POPULATION ASSESSMENT OF TRIBUTARY-SPAWNING RAINBOW SMELT IN SELECTED NH LAKES

STATE: New Hampshire

GRANT: F-50-R-28

GRANT TITLE: Anadromous and Inland Fisheries Operational Management Investigations

JOB 9: Forage Fish Population Assessment

PERIOD COVERED: July 1, 2011 – June 30, 2012

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This project was funded in part by the purchase of fishing equipment and motorboat fuels through the Federal Sport Fish Restoration Program.

EXECUTIVE SUMMARY

The study objectives were to determine the size characteristics, age composition and sex ratio of rainbow smelt spawning in selected tributaries to Winnipesaukee and Newfound lakes and Cedar Pond.. 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 runs in Winnipesaukee (Poor Farm Brook), and Newfound Lake (Georges Brook). Mean total length of spawning rainbow smelt in Newfound Lake (79 mm), was higher than Lake Winnipesaukee (71 mm). The predominance of age 1 rainbow smelt in spawning runs is unusual; it is likely that the age composition observed in both lakes is indicative of high mortality rates caused in part by salmonid (landlocked salmon, rainbow trout, and lake trout) predation.

Male rainbow smelt were dominant in both spawning runs, ranging from 66-97%. 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.

In 2012, there was no significant difference in age 1 male rainbow smelt mean total length in Lake Winnipesaukee when compared to the long-term mean (P=1.000). In Newfound Lake, the mean total length of age 1 male rainbow smelt was significantly greater than the long-term mean (P=<0.001).

INTRODUCTION

Rainbow smelt (*Osmerus mordax*) are an essential source of forage for landlocked salmon (*Salmo salar*) 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, Winnipesaukee 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 three 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 Winnipesaukee, the largest lake in New Hampshire, is 18,051 ha. It is oligotrophic with moderate chlorophyll-a (mean of 2.45 µg/L), and an MEI[1] of 0.88 (NHDES 1992). Lake Winnipesaukee is a deep, thermally stratified[2] lake with maximum and mean depths of 55 m and 13 m, respectively.

Newfound Lake is oligotrophic with a relatively low chlorophyll a level of 1.42 µ/L (NHDES 1994). Newfound is a deep lake, with a maximum depth of 55.5 m, mean depth of 22.5 m, and an MEI value of 0.29

Cedar Pond, is a productive, mesotrophic pond with a rather high chlorophyll-a level (10.03 µg/L), (NHDES 1994). Cedar Pond is moderately deep with a maximum depth of 17 m and mean depth of 9.4 m, and an MEI value of 1.37.

METHODS

Sampling of Spawning Rainbow Smelt

Random samples of spawning rainbow smelt were obtained between 2100 and 2400 hours from tributaries to Winnipesaukee Lake (Poor Farm Brook), Newfound Lake (Georges Brook) and Cedar Pond (Cedar Brook), (Table 1). Smelt were collected using a long handled (2.4 m) net (38

[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] All three study lakes thermally stratify.

cm diameter) with 9 mm wire mesh. A minimum of 100 smelt were netted from each tributary. Total length (mm), weight (g) and sex (male/female) were recorded for each fish. A subsample of five fish was kept for each 10 mm length interval for age determination.

Age Determination

Age data was derived from scales collected from smelt in 10 mm length increments. Scale samples were wet-mounted on glass slides and viewed under variable magnification (10.5x – 45x) with a Leica compound dissecting microscope. Through the scale reading process, smelt were aged and assigned to one of two groups; age 1 and >age 1. Two individuals examined scales independently and when agreement on an age could not be reached it was excluded from the analysis. Age data for Cedar Pond smelt was not obtained.

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 2012 and the long-term means for Winnipesaukee and Newfound lakes. Age data was used to construct age-length keys (Ricker 1975) for the two lakes sampled (Appendix I, Tables 1, 2). The age-length keys were used to partition overall length-frequency data into two age groups (age 1 and >age 1) of rainbow smelt.

