ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/266590716

Attractiveness and passage efficiency of two vertical slot fishways for non- salmonids in a temperate system, St. Lawrence...

Article

CITATIONS
0

READS
30

3 authors, including:

Marc Mingelbier
Ministère des Forêts, de la Faune et des Parcs, ...
60 PUBLICATIONS **615** CITATIONS
SEE PROFILE

Normand Emile Bergeron
Institut National de la Recherche Scientifique
82 PUBLICATIONS **1,269** CITATIONS
SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Project
Impact of D. geminata mats on juvenile Atlantic salmon ecology View project

Project
Lake sturgeon of the St.Lawrence River management View project

All content following this page was uploaded by Normand Emile Bergeron on 26 February 2016.

The user has requested enhancement of the downloaded file.

Attractiveness and passage efficiency of two vertical slot fishways for non-salmonids in a temperate system, St. Lawrence River, Canada

Philippe Brodeur,[1] Marc Mingelbier,[1] and Normand Bergeron[2]
[1]*Ministry of Natural Resources and Wildlife, Québec, Canada*
[2]*INRS-Eau, Terre et Environnement, Québec, Canada*

ABSTRACT
The objective of this study was to compare the attractiveness of two vertical slot fishways designed for floodplain species and passage success of seven species through them. Several automated PIT antennas were used to detect the passage of fish below the dam, at the entrance and inside the fishway. The attractiveness of the entrance and migration success inside the ladder were low and varied among species and between fishways. The study reveals that passage success was generally more limiting than entrance attraction and suggests that other fishway designs for temperate non-salmonids should be tested.

INTRODUCTION
The maintenance of shallow-water habitats in the spring and the connectivity between the mainstream of a river and its floodplain is of high importance for lentic fish spawners (Bowen et al. 2003). High spring discharge, which is particularly altered in regulated systems, connects the river bed with the floodplain and allows access to high-quality spawning areas. To compensate for discharge regulation and habitat loss, the provision of high water levels in sensitive parts of the floodplain by the construction of weirs and fish passage facilities may be beneficial. Historically, fishways were mainly designed for anadromous fish species, such as salmonids and clupeids. Few studies have tested fishways in lentic systems dominated by multiple species of non-salmonids. To be efficient, a fishway must attract fish to the entrance, enable them to swim upstream through the downstream flow of water, and do so in a minimum amount of time and with minimal expenditure of energy. A complete assessment of fishway performance should thus address both entrance attraction and passage efficiencies (Bunt et al. 1999).

The floodplain of the St. Lawrence River includes thousands of hectares of riparian wetlands suitable for lentic spawners. Most of them are still natural, but some were created (~1500 ha) with dykes and have been managed since the 1980s. They are regulated to extend the flood duration and to stabilize the water level for approximately four weeks after the spring flood. Stable levels avoid embryo and larvae drying during drawdown and increase warming of water and larval growth. These flood characteristics are typical of pristine conditions, before water discharge regulation. The Rivière aux Pins marsh was equipped with a vertical slot fishway in order to maintain fish access to the marsh in the spring. The initial configuration of the fishway was tested in the spring of 2005 and modifications were applied and tested in 2006. The objective of this study was to compare the attractiveness and passage efficiencies of two vertical slot designs for multi-species spring migrations. Efficiency was quantified for adult bowfin (*Amia calva*), brown bullhead (*Ameiurus nebulosus*), black crappie (*Pomoxis nigromaculatus*), northern pike (*Esox lucius*), pumpkinseed (*Lepomis gibbosus*), smallmouth bass (*Micropterus dolomieui*), and yellow perch (*Perca flavescens*).

METHODOLOGY
Study site and fishway design
The study was conducted in the constructed marsh of Rivière aux Pins, a small tributary of the St. Lawrence River (45º38'N, 72º26'W). The Rivière aux Pins marsh is a multi-species managed spawning marsh designed for non-salmonids. A 32 m-wide weir equipped with a 4 m-wide spillway and a vertical slot fishway was constructed in 2003. The first fishway, tested in 2005, contained 8 pools (1.2 m wide X 1.5 m long X 1.3 – 2.5 m deep; 0.15 m difference in water level between pools) with each baffle presenting a centered vertical slot (0.2 m wide; ~0.4 m of water in the slot) at the surface and a submerged orifice (0.15 X 0.15 m) on the bottom. The second fishway, tested in 2006, contained 12 pools (1.2 m wide X 1.0 m long X 0.65 m deep; 0.08 m difference in water level between pools). Each baffle had a large surface trapezoidal overflow (0.5 m wide on top and 0.15 m on the bottom; 0.20 m flowing in) and a vertical slot (0.11 cm wide; jet oriented obliquely, following design 16 reported by Katopodis (1992)) reaching the bottom of the pool. The surface overflows were opened

and the vertical slots closed when the downstream water level was high to favour large early spring migrants (northern pike), and vice versa at low water levels.

