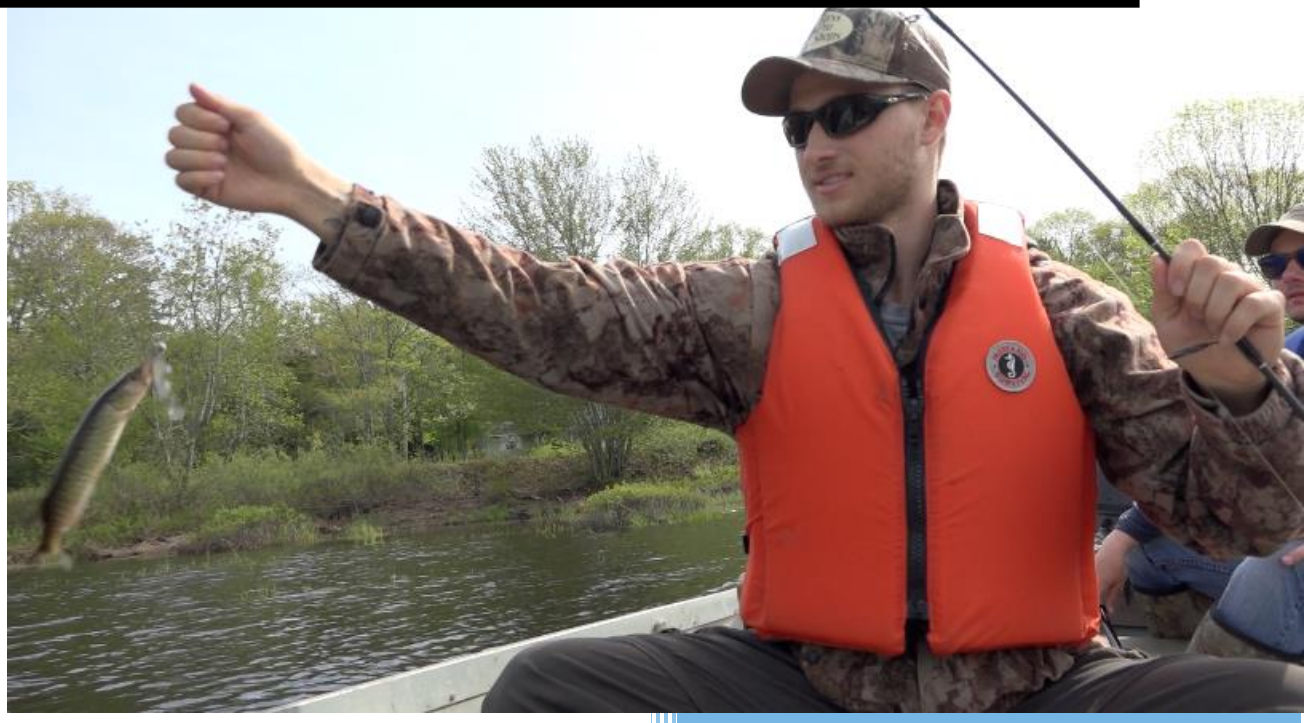
2017

LaHave River Invasive Species Project



Shawn Feener

Bluenose Coastal Action Foundation

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Bluenose Coastal Action Foundation

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- Members of the LaHave River Salmon Association
- Members of the Nova Scotia Guides Association
- Micmac Rod & Gun Club
- Bluenose Coastal Action Foundation summer staff
- Many volunteers, students, and community members who were involved with field activities

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- Graham and Susan Smith

Introduction

Bluenose Coastal Action Foundation

Bluenose Coastal Action Foundation (Coastal Action) is a community-based charitable organization with a mandate to address the environmental concerns along the South Shore region of Nova Scotia. Coastal Action's goal is to promote the restoration, enhancement, and conservation of our environment through research, education, and action. The organization receives direction from a volunteer board of directors supported through a full-time Executive Director and has been an established member of the Lunenburg County community since our inception in December of 1993.

Over the past 20+ years, Coastal Action has successfully completed a vast number of projects within the South Shore region of the province. Project themes have included such issues as River Restoration on the Mushamush, Gold, and LaHave River systems; Water Quality Monitoring in the LaHave River and Petite Rivière watersheds; Endangered Species Projects addressing the Roseate tern, Atlantic whitefish, Atlantic salmon, and American eel; Climate Change and Pollution Prevention initiatives (i.e., Active Transportation, Water and Energy Conservation, Solid Waste Education, etc.); and Clean Boating, to name but a few.

Atlantic Salmon (*Salmo salar*)

The Atlantic salmon (*Salmo salar*) is a member of the salmonid family. This fusiform-shaped fish can reach lengths of up to 100 cm. The Atlantic salmon is an anadromous fish species, meaning it migrates from freshwater to saltwater in early life stages and returns to freshwater for spawning. The summer feeding grounds for Atlantic salmon are the North Atlantic waters near Greenland. The North American population of Atlantic salmon historically ranged from Long Island north to coastal Quebec and south-east to Newfoundland.

LaHave River Population

Over the last decade, the population of Atlantic salmon in the LaHave River has dwindled from an estimated 3,974 adult salmon in 1988 to only 68 migrating up the main branch of the LaHave in 2016 (Amiro & Jefferson, 1998). The smolt migration has historically occurred between April 20 and June 1 (Appendix 1). Introduction of hatchery-raised smolt in the LaHave River ended in 2005 (Amiro & Jefferson, 1998). An estimate in 2014 suggested that the LaHave River yielded a smolt population of just over 29,000 individuals (Amiro & Jefferson, 1998).

Southern Upland Nova Scotia Population

The LaHave River population of Atlantic salmon is part of the Nova Scotia Southern Upland population, which breeds from northeastern mainland Nova Scotia along the Atlantic coast into the Bay of Fundy to Cape Split. This population of Atlantic salmon was designated as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November of 2010 and is currently under review by the Federal *Species at Risk Act* (*SARA*). On average, over the last three generations, Atlantic salmon populations in this region have declined by approximately 61% (COSEWIC, 2010). Many factors contributed to this decline and the designation by COSEWIC. Some factors include fish passage impediments in the form of dams, habitat loss caused by the damming, pollution of the rivers and streams, acidification of the watersheds (mainly caused by acid precipitation), by-catch from commercial fisheries, incompletely understood changes in marine habitat, and the introduction of invasive species such as smallmouth bass (*Micropterus dolomieu*) and chain pickerel (*Esox niger*).

