Proceedings of the Indiana Academy of Science
(1988) Volume 98 p. 181-187.

FOOD HABITS OF SALMONINE PREDATORS IN INDIANA WATERS OF LAKE MICHIGAN COMPARING THE EARLY 1970's WITH 1984-86

THOMAS S. MCCOMISH
Aquatic Biology and Fisheries
Department of Biology
Ball State University
Muncie, Indiana 47306

ABSTRACT: Salmonine predator-prey relationships were investigated for extreme southern Lake Michigan waters in Indiana from April to September of 1984-86 and compared to 1970 food habit information. Trawling on index zones in Indiana waters of Lake Michigan revealed changes in relative abundance of potential forage fish eaten by salmonines, including alewife (*Alosa pseudoharengus*), yellow perch (*Perca flavescens*), bloater (*Coregonus hoyi*), and rainbow smelt (*Osmerus mordax*). In 1973, the potential forage base was dominated by alewives (47%) followed by rainbow smelt (27%) and yellow perch (26%). By comparison, in 1984-86, yellow perch dominated (84%) followed by rainbow smelt (9%), bloater (6%), and alewife (1%). Food consumed in 1970 by the major salmonine predators, including coho salmon (*Oncorhynchus kisutch*), chinook salmon (*Oncorhynchus tshawytscha*), and lake trout (*Salvelinus namaycush*), was compared to 1984-86, revealing continued importance of the alewife in the diet even though trawl catches showed its population density had declined sharply. In 1970, alewives comprised 93-100% of food comsumed and continued as the dominant forage fish eaten in 1984-86 at 44-56% of the diet. Even though yellow perch dominated the potential forage fish base in 1984-86, it accounted for only 8-30% of the food consumed, and it was not a food item in 1970. Other major forage fish consumed in 1984-86 included rainbow smelt, also eaten in 1970, and bloater, which was not a food in 1970. Steelhead (*Oncorynchus mykiss*) food habits, evaluated only in 1984-86, also revealed the alewife as the major food item at 48%. No positive size selection by salmonine predators for forage fish prey was found. Salmonines tended to feed on all sizes of forage in 1984-86, probably due to continued preference for the alewives which were at lower population densities.

INTRODUCTION

Salmonine predatory-prey relationships in extreme southern waters of Lake Michigan in Indiana were investigated from April to September during 1984-86. The purpose of this work was to compare salmonine diets for 1984-86 to those for

TABLE 1. Sample size (n) and length ranges (cm) of salmonine species sampled from Indiana waters of Lake Michigan in 1970 and the 1984-86 average.

Predator Species	Sample Size (n) and Length Range 1970			1984-86		
	P[a]	E[b]	cm	P	E	cm
Coho salmon	34	13	46-58	720	293	30- 90
Chinook salmon	29	19	25-68	408	782	30-110
Lake trout	39	32	30-76	735	747	40- 90
Steelhead				346	416	50-100

[a]P = food present.
[b]E = empty.

1970 (McComish and Miller, 1976). Insight into diet changes was obtained by comparing the food consumed by coho salmon (*Oncorhynchus kisutch*), chinook salmon (*Oncorhynchus tshawytscha*), lake trout (*Salvelinus namaycush*), steelhead trout (*Oncorynchus mykiss*) with the forage fish available as potential food.

The fish assemblage of Lake Michigan is currently a management dependent system dominated by introduced species (Stewart, *et al.,* 1981). The introduced salmonine predators are the key to maintaining the balance with both the other exotic fishes and the native fishes (Smith, 1968). Likewise, the population density of the exotic alewife (*Alosa pseudoharengus*) appears to be central to the continued success of the salmonine predators. The importance of the alewife as the dominant forage fish consumed by the salmonine predators both in Indiana waters of Lake Michigan (McComish and Miller, 1976) and elsewhere in the lake (Smith, 1968; Jude, *et al.,* 1987) has been well documented. Stocking success and high growth rate of the stocked salmonine species has been attributed to the abundant alewife forage base (Edsall, *et al.,* 1974). To emphasize the importance of alewives in the food base, Stewart, *et al.* (1981) warned that forage for salmonids in Lake Michigan is finite and excessive salmonid stocking could result in high salmonid mortality or poor growth.

The research reported here provides important additional insight to the interrelationships between the major salmonine predators and their forage base in extreme southern Lake Michigan. Continued successful management of the Lake Michigan sport fishery is dependant on understanding the dynamics of the lake system and the complex trophic interrelationships. This research documents the changing Lake Michigan predator-prey relationships by comparing data for the early 1970's to the mid-1980's.

