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# Diet and Prey Selection of Naturalized Smallmouth Bass in an Oligotrophic Adirondack Lake

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## ABSTRACT

Smallmouth bass (*Micropterus dolomieu*) introduced nearly 50 years ago have established a permanent population in Little Moose Lake, NY. Over 500 smallmouth bass were collected by angling in the littoral zone from June to August. Gut contents were compared for differences based on length of bass, date of capture, and substrate type where each fish was caught. Crayfish were the most frequent diet item and made up the largest percent composition by number. The average number of crayfish per stomach increased with bass length as did the number of fish per stomach. Crayfish, Ephemeroptera, Odonata, and fish made up 77% of the total number of diet items, excluding zooplankton. A noticeable diet shift from smaller diet items (Ephemeroptera) to larger ones (crayfish and fish) occurred when smallmouth bass approached 150 mm. A high amount of diet overlap occurred between bass caught over different substrate types and among most size classes. Smallmouth bass in Little Moose Lake were opportunistic feeders, using benthic, terrestrial, and pelagic littoral zone food resources. The most likely processes by which smallmouth bass affect salmonid and native fishes in Little Moose Lake are competition for food resources and predation.

## INTRODUCTION

Introductions of non-native fishes have had adverse effects on native fish populations through mechanisms such as predation, competition, disease introduction, genetic interactions, and habitat modification (Courtenay and Kohler 1986, Krueger and May 1991). Adverse effects become most apparent when an introduced species competes with, or preys upon, a culturally valuable organism, such as a sport fish. An introduced species can change the amount of forage available to native species by direct predation, or by evoking a change in prey distribution and habitat selection (Crowder 1980, He and Kitchell 1990).

Several non-native fishes have been introduced into the Adirondack region of northeastern New York, often to the detriment of native fishes. Non-native species commonly introduced to lakes in this region include the yellow perch (*Perca flavescens*), northern pike (*Esox lucious*), rainbow smelt (*Osmerus mordax*), and large and smallmouth bass (*Micropterus salmoides*) and (*M. dolomieu*) (George 1980). Declines in biomass of brook trout (*Salvelinus fontinalis*) have been observed in Adirondack and other northern waters, following the naturalization of non-native fishes and resultant competition from these species (Fraser 1978, Flick and Webster 1992).

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Little Moose Lake, an oligotrophic lake in the southwestern Adirondacks, has been managed for salmonids for more than 100 years. Native brook trout and lake trout (*Salvelinus namaycush*), as well as non-native landlocked Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*), support the lake's sport fishery. Smallmouth bass were first observed in the lake in 1951 (Webster 1954a). Smallmouth bass rapidly established an abundant population and now function as an exotic littoral zone predator that may compete with or prey upon salmonids and other native fishes.

Smallmouth bass have been described as opportunistic feeders whose diet shifts to larger items as they grow. Fry and juvenile smallmouth bass depend primarily on zooplankton and small aquatic invertebrates although they may consume small fish in some waters (Coble 1975, Scott and Angermeier 1998, Duns Moor et al. 1991, Easton et al. 1996, Webster 1954b). Large macroinvertebrates, crayfish, and fish usually dominate the diet of adult smallmouth bass (Tester 1932, Surber 1941, Johnson and Hale 1977, Ross et al. 1995). Fedoruk (1966) described a smallmouth bass population where the occurrence of crayfish in the diet remained stable throughout the spring, summer, and fall, but noted a seasonal shift from small benthic invertebrates in the spring and early summer to fish in late summer and fall.

The potential for predation and competition for food resources exists between smallmouth bass and native fishes in Little Moose Lake. Previous diet descriptions for sport and other fishes suggest that a diet overlap could occur with smallmouth bass (Havey and Warner 1970, Swift 1970, Magnan 1988, Flick and Webster 1992, Jahn and Lendman 1993). Native prey fishes, small native salmonids, and stocked fingerling salmonids are all potential prey for smallmouth bass.

The purpose of this study was to describe the summer diet of naturalized smallmouth bass and assess the potential for competition or predation on other fish species in Little Moose Lake. The objective of this study was to describe and compare the diet of smallmouth bass, relative to bass length, date of capture, and substrate type within the littoral zone.

## STUDY SITE

Fish were collected for diet analysis from Little Moose Lake, Herkimer County, New York (43° 38'N, 74° 56'W). Little Moose Lake has an area of 271.5 hectares, a mean depth of 15 meters, and a maximum depth of 39 meters. Little Moose Lake is in the Black River watershed of the Great Lakes-St. Lawrence River drainage.