Figure 1: Life Stages of the Atlantic salmon (Created by Barbara Harmon, retrieved from mirimichisalmon, 2017).

Invasive Species

Invasive species are non-native species that have been introduced in an area and have the tendency to spread and establish to a degree that causes damage to the ecosystem. There are currently two invasive fish species in the LaHave River: smallmouth bass (*Micropterus dolomieu*) and chain pickerel (*Esox niger*).

Smallmouth Bass (*Micropterus dolomieu*)

Smallmouth bass are a freshwater fish species in the sunfish family (Centrarchidae). They are native to the Saint-Lawrence/Great Lakes region of Canada and the Mississippi River system in United States, but have been spread via rail to many other river systems and lakes in North America to benefit recreational fishing (Brown et al., 2009). Authorized introductions of smallmouth bass first occurred in 1942 in Yarmouth County (Leblanc, 2010). Numerous authorized and unauthorized introductions since the early 1940's have led to smallmouth bass having a presence in 188 lakes in Nova Scotia by 2008 (Leblanc, 2010). Once established, smallmouth bass can alter the local fish populations and ecosystem health.

Chain Pickerel (*Esox niger*)

Chain pickerel are a freshwater fish species from the pike family (Esocidae). In contrast to smallmouth bass's utilization of riverine habitat, chain pickerel favor lake habitat with dense vegetation. They are native to lakes, rivers, and streams along the eastern seaboard of North America, north to Maine. They have spread into Canada, and Nova Scotia, through authorized and unauthorized introductions.

Authorized introductions occurred in three separate locations in southern Nova Scotia in 1945 (Mitchell et al., 2011). After these introductions, numerous illegal introductions led to the advancement of chain pickerel into more than 95 lakes throughout Nova Scotia (Mitchell et al., 2011). Chain pickerel are large predators that can have enormous impacts on native fish populations.

Goals and Objectives

The population of Atlantic salmon in the Nova Scotia Southern Uplands region has been rapidly declining since the early 1990's. Many factors currently contribute to this decline; however, this report focuses on the impacts that non-native invasive species, such as smallmouth bass and chain pickerel, have on the Atlantic salmon smolt in the freshwater riverine and lacustrine habitat during migration to saltwater. The goals and objectives are as follows:

1. Provide evidence that smallmouth bass and chain pickerel are preying upon Atlantic salmon smolt during migration and;
2. Collect data demonstrating how invasive species have impacted other native species

Methodology

Smallmouth Bass and Chain Pickerel Extraction and Study

Scientific angling was the main method of capturing invasive species during sampling. This method is low cost and time efficient. When the correct lures are used, it may also be effective at targeting the invasive species as the native fish species have diets that exclude the mimicked bait. Groups of two anglers, or more, were used for both safety and heightened catch rates. Most of the angling occurred from a 14-ft Princecraft aluminum boat with a four stroke 4-hp Yamaha outboard motor, but this was substituted with angling from shore when the weather restricted access to the lake. Certain habitats were targeted which were known to be frequented by invasive species. These habitats were areas with dense vegetation, rock shelves, areas where small streams entered Wentzells Lake, and areas where the LaHave River entered Wentzells Lake. Angling for invasive species to confirm predation on Atlantic salmon smolts took place between April 25 and May 25, 2017. Angling gear used to target invasive species included a 1/8-ounce weighted jig head, MisterTwister™ rubber worms, steel leaders, six-foot rods, spinning reels, and a dip net. Once a targeted fish was angled, it was euthanized and placed on ice in a cooler until it could be processed.

To estimate a range for invasives on the LaHave River, angling was used in areas where fish passage could possibly be impeded or the river branched off into multiple sections. Some areas included above and below Morgan Falls, Sherbrooke Lake, Lake Torment, Lower Thirty Lake, Upper Sixty Lake, West Branch LaHave, and West River. Angling took place between May 25 and June 23, 2017. Angling gear was similar to that from the previous methodology; however, kayaks were used in place of the 14-ft aluminum boat. Angling was performed for three hours or until an invasive species was found.

Fish Processing and Data Collection

Once the fish were transported to the fish lab, measurements were taken and certain data was collected. The data obtained from the fish, as well as the area the fish were angled, includes the following:

- Total time angled at each location (in hours)
- Location
- Number of anglers
- Water Temperature (°C)
- Air Temperature (°C)
- Type of lure used (i.e., rubber worm)
- Data from captured fish (fork length, weight, mouth gape)
- Stomach contents of fish
- Sex of fish
- Age

Scale samples were taken from the smallmouth bass and used to determine the age of the fish. Fork length of each fish was measured from the front of the lower jaw to the fork in the tail and was measured in centimetres. Weight was measured in kilograms using a Berkley™ fish scale. A digital caliper was used to measure the width and height of the mouth gape and measured in centimetres (Figure 2). To determine the sex and stomach contents of the fish, a filet knife was used to open the body cavity and display the stomach and reproductive organs. The stomach content was recorded as either fish, amphibian, invertebrate, mammalian, or empty. If the stomach content could be identified further, it was also noted.

Figure 2: Mouth gape measurements taken from smallmouth bass and chain pickerel.

Area of Study

Angling efforts to catch invasive species that preyed upon Atlantic salmon smolt were focused in Wentzells Lake, located within the LaHave River Watershed. Other salmon pools located on the LaHave River were angled, although most angling occurred in the lake. Wentzells Lake was separated into three main units, labelled W1, W2, and W3 (Figure 3). W1 is the area on Wentzells Lake where the North Branch of the LaHave River flows into the lake, W2 is the area on Wentzells Lake where the Main Branch of the LaHave

River flows into the lake, and W3 is the area of Wentzells Lake where the lake re-enters the LaHave River. Bruhms Pool, Veinot Rd Bridge, and Wentzell's Eddy were areas that were angled outside of Wentzells Lake.

