

**POPULATION ASSESSMENT OF TRIBUTARY-SPAWNING RAINBOW SMELT
IN SELECTED NEW HAMPSHIRE LAKES**

STATE: New Hampshire

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GRANT TITLE: Anadromous and Inland Fisheries Operational
Management Investigations

JOB 8: Forage Fish Population Assessment

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PRINCIPAL INVESTIGATORS: Donald R. Miller, Fisheries Biologist II
John A. Viar, Fisheries Biologist I



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EXECUTIVE SUMMARY

The study objectives were to determine the size characteristics, age composition, and sex ratio of Rainbow Smelt spawning in selected tributaries to Cedar Pond and Lake Winnepesaukee. Comparison of these parameters among and within lakes and with past data sets provides information on the status of these spawning populations.

Age-1 Rainbow Smelt dominated the spawning run in Poor Farm Brook, a tributary to Lake Winnepesaukee, while, age-2-4 Rainbow Smelt were observed in Cedar Brook, a tributary to Cedar Pond. The mean total length of spawning Rainbow Smelt in Cedar Pond and Lake Winnepesaukee was 103-mm and 66-mm, respectively. The predominance of age-1 Rainbow Smelt in spawning runs is unusual; it is likely that the age composition observed in Lake Winnepesaukee is indicative of high mortality rates caused in part by salmonids (Lake Atlantic Salmon, aka “landlocked salmon”, Rainbow Trout and/or Lake Trout) predation.

Male Rainbow Smelt dominated both Cedar Pond (76%) and Lake Winnepesaukee (100%) spawning runs. Sex ratios skewed towards male smelt during spawning are normal and can be attributed to the differential behavior of male and female smelt, and the time period in which the smelt samples were obtained during the evening.

INTRODUCTION

Rainbow Smelt (*Osmerus mordax*) are an essential source of forage for Lake Atlantic Salmon (*Salmo salar*), aka “landlocked salmon” and Lake Trout (*Salvelinus namaycush*) in New Hampshire's large lakes [New Hampshire Fish and Game Department (NHFGD) 1982]. Fluctuations in abundance of Rainbow Smelt affect the growth rates of both species (Seamans and Newell 1973). Size characteristics, age composition, and sex ratios are vital statistics that can be used to measure the status of Rainbow Smelt populations (Brown 1994), and allow year class strength and recruitment variations to be assessed on an annual basis (Anderson and Nuemann 1996). In New Hampshire, Rainbow Smelt are indigenous to Big Squam, Winnepesaukee and Winnisquam lakes (Hoover 1936a, Kendall 1927).

The study objectives were to determine the size characteristics, age composition, and sex ratio of Rainbow Smelt spawning in selected tributaries to two New Hampshire lakes. Comparison of these parameters among and within lakes, and with past data sets provided information on the status of these spawning populations.

STUDY LAKES

Lake Winnepesaukee, the largest lake in New Hampshire, is 18,051 ha. It is oligotrophic with moderate chlorophyll-*a* (mean of 2.45 µg/L), and MEI¹ of 0.88 (NHDES 1992). Lake Winnepesaukee is a deep, thermally stratified² lake with maximum and mean depths of 55 m and 13 m, respectively.

Cedar Pond is 31.6 ha in size, with a maximum and mean depth of 17 m and 9.4 m respectively. Classified as mesotrophic, it is moderately fertile, with a chlorophyll-*a* of 10.03 µg/L and MEI of 1.19 (NHDES 1994).

METHODS

Sampling of Spawning Rainbow Smelt

Random samples of spawning Rainbow Smelt were obtained between 2100 and 2400 hours from tributaries to Winnepesaukee Lake (Poor Farm Brook) and Cedar Pond (Cedar Brook) (Table 1). Smelt were collected using a long handled (2.4 m) net (38 cm diameter) with 9 mm wire mesh. A minimum of 100 smelt (if available) were netted from each tributary. Total length (mm), weight (g) and sex (male/female) were recorded for each fish.

¹ The MEI (morphoedaphic index) value is a general predictor of lake productivity. Oligotrophic lakes are generally nutrient poor and thus low in productivity. Mesotrophic lakes are higher in productivity while maintaining essential coldwater habitat for Rainbow Smelt and other salmonids.

² Both study lakes thermally stratify.

