrics including: instantaneous ground speed, ascent path complexity, distance from side walls, as well as number and duration of stops in an upstream direction.

Prior to culvert ascent trials, personality traits (boldness, exploration, and activity) of groups individuals were documented, *in situ*, using standardized measures.

### PRELIMINARY RESULTS

1. Fish avoid high flow velocity structures while ascending the culvert, swimming close to side-walls where flow velocities are slower. (Figure 3)
2. Fish do not show continuous swimming behaviour while ascending a culvert. Instead, they alternate between upstream progression and stops in areas where flow velocity is lower (Figure 4). Furthermore, fish spend more than 50% of the time holding a position in a reduced velocity zone.

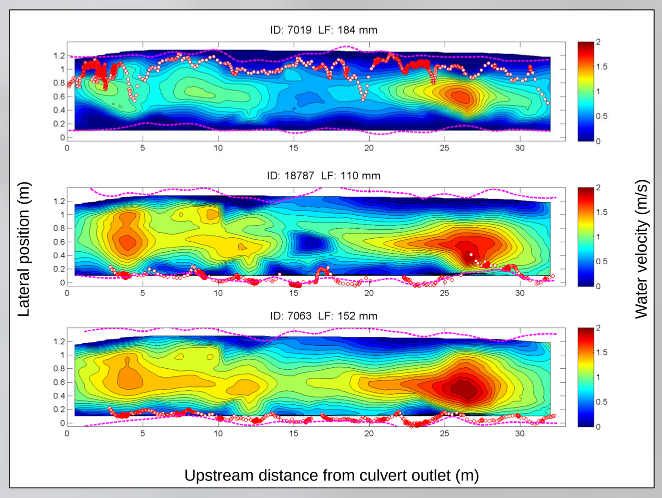


**Figure 3**. Fish path showed on mean velocity maps while ascending the culvert. Red circles represent fish trajectory coordinates at each 0.33 second. Purple dashed lines represent digitized wetted width.

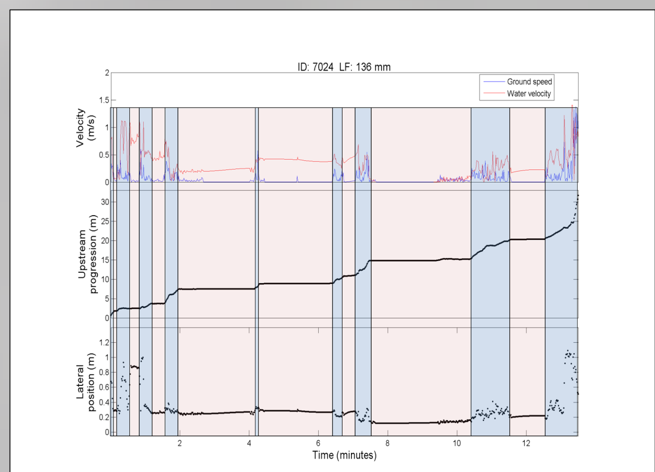


**Figure 4**. Example of the forward progression and lateral position of a trout in relation to the nose flow velocity experienced. Blue and red rectangles represent the movements and stops, respectively.

### CONCLUSIONS AND FUTURE WORK

To the best of our knowledge, this is the first work that document spatial behaviour of fish along an entire culvert. Those results show that if we give to fish the opportunity to rest, by adding baffles or even smaller rough element, their passage success would probably be higher, reducing culvert impacts on fish daily movements and migration. However, more investigations need to be done to confirm this hypothesis.

To complete this study, the relation between fish spatial behaviour, and personality traits need to be tested.

**REFERENCES**

[1]Goerig, E., Castro-Santos, T., Bergeron, N.E. (2016). *Brook trout passage performance through culverts*. Canadian Journal of Fisheries and Aquatic Sciences, **73:** 94-101.

[2] Réale D., Reader, SM., Sol, D., McDougall, PT., Dingemanse, NJ. (2007). *Integrating animal temperament within ecology and evolution*. Biological Reviews, **82:** 291-293.

[3] MATLAB®, Release 2014a, MathWorks

## Habitat fragmentation of Atlantic salmon (*Salmo salar*) by road and forest culverts

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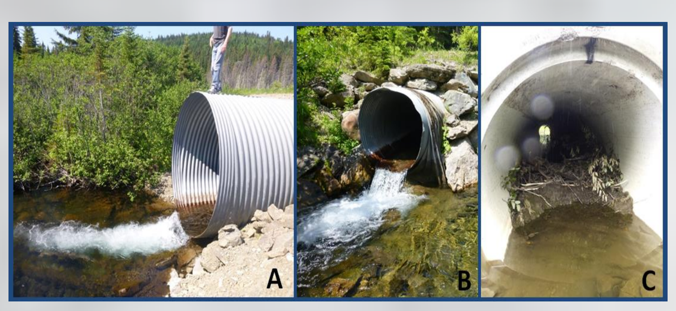
### CONTEXT AND RATIONALE

Culverts ensure the flow of small streams under roads and forest roads. However, they do not guarantee the free passage of fish. The hydraulic conditions within them as well as their physical characteristics (fig. 1) can make them completely or partly impassable by fish. This results in habitat fragmentation[1], which can cause the extirpation of fish populations or genetic isolation.

**Figure 1** Examples of conditions that can make the culvert partially or completely impassable for fish: excessive speed in the pipe exceeding the swimming ability of fish caused by a high slope, constriction of watercourses, or the roughness of the pipe (A); the presence of a drop located at the downstream end of the culvert exceeding the fish's ability to jump (B) and blockage of the culvert with plant debris and / or sediment (C).