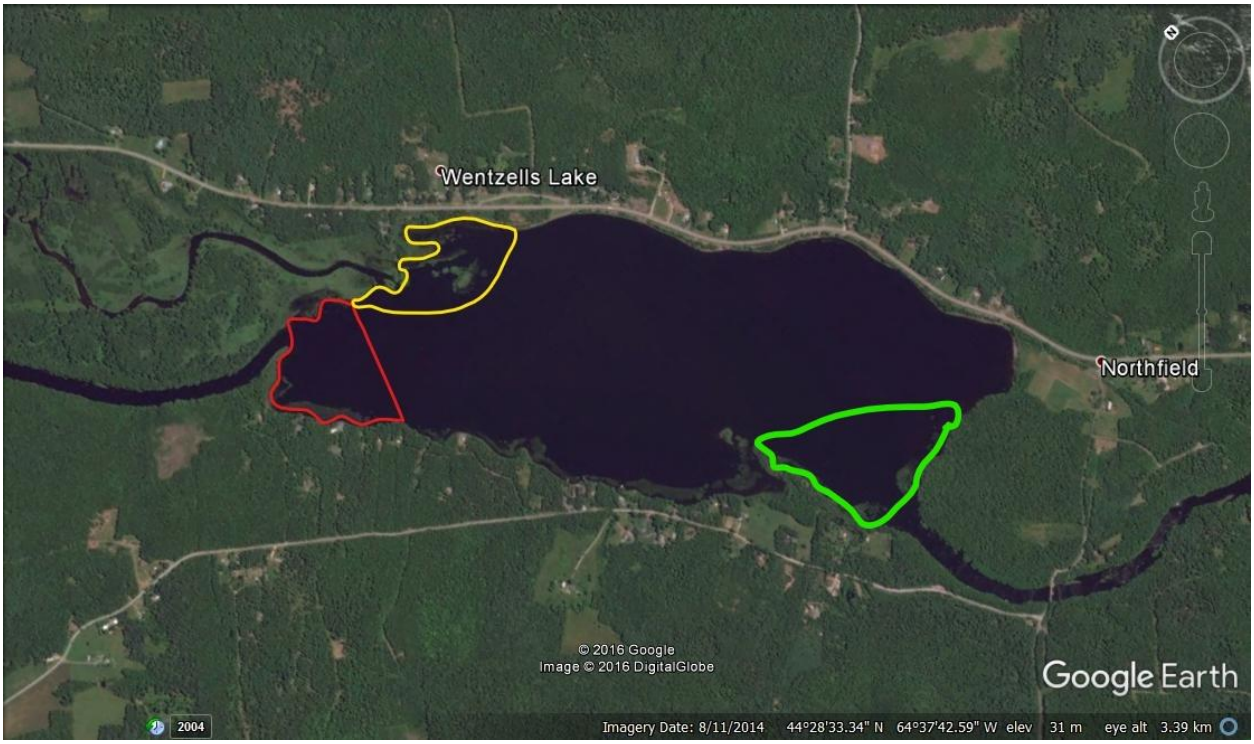

Figure 3: Aerial view of Wentzells Lake separated into three sub-locations; Yellow-W1, Red-W2, and Green-W3.

Time of Study

To maximize the possibility of collecting invasive species that had preyed upon migrating smolt, the study took place during the spring smolt migration. Angling commenced on April 25 and ended May 25, 2017. Records from the LaHave River show the smolt migration to commence between April 20 to May 1 and finish between May 25 and June 1. Angling generally occurred between 8:00 AM and 12:00 PM, but on occasion, occurred between 3:00 PM and 6:00 PM. These are common feeding times for the targeted invasive species.

Results

Water Temperature

Water temperatures from Wentzells Lake ranged from 7°C in April to 17.5°C in late May. Smallmouth bass begin feeding at water temperatures between 7°C and 10°C, whereas, chain pickerel feed with water temperatures between 0°C and 25°C (Edwards et al., 1983; Spidell & Johnston, 1985).

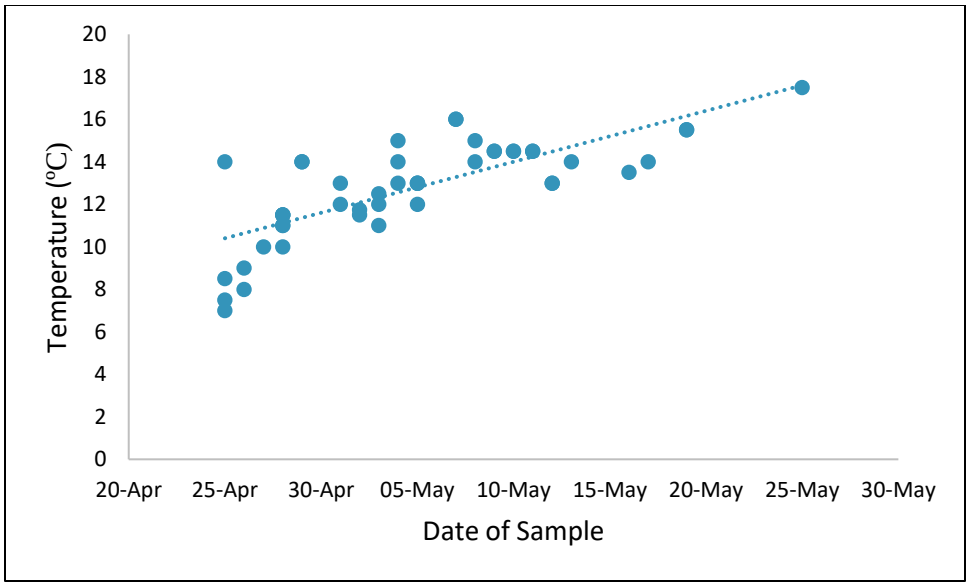

Figure 4: Water temperatures from Wentzells Lake between April 25 and May 25, 2017. Temperature in degrees Celsius. Average rate of temperature increase indicated by trendline.

CPUE for Invasive Species in Wentzells Lake

Using the data recorded during the removal of invasive species in Wentzells Lake, a catch per unit effort (CPUE) was calculated for both smallmouth bass and chain pickerel at each of the locations previously shown for Wentzells Lake.

CPUE = Number of Fish Caught/Effort (hrs)

Smallmouth Bass

Table 1: Total number of smallmouth bass angled in the three areas located on Wentzells Lake, effort (hours) of angling, and catch per unit effort for each location.

Location	Effort (hrs)	# of Fish Caught	CPUE (#fish/hr)
W1	12	13	1.08
W2	37	39	1.05
W3	19	30	1.58
Total	68	82	1.21

A total of 68 angling hours were spent in Wentzells Lake between April 25 and May 25, 2017. Over 50% of this time was spent in the area of Wentzells Lake where the Main Branch of the LaHave River enters the lake. Just under 50% of the total smallmouth bass were angled in this same area. The least amount

of smallmouth bass was angled in the area of Wentzells lake where the North Branch of the LaHave River enters the lake.