RESULTS

Age Composition and Sex Ratio

Rainbow smelt spawning runs were sampled from 20 March to 19 April, with water temperatures ranging from 5.2°C to 8.9°C (Table 1). Age 1 rainbow smelt dominated the spawning runs in Winnipesaukee Lake (Poor Farm Brook) and Newfound Lake (Georges Brook), (Table 2). Male rainbow smelt were dominant in all three spawning runs, ranging from 66-97% (Table 3). The mean length of age 1 spawning rainbow smelt was greatest in Newfound Lake (Table 6).

Size Characteristics

Mean total length of spawning rainbow smelt was greatest in Newfound Lake (79 mm) and slightly lower in Lake Winnipesaukee (71 mm) (Table 4, Figure 1). The greatest length range occurred in Newfound Lake (70-122), followed by Lake Winnipesaukee (62-76 mm) (Table 4). In 2012, age 1 male rainbow smelt mean total length in Newfound Lake was significantly greater ($P=<0.001$), while Lake Winnipesaukee showed no significant difference when compared to the long-term means for these lakes (Table 5). Both Newfound and Winnipesaukee lakes, exhibited low peak length frequencies (70-79 mm), primarily due to the high number of age 1 smelt in these spawning runs (Table 2). The peak length frequency for Cedar Pond was (110-119 mm). The maximum size attained by spawning rainbow smelt was at Cedar Pond (132 mm) (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 Winnipesaukee and it would appear this pattern continues today. Lake Winnipesaukee 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 Winnipesaukee 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 Winnipesaukee (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 pers. com.). Also, it is likely that the age composition observed at Lake Winnipesaukee, 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.

All three lakes sampled exhibited high percentages of male smelt ($\geq$66%) 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 three New Hampshire lakes in 2012.

Lake	Tributary	Date	Water Temperature C°
Winnipesaukee	Poor Farm Brook	27,29-March	5.2
Newfound	Georges Brook	20-March	6.9
Cedar	Cedar Brook	19-April	8.9

Table 2. Percent (%) age composition data for spawning rainbow smelt sampled from tributaries to three New Hampshire lakes in 2012.

Lake	Tributary	Age 1	>Age 1
Winnipesaukee	Poor Farm Brook	100	0
Newfound	Georges Brook	88	12
Cedar	Cedar Brook	*	*

* Data not obtained

Table 3. Sex ratios (percent males) of spawning rainbow smelt sampled from tributaries to three New Hampshire lakes in 2012.

Lake	Tributary	Percent Males
Winnipesaukee	Poor Farm Brook	97
Newfound	Georges Brook	94
Cedar	Cedar Brook	66

Table 4. Sample size (N), mean total length (mm), standard deviations (±SD), and length range of spawning rainbow smelt sampled from tributaries to three New Hampshire lakes in 2012.

Lake	Tributary	Sex	Sample Size (N)	Mean Length (±SD)	Length Range
Winnipesaukee	Poor Farm Brook	Both	37	71 (3)	62-76
		Male	36	70 (3)	62-76
		Female	1	74 (1)	74
Newfound	Georges Brook	Both	110	79 (8)	70-122
		Male	103	78 (7)	70-122
		Female	7	90 (18)	74-111
Cedar Pond	Cedar Brook	Both	100	116 (6)	101-132
		Male	66	116 (6)	104-132
		Female	34	116 (7)	101-127

Table 5. Results from Student's t-Test (P two-tail $\leq$0.05) comparison between 2012 and long-term mean total length (TL mm) for age-1 male rainbow smelt from two New Hampshire lakes in 2012.

Male Age-1	Long-Term N	Long-Term Mean TL	2012 N	2012 TL	Student's t-Test
Winnipesaukee	2185	70	36	70	(P=1.000)
Newfound	1174	70	98	77	*(P=<0.001)

*Denotes significant difference

Table 6. Mean length (mm), standard deviation ($\pm$SD), sample size (N) and total length range for age 1 spawning rainbow smelt sampled from two New Hampshire lakes in 2012.

