Predation by Fallfish (*Semotilus corporalis*) on Pacific Salmon Eggs in the Salmon River, New York

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ABSTRACT

Fallfish (*Semotilus corporalis*) are the largest native cyprinid in the northeastern United States and are the most abundant native species in the Salmon River, New York. The Salmon River is a high-quality spawning and nursery river for Pacific salmon (*Oncorhynchus* spp.) migrating from Lake Ontario. Because of the large number of Pacific salmon spawning in the river in the fall extensive redd superimposition occurs resulting in salmonid eggs being available on the substrate. We examined the fall diet of 647 fallfish in 2007 and 2008 to determine the extent of predation on Pacific salmon eggs. The contribution of eggs in the diet significantly increased once fallfish attained a size of 100 mm total length. The largest size category of fallfish examined (≥150 mm) had the highest proportion (86.1%) of salmon eggs in their diet. The contribution of zooplankton and chironomids in the diet of fallfish decreased with fish size. Except for the two largest groups of fallfish examined (i.e., 100–149 mm and ≥150 mm) diet overlap among size groups was low. The high contribution in the diet during the fall and high caloric value of Pacific salmon eggs could increase growth and survival of this species in the Salmon River.

Introduction

The Salmon River in central New York supports the largest spawning run of Pacific salmon (*Oncorhynchus* spp) migrating from Lake Ontario. In 2005 the return of adult salmon to the Salmon River was estimated at about 68,000 fish (Everitt 2006). Chinook salmon (*Oncorhynchus tshawytscha*) make up the majority of the spawning run but there are also large numbers of coho salmon (*Oncorhynchus kisutch*). Many of these fish return to the New York State Department of Environmental Conservation Salmon River Hatchery at Altmar, NY. However, a large number of these fish spawn in the Salmon River. Most of the spawning occurs between Pineville (river kilometer 18) and Altmar (river kilometer 26) from late September to mid November (Everitt 2006). Because most spawning occurs in a fairly restricted reach of the river there is a great amount of redd superimposition. Johnson and Ringler (1981) speculated that redd superimposition by coho salmon in Orwell Brook, a tributary of the Salmon River, increased the availability of Pacific salmon eggs to salmonid egg predators.

Predation on Pacific salmon eggs has been reported by several investigators (Cederholm et al., 1999). The majority of these studies have examined the consumption of eggs by stream resident salmonids (Greeley 1932; Idyll 1942; Reed 1967; Stauffer 1971, Johnson and Ringler 1981, Johnson 1981). The most extensive use of Pacific salmon eggs was observed by Johnson and Ringler (1981) in Orwell Brook, where eggs composed 91% to 99% of the diet of subyearling coho salmon, juvenile steelhead (0+, 1+) (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*). Besides salmonids, sculpins (*Cottus* spp) have also been observed to feed on Pacific salmon eggs (Greeley 1932; Reed 1967; Stauffer 1971; Foote and Brown 1998; Dittman et al., 1998). Sculpins have also been reported to be a predator on lake trout (*Salvelinus namaycush*) eggs (Hudson et al., 1995, Biga 1996).

Fallfish (*Semotilus corporalis*) are the largest native minnow in the northeastern United States, attaining sizes up to 430 mm (total length) (Smith 1985); it is also the most abundant native fish species in the Salmon River (Everitt 2006). Because of their size, fallfish have the potential to be a major predator of Pacific salmon eggs. The purpose of this study was to determine (1) if fallfish consumed Pacific salmon eggs in the fall, (2) the contribution of eggs in fallfish diets, and (3) at what size fallfish begin feeding on eggs.

Methods

The Salmon River in central New York drains the Tug Hill Plateau and flows 71 km before discharging into Lake Ontario at Port Ontario (Fig. 1). Only the lower 28 km of the river are accessible to fish migrating from Lake Ontario because of a hydroelectric dam at Altmar, NY. Fallfish were collected during October and November 2007 and 2008 in the Salmon River with a 6.1 m long bag seine