METHODS AND MATERIALS

Forage fish densities were monitored on index trawl zones at depths ranging from about 3 to 7 m. A semi-balloon trawl was used to sample forage fish. It had a 4.9 m headrope and a 5.8 m footrope and was constructed of green Net-Set treated nylong thread woven to 38 mm stretch meshes in the body fitted with a 13 mm stretch mesh cod liner. It was towed at an average speed of about 3.5 mph. All trawling was completed at night in order to minimize trawl avoidance. A total of 24 tows, each of 10 min. duration, were completed each month during June,

TABLE 2. Trawl catch of utilized forage fish by species, total sampled (n), and composition (%) from Indiana waters of Lake Michigan in 1973 and the 1984-86 average.

Prey Species	Catch 1973		1984-86	
	n	%	n	%
Alewife	532	47	179	1
Yellow perch	286	26	19,489	84
Rainbow smelt	306	27	2,072	9
Bloater	1	T[a]	1,451	6

[a]T = less than 1%.

July, and August of 1973 and 1984-86. Additional details are given in McKeag (1987).

Stomach samples from salmonine predators were collected at sites in the Michigan City and Gary/Hammond, Indiana vicinities with the majority at Michigan City. Fish caught by sport fishermen were generally taken in or very near to Indiana waters of Lake Michigan. No attempt was made to determine the exact locations of fish capture due to potential error, but they represented a large number of dates and sites and were considered a representative sample for diet analysis.

Salmonine predators were made available for analysis due mainly to the cooperation and assistance of the charter boat captains and their personnel. Large numbers of fish were brought to onshore fish cleaning stations for stomach collection. Stomachs were removed intact from the fish, placed in Whirl-Paks, and preserved in 10% formalin for later analysis. In the laboratory, the stomach contents were rinsed with water into petri dishes, and the organisms they contained were removed, identified, counted, and measured.

STUDY AREA

Trawling to sample forage fishes was completed in established sample zones in Lake Michigan near Michigan City, Indiana (McKaeg, 1987). The lake bottom slopes gently toward offshore areas slowly increasing in depth and reaching a maximum of about 20-25 m at locations near the State line. The substrate is varied but consists mainly of a sand, clay, and shale mixture. Little structure exists on the bottom, but sharp crevice-like depressions oriented from near shore toward off shore are common westward from Michigan City, especially in the Kintzele Ditch area.

RESULTS AND DISCUSSION

Salmonine predators sampled. Large numbers of salmonine stomachs were collected for analysis in 1984-86 (Table 1). The numbers of stomachs examined by species were as follows: 1013 coho salmon, 1190 chinook salmon, 1482 lake trout, and 762 steelhead. On the average, 50% of all stomachs had food present.

TABLE 3. Diet composition (%) for major salmonine species from Indiana waters of Lake Michigan comparing 1970 with the 1984-86 average.

Prey Species	Diet by Species (%)[a]						
	Coho		Chinook		Lake Trout		Steelhead
	1970	1984-86	1970	1984-86	1970	1984-86	1984-86
Alewife	97	49	100	44	93	56	48
Yellow Perch		23		30		8	30
Rainbow smelt	3	23		17	6	31	21
Bloater				6		5	
Miscellaneous[b]		5		3	1		1

[a]1970 results (McComish and Miller, 1976) compared to 1984-86 numerical average (%).
[b]Category includes: spottail shiners, trout-perch, and sculpins (*Cottus* spp.).

The number of salmonine stomachs sampled in 1970 included 47 coho salmon, 48 chinook salmon, and 71 lake trout (Table 1). No steelhead were available for diet analysis. Food was present in 61% of the total stomachs examined.

The sizes of fish sampled for stomachs in 1970 ranged from 25 to 76 cm and in 1984-86 from 30 to 110 cm (Table 1). Most fish (94%) were 50 cm or longer in total length.

Potential and utilized forage fishes. Changes in the numerical abundance of major potential forage fish species occurred between 1973 and 1984-86. Adult fish, here defined as age one or older, were separated from the total trawl catch for sample periods from June through August of each year (McKeag, 1987). The total trawl catch for the June through August period was compared, since annual sampling effort did not vary for 1973 or the 1984-86 period.

The major potential forage fish species available as a food source for larger predator fish included: alewives, yellow perch (*Perca flavescens*), rainbow smelt (*Osmerus mordax*), bloaters (*Coregonus hoyi*), trout-perch (*Percopsis omiscomaycus*), and spottail shiners (*Notropis hudsonius*). Although these six species made up the potential forage base, salmonine predators preferentially ate alewives, yellow perch, rainbow smelt, and bloaters. These four species comprised the utilized forage fish base.

