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Recruitment of lake trout in Lake Champlain

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ABSTRACT

Lake trout were extirpated from Lake Champlain by 1900, and are currently the focus of intensive efforts to restore a self-sustaining population. Stocking of yearling lake trout since 1972 has re-established adult populations, spawning occurs at multiple sites lake-wide, and fry production at several sites is very high. However, little to no recruitment past age-0 has occurred, as evidenced by the absence of adults without hatchery fin clips in fall assessments; no regular sampling for juveniles is conducted. We began focused sampling for juvenile lake trout in fall, 2015, in the Main Lake using bottom trawling, and expanded sampling to sites in the north and south of the lake in 2016. In 2015 we collected 303 lake trout < 350 mm total length, of which 23.8% were unclipped. Based on non-overlapping length modes, these wild fish comprised at least three age classes (young-of-year, age-1, and age-2). In 2016, we collected 1215 lake trout < 350 mm, including a fourth wild year class (2016 young-of-year). Forty-nine percent of juvenile lake trout from the Main Lake were unclipped; however, only 20% from the north lake and 9% from the south lake were unclipped. The absence of older unclipped fish indicates that recruitment of wild fish began recently. We discuss several hypotheses to explain this sudden, substantial recruitment success, and factors that may be affecting lake trout restoration in Lake Champlain and the Great Lakes.

Introduction

Restoration of self-sustaining populations of lake trout (*Salvelinus namaycush*) in the Great Lakes and Lake Champlain has been an elusive goal. Native lake trout populations collapsed in the lower Great Lakes in the 1950s and 1960s as a consequence of commercial harvest and predation by invasive sea lamprey (*Petromyzon marinus*; Krueger and Ebener, 2004; Muir et al., 2012). High survival of lake trout stocked as yearlings has re-established populations in all of the lakes (Hansen et al., 1995). Spawning and fry emergence have been documented throughout the lakes (e.g., Anderson and Collins, 1995; Hanson et al., 2013; Jude et al., 1981; Marsden et al., 1988, 2005), but absence of wild yearling and older lake trout for several decades suggested that a bottleneck was present between fry emergence and survival to the first year. Evidence of natural recruitment into the spawning population appeared first in Lake Superior, as remnant wild stocks began to recover, then in Parry Sound and the main basin of Thunder Bay, Lake Huron (Hansen et al., 1995; Johnson and VanAmberg, 1995; Nester and Poe, 1984; Reid et al., 2001; Riley et al., 2007; He et al., 2012; Johnson et al., 2015; Madenjian et al., 2017). More recently, several consecutive years of wild recruitment have been documented in western Lake Michigan (Hanson et al., 2013), and western Lake Ontario, where natural recruits up to age-4 have been noted (Brian Lantry, USGS, pers. comm.).

In Lake Champlain, lake trout were extirpated around 1900, but the causes of their disappearance are not known (Plosila and Anderson, 1985). Commercial harvests were limited to shoreline seining and were closed by the early 1900s; there were no published reports of lamprey wounding, suggesting that lamprey abundance was low (Marsden and Langdon, 2012). Sporadic lake trout stocking in the late 1800s was unsuccessful at producing a feral population (Anderson, 1978; Halnon, 1963). Moderate annual stockings beginning in 1958 produced a limited localized lake trout fishery (Plosila and Anderson, 1985). Sustained stocking began in 1973; multiple strains were used, but the majority originated from Seneca Lake, NY. An average of 171,000 yearling-equivalent lake trout (5 fall fingerlings = 1 spring yearling) were stocked annually until 1995 (Fig. 1). Sea lamprey wounding rates, approaching 100 wounds per 100 lake trout in some years, motivated initiation of an experimental sea lamprey control program in 1990. The success of this program at reducing wounding rates and improving survival led to establishment of a long-term sea lamprey control program in 2002 (Marsden et al., 2010). Lake trout stocking was reduced to an average of 83,250 yearling-equivalent lake trout in 1996, due to concerns that rainbow smelt (*Osmerus mordax*) populations, which are native in Lake Champlain and comprise the majority of the salmonid forage

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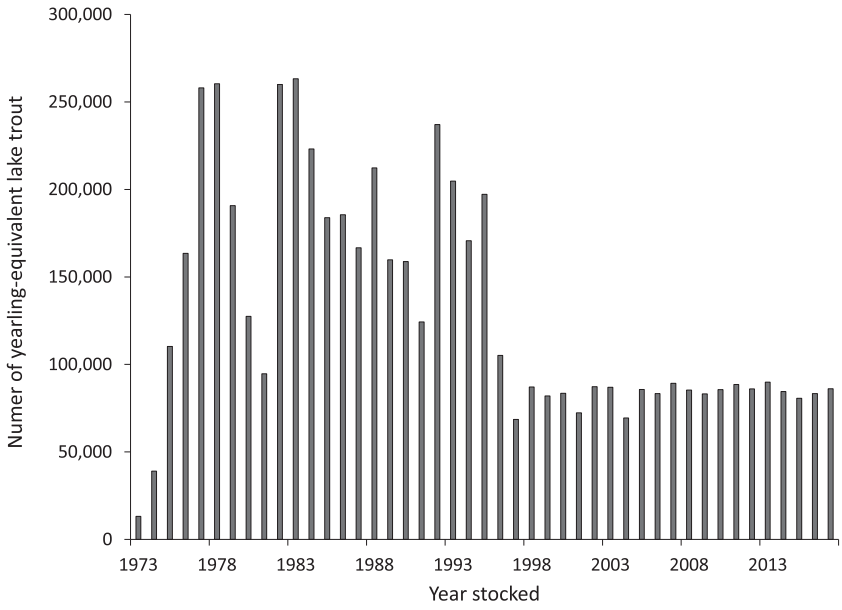