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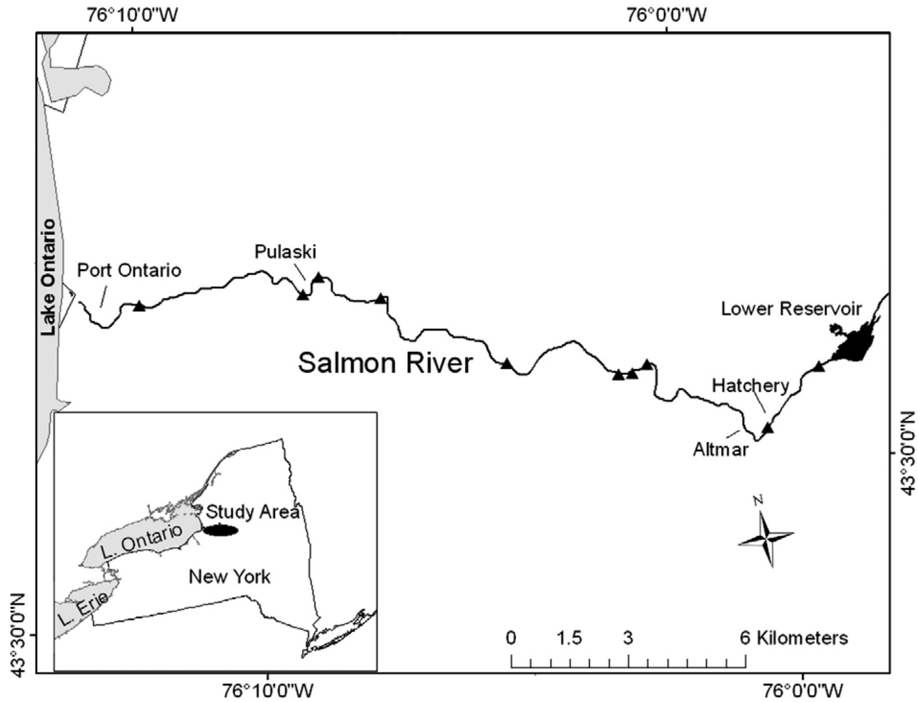

Fig. 1. Location of the Salmon River and sampling sites (▲) in central New York.

(0.32 cm mesh). Collection sites ranged from Port Ontario to Altmar. Upon collection, fish were immediately placed in 10% buffered formalin.

In the laboratory, fallfish were measured (total length in mm) prior to stomach removal. Except for Chironomidae (which were the only aquatic dipteran found in the stomachs) and zooplankton, invertebrate prey were identified to order. Salmonid eggs were identified as either Pacific salmon (i.e., Chinook salmon or coho salmon) or brown trout based on egg size (Smith, 1985). Brook trout, a fall spawning native salmonid, occurs in tributaries of the Salmon River but are rare in the river. Dry weight estimates (24 h at 105 °C) were derived for all prey taxa, including salmon eggs, to determine their relative contribution in fallfish diets.

A Kruskal–Wallis one-way analysis of variance was used to compare the proportion of Pacific salmon eggs, zooplankton, and chironomids in the diet by size class of fallfish. Tukey's HSD all-pairwise comparison test was performed to identify significant homogenous groups (Statistix for Windows, 2003, version 8.0 Tallahassee, FL). A significance level of 0.05 was used for all comparisons. Diet overlap was determined using the equation of Horn (1966). Overlap values ≥0.60 are considered biologically significant (Zaret and Rand 1971).

Results and discussion

The diets of 647 fallfish were examined (Table 1). There was little variation in fallfish diets between years so yearly samples were pooled. Size-specific differences in the consumption of Pacific salmon were apparent, so fallfish diets were examined by size category (i.e., <50 mm, 50–99 mm, 100–149 mm, ≥150 mm). The fallfish examined ranged in size from 30 mm to 262 mm. The number of Pacific salmon eggs observed in fallfish stomachs ranged from 0 to 23.

Size of fallfish had a highly significant effect ($P<0.000$) on consumption of eggs (Table 2). Fallfish less than 50 mm did not consume salmonids eggs and eggs only composed 2.8% of the diet of fallfish 50–99 mm (Figs. 2a, b). Pacific salmon eggs increased markedly in the diet of fallfish once fish reached 100 mm. Pacific salmon eggs were the major dietary item of fallfish 100-149 mm (40.2%) and ≥150 mm (86.1%) (Figs. 2c–d). Tukey's test showed that the contribution of Pacific salmon eggs in the diet of the two smallest size categories (i.e., <50 mm, 50-99 mm) did not significantly differ but all other comparisons were significantly different ($P<0.05$) (Table 2). Brown trout eggs contributed 0.1% and 1.1% of the diet of fallfish 100–149 mm and ≥150 mm, respectively (Figs. 2c–d).

There were also size-specific differences in the consumption of zooplankton and chironomids by fallfish, the contribution of zooplankton in fallfish diets decreased from 26% (fish <50 mm) to 1.2% (fish ≥150 mm), and the contribution of chironomids decreased from 66.2% to 1.4% (Figs. 2a–d). The ANOVA comparing the percent composition of zooplankton ($P<0.0006$) and chironomids ($P<0.0006$)

Table 1
Number, mean total length (TL, mm), and length range of fallfish, by size category, examined by diet composition from the Salmon River, New York during October and November, 2007 and 2008.