Trawling on index zones revealed significant changes in the relative abundance of the utilized forage fish base between 1973 and 1984-86 (Table 2). The yellow perch population expanded very rapidly from only 286 captured in 1973 to an average per year of 19,489 in 1984-86 for nearly a 70-fold increase. By comparison, the alewife catch declined dramatically from 532 fish captured in 1973 to an average of 179 in 1984-86, representing a 66% decline. Rainbow smelt increased during the period from a 1973 low of 306 to an average of 2,072 in 1984-86 but with wide fluctations (McKeag, 1987). The trawl catch for bloater showed a major increase from only one fish in 1973 to an average of over 1,450 during 1984-86. These data reveal dramatic changes in the population densities of forage fish species utilized as food by salmonine predators between 1973 and 1984-86.

A comparison of the utilized forage fish in the trawl catch by percent composition for 1973 and 1984-86 also revealed major shifts in the dominant species

TABLE 4. Invertebrate prey frequency of occurrence (%) in stomachs of salmonine species sample from Indiana waters of Lake Michigan by 1984-86 average.

Invertebrate Prey	Frequency of Occurrence (%) by Predator Species			
	Coho	Chinook	Lake Trout	Steelhead
Invertebrates	75	T[a]	T	47
Amphipoda	33			5
Coleoptera	31			37
Diptera	69	T	T	39
Hemiptera	14			9
Lepidoptera	28		T	30

[a]T = Less than 1%.

(Table 2). In 1973, the major forage fish catch was dominated by alewives (47%) followed by rainbow smelt (27%) and yellow perch (25%). By 1984-86, there was a dramatic shift to dominance by yellow perch (84%) followed by rainbow smelt (9%), bloaters (6%), and alewives (1%).

Diet shifts of salmonines. A comparison of forage fish consumed in 1970 (McComish and Miller, 1976) with 1984-86 revealed the continued importance of the alewife in salmonine diets (Table 3) even though it was nearly 70% less abundant in the forage base (Table 2). The 1970 diet evaluation for coho salmon revealed alewives as the single dominant forage fish (present in 97% of the stomachs analyzed). The 1984-86 diet evaluation revealed a striking change due to the altered population levels of forage fish available. However, the strong "preference" for alewives continued. During the 1984-86 period, coho salmon ate predominantly alewives (49%) followed by yellow perch (23%) and rainbow smelt (23%).

In 1970, diet studies for chinook salmon revealed that only alewives were consumed. In 1984-86, chinook salmon had a more diverse diet but ate mostly alewives (44%) followed by yellow perch (30%), rainbow smelt (17%), and bloaters (6%).

In lake trout, the dominant food item in 1970 was alewives (93%) followed by rainbow smelt (6%). In 1984-86, lake trout food habits were also more diverse, as they consumed mainly alewives (56%) followed by rainbow smelt (31%), yellow perch (8%), and bloater (5%).

These diet data reveal a continued dominance of the alewife in the 1984-86 diet of all major salmonine species (44-56%). Although yellow perch dominated the potential forage fish species available, comprising 84% of the trawl catch for the 1984-86 period, it was far less important than alewives as a salmonine food. Coho salmon, chinook salmon, and steelhead all consumed relatively high overall precentages of yellow perch in 1984-86 (23-30%), while the percentage eaten by lake trout was low (8%). Bloaters were eaten by both chinook salmon and lake trout in 1984-86, but they were not consumed by coho salmon or steelhead. These data seem to show that the chinook salmon has responded better to recent changes in the forage fish base than other salmonines.

Prey fish size selection. Correlations between the size of the prey fish consumed and the size of the predator salmonines were calculated for the 1984-86

period. No significant relationships were found due to the tendency by predators to consume all sizes of prey. Foraging theory promotes the concept that as predator fish increase in size, feeding efficiency requires larger prey. Jude, *et al.* (1987) found that salmonines collected inshore in southeastern Lake Michigan from 1973-82 showed significant postive size selection for both alewives and rainbow smelt. The lack of size selection for forage fish species in 1984-86 when compared to the 1973-82 data of Jude, *et al.* (1987) reflects a recent dramatic decline in the nearshore density of alewives. The density changes of forage species, especially alewives, has apparently made it necessary for salmonine predators to feed on all sizes of prey.

Invertebrates consumed. Invertebrate food items were consumed by some of the salmonine species (Table 4). Invertebrates were unimportant to both chinook salmon and lake trout (less than 1% consumed any invertebrates). Invertebrates were frequently consumed by coho salmon and steelhead from April through June of 1984-86, when 75-85% of the coho salmon and 85-100% of the steelhead were found to have eaten some kind of invertebrate. Insects in the order Diptera (flies) were the major invertebrate group consumed by both coho salmon and steelhead. Although a large percentage of coho salmon and steelhead consumed invertebrates through June, invertebrate occurrence was low after June, ranging from 0 to 13%. Fish comprised 6% to 53% of the diet of coho salmon and steelhead through June, but afterwards coho salmon and steelhead consumed fish exclusively. The shift away from invertebrates as prey was complete after June. Overall occurrence for invertebrates between April and September of 1984-86 was 75% for coho salmon and 47% for steelhead. Invertebrates were an early growth season food for coho salmon and steelhead, but they became relatively unimportant as summer progressed.

