Journal of Great Lakes Research xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

# Predation on Pacific salmonid eggs and carcass's by subyearling Atlantic salmon in a tributary of lake Ontario

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ARTICLE INFO

*Article history:*
Received 9 July 2015
Accepted 17 December 2015
Available online xxxx

Communicated by Robert E. Hecky

*Index words:*
Atlantic salmon
Egg predation

ABSTRACT

A binational effort to reintroduce Atlantic salmon (*Salmo salar*) that were extirpated in the Lake Ontario ecosystem for over a century is currently being undertaken by the New York State Department of Environmental Conservation and the Ontario Ministry of Natural Resources. Reintroduction actions include the release of several life stages including fry, fall fingerlings, and yearling smolts. In this study we describe the diet of recently released fall fingerling Atlantic salmon in a tributary of the Salmon River, New York. A specific objective of the study was to determine if juvenile Atlantic salmon would utilize the high caloric food source provided by introduced Pacific salmonids (*Oncorhynchus* spp.) that includes eggs and carcass flesh. Salmon eggs and carcass flesh comprised 20.5% of the October to January diet in 2013–14 and 23.9% in 2014–15. The consumption of steelhead (*O. mykiss*) eggs was a major part of the diet in April in both 2014 (54.1%) and 2015 (33.2%). This study documented that recently released Atlantic salmon will consume the high caloric food material provided by Pacific salmonids and that the consumption of this material extends for several months.

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## Introduction

The importance of nutrient transport by Pacific salmonids (*Oncorhynchus* spp.) from marine ecosystems to natal spawning areas has long been recognized (Juday et al., 1932; Donaldson, 1967) and has recently received more attention (Scheuerell et al., 2007; Denton et al., 2009; Harvey and Wilzbach, 2010). This "nutrient subsidy" (Naiman et al., 2002) has been found to enhance overall productivity of stream ecosystems and riparian zones. Although the physical disturbance of the substrate caused by the redd building activity of adult salmon has been shown to cause a short term reduction in aquatic invertebrate densities in spawning streams (Hildebrand, 1971; Minikawa, 1997), overall, nutrients from salmon carcasses have been found to increase aquatic invertebrate densities (Piorkowski, 1995; Wipfli et al., 1998). A more immediate benefit to the fish community in Pacific salmon spawning streams are the eggs, and to a lesser extent, the carcass flesh that are brought into the ecosystem annually by adult salmon. Bilby et al. (1998) found that in stream reaches where salmon carcasses were added juvenile fish densities, fish body weight, and condition factor increased. Wipfli et al. (2003) reported similar results from carcass addition in southwestern Alaskan streams and found that body mass and length of coho salmon (*Oncorhynchus kisutch*) increased significantly. Similarly, Williams et al. (2009) found a significant positive relationship between carcass addition and juvenile Atlantic salmon (*Salmo salar*) biomass in rivers in Scotland.

Pacific salmon were first introduced into the Great Lakes in 1873 (Parsons, 1973) but viable populations were not established until effective sea lamprey (*Petromyzon marinus*) control was initiated in the early 1970s (Christie and Goddard, 2003). Pacific salmonids are now established in each of the Great Lakes and spawning runs occur in many tributaries. Prior to the introduction of Pacific salmon in the Great Lakes perhaps the most likely transfer of lake origin nutrients to stream ecosystems that occurred historically in the Great Lakes was by white sucker (*Catostomus commersoni*) (Childress et al., 2014), and by Atlantic salmon which were only native to Lake Ontario. However, even though the runs of Atlantic salmon to Lake Ontario were reported to be large (Webster, 1982), the amount of nutrients transferred between lake and stream ecosystems was likely much less than is presently occurring with Pacific salmonids because of the difference in life history strategies between Pacific salmon and Atlantic salmon. Of the introduced Pacific salmonids, only steelhead (*O. mykiss*) have an iteroparous life history, similar to that of Atlantic salmon. The other two introduced Pacific salmonid species, Chinook salmon

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http://dx.doi.org/10.1016/j.jglr.2015.12.004
0380-1330/Published by Elsevier B.V. on behalf of International Association for Great Lakes Research.

