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Notes

Contribution of lake trout stocked as fry to an adult population in Lake Superior

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ABSTRACT

Lake trout *Salvelinus namaycush* fry treated with heated water to create thermal marks in their otoliths were stocked at Sve's Reef in Minnesota waters of Lake Superior in 1994, 1995, and 1996. These fish began to reach maturity in 2000, and were vulnerable to annual assessment gill nets set at several locations along the Minnesota shoreline. Captured fish also included fin-clipped lake trout stocked as yearlings, and naturally reproduced (wild) lake trout. Otoliths from 3106 unclipped lake trout were aged and examined for thermal marks from 2000 to 2007, of which 1152 were from the target year classes (1994–1996). Thermal marks were found in otoliths from 64 fish, or 5.6% of those in the target year classes, demonstrating that stocked fry contributed to the adult lake trout population in Minnesota waters. Although numbers of recaptured fish were too low to demonstrate statistically significant differences, higher recapture rates of marked fish at Sve's Reef in fall and spawning assessments suggest that these fish may have imprinted at the stocking location and homed back to this area to spawn. Wild lake trout populations in Lake Superior may be approaching fully rehabilitated levels, but recovery in the lower Great Lakes has progressed more slowly, and evidence of success with fry stocking could benefit those populations.

Introduction

An evaluation of fry stocking as a lake trout *Salvelinus namaycush* rehabilitation strategy was initiated from 1994 to 1996 in Minnesota waters of Lake Superior when fry were stocked on Sve's Reef near the Split Rock River (Fig. 1; Negus, 1999, 2009). These fry were thermally marked by subjecting them to periods of heated water soon after hatching, which induced unique banding patterns in their otoliths. Identification of thermal marks in the otoliths of recaptured lake trout provided a means to positively track the efficacy of fry stocking, and the contribution of these fish to the adult and spawning populations in this region.

Lake trout are the native top predator in Lake Superior, and they are particularly suited to the cold deepwater food chain (Eshenroder et al., 1995b), but populations suffered severe declines in the 1950s due to an intense fishery and sea lamprey *Petromyzon marinus* predation (Hansen et al., 1995). The Great Lakes Fishery Commission (GLFC) has promoted reestablishment of lake trout in all the Laurentian Great Lakes (GLFC, 2001), and efforts to reestablish lake trout by stocking yearlings (marked with a fin clip) into the Great Lakes have met with varying success. Spawning populations have not been established at some historical spawning reefs despite continued stocking (Eshenroder et al., 1995a; Krueger et al., 1986; Selgeby, 1995). The survival of stocked lake trout has been declining in U.S. waters of Lake Superior since the late 1970s, probably due to predation by wild lake trout, and gill net fishing (Hansen et al., 1996). Although recovery has been slow in Lake Superior (Hansen et al., 1995; Schreiner and Schram, 1997), wild lake trout abundance has increased and may be approaching fully rehabilitated levels (Ebener, 2007; Schreiner et al., 2006). Unfortunately, recovery of populations in the lower Great Lakes has progressed more slowly (Hansen, 1999; Krueger et al., 1995), and evidence of successful rehabilitation with fry stocking may benefit those populations.

Wild lake trout tend to return to the vicinity of their natal reefs to spawn (Bronte et al. 2007; Kapuscinski et al. 2005; Krueger et al. 1986), but yearling lake trout stocked directly onto reefs failed to imprint, providing evidence that imprinting occurs at an earlier life stage (Krueger et al. 1986). Lake trout stocked as yearlings, regardless of stocking location, tend to spawn in shallow water along shorelines where wave action, ice scour, and siltation limit egg survival (Eshenroder et al., 1995a; Krueger et al., 1986; Peck, 1979). Stocking of eggs or sac fry directly onto historical spawning reefs where natural reproduction is low or absent, in the season when that life stage would normally be found in the wild, has been recommended to promote imprinting and survival of lake trout and their progeny (Eshenroder et al., 1995b, 1999; Horrall, 1981; Marsden et al., 1995). Citing these reasons, recent lake trout rehabilitation plans for most of the Great Lakes include the stocking of early life history stages to reduce time to rehabilitation (Bronte et al., 2008; Ebener, 1998; Hansen, 1996; Markham et al., 2008), though evidence of successful fry stocking has been lacking.

Early life history stages are economical to stock and provide benefits in terms of imprinting and genetic fitness, but evaluation of

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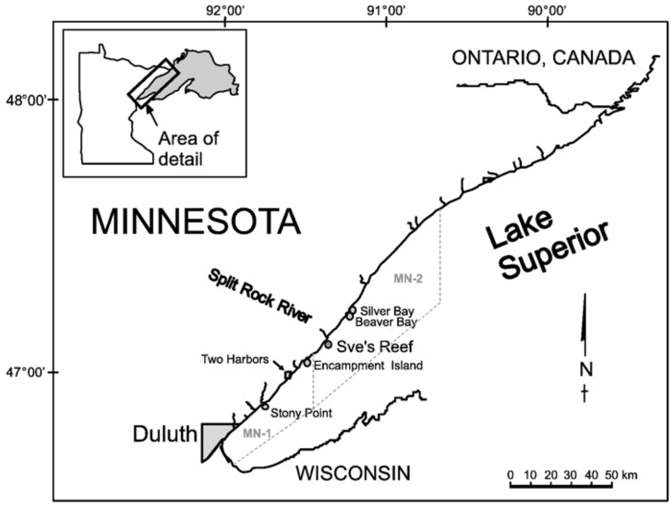