Size category	Sample size	Mean (length)	Length range
<50	42	40.4	30–49
50–99	199	69.4	50–99
100–149	214	124.6	101–149
≥150	192	198.2	150–262

Table 2
Percent composition of Pacific salmon eggs, zooplankton, and Chironomidae in the diet of four size categories of fallfish.

Size category (mm)	Pacific Salmon eggs	Zooplankton	Chironomidae
<50	0^{a}	26.1^{a}	66.2^{a}
50–99	2.8^{a}	23.9^{a}	23.3^{b}
100–149	40.2^{b}	4.8^{b}	17.0^{c}
≥150	86.1^{c}	1.2^{b}	1.4^{d}
ANOVA			
Error MS ($df=643$)	1,349	12,248	17,825
$F_{3,643}$	35.2	99	85.4
P	0.0000	0.0006	0.0006

Values in each column not followed by the same superscript letter significantly differ ($P<0.05$, Tukey's test).

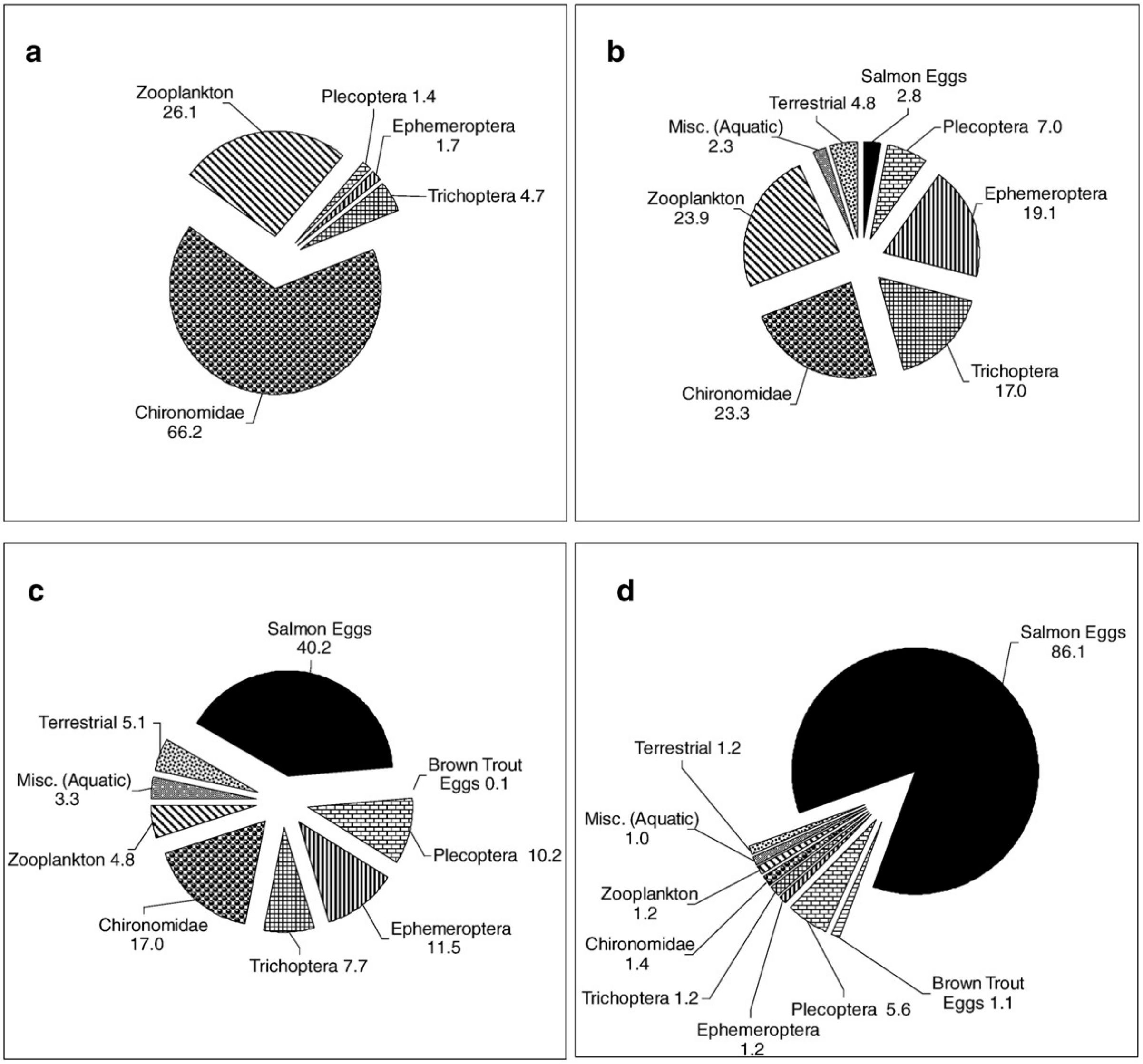

Fig. 2. Percent dry weight composition of the fallfish of (a) <50 mm, (b) 50–99 mm, (c) 100–149 mm, (d) ≥150 mm in the Salmon River, N.Y., during October thru November, 2007 and 2008.

in the diet of the four size categories of fallfish was significant (Table 2). Tukey's test showed a significant ($P<0.05$) difference in consumption of zooplankton between the two smallest and two largest size groups of fallfish (Table 2). The contribution of chironomids in the diets was significantly ($P<0.05$) different among all four size groups of fallfish (Table 2). High diet overlap (0.75) was observed only between the two largest size groups of fallfish (i.e., 100-149 mm, ≥150 mm) (Table 3). The lowest diet overlap occurred between fallfish ≥150 mm and fallfish <50 mm (0.02) and fallfish ≥150 mm and fallfish 50–99 mm (0.08) (Table 3).

Fallfish are considered omnivorous (Smith 1985), but little work has been done describing their diet (Scott and Crossman 1973). The data presented herein may represent the most intensive investigation into the diet of fallfish. Ontogenetic variation in diet among size categories of fallfish was evident with smaller prey taxa, i.e., zooplankton and chironomids, decreasing in importance in the diet with increasing fish size. Conversely, Pacific salmon eggs, one of the largest food items consumed, increased in the diet with fish size. Fallfish appear to transition to Pacific salmon eggs when they reach approximately 100 mm.

