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Sea lamprey mark type, marking rate, and parasite–host relationships for lake trout and other species in Lake Ontario

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ABSTRACT

We examined how attack frequency by sea lampreys on fishes in Lake Ontario varied in response to sea lamprey abundance and preferred host abundance (lake trout >433 mm). For this analysis we used two gill net assessment surveys, one angler creel survey, three salmonid spawning run datasets, one adult sea lamprey assessment, and a bottom trawl assessment of dead lake trout. The frequency of fresh sea lamprey marks observed on lake trout from assessment surveys was strongly related to the frequency of sea lamprey attacks observed on salmon and trout from the creel survey and spawning migrations. Attack frequencies on all salmonids examined were related to the ratio between the abundances of adult sea lampreys and lake trout. Reanalysis of the susceptibility to sea lamprey attack for lake trout strains stocked into Lake Ontario reaffirmed that Lake Superior strain lake trout were among the most and Seneca Lake strain among the least susceptible and that Lewis Lake strain lake trout were even more susceptible than the Superior strain. Seasonal attack frequencies indicated that as the number of observed sea lamprey attacks decreased during June–September, the ratio of healing to fresh marks also decreased. Simulation of the ratios of healing to fresh marks indicated that increased lethality of attacks by growing sea lampreys contributed to the decline in the ratios and supported laboratory studies about wound healing duration.

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Introduction

Sea lamprey (*Petromyzon marinus*) populations possess great potential to damage stocks of native and introduced fish species that support highly valued fisheries in the Great Lakes. While indices of that potential, based on sea lamprey and lake trout (*Salvelinus namaycush*) abundance, have been refined over the past thirty years, the presence of thriving populations of desirable alternate hosts continues to introduce substantial uncertainty into damage estimates (Bence et al., 2003; Christie and Goddard, 2003; Stewart et al., 2003). In reviews of research used to inform the Sea Lamprey Control Program (SLCP), wound healing time, the probability of a host surviving a sea lamprey attack, and the functional response of the parasite–host interaction in the presence of varying abundances of alternate hosts have been identified as substantial uncertainties (Bence et al., 2003; Stewart et al., 2003). Bence et al. (2003), in their examination of the parasite–host interaction analyses that influenced the SLCP process, indicated that great uncertainty exists around all estimates of host damage. To diminish uncertainty in SLCP model predictions of fish loss rates from juvenile sea lamprey, Stewart et al. (2003) recommended consolidating lake wide data on marking rate and host abundance, estimation of the maximum number of attacks, and the influence of alternate hosts on preferred host deaths due to sea lamprey attacks. Stewart et al. (2003) also recommended the exploration of less costly alternatives to stream treatment including the possibility of increasing lake trout host abundance through greater stocking levels or increased host survival.

Long-term datasets, seasonal observations, unique assessment series, and observed contrast in abundances over time make Lake Ontario an important location to study sea lamprey–host interactions. Marking data has been collected for lake trout in fishery independent

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assessment surveys conducted each September (U. S. Geological Survey (USGS), New York State Department of Environmental Conservation (NYSDEC), Ontario Ministry of Natural Resources (OMNR)) and from monthly community index gill netting (OMNR). Marking data has also been collected for Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*) and lake trout during a recreational fishing survey and from Chinook salmon, coho salmon, and rainbow trout spawning migration monitoring (NYSDEC and OMNR). These datasets, coupled with estimates of adult sea lamprey abundance from Fisheries and Oceans Canada (DFO)/U.S. Fish and Wildlife Service (USFWS) assessments, contain a record of the intensity of sea lamprey predation on lake trout and other species. In addition to these on-going surveys, past collections of lake trout carcasses from trawl surveys during 1982–1992 (Bergstedt and Schneider, 1988; Schneider et al., 1996) allowed unique, direct estimates of the number of lake trout killed by sea lampreys. Combined, these data series allow a retrospective examination of sea lamprey–host interaction dating back to the early 1980s in which contrast has been observed in the abundances of sea lampreys and lake trout, mortality of lake trout, and marking rates on other salmonids.

For most of the Lake Ontario lake trout restoration program, assessment data has been collected using consistent or comparable methods that have allowed examination of the status of the lake trout population and an indexing of the important sources of mortality (Elrod et al., 1995; Lantry and Lantry, 2011). Trends in lake trout abundance, sea lamprey abundance, and recreational catch have changed substantially since restoration began in the early 1970s. In Lake Ontario, sea lamprey control began in 1971, lake trout restoration stocking resumed in 1973, and a large population of adult lake trout accumulated by 1986 (Elrod et al., 1995). Lake trout restoration objectives included adult annual survivorship values of ≥60% and a sea lamprey marking rate on lake trout (>433 mm total length) of less than two fresh (A1) marks per 100 fish (King and Edsall, 1979; Ebener et al., 2003; Schneider et al., 1983, 1997). Large reductions in the number of fresh marks on lake trout occurred by 1983, sea lamprey population targets were approached by 1984, and marking rates were near or below target level during 1988–1996 (Larson et al., 2003; Lantry and Lantry, 2011). Poor recruitment of stocked yearlings after 1993 led to a 31% decrease in the adult stock during 1998–1999 and declines in lake trout of the size preferred (>433 mm) by sea lampreys by 1995. During 1997–2007, the marking rate on lake trout exceeded the target in 8 out of 11 years, and was double the target value in 2005 and 2007 (Lantry and Lantry, 2011). Coincident with declining lake trout numbers, creel survey data from U.S. waters indicated observations of sea lampreys attached to angler-caught Chinook salmon increased from a range of 1–3 sea lamprey per 1000 Chinooks during 1986–1995 to over 9 per 1000 in 1996, and up to 44 per 1000 by 2007 (Eckert, 2007; Lantry and Eckert, 2012). Patterns were similar for other stocked salmonids (i.e., coho salmon, brown trout, and rainbow trout). Our combination of data series allows examination of the rates of accumulation of mark types for lake trout from spring through fall, and comparison of marking rates to sea lamprey abundance and host abundance indices.