Fish collection and tagging

Field experiments on fishway attractiveness and passage efficiencies were conducted in the spring of 2005 and 2006 (attractiveness: April 20 to April 29 and May 4 to May 20 in 2005, and April 5 to May 13 in 2006; passage: April 20 to April 24 and May 8 to May 20 in 2005, and April 5 to May 18 in 2006). Upstream migrants were collected from a trap installed 50 m downstream from the fishway. The trap was visited daily between 09:00 and 10:00 and fish were identified, measured (± 0.1 mm TL), sexed, and their level of maturity was noted. A passive integrated transponder (PIT tag; 23 mm long) was inserted between skin and muscle under the dorsal fin of adult bowfin, brown bullhead, black crappie, northern pike, pumpkinseed, smallmouth bass, and yellow perch (2005: n = 42, 207, 20, 19, 60, 39, 44, respectively; 2006: n = 23, 231, 27, 164, 20, 36, 99, respectively). Fish were given a recovery period of approximately four hours before being released. In 2005, half the fish marked daily were released inside the second pool of the fishway, closed at its downstream end by a wire mesh blocking screen (0.01 m square mesh cleared of debris two times daily). Half the fish were released downstream from the fishway, in a large holding pond formed by the body of water located between the weir and the upstream end of the trap. After a five day experimental period, all fish were removed from the fishway with a large dipnet. In 2006, because of the lower volume of water in each pool, all fish were released daily downstream from the fishway. An effort was made to include a minimum of ten fish of each species daily, which was not always achieved because of low fish availability at the trap. Fish that successfully ascended the fishway were trapped at the upstream end. The trap was cleared daily between 10:00 and 11:00 and the fish were identified, measured and their tag number was noted. Tag retention was estimated at 97% from the captures at the upstream end of the fishway.

Passage monitoring and data analysis

Seven PIT antennas were used to monitor fish movements: two downstream from the weir (1.5 m downstream from the fishway entrance and 2 m downstream from the spillway), and five at different slots of the fishway (entrance, exit and three at evenly spaced intermediate locations). The system recorded tag number and position (within ~2 cm of each antenna of the fishway and ~30 cm from downstream antennas), along with date and time (± 1.0 s). Detection efficiency inside the facility was estimated at 97% in 2005 and 96% in 2006 by comparing detection at the fishway exit to that at intermediate locations. Fishway attractiveness for each species was quantified as being the percentage of individual fish detected at the fishway entrance relative to the sum of individuals detected downstream from the fishway and at the spillway. Percentage was considered for a given species only when the total number of individuals detected was higher than eight (n = 8 – 106 in 2005 and 21 – 179 in 2006). Passage efficiency in the fishway was estimated as the ratio of successful ascents (fish detected at exit) to overall attempts of individual fish (sum of individuals detected at least at one location in the fishway). Calculations with groups of less than five detected fish per species were omitted from the analyses (n = 6 – 54 in 2005 and 5 – 100 in 2006). Water temperature was recorded (± 0.1℃) at the fishway exit every 15 min utes using a thermograph (Minilog-T; Vemco; ± 0.1ºC) and water level upstream and downstream from the weir was noted twice daily. Water velocity was recorded once every three days using a digital flow meter.

RESULTS AND DISCUSSION

Thermal and hydraulic conditions

The water temperature was slightly higher in 2005 than in 2006 during attractiveness experiments (12.1 ± 2.9℃, 7.4 – 17.5℃ and 10.6 ± 3.2℃, 4.3 – 17.0℃, respectively) and passage tests (13.4 ± 2.7℃, 7.4 – 17.5℃ and 11.0 ± 3.2℃, 4.3 – 17.0℃, respectively). The water level upstream from the dam was relatively stable during the study period and was similar in 2005 and 2006 (7.5 ± 0.1 m, 7.3 – 7.8 m and 7.6 ± 0.1 m, 7.5 – 7.7 m, respectively). The water level downstream from the fishway showed high intra-annual variations and was higher in 2005 than in 2006 (6.7 ± 0.6 m, 5.8 – 7.8 m and 6.6 ± 0.4 m, 5.8 – 7.0 m, respectively). The water velocity in the fishway was lower in 2005 than in 2006 (0.59 ± 0.12 $m \cdot s^{-1}$, 0.37 – 0.97 $m \cdot s^{-1}$ and 0.69 ± 0.26 $m \cdot s^{-1}$, 0.04 – 1.28 $m \cdot s^{-1}$, respectively).

