Notes on the Biology of the Lake Trout and Other Selected Salmonidae in Indiana Waters of Lake Michigan

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Abstract

Lake trout (*Salvelinus nomaycush*), coho salmon (*Oncorhynchus kisutch*), and chinook salmon (*Oncorhynchus tshawytscha*) were collected with gill nets in Indiana waters of Lake Michigan from April to November 1970. Collection sites were mainly in the vicinity of Michigan City, Burns Ditch, and Gary at depths ranging from 5 to 18 m.

The mean calculated total lengths of known-age reintroduced lake trout for the first through fifth years of age revealed faster growth than reported for original native Lake Michigan lake trout. Genetic differences in the stocked lake trout strain and the abundant alewife (*Alosa pseudoharengus*) forage base may be implicated.

Sea lamprey (*Petromyzon marinus*) scars or wounds were found on 25% of the lake trout captured and were restricted to fish 50 cm or greater in total length. No scars or wounds were noted on coho salmon or chinook salmon.

Alewives were the major food consumed by lake trout (93 percent volume), coho salmon (97 percent volume) and chinook salmon (100 percent volume). Lake trout smaller than 58 cm total length tended to consume small alewives (70-187 mm) while larger lake trout ate large alewives (126-182 mm) excusively.

Introduction

Drastic changes in the community structure of Lake Michigan have occurred since 1900. These changes have been brought about by numerous factors (17). The sea lamprey (*Petromyzon marinus*) was a major factor because it decimated the native lake trout (*Salvelinus namaycush*) to near extinction by the mid 1950's (8). The absence of the lake trout as a top carnivore allowed a dramatic population explosion of the alewife (*Alosa pseudoharengus*) between 1949 and the late 1960's (2). Recent large-scale reintroductions of lake trout and introductions of Pacific salmonids have met with success in utilization of the huge alewife forage base and improvement of the trophic imbalance.

The main objective of this research is to provide insight to aspects of the biology of the reintroduced lake trout in the southern basin of Lake Michigan including growth, lamprey scarring, and food habits. A secondary objective is to elucidate the food habits of coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*Oncorhynchus tshawytscha*). This information will be useful in understanding current Lake Michigan fish community dynamics.

Methods and Materials

Salmonids were collected from April 30 to November 18, 1970 in Indiana waters of Lake Michigan. Collection sites were mainly in the vicinity of Michigan City, Burns Ditch, and Gary at depths ranging from 5 to 18 m. Miller (16) describes the sample areas in detail.

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Fish were captured with 366 m long by 1.5 m deep white nylon gill nets composed of four 91.5 m panels of 6, 8, 10, and 13 cm stretch mesh netting. Nets were usually set on the bottom and lifted 24 hr. later. All salmonids were removed from nets and taken to shore. After return to shore, usually within 1 to 2 hr. after lifting nets, fish were identified, weighed to the nearest 0.03 kg, measured in total length to the nearest 0.25 cm, sexed and examined for fin clips and sea lamprey scars or wounds. A scale sample was collected from each fish in the area above the lateral line and below the dorsal fin. Finally, the stomach was removed by cutting at the esophagus and the pyloric valve, wrapped in cheesecloth, labeled and preserved in about 10% formalin.

In the laboratory, each stomach was flushed into a white enamel pan and contents were allowed to settle for about one hour. Obvious food items were removed for immediate identification and measurement. The remaining contents were examined at 6 to 16 X magnification and additional food items were identified and counted. The volume of individual items in a stomach were estimated either directly by water displacement of intact specimens or indirectly by measurement of specimens and calculation of volume based on their form. Miller (16) describes methods of stomach analysis in detail.

Lake trout scales for age analysis were cleaned with detergent, rinsed with water, placed into Diaphane on a glass slide, covered with a cover slip and allowed to dry for about one week. Prepared scales were projected onto a white background at 85 X with a Baush and Lomb Tri-Simplex Microprojector. Annuli on scales were located on the basis of criteria presented by Cable (4). The number of annuli found was checked against the known age of the fish from fin clip records. Calculated total lengths at annulus formation were computed by the direct proportion formula: $S_n/S_c = L_n/L_c$ where S_c and L_c are observed scale length and total length at capture and S_n and L_n are scale length and total length at annulus formation (5). The body-scale relationship was computed by the formula $TL = a + bSc$ where TL is total length and Sc is the anterior scale radius. The length-weight relationship was computed from the formula $\log W = \log a + n \log L$ where W is weight in kilograms and L is total length in centimeters (11).

Results and Discussion

A total of 69 known-age lake trout, captured between May 1 and November 18, 1970, were used for age and growth analysis. Since the analysis is based on known-age fish having specific fin clips depending on planting date and site, the information is known to be reliable. Therefore, while this is a minimal number of fish for age and growth interpretation it will provide useful preliminary information on the species.

The body-scale relationship of the stocked lake trout is expressed by the formula $TL = 14.5397 + 0.3199\ Sc$ ($r = 0.771$) where TL is total length in centimeters and Sc is anterior scale radius in millimeters. The intercept on the determinate axis (14.5) was not used to correct for total length at scale formation in back calculations. The body-scale

relationship results demonstrate that proportionality exists between body length and scale length for the sample fish.