The abundance of fallfish ≥100 mm in the Salmon River suggests that the species may be a major predator of Pacific salmon eggs. However, it is most likely that the vast majority of the eggs that are eaten are on, rather than in, the substrate and were exposed from redd superimposition. Consequently, survival of these exposed eggs would likely be negligible. Johnson and Ringler (1981) found that consumption of Pacific salmon eggs by stream salmonids in the fall significantly increased their condition factor. They speculated that because of their high caloric value and high contribution in the diet for almost 2 months in the fall, the consumption of Pacific salmon eggs may increase growth and survival of stream salmonids that were eating eggs. Such speculation appears warranted based on recent reports by Heinimaa and Heinimaa (2004) and Jonsson and Jonsson (2005) showing that the energy content of salmon eggs (10.5 kJ/g) is much higher

Table 3
Overlap analysis comparing the diet of four size categories of fallfish from the Salmon River, New York during October and November, 2007 and 2008.

Size category	<50	Size category		
		50–99	100–149	≥150
<50	–	0.05	0.26	0.02
50–99	–	–	0.38	0.08
100–149	–	–	–	0.75
≥150	–	–	–	–

relative to that of whole salmon (4.9 kJ/g) or trout (4.4 kJ/g) parr. Further, feeding studies by Ketola (1982) showed that eggs of salmon and trout contain proteins having an essential amino acid balance of high nutritional quality, superior to other sources of protein. Migratory salmonid eggs also make up a large portion of the diet of stream fishes during spring in the Salmon River system. Johnson (1981) found that steelhead eggs contributed 20% (brook trout) to 55% (juvenile steelhead) of the diet in Orwell Brook in April. Consequently, consumption of salmonid eggs in the fall, and possibly in the spring, could result in more and perhaps larger fallfish in the Salmon River, thus increasing predation on naturally reproduced subyearling Chinook salmon.