Age Determination

Age data from previous years' surveys was used to construct age-length keys (Ricker 1975) for each lake (Appendix I, Tables 1, 2). Smelt total lengths were inserted into the long-term age-length keys for each lake. The age-length keys were used to partition overall length-frequency data into age-frequency data (Table 2).

Data Analysis

Student's t-test was used to determine if significant differences ($P \leq 0.05$) existed between age-1 spawning male Rainbow Smelt mean total length in 2015 and the long-term means for Lake Winnepesaukee and Cedar Pond. Age data was used to construct age-length keys (Ricker 1975) for each lake sampled (Appendix I, Tables 1-2). The age-length keys were used to partition overall length-frequency data into age-frequency data (Table 2).

RESULTS

Age Composition and Sex Ratio

Rainbow Smelt spawning runs were sampled on 13 and 30 April, and 04 May, with water temperatures at 4.4°C (Table 1). Age-1 Rainbow Smelt dominated the spawning run in Winnepesaukee (Poor Farm Brook) (Table 2). Male smelt dominated the Poor Farm Brook run at 100%, while Cedar Pond (Cedar Brook) exhibited a male run of 76%, Table 3. The mean length of age-1 spawning Rainbow Smelt in Lake Winnepesaukee was (66 mm), Table 6.

Size Characteristics

Mean total length of spawning Rainbow Smelt was greatest in Cedar Lake (103 mm), and lowest in Lake Winnepesaukee (66 mm) (Table 4, Figure 1). The greatest length range occurred in Cedar Lake (84-126 mm) (Table 4). In 2015, the age-1 male Rainbow Smelt mean total length in Lake Winnepesaukee ($P \leq 0.001$) was significantly different (shorter) compared to the long-term mean (Table 5). Lake Winnepesaukee exhibited the lowest peak-length frequency (60-69 mm), primarily due to the high number of age-1 smelt in the spawning run (Figure 1). Cedar Lake exhibited the greatest peak-length frequency (100-109 mm), followed by Lake Winnepesaukee (60-69) Figure 1. The maximum size (126 mm) of spawning Rainbow Smelt observed was at Cedar Lake (Table 4).

DISCUSSION

Kendall (1927), (citing the NH Commissioners on Fisheries report of 1870) noted that smelt in area ponds were larger than smelt in Lake Winnepesaukee and it would appear this pattern continues today. Lake Winnepesaukee continues to exhibit a high percentage of age-1 smelt in

the spawning run at Poor Farm Brook. Tributary runs of spawning smelt in Lake Winnepesaukee are rare, except for the long-term runs (primarily age-1 males) associated with Poor Farm Brook. The continued abundance of forage fish in Lake Winnepesaukee (Viar 2010) lends credence to a high probability that the smelt population maintains this abundance through shoreline spawning, a common occurrence in New Hampshire and elsewhere (Lischka and Magnuson 2006; Rupp 1965). The predominance of age-1 Rainbow Smelt in spawning runs is unusual, although it has continually occurred in Poor Farm Brook for several decades (D. Miller, NHFGD, pers. com.). Also, it is likely that the age composition observed at Lake Winnepesaukee is indicative of high mortality rates caused by salmonid (Rainbow Trout, Lake Trout, and landlocked salmon) predation. Smelt typically become sexually mature at age-2. Brown (1994) found that age-2 and 3 fish dominated smelt spawning populations and Bailey (1964) noted that none of the smelt examined in Lake Superior were mature after one growing season. Nevertheless, age-1 Rainbow Smelt spawning has been documented in the literature. Rupp (1968) noted in Maine lakes that under conditions where growth is slow, spawning of age-1 males does occur. Brown (1994) noted that high levels of harvest altered the spawning age-class composition of Rainbow Smelt. In New Hampshire, salmonid predation may lead to a similar shift in age-class composition, since most large oligotrophic lakes are managed for coldwater fisheries that consist of stocked yearling landlocked salmon and Rainbow Trout and self-sustaining Lake Trout populations.