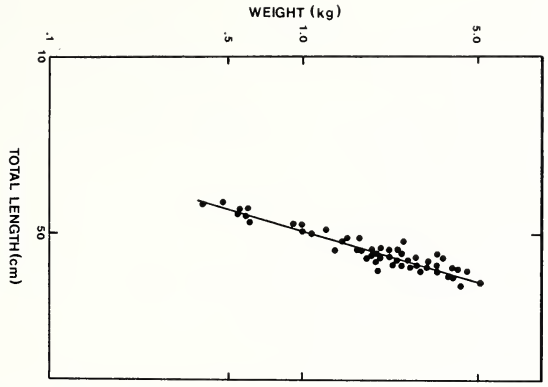

FIGURE 1. *Length-weight relationship of 69 lake trout collected in Indiana waters of Lake Michigan in 1970.*

The length-weight relationship for the stocked lake trout is expressed by the formula log W = —12.4248 + 3.2057 log TL (r = 0.934) (Fig. 1). These results are similar to findings by Cable (4) who reported the length-weight relationship of 1,319 native Lake Michigan lake trout as log W = —5.391 + 3.1125 log TL. The intercept values of the two regression equations vary slightly but the slopes are similar. These results show the reintroduced lake trout are slightly heavier at a given length than the native lake trout.

Scales from four lake trout captured May 1 revealed only two with annuli formed for the current year. Only one specimen captured after July 1 had not formed an annulus. Annulus formation appears to occur between May and the end of June in Indiana waters. These results are in general agreement with Cable (4) who reported annulus formation occurred mainly between May and August in native Lake Michigan lake trout with the 50% level being reached in mid June.

The mean calculated total length and annual growth of stocked lake trout captured in Indiana waters of Lake Michigan in 1970 (Table 1) was greater than reported for native Lake Michigan lake trout (4) (Table 2). Mean calculated total lengths for the first through fifth years of age were 13.9, 26.4, 40.5, 52.1, and 60.8 cm which agreed well with total lengths derived from summation of mean increments of growth. The mean calculated total length ranges of native Lake Michigan lake trout for the first through fifth years of age, summarized from Van Oosten (18), Cable (4), and Van Oosten and Eschmeyer (20) are as follows: 8.4-15.0, 18.0-22.1, 25.7-30.2, 30.7-39.1, and 35.6-46.7 cm (Table 2). Cable (4) reported mean calculated total lengths of 1,319 native Lake Michigan lake trout for the first through fifth years of age were 15.0, 22.1, 28.4, 34.5, and 39.4 cm.

The growth of reintroduced lake trout in Indiana waters of Lake Michigan, based on the 1970 collection, is considerably greater than

TABLE 1. *Mean calculated total length with increments of annual growth(parenthesis) for lake trout collected in Indiana waters of Lake Michigan in 1970.*

Year Class	Age Group	No.	Mean Size at Capture		Total Length at Annulus (cm)				
			TL(cm)	Wt(kg)	1	2	3	4	5
1968	2	8	35.3	0.45	13.5	25.9			
					(13.5)	(12.4)			
1967	3	12	49.5	1.36	13.2	27.7	41.4		
					(13.2)	(14.5)	(13.7)		
1966	4	44	60.5	2.59	13.5	26.2	41.7	53.6	
					(13.5)	(12.7)	(15.5)	(11.9)	
1965	5	5	65.9	3.27	15.2	25.7	38.4	50.5	60.8
					(15.2)	(10.5)	(12.7)	(12.1)	(10.3)
Mean Calculated Total Length (cm)					13.9	26.4	40.5	52.1	60.8
Mean Increment of Growth (cm)					13.9	12.5	14.0	12.0	10.3
Total Length from Sum of Increments (cm)					13.9	26.4	40.4	52.4	62.7
Mean Calculated Weight (kg)					0.05	0.18	0.72	1.68	2.54

reported for native lake trout in Lake Michigan. An obvious possible explanation is that the studies cited on native Lake Michigan lake trout were conducted before the dominance of the alewife as a forage species in Lake Michigan. Change in food availability through introduction of forage fish has been reported previously as a factor improving lake trout growth (12, 15). Another possible consideration is a difference in genetic growth potential of the reintroduced lake trout compared with the native stock. The role of hatchery selection and the exact genetic background of the stocked strain could be major factors involved. The possibility of sampling bias due to small sample size may also be a consideration. Studies of lake trout age and growth in Lake Michigan (18, 20) and Bear Lake, Utah (3, 14) tend to show small sample size results in an over estimate of growth (Table 2). It is unlikely, however, that the degree of difference noted for growth of the reintroduced fish compared to native fish could be due to sample size alone.

