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NOTE

Comparative Diets of Subyearling Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead (*O. mykiss*) in the Salmon River, New York

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ABSTRACT. *Chinook salmon* (Oncorhynchus tshawytscha) *and steelhead* (O. mykiss) *have established naturalized populations throughout the Great Lakes. Young-of-year of these species occur sympatrically for about one month in Lake Ontario tributaries. This study examined the diets of subyearling Chinook salmon and steelhead relative to available food in the Salmon River, New York. Terrestrial invertebrates and trichopterans were the major prey of Chinook salmon, whereas steelhead fed primarily on baetid nymphs and chironomid larvae. Diet overlap was low (0.45) between the species. The diet of Chinook was closely associated to the composition of the drift (0.88). Steelhead diet drew equally from the drift and benthos during the first year of the study, but more closely matched the benthos during the second year. Differences in prey selection, perhaps associated with differences in fish size, in addition to apparent differences in feeding mode (drift versus benthic), likely reduce competitive interactions between these species.*

INDEX WORDS: *Chinook salmon, steelhead, diets, competition, naturalized, Salmon River (NY).*

INTRODUCTION

Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) are probably the two most important non-native sport fish in the Great Lakes. Both of these species have established naturalized populations in the basin (Johnson 1980, Carl 1982, McKenna and Johnson 2005). Chinook salmon spawning occurs in fall, whereas steelhead spawn in late winter-early spring. Due to their earlier spawning time, Chinook fry emerge from the gravel beginning in late April, with peak emergence occurring in mid-May, in Lake Ontario tributaries (Johnson and Ringler 1981a). Emergence of steelhead fry begins in early June, peaking about mid-June. Most Chinook will migrate to the lake within two months of emergence (Johnson 1980, Carl 1982) whereas the majority of steelhead will remain in streams 2 years before outmigrating (Seelbach 1987, 1993; McKenna and Johnson 2005). Because of these two divergent life history strategies subyearlings of these species occur sympatrically in large numbers only for a short time period in Lake Ontario tributaries.

Everitt (2006) reported a population estimate of about 5 million naturally produced subyearling Chinook salmon in the Salmon River, New York in May, 2005 with densities as high as 3.2 fish/m^2. The population estimate almost doubled when adjusting for seine catchability. No information is available on the densities of subyearling steelhead in the Salmon River. However, based on visual observations they are substantially lower than densities of subyearling Chinook salmon. Based on Chinook salmon outmigration times and steelhead emergence times the greatest opportunity for competitive interactions between these two species occurs mainly during mid-June. The objective of this study was to examine the diets of subyearling Chinook salmon and steelhead trout in the Salmon River during mid-June to access the potential for competitive interactions.

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METHODS

The Salmon River drains the Tug Hill Plateau in north-central New York and discharges into eastern Lake Ontario at Port Ontario. The lower 28 km of the river is accessible to fishes migrating from the lake. Subyearling salmonids were collected during mid-June 2000 and 2001 in the Salmon River, NY. Fish collections were made with a 6.1 m bag seine (0.32 cm mesh) at Pineville, NY (river km 19). A total of four dates were sampled in 2000 and five dates in 2001. Both species were not present in sufficient numbers to quantify diets on all dates. River temperatures during collections ranged from 15° to 17.5°C. Upon collection all salmonids were placed in 10% buffered formalin. Invertebrate drift samples and benthic samples were taken concurrent with (but prior to) fish collections. Invertebrate drift was sampled with five drift nets (aperture 30.5 × 30.5 cm; mesh size 0.60 mm). Drift nets were set 3 h prior to fish collections. Five Surber samples (0.092 m^2; mesh size 0.75 mm) were used to quantify the bottom fauna. Substrate composition at the sampling sites was about 60% boulder, 30% cobble, and 10% gravel. Invertebrate samples were preserved in 70% ethanol.