Both lakes sampled exhibited high percentages of male smelt ($\geq 76\%$) in spawning runs, which is typical (Lischka and Magnuson 2006, Kendall 1927). Hoover (1936b) noted the percentage of males in the spawning run fluctuated during the night, with females only being prevalent during certain time periods. Lischka and Magnuson (2006) and Bailey (1964) reported that male smelt were most abundant at the start of the spawning run, followed by a change in the sex ratio that approaches 50:50 (male/female) during the peak, and reverts back to predominantly males at the end of the run. Male dominance in spawning runs can be attributed to the differential spawning behavior of male and female smelt (Brown 1994). Females tend to ascend a tributary and complete spawning in a single night, whereas males repeatedly return to streams throughout the spawning season (Bailey 1964). Lischka and Magnuson (2006) reported that female smelt, upon ripening, entered the spawning grounds (shoreline cobble substrate) and spawned with the male smelt found swimming along the shoreline. When spawning ceased, female smelt returned to open (deeper) water and male smelt returned to their pattern of random shoreline distribution.

RECOMMENDATIONS

Monitoring Rainbow Smelt tributary spawning runs is one of several assessment tools used to aid in the determination of annual landlocked salmon, and to a lesser degree Rainbow Trout, stocking rates. There is a critical need to fine-tune the stocking rate of salmonids in order to protect Rainbow Smelt spawning stocks, and when possible, to utilize abundant Rainbow Smelt populations to generate optimal salmonid growth and body condition. Therefore, smelt populations should continue to be monitored as closely as possible. Through annual hydro-acoustic and trawl net sampling, and the monitoring of select spawning tributaries, indications of Rainbow Smelt abundance and age-class distribution can be obtained.

Due to time and personnel constraints, it is difficult to obtain representative samples of Rainbow Smelt from numerous water bodies with tributary spawning runs; ideally, multiple tributaries should be sampled on several different nights during various times of night.

Table 1. Dates spawning Rainbow Smelt were sampled from tributaries to two New Hampshire lakes in 2015.

Lake	Tributary	Date	Water Temperature Range C°
Cedar	Cedar Brook	30 April, 04 May 2015	4.4
Winnepesaukee	Poor Farm Brook	13 April 2015	4.39

Table 2. Percent (%) age composition data for spawning Rainbow Smelt sampled from tributaries to two New Hampshire lakes in 2015.

Lake	Tributary	Age 1	Age 2	Age 3	Age 4
Cedar	Cedar Brook	0	85%	9%	6%
Winnepesaukee	Poor Farm Brook	99%	1%	0	0

Table 3. Sex ratios (percent males) of spawning Rainbow Smelt sampled from tributaries to two New Hampshire lakes in 2015.

Lake	Tributary	Percent Males
Cedar	Cedar Brook	76%
Winnepesaukee	Poor Farm Brook	100%

Table 4. Sample size (N), mean total length (mm), standard deviations (\pm SD), and length range of spawning Rainbow Smelt sampled from tributaries to two New Hampshire lakes in 2015.

Lake/Pond	Tributary	Sex	Sample Size	Mean Length (\pm SD)	Length Range
Cedar	Cedar Brook	Inclusive	153	103 (6.6)	84-126
		Male	117	103 (6.9)	84-126
		Female	36	103 (5.5)	90-111
Winnepesaukee	Poor Farm Brook	Male	101	66 (4.9)	57-89

Table 5. Results from Student's t-Test (P two-tail ≤ 0.05) comparison between 2015 and long-term (1986-2014) mean total length (TL mm) for Lake Winnepesaukee age-1 male Rainbow Smelt.

Lake Winnepesaukee	Long-Term N	Long-Term Mean TL	2015 N	2015 TL	Student's t-Test
Male Age-1	2328	70	100	66	*P=<0.001

*Denotes significant difference

Table 6. Mean total length (mm), standard deviation (\pm SD), sample size (N) and total length range for age-1 spawning Rainbow Smelt sampled from Lake Winnepesaukee in 2015.

