Developing Catch Indices for Rainbow Smelt Fry Outmigration on North Brook, Lily Bay Moosehead Lake

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April 2022

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INTRODUCTION/BACKGROUND

Rainbow smelt are the most important forage item for landlocked salmon, lake trout, and to a lesser extent brook trout (likely those greater than 14 inches) in Moosehead Lake. Over the past decade, we have documented declines in smelt abundance that may not be related to predator abundance. We believe that these declines in abundance are due to weak year classes in smelt recruitment. Currently, we rely on a variety of indices including salmonid growth and stomach content data to assess smelt abundance. The purpose of this study is to develop estimates for smelt fry outmigration to determine smelt year class failures/ successes early in their development.

Since the initiation of the Moosehead Lake Study in 1967, fisheries biologists have been collecting angler-caught landlocked salmon, lake trout, and brook trout stomachs from Moosehead Lake during winter clerk surveys to assess the occurrence and volumes of food utilized by these species. This long-term sampling of stomachs demonstrates the importance of smelt as a forage to obtain good growth and condition of salmonids in Moosehead Lake. Salmonids from Moosehead Lake show a response in growth rates and condition which follow trends in smelt volume. However, these results are a measurement of abundance and availability "after the fact"; a snapshot of the relative abundance of smelt at the time stomachs were collected and may not be a good indication of smelt abundance in subsequent years. Literature suggests that sampling annual smelt recruitment may be a better indicator to measure the abundance and availability forthcoming in Moosehead Lake's smelt population. The smelt population's cyclic nature may be more related to seasonal and interannual pattern complexity in tributary larval production.

In an effort to quantify the smelt abundance and availability on a yearly basis, we based our research off a previous study conducted by Brown (1994), as a templet for our study design. Brown's study was conducted on Lake Huron.

Cursory work for this study was conducted in 2015 and 2016 on Moosehead Lake and Sebec Lake. The purpose of this early sampling was to determine what we could accomplish effectively. Preliminary work was trial and error to develop sampling protocols. This early work was beneficial in the development of our study plan and we were confident we would be able to develop CPUE (Catch-Per-Unit- Effort) and total production estimates for smelt fry at hatch-out.

The goal of this study was to estimate smelt fry outmigration, as well as determining if North Brook was a good measure of the total smelt population abundance in Moosehead Lake. Our objectives were to:

1. Determine the timing and duration of smelt spawning.
2. Measure the length-frequency, age, and sex ratio of spawning smelt.
3. Measure the timing and duration of larval smelt outmigration.
4. Estimate total smelt fry outmigration.

5. Determine the cause for smelt class failures and possibly identify opportunities to alleviate the problem and maintain stable populations.

In the past, smelt runs have been evaluated by anecdotal spot checks, a collection of small narrative incidents. An observer may check a smelt run only one or two nights during the run then attribute an anecdotal measure to the success of the run, usually based on the number of adults or egg deposition observed. While these observations offer a quick qualitative assessment, they do not provide a constant measure over time to gauge smelt run year class failures/ successes. However, the decades of observing the smelt runs at North Brook proved valuable and led to its selection for this study. North Brook has an annual smelt run with roadside access to the sampling location were the tributary meets the lake, making it a logical choice for our nighttime sampling work.

BRIEF METHODOLOGY

Sampling of Spawning Adults

Samples of spawning adult smelts were obtained using an aluminum framed hoop trap net with ¼ inch mesh. The trap net was set with the opening of the net facing upstream, fishing with one wing tied off to the shore and the other wing set into the channel of the brook, sampling no more than one third of the mouth of the brook. The net was fished in this manner as to not impede smelt movement up the brook to their spawning habitat, but to capture a sample of adult smelt as they descended the brook after a night of spawning. This technique enabled us to determine the timing and duration of each spawning season and allowed us to sample the adult population at the time of spawning with low impact.

Sampling was conducted on North Brook from May 3 to May 19, 2019, from April 28 to May 16, 2020, and from April 20 to May 13, 2021. The trap net was tended each morning to obtain a sample from the previous nights' spawning activity. During each tend we enumerated total smelt catch, recorded lengths and sex of a random sub-sample, roughly 100 individuals from each sampling event. Sex was determined by the extrusion of gametes. In 2021, we began collecting otoliths from our daily sub-sample, a random 100 fish male/female sample over the course of the sampling season for age analysis. Otoliths were aged whole, submerged in clove oil, using a dissecting microscope. Since otolith samples were collected in early spring prior to significant growth, the outer edge of the otolith was assumed to represent the last annuli.