Lake/Tributary	Length	SD	N	Range
Winnipesaukee / Poor Farm Brook	71	3	37	62-76
Newfound / Georges Brook	76	3	97	70-82

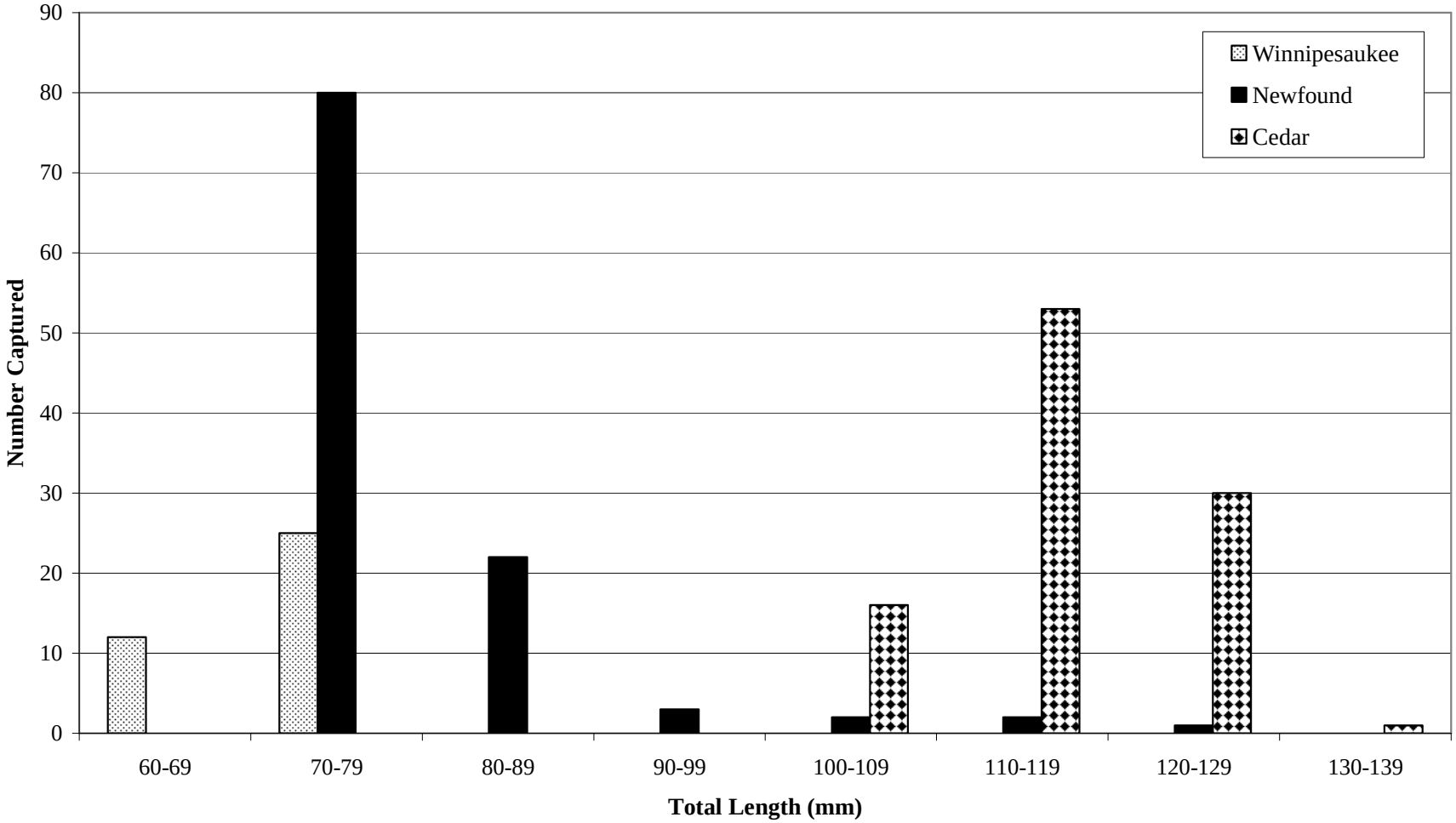

Figure 1. Length-frequency distributions of spawning rainbow smelt sampled from Winnipesaukee, Newfound, and Cedar lakes spring 2012.