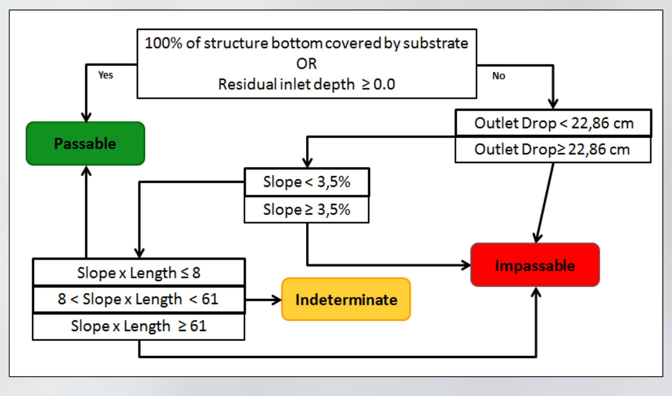

Small rivers are habitats of high quality for juvenile Atlantic salmon (*Salmo salar*), serving as thermal refuges and feeding areas. Thus, maintaining connectivity between mainstem rivers and small tributaries is important for persistence of salmon populations.

Many studies have been done on the impact of culverts on brook trout (*Salvelinus fontinalis*)[2][3], but no similar studies have been conducted in Québec for Atlantic salmon.

### OBJECTIVES OF THE SUDY

1. Assess the fragmentation of juvenile Atlantic salmon habitat by culverts in the watersheds of salmon rivers in Québec (Grande Cascapédia in Gaspésie and Sainte-Marguerite in Saguenay) using the Passive Integrated Transponder technology.
2. Validate and refine the predictive model for upstream passage though culverts developed by Coffman[4] (Fig. 2) specifically for juvenile Atlantic salmon using fish movement data and physical characteristics of culverts.
3. Calculate habitat loss associated with culverts classified as impassable and prioritize restoration according to the expected benefits.

**Figure 2** Coarse filter of the predictive model for upstream passage through culverts for juvenile salmonids (Coffman, 2005) classifying culverts in three categories according to threshold values of physical parameters.




### METHODS

#### Summer and Fall 2014

- Characterisation of 126 culverts (Cascapédia n=27, Matapédia n=80, Patapédia n=6 and Sainte-Marguerite n=13) based on morphometric measurements.
- The classification of culverts based on the coarse filter (Coffman, 2005) shows that 64% of inventoried culverts could be a barrier for juvenile salmonids that fragments their freshwater habitat (Fig. 3).

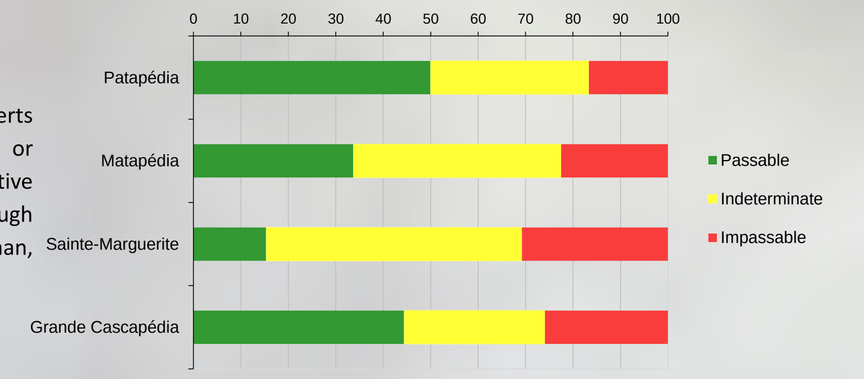



**Figure 3** Percent (%) of inventoried culverts classified as passable, indeterminate, or impassible according to the predictive model for upstream passage through culverts for juvenile salmonids (Coffman, 2005)

#### Summer 2015

Evaluation of passage success of juvenile salmon through a sub-sample of culverts in Grande Cascapédia and Sainte-Marguerite watersheds with a mark and recapture approach using electrofishing, PIT telemetry (fig. 4) and portable antennas (Fig.4).


**Figure 4** HDX Passive Integrated Transponder used to mark the fish

### FUTURE WORK

Field work will focus on two variables of interest: the slope and length of culverts. Culverts in the Sainte-Marguerite watershed will be instrumented with fixed antennas and PIT tagged juvenile salmon will be released into a cage attached to the downstream end of the culvert. The antenna system can detect passage attempts of each individual.

**REFERENCES**

**[1]** Poplar-Jeffers, I.O., Petty, J.T., Anderson, J.T., Kite, S.J., Strager, M.P. & Fortney, R.H. (2009) "Culvert replacement and stream habitat restoration: implications from brook trout management in an Appalachian watershed, USA." Restoration Ecology 17(3): 404-413. **[2]** Torterotot, J.-B., PERRIER, C., Bergeron, N.E. & Bernatchez L. (2014) Influence of road culverts and waterfalls on the fine scale distribution of Brook charr (Salevlinus fontinalis) genetic diversity in a boreal watershed. Transactions of the American Fisheries Society, 143, 1577-1591. **[3]** Goerig, E., Castro-Santos, T., Bergeron, N.E. (2016). *Brook trout passage performance through culverts*. Canadian Journal of Fisheries and Aquatic Sciences, 73: 94-101. **[4]** Coffman, J. S. (2005) Evaluation of a predictive model for upstream fish passage through culverts. Masters's thesis. James Madison University, Harrisonburg, Virginia.