Chain Pickerel

Table 2: Total number of chain pickerel angled in the three areas located on Wentzells Lake, effort (hours) of angling, and catch per unit effort in each location.

Location	Effort (hrs)	# Fish Caught	CPUE (#fish/hr)
W1	12	24	2.00
W2	37	45	1.22
W3	19	40	2.11
Total	68	109	1.60

The location where Wentzells Lake re-entered the LaHave River yielded the highest catch per unit effort with just over two fish per hour. The lowest catch per unit effort was in the area where the Main Branch of the LaHave River entered Wentzells Lake; however, this area yielded the highest number of chain pickerel.

Stomach Content Analysis for Invasive Species in Wentzells Lake

Stomach contents were recorded for every chain pickerel and smallmouth bass angled between April 25 and March 25, 2017. The following is an analysis of the stomach contents from chain pickerel and smallmouth bass angled from Wentzells Lake.

Smallmouth Bass

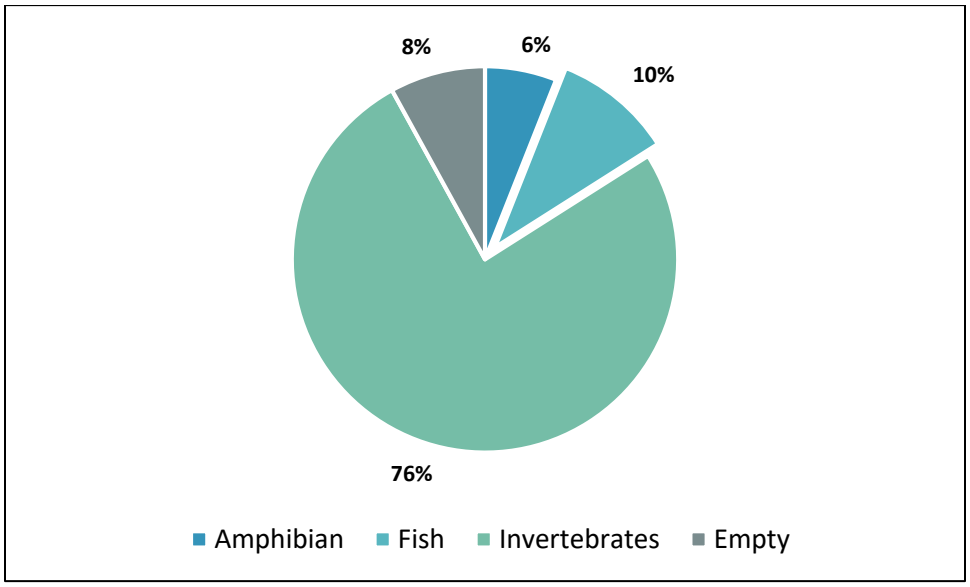

Figure 5: Stomach content analysis of smallmouth bass in Wentzells Lake between April 25 and May 25, 2017. Calculated by presence of stomach content.

Invertebrates, which included dragonfly, mayfly, and caddisfly nymphs, formed the largest portion of the smallmouth bass' diet during the sampling period. The smallest portion of the diet was filled by amphibians, which consisted of frogs and one eastern newt (*Notophthalmus viridescens*). The 10% fish in the smallmouth bass' diet consisted of juvenile American eel (*Anguilla rostrata*) and one Atlantic salmon smolt.

Chain Pickerel

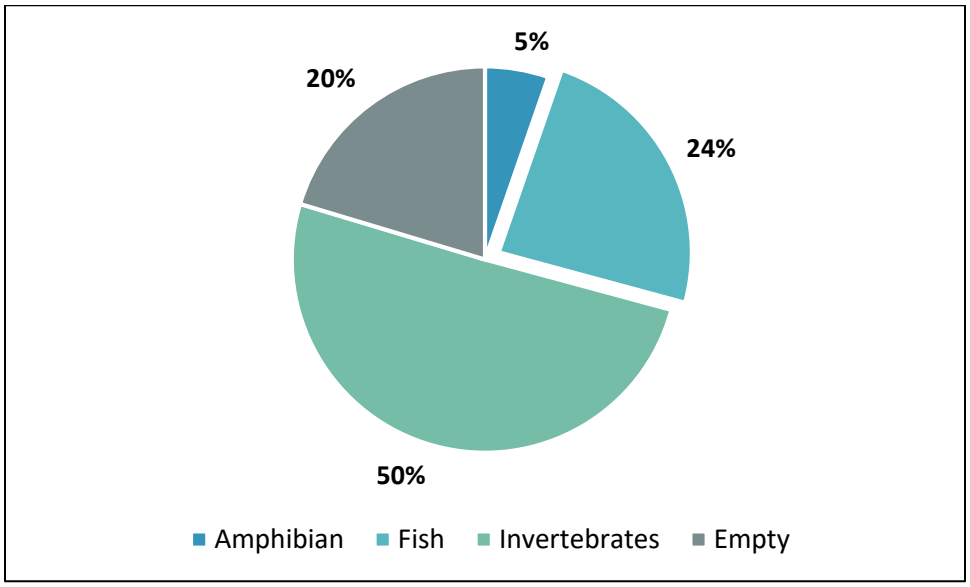

Figure 6: Stomach content analysis of chain pickerel in Wentzells Lake between April 25 and May 25, 2017. Calculated by presence of stomach content.

Fish accounted for a larger portion of the sampled chain pickerel's diet with 24% of the total stomach contents consisting of fish. A smaller portion of the chain pickerel's diet contained invertebrates than that of the sampled smallmouth bass. Approximately 20% of the chain pickerel that were sampled between April 25 and May 25, 2017 were found to be empty. This was included in the data to represent individuals that had the capability to prey upon Atlantic salmon smolt.