Please cite this article as: Johnson, J.H., et al., Predation on Pacific salmonid eggs and carcass's by subyearling Atlantic salmon in a tributary of lake Ontario, J. Great Lakes Res. (2016), http://dx.doi.org/10.1016/j.jglr.2015.12.004

(*O. tshawytscha*) and coho salmon, are semelparous, a life history where fish generally spawn at much higher densities than iteroparous species and die on the spawning grounds. This tends to reverse the typical trend for nutrients to flow downstream (Quinn, 2005).

The Salmon River in New York supports the largest run of adult Pacific salmonids in Lake Ontario and one of the largest runs of salmonids in all of the Great Lakes. Runs of white sucker, a migratory species that has been shown to provide nutrient subsidies to some Great Lakes tributaries (Childress et al., 2014) are minimal in the Salmon River. The influence of these spawning runs on the feeding ecology of juvenile stream salmonids was documented soon after these runs were established (Johnson and Ringler, 1979; Johnson, 1981) and more recently on fallfish (*Semotilus corporalis*) (Johnson et al., 2009). Similar to the positive benefits observed on stream salmonids that consume Pacific salmon eggs on their growth and condition factor in their native range, Johnson and Ringler (1979) found a significant increase in the condition factor of juvenile Pacific salmonids and stream resident brook trout (Salvelinus fontinalis) and brown trout (*Salmo trutta*) in a tributary of the Salmon River and speculated that this may increase overwinter survival.

New York's effort to restore Atlantic salmon in Lake Ontario consists of stocking fall fingerlings and yearling smolts. A small percentage of fall fingerlings will smolt the following spring but most remain in the stream approximately 18 months, smolting at age two. The vast majority of yearling smolts that are released descend to Lake Ontario within two weeks of stocking. Although there is evidence that the stocking of smolts provides a higher adult Atlantic salmon return (Boucher and Warner, 2006; Salminen et al., 2007; Jonsson and Jonsson, 2009), there is an associated increase in cost from rearing fish in a hatchery for a longer period (Quinn, 2005). Foraging on abundant Pacific salmon eggs could greatly enhance growth and survival of fall fingerlings. The objective of this study was to determine the potential consumption and the duration of consumption of Pacific salmonid eggs by hatchery released fall fingerling Atlantic salmon in a tributary of the Salmon River.

## Methods

Fall fingerling (subyearling) Atlantic salmon were stocked in Beaver Dam Brook (43.50921 N, 75.99695 W), a tributary of the Salmon River in Oswego County, New York in late September 2013 and early October, 2014. Juvenile salmon were collected for diet analysis with a backpack electroshocker post release. Collections were made each year beginning two weeks post release and continued monthly for six months. A monthly sample target of 30 subyearling Atlantic salmon was set but was not always met. During each of the two sampling periods mid-winter stream conditions (ice cover) precluded collections entirely during some months, at other times available stream habitat was restricted such that a sufficient number of individuals were not collected resulting in combined collections for January and February in 2014 and December 2014 and January 2015. Upon collection subyearling Atlantic salmon were placed in 10% buffered formalin.

In the laboratory subyearling Atlantic salmon were measured (total length, mm) prior to their stomachs being removed. Aquatic invertebrate prey were identified to family. Salmonid eggs were identified based on egg size (Smith, 1985). Dry weights of each prey taxon were used to determine their relative contribution in the diet. Dry weights (24 h at 105 °C) were derived for all prey taxa, including salmonid eggs and carcass tissue. The diet composition of each individual fish was then determined based on the dry weight proportion that each prey taxa made to the overall diet. A paired T-test was used to determine differences in the length of salmon consuming salmonid eggs in October and November and those not using Statistix 8.2 statistical software (Statistix 8.2, Tallahassee, Florida). An alpha level $\alpha = 0.05$ was considered to be significant.