Nightly Sampling of Out-migrating Larval Smelt

Scott and Crossman (1998) estimated that smelt eggs hatch in 2-3 weeks depending on temperature and that immediately after hatching, larvae are then transported downstream to their receiving water by currents. Therefore, we began nightly sampling roughly two weeks after the peak spawning activity observed during trap netting. Since Brown (1994) found that night larval outmigration was approximately normally distributed and that 90% + of larval outmigration occurred between 9pm and 6am with peak outmigration occurring between 11pm and 1am. We chose this peak outmigration period as our sampling time parameter to estimate larval smelt production of North Brook through drift net surveys.

Net location varied annually based on the location of egg deposition. Yearly sampling transects were selected below where egg deposition was observed and where the stream cross section had the most consistent depth profile. The total area of these transects was calculated by measuring the stream width and depth at one-foot increments along the transect. Based on these measurements we calculated the percentages of the transects our drift nets were sampling annually. Nets were located along the transect nearest to the mean depth of the transect, while allowing the net to fish from the surface to the bottom. To mark these locations, we installed two pieces of rebar into the streambed along the transect, equal to the width of the net frame apart. Four metal rings attached to the net frame slide down over the rebar to hold the net in place for sampling.

Sampling occurred between May 18 to June 9, 2017, from May 21 to June 4, 2018, from May 15 to June 13, 2019, from May 15 to June 7, 2020, and May 10 to June 7, 2021, between 11 pm and 1am. We timed the start of our sampling to coincide with the two weeks after the peak spawning activity. Sampling was conducted every 2-4 nights during the beginning and end of outmigration, but during the peak of outmigration we sampled every night. Each night we collected three 20-minute samples. Sampling was conducted using a 20-inch diameter, 99-inch long, 363-micron mesh conical plankton net attached to a frame designed to eliminate disturbance (pressure wave) in front of the net opening. Material collected from each 20-minute sample was preserved in separate 250-ml collection jars with 95% reagent alcohol. In the laboratory, larval smelt were separated from other collected material and counted from each of the three jars using a dissecting microscope.

Estimating Total Production

To estimate total production, we developed an effective count curve from Brown's data. We were able to expand our nightly mean catch per hour for the entire channel width and then for an entire 24-hour period by date, based on the area of the channel sampled and the number of smelt collected. We used the mean CPUE from the previous and subsequent sampling events to extrapolate the outmigration on nights we did not sample.

SUMMARY OF RELEVANT FINDINGS

Length-Frequency and Age Distribution of Spawning Adults

Length-frequency distribution for adult smelt spawning in North Brook for years 2019-2021 are shown in Figure 1. Length-frequency were similar in all years sampled. Greater than 96% of smelt sampled during spawning runs were between 80 to 110 mm in total length. Samples of spawning fish were dominated by males in all years, which increased in each of the sampling years (Table 1).