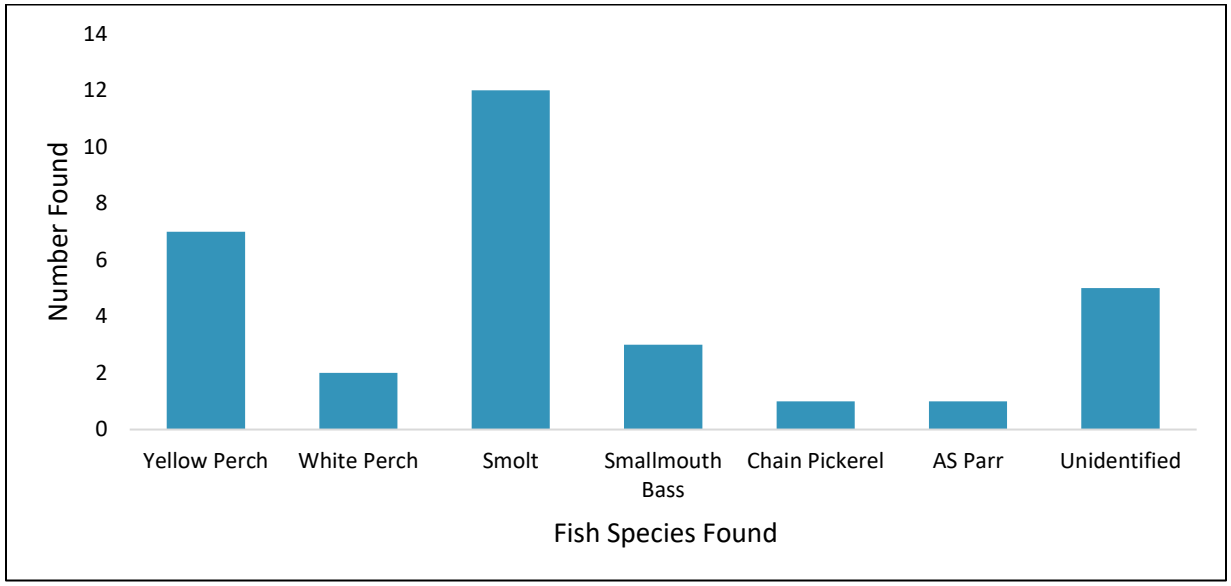

Figure 7: Fish species that made up the 24% of the sampled chain pickerel's diet. Chain pickerel sampled between April 25 and May 25, 2017. Calculated by presence of fish species.

Atlantic salmon smolt were the most abundant fish species found in the stomach content of chain pickerel. Approximately 9% of the total diet of the sampled chain pickerel consisted of Atlantic salmon smolts. The second most abundant fish species found in the stomach content of chain pickerel was yellow perch (*Perca flavescens*). One Atlantic salmon parr was found during the stomach content analysis of chain pickerel in Wentzells Lake.

Probable Portion of the Invasive Species Population

A minimum size of fish was set for smallmouth bass and chain pickerel which indicated the size of predator that had a higher probability of ingesting an Atlantic salmon smolt. This size was given as a fork length in centimetres and was assigned using average mouth gape and relative stomach size. For smallmouth bass, this minimum size was 35 centimetres in fork length and for chain pickerel it was 30 centimetres in fork length.

Smallmouth Bass

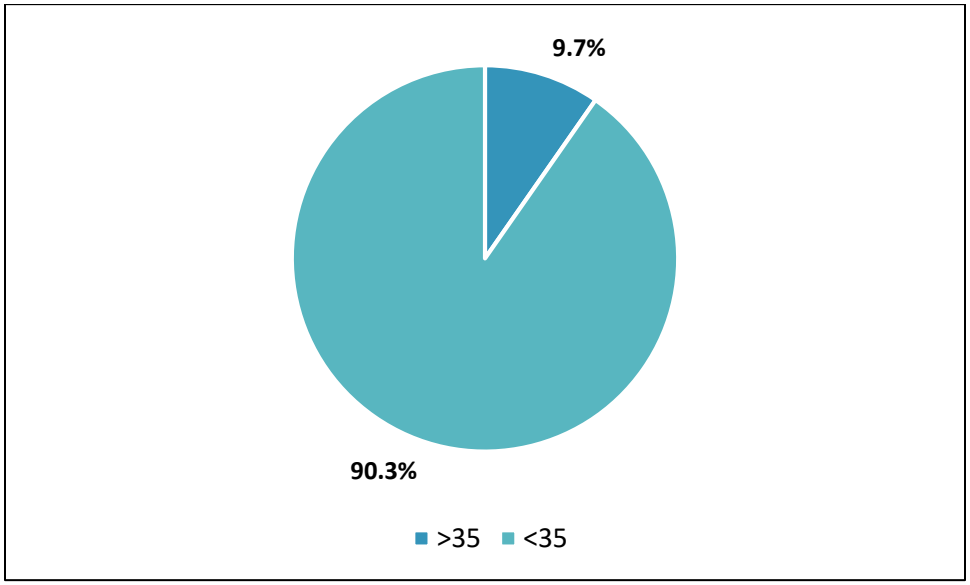

Figure 8: Percentage of the sampled smallmouth bass that were larger than 35 centimetres. Smallmouth bass sampled from Wentzells Lake between April 25 and May 25, 2017.

Out of the 82 smallmouth bass collected between April 25 and May 25, 2017, only 9.3% were larger than 35 centimetres. This lowered the sample size of smallmouth bass that had a high probability of being capable of ingesting Atlantic salmon smolt to eight individuals.

Chain Pickerel

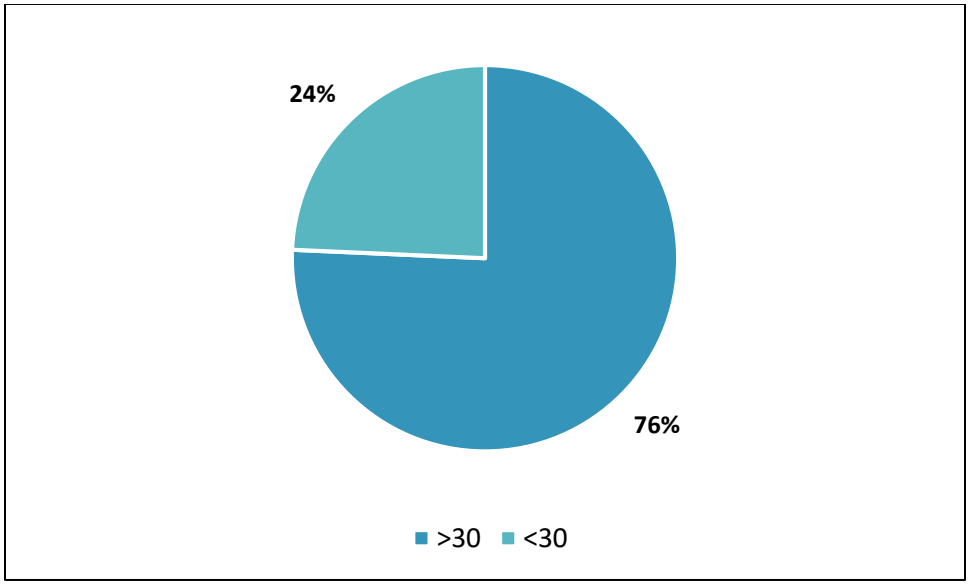

Figure 9: Percentage of the sampled chain pickerel that were larger than 30 centimetres. Chain pickerel sampled between April 25 and May 25, 2017 in Wentzells Lake.