In the laboratory, subyearling salmonids were measured (total length in mm) prior to stomach removal. Aquatic invertebrates from both fish stomachs and benthic samples were generally identified to family, whereas terrestrial invertebrates were identified to order using Peckarsky *et al.* (1995) and McCafferty (1998). Dry weight estimates (24 h at 105°C) were derived for prey taxon to quantify their contribution in benthic samples and fish diets. Measures of overlap between subyearling salmonid diets and benthic samples were determined using the equation of Morisita (1959) as modified by Horn (1966). Values greater than or equal to 0.60 are considered to represent significant overlap (Zaret and Rand 1971). One-way analysis of variance (ANOVA) was used to compare the proportion of one representative invertebrate taxon in the diet of subyearling Chinook salmon and steelhead and the proportion of that taxon in either the drift or Surber samples. The taxon selected to represent drift feeding was terrestrial invertebrates, because they were common in the drift, but not the benthos. The taxon chosen to represent benthic feeding was heptageniid mayfly nymphs because they were much more common in Surber samples than in drift samples. Turkey's test was used to test for post-hoc pairwise comparisons in the proportions of the representative invertebrate taxon in fish diets and benthic samples. Percentage composition data were arc-sine-square-root transformed. A significance level of 0.05 was used for all comparisons.

TABLE 1. Number, mean total length (mm), and size range of subyearling Chinook salmon and steelhead examined for diet composition from the Salmon River, New York during June, 2000 and 2001.

		No.	$\bar{x}$ (TL, mm)	Size range
2000	Chinook Salmon	151	52.2	37–81
	Steelhead	52	33.8	28–43
2001	Chinook Salmon	166	51.1	38–82
	Steelhead	97	31.1	25–43

RESULTS AND DISCUSSION

The diets of 466 subyearling salmonids were examined including 317 Chinook salmon and 149 steelhead (Table 1). Chinook salmon fry were about 20 mm larger during both years of this study because they emerge about a month earlier than steelhead. Subyearling Chinook salmon abundance at the sampling site was similar between years (Bishop and Johnson 2001, 2002) whereas the number of subyearling steelhead appeared to be slightly higher in 2001. Two prey taxa, baetid nymphs (Ephemeroptera) and chironomid larvae dominated the diet of subyearling steelhead. In 2000, these two taxa made up 94% of the diet and in 2001 represented 73% (Fig. 1). The only other prey taxon that contributed substantially to the diet of steelhead were trichopterans (mostly hydropsychids) which made up 10.2% of the diet in 2001.

Terrestrial invertebrates and trichopterans were the major prey of subyearling Chinook salmon during both years, contributing 63% and 60% of the diet in 2000 and 2001, respectively (Fig 1.). Baetid nymphs and chironomid larvae, the two primary prey of steelhead fry, were also important in Chinook diets. Baetids contributed 21% of the 2001 Chinook diets and 12% of the 2002 diet, whereas chironomids made up 6% and 13% (Fig. 1.). The contributions of other prey taxa in the Chinook diets were minor except for ephemeropterans (non-baetids) (6% in 2000 and 11% in 2001).

Densities (number/m^2) of benthic invertebrates in the Salmon River ranged from 1,212 to 2,463 and averaged 1,744. Diurnal drift rates of invertebrate taxa average 37/h (range 41/h–176/h). Baetid