Tributary	Length	SD	N	Range
Poor Farm Brook	66	4.91	101	57-89

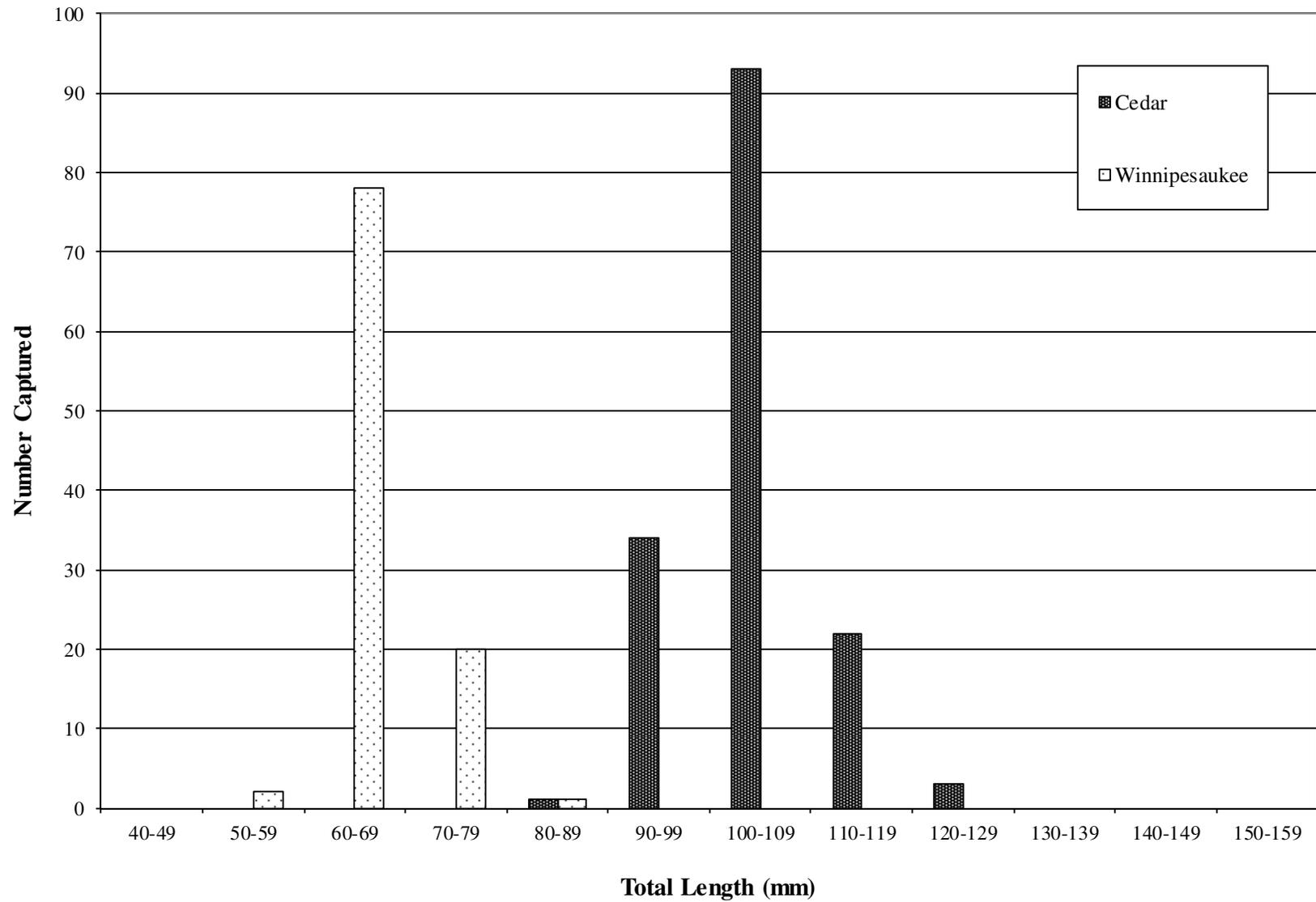


Figure 1. Length-frequency distributions of spawning Rainbow Smelt sampled from two New Hampshire lakes, spring 2015.

APPENDIX I

Table 1. Age-length key (%) for spawning Rainbow Smelt sampled from Cedar Brook, Cedar Pond tributary, 2015.

Length Interval (mm)	N	Age 1	Age 2	Age 3	Age 4
80-89	0				
90-99	8		100		
100-109	33		100		
110-119	8		40	60	
120-129	3				100

Table 2. Age-length key (%) for spawning Rainbow Smelt sampled from Poor Farm Brook, Lake Winnepesaukee tributary, 2015.

Length Interval (mm)	N	Age 1	Age 2	Age 3
50-59	2	100		
60-69	78	100		
70-79	20	100		
80-89	1		100	

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