SUMMARY AND CONCLUSIONS

Trawling on index zones in Indiana waters of Lake Michigan revealed significant changes in the forage fish populations between 1973 and 1984-86. The major shifts taking place included a near 70-fold increase in abundance of yellow perch and a concurrent 66% decline in alewives. Bloaters experienced a population explosion between 1973 and the 1984-86 period. The other forage fish, rainbow smelt, fluctuated widely in number between 1984-86 (McKeag, 1987), a characteristic of this species in many lakes including the Great Lakes.

The percent composition of the forage base sampled by trawling and eaten by salmonine predators shifted dramatically between 1973 and 1984-86. In 1973, the forage base was dominated by alewives (47%) followed by rainbow smelt (27%) and yellow perch (26%). In 1984-86, the yellow perch population was the overwhelming dominant followed by rainbow smelt (9%), bloater (6%), and alewife (1%).

A comparison of the food consumed in 1970 by salmonine predators (McComish and Miller, 1976) with that eaten in 1984-86 revealed the continued importance of the alewife in the diet even though the population had declined sharply. In 1970, coho salmon consumed predominately alewives (97%). In 1984-86, coho salmon ate alewives (49%), yellow perch (23%), and rainbow smelt (23%). Chinook salmon ate only alewives in 1970 but had a diet consisting of alewives (44%), yellow perch (30%), rainbow smelt (17%), and bloater (6%) in 1984-86. In 1970, lake trout ate alewives (93%) and rainbow smelt (6%). By 1984-86, the lake trout

diet included alewives (56%), rainbow smelt (31%), yellow perch (8%), and bloaters (5%). Although steelhead diet analysis was not completed in the early 1970's, they consumed alewives (48%), yellow perch (30%), and rainbow smelt (21%) in 1984-86.

Due to changes in the population densities of the utilized forage fish, significant changes have occurred in diets of all the salmonine predators from the early 1970's to the mid-1980s. Nevertheless, the alewife has continued to be a major dietary component even though its population has declined sharply and it is less available in relation to other forage fish.

The Lake Michigan salmonine sport fishery is very dependent on the alewife as a food source. The data collected between 1984-86 emphasize this fact even though the alewife population has declined to comparatively low levels. The dominance of yellow perch in the 1984-86 period has not resulted in a shift in the foraging behavior of the salmonine predators. Careful scientific management must be directed not only toward the salmonine populations but also toward the alewife population. Continued high survival and rapid growth rates of the salmonine species appears to be closely tied to the alewife and its dynamics in the Lake Michigan system. Future management decisions involving the salmonine sport fishery must carefully consider alewife population dynamics as a major impacting factor.

ACKNOWLEDGMENTS

This research was supported with funding from the U.S. Department of Commerce, National Marine Fisheries Service; an Illinois-Indiana Sea Grant; and Ball State University. The cooperation and assistance of the Indiana Department of Natural Resources, particularly William D. James, Dan Brazo, and Kenneth C. Nettles, is greatefully acknowledged. The effort, hard work, and dedication of numerous undergraduate and graduate students associated with the project, especially Michael P. Gallinat and Kevin J. McKeag, is very much appreciated.

LITERATURE CITED

Edsall, T., E. Brown, Jr., T. Yocum, and R. Wolcott, 1974. Utilization of alewives by coho salmon in Lake Michigan. U.S. Fish and Wildlife Service, Great Lakes Fishery Laboratory Administrative Report, Ann Arbor, Michigan.

Jude, D.J., F.J. Tesar, S.F. Deboe, and T.J. Miller. 1987. Diet and selection of major prey species by Lake Michigan salmonines, 1973-1982. Trans. Amer. Fish. Soc. 116: 677-691.

McComish, T.S. and W. Miller. 1976. Notes on the biology of the lake trout and other Salmonidae in Indiana waters of Lake Michigan. Proc. Indiana Acad. Sci. 85: 161-169.

McKeag, K.J. 1987. An evaluation of the potential forage fish populations in Indiana waters of Lake Michigan: 1973 vs. 1984-86. Masters Thesis, Ball State Univ., Muncie, Indiana, 121pp.

Smith, S.H. 1968. Species succession and fishery exploitation in the Great Lakes. J. Fish. Res. Bd. Canada 25: 667-693.

Stewart, D.J., J.F. Kitchell, and L.B. Crowder. 1981. Prey fishes and their salmonid predators in Lake Michigan. Trans. Amer. Fish. Soc. 110: 751-763.