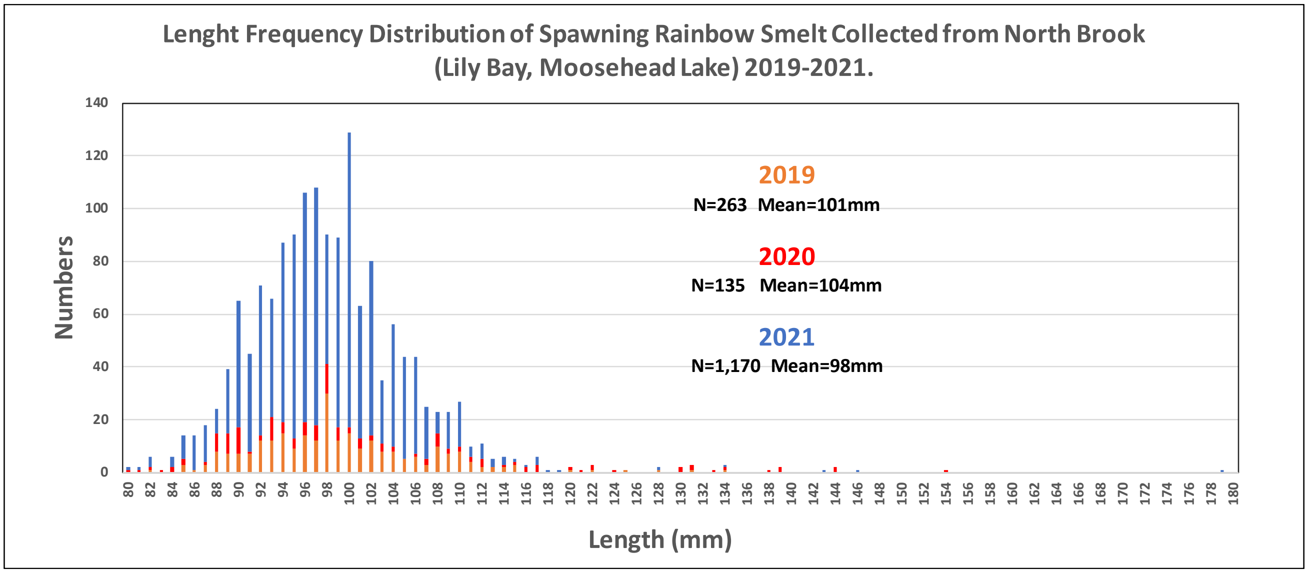

Figure 1. Length frequency distribution of spawning rainbow smelt collected from North Brook (Lily Bay, Moosehead Lake) from 2019 to 2021.

Table 1. Sample size, mean length (mm), standard error (SE), and range in length of spawning rainbow smelt sampled from North Brook (Lily Bay, Moosehead Lake) 2019-2021.

Year	Sex	Sample Size (%)	Mean Length in mm	Standard Error	Range in mm
2019	Both	263	101	0.49	84 - 136
	Male	182 (69%)	101	0.57	87 - 133
	Female	81 (31%)	101	0.97	84 - 136
2020	Both	135	104	1.27	82 - 156
	Male	96 (71%)	103	1.47	82 - 146
	Female	39 (29%)	105	2.50	87 - 156
2021	Both	1,170	98	0.18	80 - 179
	Male	1,010 (86%)	98	0.20	80 - 146
	Female	160 (14%)	98	0.74	82 - 179

In 2021, we aged 107 smelt throughout the spawning season (Table 2). The composition of smelt was dominated by 2-year-old smelt. Two-year-old smelt represented 90% of the aged sample. Mean length of age 2-year-old smelt was similar for males and females. The greatest difference in mean length between males and females was observed in our 4-year-old smelt.

Table 2. Sample size, mean length (mm), standard error (SE), and range in length at age of spawning rainbow smelt sampled from North Brook (Lily Bay, Moosehead Lake) 2021.

Age	Sex	Sample Size	Mean Length in mm	Standard Error	Range in mm
II	Both	97	100	0.55	85 - 110
	Male	58	100	0.67	88 - 110
	Female	39	99	0.92	85 - 110
III	Both	6	115	2.87	109 - 128
	Male	5	116	3.31	109 - 128
	Female	1	110	-	110
IV	Both	4	151	9.84	134 - 179
	Male	2	145	1.50	143 -146
	Female	2	157	22.50	134 - 179

Total Smelt Fry Outmigration Estimates

Total larval production from the five years (2017-2021) of sampling ranged from approximately 10 million smelt fry to just over 3,000 smelt fry (Table 3). Total larval production was highest in 2017 and lowest in 2020. The earliest date of peak outmigration was May 20, 2021, and the latest was May 31, 2020. The number of days with outmigration ranged from 25 days to 9 days. The longest duration was in 2021 and the shortest was in 2020. The earliest ice out date was observed in 2021 and the latest date Moosehead Lake was free of ice was during 2019. The average ice out date for Moosehead Lake from 2003-2021 was May 1st, which was summarized from the Maine Department of Agriculture, Conservation and Forestry Ice Out Dates (http://www.maine.gov/dacf/iceout).

Table 3. Ice out date, estimated out-migration, number of days with out-migration, and date of peak out-migration by year for rainbow smelt sampled from North Brook (Lily Bay, Moosehead Lake) 2017-2021.