Everitt (2006) estimated that about 10 million Chinook salmon were produced in the Salmon River in 2004. Salmon emerge from the gravel at about 35 mm in length by early May, and most migrate to Lake Ontario by late June at about 60–70 mm (Johnson 2008). In our 406 samples of large (≥100 mm) fallfish food items, we found only two fish (lengths 39 and 44 mm) during autumn while Pacific salmon eggs were available. Flemer and Woolcott (1966) reported that fish contributed 17% of the diet of fallfish. In an unpublished study on the summer diet of fallfish conducted in 1980 in the Salmon River (when no salmon spawning was occurring) the senior author (JHJ) found that fish made up 10% of the diet of 40 fallfish ranging in length from 50 mm to 149 mm total length ($\bar{x} = 101.3$ mm). Fish in that study contributed 61% of the diet of 32 fallfish that ranged in length from 153 mm to 235 mm ($\bar{x} = 183.2$ mm). Although most of the fish consumed by fallfish were blacknose dace (*Rhinichthys atratulus*), 17% of the diet of larger fallfish consisted of subyearling salmonids. Naturally reproduced subyearling Chinook salmon at the size range present in the Salmon River (i.e., 35–70 mm) are small enough to be consumed by large fallfish. Because hatchery Chinook salmon are stocked in the Salmon River at a larger size (80 mm), within 0.25 km of Lake Ontario, and immediately enter the lake (Johnson 2008), predation by fallfish on hatchery salmon is probably minimal.

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References

Biga, HC. Sculpin as predators of lake trout eggs and larvae: an assessment of their predatory capabilities and constraints. M.S. thesis, Loyola University, Chicago, IL; 1996.

Cederholm JC, Kunze MD, Murota T, Sibatani A. Pacific salmon carcasses: essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. Fish Manag/Habitat 1999;24(10):6-15.

Dittman AH, Brown GS, Foote CJ. The role of chemoreception in salmon-egg predation by coastrange (*Cottus aleuticus*) and slimy (*C. cognatus*) in Iliamna Lake, Alaska. Can J Zoo 1998;76:405–13.

Everitt, DW. Natural reproduction and spawning site characteristics of Chinook salmon (*Oncorhynchus tshawytscha*) in the Salmon River, New York. M.S. Thesis, State University of New York college of Environmental Science and Forestry, Syracuse, NY; 2006.

Flemer DA, Woolcott WS. Food habits and distribution of the fishes of Tuckahoe Creek, Virginia, with special emphasis on the bluegill, *Lepomis m. macrochirus* Rafinesque. Chesapeake Sci 1966;7(2):75–89.

Foote CJ, Brown GS. The ecological relationship between slimy sculpins (*Cottus cognatus*) and beach spawning sockey salmon (*Oncorhynchus nerka*) in Iliamna Lake, Alaska. Can J Fish Aquat Sci 1998;55(6):1524–33.

Greeley JR. The spawning habits of brook, brown and rainbow trout, and the problem of egg predators. Trans Am Fish Soc 1932;62:239–48.

Heinimaa S, Heinimaa P. Effect of the female size on egg quality and fecundity of the wild Atlantic salmon in the sub-artic River Teno. Boreal Env Res 2004;9:55–62.

Horn HS. Measurement of "overlap" in comparative ecological studies. Am Nat 1966;100:419–24.

Hudson PL, Savino JF, Bronte CR. Predator–prey relations and competition for food between age-0 lake trout and slimy sculpins in the Apostle Island region of Lake Superior. J Great Lakes Res 1995;21(Suppl. 1):445–57.

Idyll C. Food of rainbow, cutthroat and brown trout in the Cowichan River system, B.C. J Fish Res Board Can 1942;5:448–58.

Johnson JH. Predation on the eggs of steelhead trout by stream salmonids in a tributary of Lake Ontario. The Progressive Fish-Cult 1981;43(1):36–7.

Johnson JH. Diet composition and feeding periodicity of wild and hatchery subyearling Chinook salmon in Lake Ontario. J Great Lakes Res 2008;34:590–8.

Johnson JH, Ringler NH. Predation on Pacific salmon eggs by salmonids in a tributary of Lake Ontario. J Great Lakes Res 1981;5(2):117–81.

Jonsson B, Jonsson N. Lipid energy reserves influence life-history decision of Atlantic salmon (*Salmo salar*) and brown trout (*S-trutta*) in fresh water. Ecol Freshw Fish 2005;14:296–301.

Ketola HG. Amino acid nutrition of fishes: requirements and supplementation of diets. Comp Biochem Physiol 1982;73B(1):17–24.

Reed RJ. Observation on fished associated with spawning salmon. Trans Am Fish Soc 1967;96:62–7.

Scott, WB, Crossman, EJ. Freshwater fishes of Canada. *Bulletin 184, Fish Res Bd Can*; 1973.

Smith CL. The inland fishes of New York State. New York State Dep Envir Conserv Albany: NY; 1985.

Stauffer TM. Salmon eggs as food for stream salmonids and sculpins. Mich Dep Nat Resour, Res Dev Rep 1971;233:10.

Zaret TM, Rand AS. Competition in tropical stream fishes: supports for competitive exclusion principle. Ecol 1971;52:336–42.