## Results and discussion

We examined the diet of 297 subyearling Atlantic salmon (Table 1). As a group, aquatic invertebrates were the major component of the diet of subyearling Atlantic salmon during all months, except for April 2014, when steelhead eggs comprised 54.1% of the diet (Table 1). Steelhead eggs also contributed 33.3% of the April, 2015 diet of subyearling Atlantic salmon, but declined to 3.9% in May. The major aquatic invertebrate taxa consumed were isopods, hydropsychids, chironomids, and heptageniids. During the fall and winter, Chinook salmon eggs made up 0–33.3% of the monthly diet of salmon compared to 0–28.3% for coho salmon eggs. Steelhead eggs were consumed in April of both years, contributing 43.7% of the diet. Pacific salmon carcass flesh was observed in the diet of subyearling Atlantic salmon during both years, making up 5% and 11.2% of the November and December diet in 2013 and 2014, respectively. The combined contribution of Pacific salmon eggs and carcass flesh in the diet of Atlantic salmon from October through January was similar (20.5%—2013–2014, 23.9%—2014–2015) during both years (Table 1).

Although there is a considerable amount of evidence that overyearling salmonids readily consume Pacific salmon eggs in the fall, these same studies have reported disparate use of eggs by subyearling salmonids. Several studies (i.e., Reed, 1967; Stauffer, 1971; Denton et al., 2009; Lowery, 2009) found limited consumption of Pacific salmon eggs by subyearling salmonids while others have reported high consumption (Johnson and Ringler, 1979; Bilby et al., 1998). The study by Johnson and Ringler (1979) was done in Orwell Brook, another tributary of the Salmon River, and found that Pacific salmon eggs made up over 90% of the October diet of subyearling coho salmon and subyearling steelhead. They also observed that consumption of salmon eggs declined in November, but still made up 39% and 75% of the diet of subyearling Coho Salmon and steelhead, respectively. Consumption of Pacific salmon eggs by subyearling salmonids in Orwell Brook resulted in a significant increase in condition factor which Johnson and Ringler (1979) speculated would increase overwinter survival. Although consumption of Pacific salmonid eggs by subyearling Atlantic salmon did not approach the level previously reported by Johnson and Ringler (1979) for subyearling coho salmon and steelhead, consumption of this high energy food material extended over a seven month period (October–May) when also considering steelhead egg consumption.

Differential consumption of Pacific salmon eggs between subyearling and overyearling salmonids in streams may be due to differences in mouth gape. Pacific salmon eggs may be at the upper prey size range for subyearling salmonids. Denton et al. (2009) suggested that subyearling dolly varden (*Salvelinus malma*) (40–60 mm) were unable to consume Pacific salmon eggs. Bilby et al. (1998) did not report the size of the subyearling coho salmon and steelhead that were consuming Pacific salmon eggs in their study, but Johnson and Ringler (1979) reported that the average total length of these egg consumers was 86 mm and 73 mm, respectively. We found that subyearling Atlantic salmon as small as 70 mm consumed Pacific salmon eggs in Beaver Dam Brook. Conversely, Atlantic salmon as small as 59 mm consumed carcass flesh. The average size of subyearling Atlantic salmon stocked into Beaver Dam Brook was 103 mm (range 60 mm–120 mm) in 2013 and 100 mm (range 58 mm–122 mm) in 2014. Atlantic salmon that consumed Pacific salmon eggs within two months of release were significantly larger (106.1 mm) than those that did not consume eggs (95.6 mm). The consumption level of Pacific salmon eggs by subyearling Atlantic salmon that we observed seems to be intermediate between the previous studies that found little consumption of eggs and those that reported high consumption.

The increase in consumption of steelhead eggs in the spring, as compared to consumption of Pacific salmon eggs in the fall, may be due to the smaller size of steelhead eggs (5.3 mm diameter) compared to Chinook salmon (7.2 mm diameter) and coho salmon (6.8 mm

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