The nearshore littoral zone ( $\leq 6$  m depth) of Little Moose Lake had typical summer habitat characteristics of an oligotrophic Adirondack Lake. Water temperature within the littoral zone during the summer of 1996 varied from 15-22°C, pH ranged from 6.6-7.0, and Secchi disc readings ranged from 5.5-8.25 meters. Total phosphorus levels during the summer ranged from 1.2-8.1  $\mu\text{g/l}$ , and chlorophyll *a* concentrations ranged from 0.27-1.32  $\mu\text{g/l}$ . Based on particle size, bottom substrate within the littoral zone of Little Moose Lake can be classified as sand, silt, and rock (Cummins 1962). Coarse woody material, in the form of submerged blowdowns, is present in approximately 15% of the littoral zone, based on shoreline perimeter.

## METHODS AND MATERIALS

Five hundred and thirty one smallmouth bass were caught by angling in the littoral zone. Fish were collected over an eight-week period from June 11 to August 9, 1996. Efforts to catch all sizes of bass were made by varying lure type and size and depth of angling. The entire littoral zone was fished once every two weeks to account for changes in lakewide distribution of bass during the sampling period.

Location in the lake, approximate depth of capture, and lure type were recorded for each fish collected. Digestion of gut contents was stopped by using a syringe (30 ml) and hypodermic needle (18 gauge, 38mm) to inject 3-5ml of 37% formaldehyde into the coelom through the anal opening (Emmett et al. 1982). For large fish (> 300 mm), a second injection was made between the pelvic fins and anal opening to insure adequate amounts of formalin penetrated the abdominal cavity.

Fish were preserved in the field and then measured and dissected in the laboratory. Total length (mm) and weight (g) were collected from each fish prior to dissection in the laboratory. The gut was defined as from the buccal cavity to the pyloric caeca. The entire gut was removed and stored in 80% ethanol. Gut contents were identified to the lowest practical taxon and counted, and length of prey items were estimated or measured if whole. Heads, tails, and head parts were used to identify and count fish and invertebrates that were not whole. Carapaces, claws, and eyes were used to identify and count partially digested crayfishes.

Percent occurrence and percent composition were used to describe the summer diet of smallmouth bass in Little Moose Lake. The percent occurrence for a diet item was the percent of bass from a sample that contained that particular diet item. Percent composition was the percentage of a diet item within the total number of bass food items counted (Bowen 1996). Diets of different length classes of bass were graphically compared for commonly consumed diet items by using the number of each item per bass. Zooplankton were excluded from the percent composition calculations because of their small size, and because few bass consumed them. Presence of zooplankton in diets was recorded.

An index of overlap (Schoener 1970) was used to compare the diets of smallmouth bass caught on three different substrates (rock, silt, and sand) and to compare overlap between various size classes. Schoener's index describes the amount of diet overlap between two groups of fish by comparing the average percent composition for the diet items. The index produces an alpha value, representing the degree of overlap. An alpha of one represents complete overlap, and zero represents no overlap.

## RESULTS

Smallmouth bass diets in Little Moose Lake were dominated by benthic invertebrates. A total of 1,510 diet items, excluding zooplankton, were counted from the 531 smallmouth bass stomachs examined. Crayfish occurred in 49.2% of the bass and comprised 26.6% of the total number of diet items (Table 1). Ephemeroptera (25%), Odonata (22%), and fish (12%) were the next three most frequently occurring items in smallmouth stomachs. Slimy sculpin,

(*Cottus cognatus*), was the only fish identified in the diet. Thirteen percent of the smallmouth bass sampled had empty stomachs.

The number of diet items per bass changed according to bass length (Figure 1). The number of crayfish and fish per stomach increased as bass length increased. Conversely, Ephemeroptera numbers per stomach decreased with length. Odonata numbers per bass increased from small size classes to mid size classes, peaked, then decreased for large bass. Fish and crayfish were the largest diet items consumed by smallmouth bass (mean diet item lengths = 40.3 mm ± 3.06 and 34.4 mm ± 1.25, respectively). Odonata and Ephemeroptera were smaller diet items (mean lengths = 16.5 mm ± 0.92 and 15.0 mm ± 0.91 respectively). A shift towards large diet items occurred when smallmouth bass reach an approximate length of 150 mm (Figure 1).

Table 1. Percent occurrence (Occurrence) and percent composition (Composition) of smallmouth bass diet items, Little Moose Lake, NY. Diet items are listed in descending order by percent occurrence. "Other" included Talitridae, Corixidae, and unidentifiable aquatic invertebrates. Zooplankton were excluded from the analyses.