Fishway attractiveness

The proportion of total individuals detected at the fishway entrance compared to those detected downstream from the weir was relatively low in both fishways (Fig. 1). Entrance attractiveness was similar for both fishways, except for the northern pike, which showed higher values in 2006 due to the use of large surface overflows early in the spring. Levels of attraction to both fishways varied greatly

among species. The best results were obtained with late spring migrants, the brown bullhead, smallmouth bass, and pumpkinseed, which typically reach the Rivière aux Pins marsh in the second half of April and in May (Massé et al. 1988).

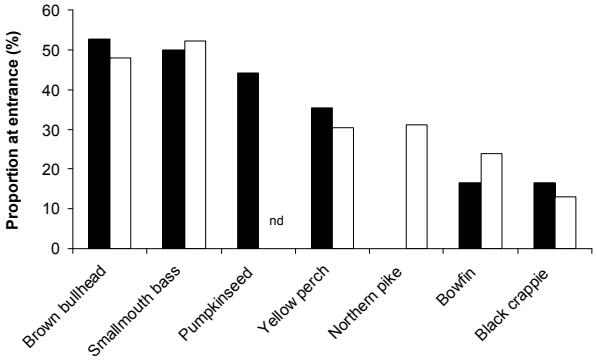

Figure 1. Percentage of individual fish detected at the fishway entrance relative to the sum of individuals detected downstream from the fishway and at the spillway. Data are presented for two vertical slot designs tested in 2005 (solid bars) and 2006 (open bars) in the Rivière aux Pins marsh.

The attractiveness of the fishway was significantly affected by water temperature, with fish migrating into the facility mainly when temperature was high (data not shown). Temperature has been demonstrated to have a positive effect on fishway use in several types of design (Haro et al. 1999). A higher number of fish entered the fishway when the water level upstream from the dam was low, and discharge was concentrated in the fishway (data not shown). Fish located at the spillway antenna during upstream migration bypassed the fishway entrance located 4.3 m downstream. In that situation, fish seem reluctant to swim back downstream and consequently may not be attracted to the fishway (Bunt 2001). Attraction failure was thus probably caused by improper location of the fishway entrance combined with the reluctance of floodplain fish species to swim at high speeds through the entrance and with weir discharge that attracted them to an upstream location (Schwalme et al. 1985, Bunt 2001). As suggested by Bunt (2001), fishway entrances should be located as close to a dam or weir face as possible, without compromising fish access due to velocity barriers from spillway discharge.

Fish passage

Fish passage inside the fishway was low, except for smallmouth bass in 2005 (Fig. 2). Ascent success was highly variable depending on the species and on the structure of the fishway. The 2005 design showed better ascent success for smallmouth bass and brown bullhead. The modifications applied in 2006 favoured northern pike and yellow perch, which migrate early in the spring. This increase is due to the use of the surface overflows which permitted the migration of 70% of all fish that ascended the fishway in 2006. The disadvantage of this design is its inability to handle large variations in water level and it thus can only be used with relatively high downstream water levels.

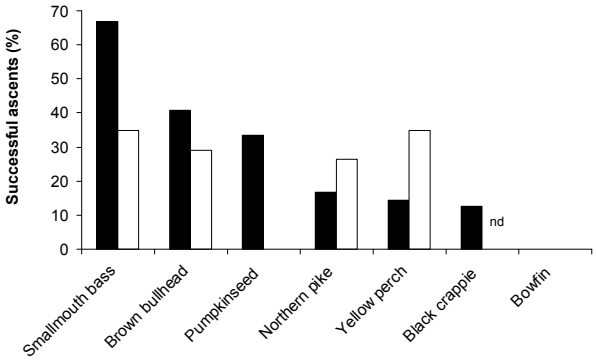

Figure 2. Percentage of passage of five species in two vertical-slot designs tested in 2005 (solid bars) and 2006 (open bars) in the Rivière aux Pins marsh.