Between April 25 and May 25, 2017, approximately three quarters of the fish sampled were larger than 35 centimetres. This allowed for a large sample size of chain pickerel that had a high probability of ingesting Atlantic salmon smolt.

Sex Ratio

Once the sampling was finished on May 25, 2017, the sex of each fish was used to form ratios for both smallmouth bass and chain pickerel. The following data was collected from Wentzells Lake between April 25 and May 25, 2017.

Smallmouth Bass

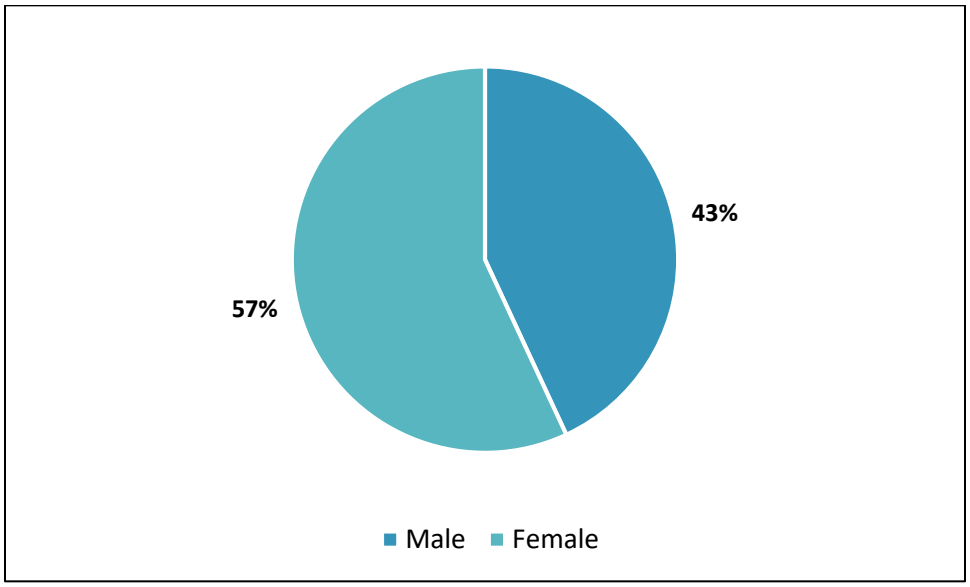

Figure 10: Sex ratio of smallmouth bass sampled from Wentzells Lake between April 25 and May 25, 2017.

From the sampled portion of the smallmouth bass population, there were 14% more females than males. Angling took place during the pre-spawn for smallmouth bass. Females require high amounts of nutrients during the pre-spawn to account for egg production and development. During nesting, males become aggressive and protect the nest (Winemiller & Taylor, 1982). All sampling took place before the nesting season which influenced the portion of females sampled.

Chain Pickerel

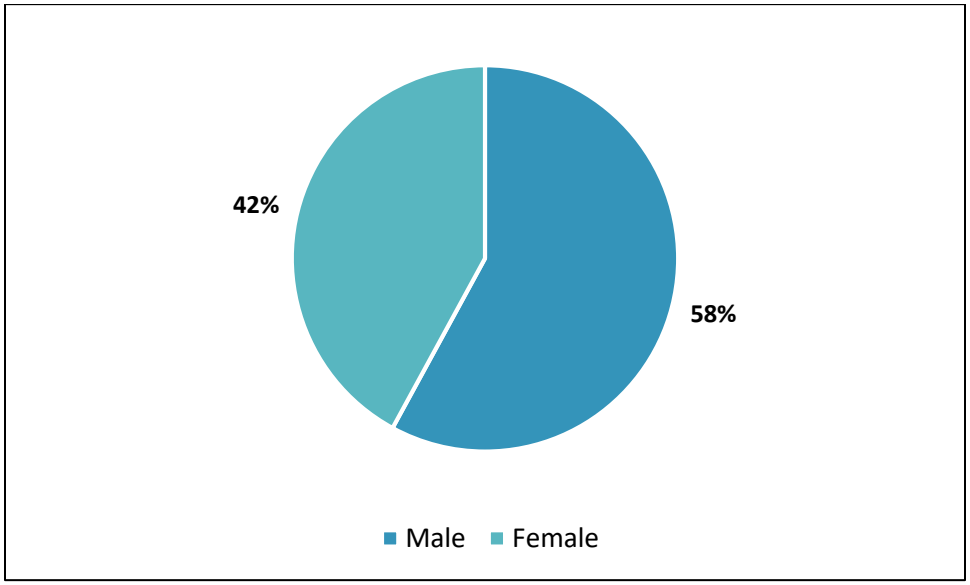

Figure 11: Sex ratio of chain pickerel sampled from Wentzells Lake between April 25 and May 25, 2017.

Males were slightly more numerous than females from the sampled population of chain pickerel in Wentzells Lake. However, on average, female chain pickerel were larger than males.

Smolts Found

Table 3: Total smolts found in stomach content, species in which they were found, sex of the predator that ingested smolt, date of occurrence, and location on Wentzells Lake where predator was sampled. All sampling took place between April 25 and May 25, 2017.

Smolt Number	Species	Sex of Predator	Date	Location
Smolt #1	Chain Pickerel	Female	03-May	W2 Wentzells Lake
Smolt #2	Chain Pickerel	Male	03-May	W2 Wentzells Lake
Smolt #3	Chain Pickerel	Male	09-May	W3 Wentzells Lake
Smolt #4	Smallmouth Bass	Female	09-May	W2 Wentzells Lake
Smolt #5	Chain Pickerel	Female	10-May	W2 Wentzells Lake
Smolt #6	Chain Pickerel	Female	10-May	W2 Wentzells Lake
Smolt #7	Chain Pickerel	Female	10-May	W2 Wentzells Lake
Smolt #8	Chain Pickerel	Female	10-May	W2 Wentzells Lake

Smolt #9	Chain Pickerel	Male	10-May	W2 Wentzells Lake
Smolt #10	Chain Pickerel	Male	11-May	W2 Wentzells Lake
Smolt #11	Chain Pickerel	Male	12-May	W2 Wentzells Lake
Smolt #12	Chain Pickerel	Female	12-May	W2 Wentzells Lake
Smolt #13	Chain Pickerel	Female	19-May	W1 Wentzells Lake

Out of the total 13 smolts found in the stomach content of invasive species, 12 occurred in chain pickerel. Four of the 12 smolts found in chain pickerel were found in one specimen. Approximately 85% of all the smolts found in the stomach contents of invasive species were found in the W2 area of Wentzells Lake. One smolt was found in the stomach contents of a chain pickerel in both the W1 and W3 area of Wentzells Lake. All smolts were found between May 3 and May 19, 2017.