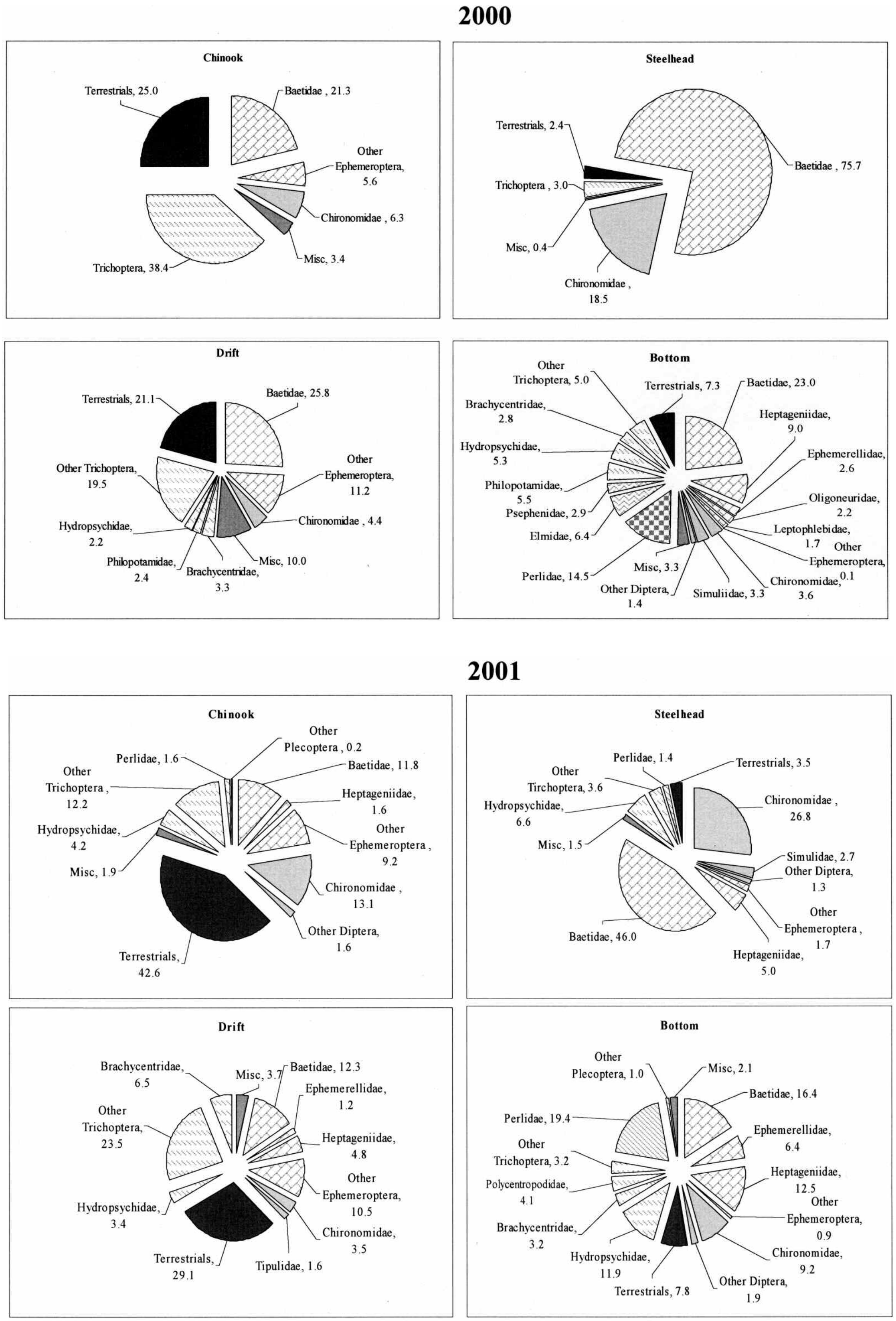

FIG. 1. Percent dry weight composition of subyearling Chinook salmon and steelhead diets and drift and Surber samples during early June, a) 2000 and b) 2001. Some aquatic insect orders (i.e., Diptera, Ephemeroptera, Plecoptera, Trichoptera) although represented by the same symbol are further partitioned by family.

nymphs as well as all other ephemeropteran families were about equally abundant in the drift and bottom samples (Fig. 1). Trichopterans were also well represented in both the drift and bottom samples, but were somewhat more abundant in the drift samples, comprising about 30% of invertebrate drift and 20% of bottom fauna (Fig. 1). Terrestrial invertebrates were also much more abundant in drift samples ($\bar{x}$ = 25%) than in bottom samples ($\bar{x}$ = 7%). Perlid nymphs comprised a substantial amount of the bottom samples ($\bar{x}$ = 17%), but were not well represented in the drift ($\bar{x}$ = 1%). Chironomids, a major component of the diet of both subyearling steelhead and Chinook salmon, only made up 4% of the drift and 5% of bottom samples during both years (Fig. 1).