In both fishways, fish required burst effort to migrate. Water velocity in both fishways was usually less than maximum burst speeds (Wolter and Arlinghaus 2003). Such conditions should have permitted successful fishway acsent. Passage failure is thus attributed here as being due to a reluctance of floodplain fish species to swim at high speeds and by negative behavioural responses to turbulence and entrained air bubbles (Bunt et al. 1999). Numerous species experience significant delays in passing river barriers, with several weeks reported for northern pike in Canada (Fernet 1984), barbel (*Barbus barbus*) in England (Lucas and Frear 1997), and several percid species in Australia (Harris and Mallen-Cooper 1994). At Rivière aux Pins, it was reported that northern pike that cannot have access to the marsh are forced to spawn in less suitable habitats (Massé et al. 1988).

CONCLUSION

This study tends to demonstrate that the efficiency of vertical slot fishways as constructed in Rivière aux Pins varies greatly among species, illustrating the difficulty of designing efficient facilities for multiple floodplain spawners. The study reveals that passage success was more limiting than entrance attraction for all species except smallmouth bass. The large surface overflows tested in 2006 increased fishway efficiency in terms of both attractiveness and passage success for early spring migrants (northern pike and the yellow perch). However, the use in 2006 of the design 16 flow pattern with reduced slot width was less efficient for the passage of late migrants (brown bullhead, pumpkinseed and smallmouth bass). Bowfin and black crappie experienced reduced migration success in both fishways. This assessment suggests that the global efficiencies of the 2005 and 2006 fishways were low when attractiveness and passage estimates were integrated (smallmouth bass: 33% and 19%; brown bullhead: 22% and 14%; pumpkinseed: 15% in 2005; yellow perch: 5% and 11%; northern pike: 0% and 8%; black crappie: 2% in 2005; bowfin: 0% and 0%). Low fishway efficiency such as that reported here may reduce or even prevent access to the marsh and affect both community composition and fish production in the marsh. We suggest that other fishway designs for temperate non-salmonids should be tested, with priority given to nature-like facilities.

REFERENCES

Bowen, Z. H., K. D. Bovee and T.J. Waddel 2003. Effects of flow regulation on shallow-water habitat dynamics and floodplain connectivity. Transactions of the American Fisheries Society 132: 809-823.

Bunt, C. M. 2001. Fishway entrance modifications enhance fish attraction. Fisheries Management and Ecology 8: 95-105.

Bunt, C. M., C. Katopodis and R.S. McKinley 1999. Attraction and passage efficiency of white suckers and smallmouth bass by two denil fishways. North American Journal of Fisheries Management 19: 793-803.

Fernet, D. A. 1984. An evaluation of the performance of the Denil 2 fishway at Fawcett Lake during spring of 1983. Environment Management associates, Calgary, Alberta.

Haro, A., M. Odeh, T. Castro-Santos and J. Noreika 1999. Effect of slope and headpond on passage of American shad and blueback herring through simple denil and deepened Alaska steeppass fishways. North American Journal of Fisheries Management 19: 51-58.

Harris, J. H. and M. Mallen-Cooper 1994. Fish-passage development in the rehabilitation of fisheries in mainland south-eastern Australia. Rehabilitation of freshwater fisheries. I. G. Cowx, Fishing New Books. Chapter 17: 185-193.

Katopodis, C. 1992. Introduction to fishway design. Department of fisheries and Oceans Canada, Winnipeg.

Lucas, M. C. and P. A. Frear 1997. Effects of a flow-gauging weir on the migratory behavior of adult barbel, a riverine cyprinid. Journal of fish biology 50: 382-396.

Massé, G., R. Fortin, P. Dumont and J. Ferraris 1988. Étude et aménagement de la frayère multispécifique de la rivière aux Pins et dynamique de la population de grand brochet, *Esox lucius* L., du fleuve Saint-Laurent, Boucherville, Québec. Ministère du Loisir, de la Chasse et de la Pêche, Direction régionale de Montréal, Service de l'aménagement et de l'exploitation de la faune, Montréal.

Schwalme, K., W. C. Mackay and D. Lindner 1985. Suitability of vertical slot and Denil fishways for passing north-temperate, non-salmonid fish. Canadian Journal of Fisheries and Aquatic Sciences 42: 1815-1822.

Wolter, C. and R. Arlinghaus 2003. Navigation impacts on freshwater fish assemblages: the ecological relevance of swimming performance. Reviews in fish biology and fisheries 13: 63-89.

View publication stats