Figure 12: Photo of the chain pickerel that had ingested four smolt (May 10, 2017) and the first smolt found in a chain pickerel (May 3, 2017).

Presence of Invasives in the LaHave River Watershed

Chain pickerel were found in all portions of the LaHave River below the Morgan Falls Fishway except for a small section of the West Branch that contained a large fall. Sampling directly below Morgan Falls indicated the presence of chain pickerel, while sampling in New Germany Lake (above Morgan Falls) indicated the absence of chain pickerel. However, smallmouth bass were found in all portions of the LaHave River except for a small section of the Main Branch flowing from the Cloud Lake Wilderness Area.

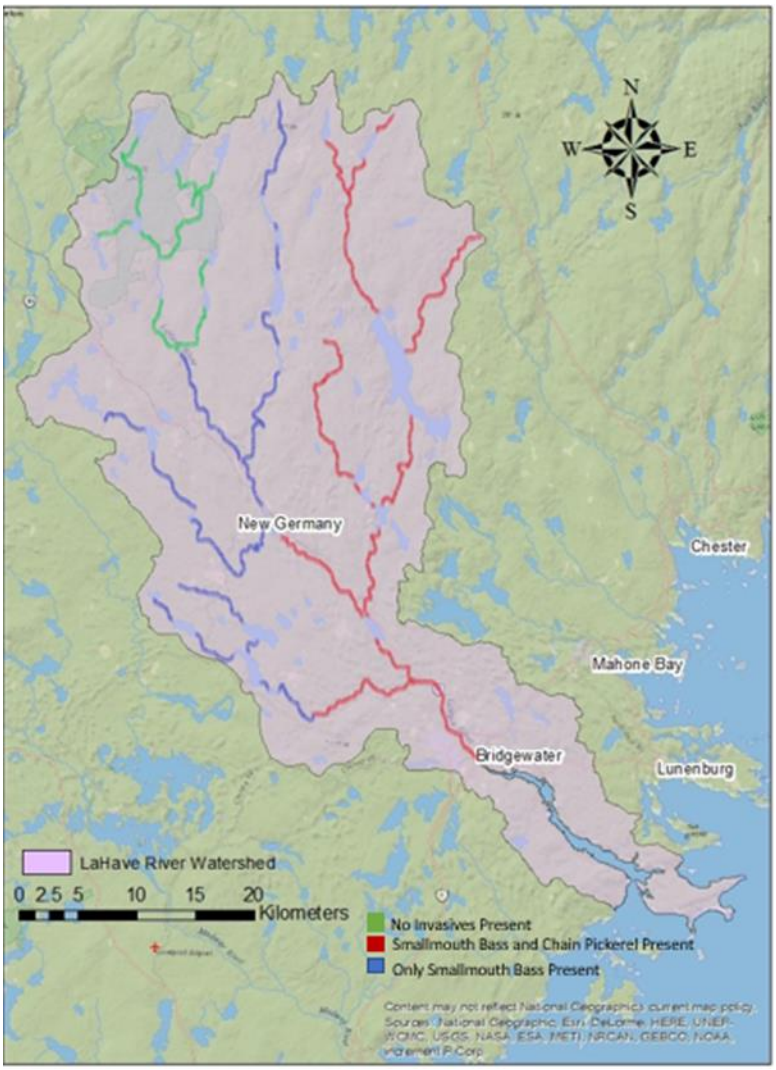

Figure 13: Map of LaHave River Watershed showing presence of invasive fish species (Chain Pickerel and Smallmouth Bass). Presence sampled using scientific angling.

Discussion

Throughout the duration of the sampling, effort was focused in Wentzells Lake, Lunenburg County, Nova Scotia. This lake is located within the LaHave River Watershed and is an area where two large branches of the river connect. Wentzells Lake was anecdotally known to contain dense populations of chain pickerel and smallmouth bass. These invasive species are among the largest fish predators in the LaHave River system and a hypothesis was formed as to their predation on Atlantic salmon smolt during the smolt migration to salt water. The hypothesis was that chain pickerel and smallmouth bass were directly preying on Atlantic salmon smolt during the smolt migration.

W3 held the highest catch per unit effort for both chain pickerel and smallmouth bass. This could be attributed to many factors, but mainly to the habitat diversity that was present in this area. Shallow, densely vegetated, sheltered coves were contrasted by sparsely vegetated rock ledges, both of which are

favoured habitats of both invasive species (Edwards et al., 1983; Mitchell et al., 2011; Winemiller & Taylor, 1982). Effort was focused on, but not limited to, the area in W2 due to the fact that smolt migration data was available for the Main Branch of the LaHave River and because the highest population of smolt migrate down the Main Branch of the LaHave River. This area was presumed to allow for the highest possibility of sampling a chain pickerel and/or smallmouth bass that had preyed upon an Atlantic salmon smolt. Numerous fish were observed feeding in this area, indicating that it was a productive area for multiple fish species.

In total, 13 smolts were found in the stomach content of invasive species during the sampling period in Wentzells Lake, 12 of which were found in chain pickerel. From the 13 total smolts found, 11 were sampled from the W2 area. After accounting for the difference in effort between sites, the data still suggests that the largest population of smolts are migrating from the Main Branch of the LaHave River. One chain pickerel, which was sampled in W2, contained four smolts at one time. This pickerel was a 54.9 cm female, which is the third largest chain pickerel sampled throughout the sampling period. However, the presence of four smolts in one individual indicates chain pickerel have alarmingly large stomach capacities. Also, it indicates that the chain pickerel may feed out of aggression as well as necessity.

Smallmouth bass are reported to begin feeding at a water temperature of between 7^{o}C and 10^{o}C (Edward et al., 1983; Brown et al., 2009). Water temperatures in the first week of sampling were below or at this initial feeding temperature. Chain pickerel are reported to feed between temperatures of 5^{o}C and 25^{o}C, which is earlier than smallmouth bass in the sampling period and would pertain to a larger portion of the smolt migration. This suggests that chain pickerel have a longer period of time to actively feed on migrating smolt.