The goal of our work was to assemble all available Lake Ontario data that contains information on sea lamprey–host interactions to determine whether we can provide information that can refine estimates of damage caused by sea lampreys. Similar to recent evidence found in Lake Superior (Harvey et al., 2008), we hypothesized that lake trout are the preferred prey of sea lamprey. We predicted that the rate of sea lamprey marking on alternate hosts (e.g., Chinook salmon) would be proportional to sea lamprey abundance and inversely related to the abundance of lake trout. Our objectives were: 1) re-calculate indices based on 1982–1992 lake trout carcass trawling described in Schneider et al. (1996) adding in three additional years of sampling (1993–1995) and compare those indices to results from our other comparisons, 2) evaluate relationships between healing and fresh marks on lake trout and compare those to sea lamprey abundance, and 3) evaluate the relationship between sea lamprey abundance, lake trout abundance, and marking rates on lake trout and other species.

Methods

Data collection

Direct evidence of lake trout killed by sea lampreys was collected during October–November 1982–1995 using USGS/NYSDEC bottom trawl collections of lake trout carcasses in Lake Ontario at two sites each along the western, central and eastern portions of the south shore and at two sites in the eastern basin (hereafter: USGS/NYSDEC Carcass Survey). A complete description of the collection methods and a map depicting sampling locations are presented in Bergstedt and Schneider (1988) and Schneider et al. (1996). In general, lake trout carcasses were collected from October prey fish surveys using a 12 m head-rope trawl fitted with a 9 mm stretch mesh cod end and fished for 10 min along contours, and from trawling targeting carcasses in October and November using a 20 m head-rope trawl fitted with an 89 mm stretch mesh cod end and fished across contours for durations up to 120 min. Carcass density was determined from tow duration and area swept, measured by wing spread determined with Scanmar® acoustic sensors. Density was converted to total numbers by multiplying by the area within the 30–100, 100–160, and ≥160 m depth strata. From all recovered carcasses, length, sex, and fin clip were recorded and when present, coded wire tags were recovered and decoded. Tag information was used to determine strains and ages of carcasses.

Abundance, biological and marking data were collected from lake trout during two fishery independent surveys: The USGS/NYSDEC south shore September gill net assessment of adult lake trout (hereafter: USGS/NYSDEC SGNS) (Lantry and Lantry, 2011), and the OMNR June–November community index gill netting survey in northeastern Lake Ontario (hereafter: OMNR CIS) (Ontario Ministry of Natural Resources, 2011). During September 1983–2010, the USGS/NYSDEC SGNS collected lake trout with gill nets at random transects within 14 to 17 geographic areas distributed uniformly within U.S. waters of Lake Ontario. Survey gill nets consisted of nine, 15.2 × 2.4-m panels of 51 to 151 mm (stretched measure) mesh in 12.5 mm increments. Generally, four survey nets were fished along a transect set parallel to contours beginning at the 10 °C isotherm and proceeding deeper in 10-m increments. Survey design (e.g., size of geographic areas) and gill net construction (multi- vs. mono-filament netting) has changed through the years. For a description of survey history including gear changes and corrections and a map depicting sample locations see Elrod et al. (1995). From all fish, length, weight, sex, maturity, and counts and classifications of sea lamprey marks (King and Edsall, 1979; Ebener et al., 2003) were recorded. Fish were also checked for fin clips and coded wire tags and when present, tags were recovered, decoded and strains and ages were determined from tag information. The OMNR CIS was conducted in the summer months, normally June through August, with some variation over the years. Eight locations were fished in the main basin of Lake Ontario east of Brighton, and in the Kingston Basin. Bottom set gill net gangs consisting of ten 15. × 2.4 m panels of meshes between 68 and 151 mm (stretched measure) at 12.5 mm increments were used. The nets were set parallel to the bottom contours at depths between 7.5 and 27.5 m at 5 m bottom depth intervals. For all lake trout caught in the OMNR CIS length, weight, sex, diet, fin clip, and counts and classifications of sea lamprey marks were recorded. When present, coded wire tags were recovered and decoded for determining age and otoliths were collected for aging fish that did not have tags. For a more thorough description of survey methods and a map depicting sample locations, see Bowlby and Hoyle (2011).

Sport-fishing data for six species of trout and salmon (Chinook, coho and Atlantic salmon, and brown, rainbow and lake trout) were collected during the NYSDEC Lake Ontario Fishing Boat Survey from April through