Fig. 1. Lake trout assessment netting locations in Lake Superior, where otoliths were obtained for aging and thermal mark evaluation. Thermally marked lake trout fry were stocked at Sve's Reef in 1994, 1995, and 1996. Dashed lines demarcate Minnesota's lake trout management zones MN-1 and MN-2.

their long-term contribution requires the application of persistent and identifiable marks. Eggs have been stocked in artificial-turf incubators in Lake Superior (Bronte et al., 2002; Swanson, 1982), but survival of these fish must be inferred indirectly from increases in population abundance of the stocked year classes. Thermal marks have been used in Pacific salmon *Oncorhynchus* spp. for identification and management of stocks in Washington and Alaska (Blankenship and Volk, 1991; Hagen et al., 1995; Munk et al., 1993; Volk et al., 1994). Lake trout fry with thermal marks in their otoliths were stocked on an offshore Lake Huron reef (Bergstedt et al., 1990), but survival of these fry was never confirmed.

Lake trout populations in Minnesota waters of Lake Superior are monitored annually by Minnesota Department of Natural Resources (MNDNR) Lake Superior Area personnel using small-mesh and large-mesh gillnets, and spawning populations are sampled with large-mesh gillnets in odd-numbered years. The small-mesh nets target juvenile lake trout (ages 3–6), and the large-mesh nets target adult lake trout (ages 6 and older) (Schreiner et al., 2006). Thermally marked fish in the 1994–1996 year classes were expected to reach maturity beginning as early as 2000–2002, although most spawning lake trout are older than age 7 (Bronte et al., 2002). Recapture of thermally marked fish in spawning condition could be expected in the alternate-year spawning assessments from 2001 to 2007 (the final year of this study), and probably for many years after. The objectives of the current study were to evaluate the effectiveness of fry stocking in Minnesota waters of Lake Superior; to determine if fish stocked as fry imprint on their stocking reef and return to that location in preparation for spawning; and to evaluate the effectiveness of thermal marking as a lake trout stock identification tool. In addition, the potential application of fry stocking to the other Laurentian Great Lakes is discussed.

Methods

Lake trout fry stocking was conducted in Minnesota waters of Lake Superior from 1994 to 1996, when approximately 1,450,000 fry (551,100 fry in 1994; 540,100 fry in 1995; and 358,000 fry in 1996) were stocked on Sve's Reef near the Split Rock River (Fig. 1). This reef is located about 0.15 km to 0.5 km offshore, and encompasses about 0.1 km^2. Prior to stocking, the reef was examined by scuba divers to ensure that it was composed of rocky substrate with prevalent interstitial spaces, which characterize good spawning habitat (Fitzsimons, 1995; Marsden et al., 1995; Schreiner et al., 1995). Although this emergent reef is located fairly near shore, the bottom slopes steeply, and the offshore side of the exposed portion drops quickly to > 15 m in depth. Stocking was accomplished by flushing the fry through a funnel/hose apparatus to within 3 m of the reef surface to ensure that the fry were delivered to the intended location (Negus, 1998).

During incubation after hatching, fry were subjected to periodic episodes of heated water to create thermal marks in their otoliths, and patterns were varied each year to distinguish year classes (Negus, 1999). The pattern applied in 1994 consisted of two sets of five closely-spaced bands created by heated water treatments on five consecutive days; in 1995, the mark consisted of repeated three-band clusters created by heated water treatments on three consecutive days; and in 1996, the mark consisted of repeated sets of four widely-spaced bands created by applying four heated water treatments on alternate days. Marked fry were stocked during the first week of May each year, which was about 7 weeks after hatching for most fish, when the yolk sacs were nearly absorbed. In 1994, however, about 117,000 fry did not hatch until mid-April due to cooler incubation temperatures, and at the time of stocking just three weeks later, their yolk sacs were still large (Negus, 1998). The stocked fry supplemented natural reproduction by wild populations, and together they are referred to as "unclipped" lake trout. These unclipped fish could be

Table 1
Sampling locations, assessment season, and numbers of lake trout otoliths examined for thermal marks from 2000 to 2007. Spring gill net assessments were conducted in May, the late spring "siscowet" assessment was in June, summer assessments were in July, fall assessments were in September, and spawning assessments were conducted in October and November. One immature marked fish, caught at Sve's Reef in summer, was eliminated from this list. Target year class fish were limited to those ≥age 6.

Capture location	Season (target)[a]	Assessment frequency	Gill net mesh size (stretch)	Total samples	Number in target year classes	Number marked
Beaver Bay	Spring	Annual	11.4 cm	561	217	10
Stony Point	Spring	Annual	11.4 cm	14	3	1
Sve's Reef	Spring	Annual	11.4 cm	1035	424	22
Two Harbors	Spring	Annual	11.4 cm	106	29	1
Two Harbors	Late spring (siscowet)	Every 3 yrs	All sizes	14	4	0
Encampment Island	Summer	Annual	3.8–6.4 cm	25	8	1
Silver Bay	Summer	Annual	3.8–6.4 cm	39	9	0
Sve's Reef	Summer	Annual	3.8–6.4 cm	82	9	0
Two Harbors	Summer	Annual	3.8–6.4 cm	1	0	0
Beaver Bay	Fall	Annual	11.4 cm	234	87	3
Stony Point	Fall	Annual	11.4 cm	23	4	
Sve's Reef	Fall	Annual	11.4 cm	457	197	16
Two Harbors	Fall	Annual	11.4 cm	179	67	5
Stony Point	Spawning	Odd-numbered years	14.0 cm	58	15	0
Sve's Reef	Spawning	Odd-numbered years	14.0 cm	278	79	5
Total				3106	1152	64

[a] If other than from lean lake trout.