Diet Item	Diet Parameter	Size Classes (50mm increments)					All Fish (n=531)
		90-149 (n=121)	150-199 (n=230)	200-249 (n=110)	250-300 (n=45)	300+ (n=25)	
Crayfish	Occurrence	11.6	50.9	70.0	77.8	72.0	49.2
	Composition	5.9	22.6	35.0	52.0	57.9	26.6
Ephemeroptera	Occurrence	37.2	28.7	16.4	8.9	12.0	25.6
	Composition	37.0	16.1	19.3	4.7	7.0	19.1
Odonata	Occurrence	16.5	20.0	28.2	37.8	12.0	22.0
	Composition	8.1	11.3	16.0	23.3	5.3	12.7
Fish	Occurrence	9.1	11.3	12.7	6.7	28.0	11.5
	Composition	4.1	5.2	6.4	4.7	22.8	5.9
Terrestrial	Occurrence	14.0	11.3	8.2	8.9	4.0	10.7
	Composition	15.9	8.3	2.8	2.7	1.8	7.7
Trichoptera	Occurrence	5.8	9.1	13.6	11.1	8.0	9.4
	Composition	2.6	4.0	14.1	7.3	3.5	6.2
Diptera	Occurrence	15.7	8.7	1.8	4.4	0.0	8.1
	Composition	22.2	28.1	4.0	1.3	0.0	18.1
Other	Occurrence	8.3	8.7	5.5	6.7	4.0	7.5
	Composition	4.1	4.2	2.5	4.0	1.8	3.7

The percent occurrence of various diet items changed relative to the time smallmouth bass were captured within the eight week sampling period. The percent occurrence for Ephemeroptera and Trichoptera in bass diets peaked between late June and early July (Table 2). The average numbers of Ephemeroptera and Trichoptera per bass were also highest during this time period. Odonata occurred in the diet most in late June and July. The percent occurrence and the average number of zooplankton per bass increased with time. Sixty-eight percent of the smallmouth bass that consumed zooplankton ( $n=31$ ) were in the smallest size class (90-150mm).

Schoener's index values for diets were similar across all three habitats and similar among different size categories of smallmouth bass. Schoener's index values had high overlap among substrate types (alpha values:0.78-0.86). Schoener's index indicated high diet overlap (alpha > 0.70) between all size classes except for the smallest size class (90-149mm) and largest size class (300+ mm) of bass, which had an alpha of 0.55.

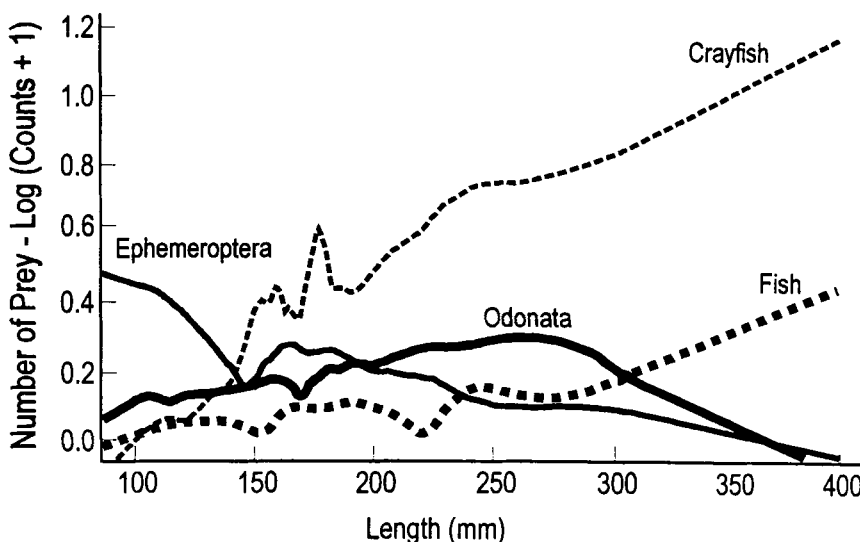


Figure 1. Changes in abundance of the four most frequently occurring diet items by smallmouth bass length. Results were plus one log transformed and graphically presented using a Supersmoother scatterplot smoothing algorithm (Venables and Ripley 1997).

## DISCUSSION

### Smallmouth Bass Diet

The diet of smallmouth bass from Little Moose Lake indicated that this species functions as an opportunistic feeder during the summer. Smallmouth bass preyed on a variety of benthic, terrestrial, and pelagic food resources found in the littoral zone. Gape limitations and seasonal availability of various invertebrates played a role in structuring the observed smallmouth bass diet.

The opportunistic feeding nature of smallmouth bass was apparent in the seasonal use of various diet items. The high frequency of Ephemeroptera,

Table 2. Percent occurrence, by date, for smallmouth bass diet items, Little Moose Lake, NY. Number of stomachs examined in parentheses.