APPENDIX I

Table 1. Age length key (%) for spawning rainbow smelt sampled from Poor Farm Brook, a tributary to Lake Winnipesaukee, in 2012.

Length Interval (mm)	N	Age 1	>Age 1
60 - 69	12	100	
70 - 79	25	100	

Table 2. Age length key (%) for spawning rainbow smelt sampled from Georges Brook, a tributary to Newfound Lake, in 2012.

Length Interval (mm)	N	Age 1	>Age 1
70 - 79	80	100	
80 - 89	22	80	20
90 - 99	3		100
100 - 109	2		100
110 - 119	2		100
120 - 129	1		100

ACKNOWLEDGMENTS

I would like to thank John Viar, NHFG Region 2 Fisheries Biologist, for collecting smelt samples, performing statistical tests and production of graphical images of the smelt data. I would also like to thank Region 1 Fisheries Biologist Andy Schafermeyer for collecting the smelt sample from Cedar Pond.

LITERATURE CITED

Anderson, R.O. and R.M. Nuemann. 1996. Length, weight, and associated structural indices. Pages 447-482 *in* B.R. Murphy and D.W. Willis, editors. Fisheries Techniques, 2nd Edition. American Fisheries Society, Bethesda, Maryland.

Bailey, M.M. 1964. Age, growth, maturity, and sex composition of the American smelt, (*Osmerus mordax*) (Mitchill), of western Lake Superior. Transactions of the American Fisheries Society 93:382-395.

Brown, R.W. 1994. Reproduction, early life history, and recruitment of rainbow smelt in St. Martin Bay, Lake Huron. Doctoral dissertation. Michigan State University, East Lansing. 176p.

Hoover, E.E. 1936a. Preliminary Biological Survey of Some New Hampshire Lakes, Survey Report No. 1. New Hampshire Fish and Game Department, Concord, N.H.

Hoover, E.E. 1936b. The spawning activities of fresh water smelt; with special reference to sex ratio. Copeia, No. 2 85-89.

Kendall, W.C. 1927. The smelts. Bulletin of the Bureau of Fisheries. Volume XLII. 375p.

Lischka, S. A., and Magnuson, J.J. 2006. Timing and site selection of spawning in a landlocked population of rainbow smelt in Wisconsin. Environmental Biology of Fishes. Springer Science and Business Media.

NHFGD (New Hampshire Fish and Game Department). 1982. Fisheries management plan for rainbow smelt (*Osmerus mordax*). New Hampshire Fish and Game Department, Concord. 11p.

LITERATURE CITED (cont.)

NHDES (New Hampshire Department of Environmental Services). 1990. New Hampshire lakes and ponds inventory. Vol. VI.

NHDES (New Hampshire Department of Environmental Services). 1992. New Hampshire lakes and ponds inventory. Vol. VIII.

NHDES (New Hampshire Department of Environmental Services). 1994. New Hampshire lakes and ponds inventory. Vol. X.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191:382p.

Rupp, R.S. 1965. Shore-spawning and survival of eggs of the American Smelt. Trans. Am. Fish. Soc. 94:160 – 168.

Rupp, R.S. 1968. Life history and ecology of the smelt (*Osmerus mordax*) in inland waters of Maine. Maine Department of Inland Fisheries and Wildlife, Augusta. 36p.

Seamans, R.G. and A.E. Newell. 1973. Management of lake Atlantic salmon (*Salmo salar*) in New Hampshire. Survey report No. 10. New Hampshire Fish and Game Department. Concord, N.H. 14pp.

Viar, J.A. 2010. Abundance of forage fish in selected New Hampshire lakes, 2010. F-50-R-26, Job 9. New Hampshire Fish and Game Department. Concord, NH.