Fig. 1. Number of yearling-equivalent lake trout stocked in Lake Champlain from 1973 to 2016 (5 fall fingerlings are equivalent to 1 spring yearling).

base, would decline as lake trout survival increased. All lake trout were stocked as spring yearlings through spring 1999, when Vermont began to stock fall fingerlings while New York continued to stock spring yearlings. These "fall fingerlings" were the size of yearlings and converted 1:1 as yearling equivalents.

The early goal of lake trout stocking in Lake Champlain was to re-establish a fishery (Fisheries Technical Committee, 1977); however, the 2010 Strategic Plan for Lake Champlain Fisheries revised the goal to include progress toward a self-sustaining population, similar to the goal in the Great Lakes (Marsden et al., 2010). All stocked lake trout are marked, with a five-year rotation of fin clips (paired fins or the adipose fin). Stocked lake trout spawn at multiple sites in Lake Champlain, and fry production is high (Ellrott and Marsden, 2004, Ladago et al., 2016, Marsden et al., 2005). Wounding rates and prevalence of unclipped adult fish are assessed annually in fall at two spawning sites, Gordon Landing on Grand Isle (where lake trout spawn on cobble associated with a breakwall) in the north and Whallon Bay, a natural reef in the south (Fig. 2); no juvenile surveys are conducted. Since 2002, the percentage of unclipped fish has not exceeded 2%, below the level expected from missed clips and regrown fins.

Lack of progress toward lake trout restoration in Lake Champlain, as in the Great Lakes, appears to be due to high mortality in the first year, as survival of stocked yearlings is sufficient to maintain the population. To understand what factors limit recruitment of wild lake trout, early life stages should be sampled. Intensive bottom trawling to collect juvenile lake trout in 2006 and 2007 at two sites with high fry captures (Gordon Landing and Arnold Bay) yielded only eight lake trout, all age-2 and age-3 fin-clipped fish, in 1431 min of trawling (Riley and Marsden, 2009). An additional 42 juvenile lake trout, age-1 to age-3, were caught incidentally in bottom trawls between 2001 and 2012 but all were fin-clipped (Ellrott and Marsden, 2004; Riley and Marsden, 2009). In 2015, we again began focused sampling for juvenile lake trout in the fall, and collected several size classes of juveniles, including unclipped lake trout. In 2016, we initiated a sampling program for juvenile lake trout, including intensive sampling in the Main Lake and extensive sampling throughout the lake. Our goal was to document the distribution of juvenile lake trout, particularly young-of-year wild fish, and quantify recruitment of wild fish into yearling and older year classes.

Methods

We used a three-in-one bottom trawl (DeAlteris et al., 1989) with a 8 m headrope, 9.3 m footrope with chains attached, 1.25 mm stretch cod end liner, towed at 5.5 km/h. Tows were 20 min unless obstructions required early retrieval. Tows were done from 15 June to 13 November 2015 and 5 May to 10 November 2016. Depth of the thermocline was measured on the same date as trawling or within two days. Trawling depths ranged from 22 to 68.6 m, with the majority of tows between 35 and 55 m; tows were focused at the lower edge of the thermocline, and at 5–10 m intervals above and below that level. In 2015, we initially targeted the area offshore from Gordon Landing, where the highest densities of lake trout spawners, eggs, and fry have been collected (Ellrott and Marsden, 2004; Marsden et al., 2005), then expanded sampling to the Main Lake, within 3.5 km of Burlington. In 2016, we focused sampling in the Main Lake west of Burlington, sampling every two weeks; due to mechanical problems only a single tow was done in August and September. On single days in spring, mid-summer, and fall we did tows as far south as Arnolds Bay and as far north as Hazen Point on the island of North Hero (Fig. 2, Table 1). All lake trout were measured (total length) and assessed for fin clips. All bycatch species were counted, or their number was estimated. Catch per unit effort (CPUE) was calculated as total number of lake trout per 10 min of trawl time.

To assess survival rates, sea lamprey wounding and proportion of unclipped fish, the Vermont Department of Fish and Wildlife (VTDFW) and New York Department of Environmental Conservation (NYDEC) sampled lake trout annually in summer from 1982 to 1997 using gillnets that targeted fish age-3 and older (Marsden et al., 2003). The agencies conducted fall sampling to assess spawning lake trout in the south lake (Split Rock to Westport on the NY side, Button Bay and Arnold Bay on the Vermont side) until 1990. Since 1990, fall sampling occurred at Whallon Bay; annual sampling at Gordon Landing began in 1992 (Fig. 2).

Results

Juvenile lake trout were collected at all sites sampled, with the exception of Fields Bay, VT (one trawl); CPUE ranged from 0.04 to 17.2

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