Diet Item	Diet Parameter	6/11-6/25 (62)	6/26-7/9 (175)	7/10-7/23 (155)	7/24-8/9 (139)
Odonata	# of Items	23	59	74	36
	Occurrence	15	38	40	24
Ephemeroptera	# of Items	39	182	48	19
	Occurrence	21	65	36	14
Trichoptera	# of Items	30	54	4	6
	Occurrence	16	25	4	5
Diptera	# of Items	14	48	176	36
	Occurrence	11	12	13	7
Zooplankton	# of Items	0	278	1695	2128
	Occurrence	0	4	13	14

Trichoptera, and Odonata in the diet of bass caught in late June and July coincides with the emergence peaks for these invertebrates. Other smallmouth bass diet studies have noted the increased use of invertebrates during emergence periods (Fedoruk 1966, Gilliland et al. 1991, Scott and Angermeier 1998). Zooplankton occurrence in the diet increased throughout the sampling period, possibly caused by a depletion of preferred benthic food resources (Dunsmoor et al. 1991).

Smallmouth bass length was associated with changes in diet composition. A noticeable shift in diet from small diet items (Ephemeroptera) to larger items (crayfish and fish) occurred when fish approached the 150 mm size. Other studies have documented similar size-related diet shifts in smallmouth bass (Lachner 1950, Scott and Angermeier 1998, Gilliland et al. 1991); however, these studies described diet shifts occurring when fish were approximately 120 mm. Changes in diet, related to length, were likely due to changes in fish gape.

The high degrees of diet overlap measured by Schoener's index for the mid-size (150-249mm) class of bass between the small (90-149mm) and the large (250+ mm) size classes suggests the mid-size class can effectively capture most prey types available in the littoral zone. This overlap suggests this size class of smallmouth bass has the greatest potential to compete for food resources with the other fish species.

#### Effects on Native Fishes

Various researchers have noted a decline in salmonid populations with the establishment of smallmouth bass populations (Catt 1949, Flick and Webster 1992, McNeill 1995). In Maine, brook trout populations declined in most waters where smallmouth bass were introduced and became abundant,

especially in those waters considered marginal for trout (Watson 1955, K. Warner, Maine Dept. of Inland Fisheries, personal communication). The most likely processes by which smallmouth bass affect salmonid and other native fishes in Little Moose Lake are competition for food resources and predation.

Previous diet descriptions for salmonids and non-game fishes from other lakes suggest potential overlaps in the diets of smallmouth bass and other fishes in Little Moose Lake. Small invertebrates are the dominant prey items for all brook trout, while larger brook trout (>150 mm) consume crayfish and large macroinvertebrates or fish (Swift 1970, Fraser 1980, Peterson and Martin-Robichaud 1982). Rainbow trout and landlocked Atlantic salmon diets have been characterized as consisting primarily of pelagic forage fish, zooplankton, terrestrials insects and occasionally benthic invertebrates (Havey and Warner 1970, Warner and Havey 1985, Jahn and Lendman 1993, Lynott et al. 1995). Lake trout in Little Moose Lake feed on macroinvertebrates (Diptera and Ephemeroptera) from ice-out until mid-May then shift to primarily zooplankton for the remainder of the year (unpublished data). Diet overlap, especially for benthic invertebrates, may exist between smallmouth bass and native creek chub (*Semotilus atromaculatus*), white sucker (*Catostomus commersoni*), pumpkinseeds (*Lepomis gibbosus*), and slimy sculpin (Scott and Crossman 1973, Magnan 1988). Competition could occur between native and non-native fishes when food resources were limited.

Smallmouth bass may adversely affect the Little Moose Lake fish community through direct predation. Slimy sculpins were the only fish identified in the stomach contents although other unidentifiable fish parts were found. Recent electrofishing and predation risk experiments found evidence of direct predation by smallmouth bass on brook trout and creek chubs (unpublished data). High risk of predation on stocked fingerling landlocked salmon by smallmouth bass has been noted by Warner (1972) and may explain the low recruitment of stocked fingerling salmon in Little Moose Lake.

Prior to the introduction and naturalization of smallmouth bass, Little Moose Lake's littoral zone was dominated by salmonids and native fishes (Webster 1952, 1954a). Smallmouth bass predation and competition, coupled with the low productivity of the lake, may severely limit the preferred nearshore salmonid fishery. We hypothesize that a large reduction in the abundance of smallmouth bass will lead to increased growth and better survival of native fishes and stocked salmonids in Little Moose Lake.

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