Year	**2017**	**2018**	**2019**	**2020**	**2021**
Ice out date	1-May	8-May	9-May	4-May	16-April
Estimated out-migration	10,032,296 SLT	7,614,714 SLT	1,365,234 SLT	3,089 SLT	2,080,079 SLT
Number of days with out-migration	23	15	21	9	25
Date of peak out-migration	24-May	28-May	29-May	31-May	20-May

DISCUSSION/CONCLUSIONS/RECOMMENDATIONS

This project has been very insightful in gaining a better understanding of the naturally occurring routine of smelt in Moosehead Lake, with North Brook appearing to be a good measure of the total smelt abundance lake wide. We documented increasing volumes of smelt in the food habits of our salmonids from 2009 to 2016. Increasing forage was directly related to the large-scale removal of lake trout under new liberal size and bag limits. As a result, growth for our salmonid populations improved during this period. Clearly, the improvements in growth and smelt abundance during this period were due to management changes on Moosehead Lake. However, the variation in outmigration estimates we experienced at North Brook from 2017-2021 were during a time Moosehead Lake's salmon and lake trout were experiencing relatively stable catch rates. The changes in smelt abundance during this period were likely naturally occurring or, at a minimum, less influenced by any management change we had made regarding the harvest of predator species. For example, some literature suggests that the abundance of rotifers, the primary food source for emerging smelt fry, can influence early survival (Brown 1994). Fluctuations in rotifer abundance at the time of smelt fry emergence is influenced by weather and water quality. Stetter (2007) hypothesize that since older smelt are known to cannibalize younger smelt, that a strong year class can severally reduce the subsequent cohort through direct predation. This creates a weak cohort which can, over time, create cyclical or erratic abundance. These types of influences on smelt abundance are outside the direct purview of standard fisheries management techniques. Documenting these naturally occurring swings in smelt recruitment is enabling us to put some perspective on past fluctuations we have observed in smelt abundance and availability in Moosehead Lake. Let's call them anomalies of nature in a species known to have variable spawning success. The booms and busts!

However, there appears to be a pattern emerging between decreasing volumes of 2-year-old smelt in winter lake trout stomachs and the decline in the outmigration estimates. In 2020, our volume of 2-year-old smelt was at a historic low which coincided with the crash we experienced in our smelt outmigration in the spring of 2020, suggesting we experienced a failure in our 2018-year class. The next winter, 2021, we documented an increase in the volume of 2-year-old smelt in lake trout stomachs and our outmigration estimate increased thus suggesting the 2019-year class was a success. If this pattern stands to be true, we should see a decrease in our outmigration in 2022, since the volume of 2-year-old smelt in our 2022 winter lake trout stomachs was very low, along with the lack of outmigration in 2020. There is a good chance we will experience a depressed year class once again in 2022.

Although, we can only speculate about the age structure of the spawning adult smelt population in previous years. Age 2-year-old smelt have been the dominate age class during our study on North Brook. If 2-year-old smelt do in fact dominate the spawning adult population annually, then this research validates that examining the proportion of 2-year-old smelt in winter stomachs is a strong indicator of recruitment success the following spring. The cause of these large fluctuations in the population when year class failures occur remain unknown but may be particularly influential since older year-classes are not abundant enough annually to offset these failures.

Moving forward we plan to continue monitoring these indices for long term trends and attempt to identify the causes of these failures in age classes resulting in these wide fluctuations in the smelt recruitment to better manage the Moosehead Lake fishery. We are also looking to fine tune our sampling protocols to assure we are collecting the most appropriate data in developing these long-term indices. In 2022, we will reassess our sampling protocols as they relate to our effective count curve. We have been extrapolating our estimates by the percentage the net is sampling the transect. We feel that moving forward it may be more appropriate to base our outmigration estimates by the volume of flow the net is sampling. We will compare these differences in 2022 and determine the right course of action moving forward.

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COOPERATIVE

STATE FEDERAL

PROJECT

This report has been funded in part by the Federal Aid in Sport Fish Restoration Program. This is a cooperative effort involving federal and state government agencies. The program is designed to increase sport fishing and boating opportunities through the wise investment of angler's and boater's tax dollars in state sport fishery projects. This program which was founded in 1950 was named the Dingell-Johnson Act in recognition of the congressmen who spearheaded this effort. In 1984 this act was amended through the Wallop Breaux Amendment (also named for the congressional sponsors) and provided a threefold increase in Federal monies for sportfish restoration, aquatic education and motorboat access.

The program is an outstanding example of a "user pays-user benefits" or "user fee" program. In this case, anglers and boaters are the users. Briefly, anglers and boaters are responsible for payment of fishing tackle, excise taxes, motorboat fuel taxes, and import duties on tackle and boats. These monies are collected by the sport fishing industry, deposited in the Department of Treasury, and are allocated the year following collection to state fishery agencies for sport fisheries and boating access projects. Generally, each project must be evaluated and approved by the U.S. Fish and Wildlife Service (USFWS). The benefits provided by these projects to users complete the cycle between "user pays – user benefits."

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