Diet overlap between subyearling Chinook salmon and steelhead was low and was identical (0.45) in both years. The diet composition of Chinook was closely associated with the composition of the drift during both 2000 (0.90) and 2001 (0.89). Overlap between Chinook salmon diets and benthic samples was low (0.48 in 2000 and 0.44 in 2001). Subyearling steelhead fed about equally from the drift (0.53) and bottom (0.52) in 2000. In 2001, the diet of steelhead was more similar to the composition of the benthos (0.60) than with the drift (0.40). The ANOVA comparing the percent of terrestrial insects among drift samples and Chinook salmon and steelhead diets was significant ($F = 6.91$; 2,23 df; $P = 0.005$). The post-hoc Tukey's test showed that the proportion of terrestrial invertebrates in the drift samples and in the diet of subyearling Chinook salmon was not significantly different but was significantly lower for subyearling steelhead ($P = < 0.05$). ANOVA showed that the percent of heptageniids among Surber samples and Chinook salmon and steelhead diets was also significant ($F = 4.06$; 2,20 df; $P < 0.034$). Further examination of the data with Tukey's test showed that the percent of heptageniids in the Surber samples and in the diet of subyearling steelhead was not significantly different but was significantly lower for Chinook salmon ($P = < 0.05$) (Table 2).

Subyearling Chinook salmon and steelhead were not only feeding disproportionately on different prey in the Salmon River during mid-June, but also exhibited differences in foraging behavior (i.e., mid-water or surface feeding versus bottom feeding). It is likely that the much smaller size (~20 mm) of recently emerged steelhead fry was a major contributing factor to these differences. Williams (1981) observed that the small size of recently emerged brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*) limited the number of prey taxa that could be initially consumed. The primary prey of subyearling steelhead were baetid nymphs and chironomid larvae that are, on average, much smaller than the terrestrial invertebrates and trichopterans that were consumed by Chinook. Similarly, Johnson and Ringler (1981b) reported that recently emerged coho salmon (*O. kisutch*) fed heavily on chironomid larvae but switched to terrestrial invertebrates taken from the drift later in summer (Johnson and Ringler 1980, Johnson and Johnson 1981). Although subyearling coho salmon feed heavily at night in streams (Johnson and Johnson 1981), subyearling Chinook salmon and steelhead are mainly diurnal feeders (Johnson and Johnson 1981, Sagar and Glova 1988, Angradi and Griffith 1989, Dedual and Collier 1995). Allan (1978) found that, although individuals of aquatic taxa were smaller in diurnal drift compared to nocturnal drift (predator avoidance), drift feeding salmonids selected the largest individuals during the day. As observed in the Salmon River, subyearling Chinook salmon have been reported to feed heavily from the drift with allochthonous material contributing substantially to the diet (Johnson 1981, Sagar and Glova 1988). Also, the diet of subyearling steelhead (rainbow trout) has been found to be closely associated with the composition of the benthos (Johnson and Ringler 1980, Dedual and Collier 1995).

TABLE 2. Percent composition of one representative invertebrate taxon in the diet of subyearling Chinook salmon and steelhead and in the drift and Surber samples. Sample sizes (number of dates) are in parenthesis. Values in each column not followed by the same superscript letter significantly differ (P < 0.05, Tukey's test).

	Terrestrials	Heptageniidae
Chinook diets	31.7[a] (9)	2.7[c] (8)
Steelhead diets	2.9[b] (6)	7.9[c,d] (4)
Drift nets	29.9[a] (9)	—
Surber samples	—	10.1[d] (9)
ANOVA		
Total MS (df)	386.3 (23)	37.9 (20)
Sample MS (df)	1,762.4 (2)	117.9 (2)
Error MS (df)	255.2 (21)	29.0 (18)
P	0.005	0.04

In the Salmon River subyearling Chinook salmon and subyearling steelhead occupy similar habitat for a short time frame soon after trout emerge and before they move to faster water and before salmon outmigrate. Hillman *et al.* (1989) found that juvenile Chinook salmon occupied areas with faster water velocities when sympatric with juvenile steelhead. High water velocities provide a productive food delivery system for drift feeding salmonids (Chapman 1966). Consequently, because of limited temporal overlap and differences in microhabitat, fish size, diet composition, and foraging behavior the potential for competitive interactions between subyearling Chinook salmon and steelhead is minimal in the Salmon River.

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