A single smolt was found in the stomach content of a smallmouth bass. With a fork length of 44.3 cm, it was among the largest five bass caught in Wentzells Lake during the sampling period. All five of the largest bass were female and were sampled from the W2 area on Wentzells Lake. Three quarters of the total smallmouth bass diet consisted of invertebrates. Invertebrates formed 16% less of the sampled chain pickerel's diet, which was attributed to fish (24%) and empty specimens. This suggests that chain pickerel are more reliant on fish as a food source than smallmouth bass, but invertebrates still form a considerable portion of the pickerel's diet.

Chain pickerel were found to not only prey upon the smolt life stage of Atlantic salmon, but the parr life stage as well. A chain pickerel sampled from the W2 region of Wentzells Lake contained a single salmon parr indicating that chain pickerel effect multiple life stages of the Atlantic salmon. This data indicates that chain pickerel may have a significant impact on the survival of native salmonid populations due to the predation of multiple life stages.

A significant portion of chain pickerel and smallmouth bass that were larger than the probable sizes of ingesting smolt (30 and 35 centimetres respectively) were sampled from the W2 area. After the sampling period, a significant portion of the larger fish were angled in areas different from the habitat where the branches of the LaHave River enter Wentzells Lake. This predator relocation was timed with the movement of gaspereau (*Alosa pseudoharengus*) to the shallow regions of the lake to spawn. This movement suggests that the large invasive predators are relocating depending on the available prey species in the lake habitat.

Smallmouth bass are more likely to use riverine habitat than chain pickerel based on habitat preferences of each species (Edwards et al., 1983). Chain pickerel prefer densely vegetated lakes that offer cold-water refuges during the late summer (Moring & Nicholson, 1994). Smallmouth bass share this preference, but they may also spend considerable portions of the year in a riverine habitat (Edwards et al., 1983). Chain pickerel, however, do spend small portions of the year in riverine habitat. In the LaHave River this was noted near Bruhms Pool. Large chain pickerel were sampled in the area during the migration of gaspereau, but were not caught before the migration of gaspereau. This suggests the pickerel follow large quantities of prey and change habitat use to account for migrating prey species.

Morgan Falls continues to impede the passage of chain pickerel, but is not an impediment of passage for smallmouth bass. A number of medium-sized falls on the Main Branch have stopped or slowed the spread of invasive species into the Cloud Lake Wilderness Area and the lakes that are found within that section of the watershed. This is the only known area on the LaHave River that can be confidently labelled as invasive free. A large area of falls on the West Branch of the LaHave River has impeded the passage of chain pickerel, but has allowed the passage of smallmouth bass. Presence was estimated based on scientific angling.

Conclusion and Recommendations

Based on the data collected during the sampling period, both invasive predators pose a serious threat to the survival of migrating Atlantic salmon smolt and resident Atlantic salmon parr. Smolt form a larger portion of the chain pickerel's diet than the smallmouth bass' diet; however, smallmouth bass may have a large effect on the survival of Atlantic salmon through competition for resources and habitat in riverine settings during early life stages of both species (DFO, 2009).

Chain pickerel show patterns of movement that suggest they follow large quantities of prey species during the preys' annual migrations. This was noted during the smolt migration and the gasperau migration. Areas where the pickerel congregate can be targeted by anglers to remove the large predators and aid the successful migration of native species.

Chain pickerel have an alarming capacity for ingesting prey and may attack prey even if it cannot be ingested. This may cause delayed mortality of the smolt (any prey) and lead to portions of the population that are less likely to survive the migration. Smallmouth bass do not have the same capacity for ingestion as chain pickerel. However, they do rely on fish for a portion of their diet and they share predator qualities, such as aggressive feeding habits, with chain pickerel.

Recommendations for future actions are as follows:

- Continue an annual sampling of invasive species in the Wentzells Lake area during smolt migration
    - Removal of invasive predators
    - Gain a better understanding of the level of predation on Atlantic salmon smolts
- Explore more options for invasive species removal and/or control, such as boat electrofishing in key areas
- Monitor predator movements and prey migrations within habitats
    - Show correlation between migration of prey species and habitat use by predator species
- Monitor the spread of chain pickerel in the LaHave River watershed
    - Currently absent (or low populations) above Morgan Falls

    - Present in Main Branch LaHave below Morgan Falls
        - Assumed present in branches downstream from Morgan Falls
- Educate public on the harmful effects of moving invasive species
    - Slow the spread of invasive species
- Educate public on potential food sources to aid in removal of invasive species
    - Smallmouth bass and chain pickerel

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Appendices

Appendix 1. Smolt migration data gathered from Morgan Falls Fishway. Information retrieved from Alex Levy, DFO Maritimes.

Year	First Smolt Counted	Last Smolt Counted	Comment
2007	29-Apr	29-May	Smolts captured on April 29 (first day counts were recorded). Relatively small number of smolts were captured on May 29, and smolt trap was not operated after this date.
2008	25-Apr	28-May	Smolts captured on April 25 (first day counts were recorded). Relatively small number of smolts were captured on May 28, and smolt trap was not operated after this date.
2009	3-May	25-May	Smolts captured on May 3 (first day counts were recorded). Smolts were captured on May 25, and smolt trap was not operated after this date.
2010	23-Apr	21-May	Smolts captured on April 23 (first day counts were recorded). Relatively small number of smolts were captured on May 21, and smolt trap was not operated after this date.
2011	No Smolt Assessment	No Smolt Assessment	
2012	No Smolt Assessment: MFP Not Operational	No Smolt Assessment: MFP Not Operational	
2013	29-Apr	21-May	Smolts captured on April 29 (first day counts were recorded). Small number of smolts were captured on May 21, and smolt trap was not operated after this date.
2014	2-May	30-May	Smolts captured on May 2 (first day counts were recorded). Relatively small number of smolts were captured on May 30, and smolt trap was not operated after this date.
2015	7-May	1-Jun	First smolts captured on May 7. Small number of smolts were captured on June 1, and smolt trap was not operated after this date.
2016	20-Apr	25-May	First smolts captured on April 20. Relatively small number of smolts were captured on May 25, and smolt trap was not operated after this date.
2017	No Smolt Assessment: MFP Not Operational	No Smolt Assessment: MFP Not Operational	