TABLE 2. *Mean calculated total lengths of native Lake Michigan lake trout and lake trout from Bear Lake, Utah.*

Location/Source	No.	Total Length at Annulus (cm)				
		1	2	3	4	5
Lake Michigan						
Van Oosten (18)	97	12.4	21.6	30.2	39.1	46.7
Van Oosten and Eschmeyer (20)	811	8.4	18.0	25.7	30.7	35.6
Cable (4)	1319	15.0	22.1	28.4	34.5	39.4
Bear Lake, Utah						
McConnell *et al.* (14)	44	22.1	34.3	43.4	50.0	55.4
Bulkley (3)	295	13.7	21.3	29.5	37.6	44.5

Scar Analysis

Sea lamprey wounds or scars were found on 25% of the 69 lake trout captured in 1970 and fresh wounds occurred on 6% of the fish. Anonymous (1) found 2% of the lake trout captured in Indiana waters in 1969 had wounds. All scars and wounds on lake trout captured in 1970 were restricted to fish 50 cm or greater in total length. Of the 55 fish in this size group, 33% had scars or wounds. Daly (6) found most sea lamprey scars or wounds occurred on lake trout over 50 cm in Wisconsin waters of Lake Michigan but he also reported some heavy scarring on smaller fish. No scars or wounds were found on any coho salmon or chinook salmon captured in 1970.

Lake Trout Food Habits

Only 39 (55%) of the 71 lake trout captured had food contents in stomachs (Table 3). Fish were found in 98% of the stomachs and composed essentially all of the volume. The alewife was the single most important food item, occurring in 85% of the stomachs and comprising 93% of the total volume. Invertebrates (chironomid larvae, *Mysis* sp., and *Pontoporeia affinis*) were only a minor component of the

diet for all sizes combined. In Cayuga Lake, New York, Galligan (10) found fish in 95% of lake trout stomachs and alewives were present in 80%. Wright (21) reported a frequency of 80% for fish in his study of immature lake trout from Lake Michigan. He noted alewives and sculpins were found in 28% and 33% of the stomachs respectively.

TABLE 3. *Percent volume and percent frequency of occurrence (parenthesis) of food items in stomachs of lake trout, coho salmon, and chinook salmon collected in Indiana waters of Lake Michigan in 1970.*

Item Consumed	Lake Trout	Coho Salmon	Chinook Salmon
Fish	100(98)	100(97)	100(100)
Alewife	93(85)	97(79)	100(76)
Slimy sculpin	1(5)		
Mottled sculpin	T[1](3)		
Rainbow smelt	6(5)	3(3)	
Unidentified	(13)	(24)	(28)
Invertebrates	T(13)	T(6)	T(3)
Insects	T(5)	T(6)	
Chironomidae	T(5)		
Miscellaneous[2]		T(6)	
Crustaceans	T(8)		T(3)
Mysis sp.	T(5)		
Pontoporeia affinis	T(5)		T(3)
Stomachs Examined	39	34	29
Length Range in cm.	30-76	46-58	25-68

[1] T is trace, less than 0.5%.

[2] Composed of adult terrectrial Coleoptera, Diptera, and Hemiptera.

Fish size was a factor in determining the type food eaten by lake trout (Table 4). Alewives were the most important item consumed on a percent volume and frequency basis for lake trout in the following three length intervals: 30-37, 38-47, and 48-76 cm. Volumes ranged from 92 to 100% and frequency of occurrence ranged from 75-100%. Lake trout 58.3 cm or greater in length tended to consume large alewives (126-182 mm) while lake trout smaller than 58.3 cm tended to consume some small alewives (70-178 mm) (Table 5). Crustaceans, *Pontoporeia affinis* and *Mysis* sp., were found only in stomachs of lake trout less than 48 cm total length. They occurred in 25-50% of the stomachs and *Mysis* sp. compirsed 8% of the volume while *Pontoporeia affinis* accounted for only a trace. Lake trout less than 38 cm total length have been found to feed more extensively on invertebrates, particularly crustaceans (*Mysis* sp. or *Pontoporeia affinis*), while lake trout greater than 38 cm have been found to feed exclusively on fish (7, 9, 13, 19, 21).

Coho Salmon and Chinook Salmon Food Habits

A greater percentage of stomachs of coho salmon and chinook salmon contained food compared to those of lake trout sampled. The stomachs of 34 of 47 total coho salmon captured mainly in May had

food contents while stomachs of 29 of the 48 chinook salmon captured primarily in October contained food items. Fish were the dominant items consumed by both species (Table 3). Alewives were found in 79% of coho salmon and 76% of chinook salmon stomachs and accounted for 97% and 100% respectively of the volumes. Rainbow smelt (*Osmerus mordax*) occurred in 3% of the coho salmon stomachs and made up 3%

TABLE 4. *Percent volume and percent frequency of occurrence (parenthesis) of food items in stomachs of three length intervals of lake trout collected in Indiana waters of Lake Michigan in 1970.*

Item Consumed	Length Interval (cm)		
	30-37	38-47	48-76
Fish	92(75)	100(100)	100(100)
Alewife	92(50)	65(50)	98(94)
Slimy sculpin		35(50)	
Mottled sculpin			1(3)
Rainbow smelt			1(7)
Unidentified	(25)	(25)	(10)
Invertebrates	8(50)	T(50)	T(10)
Insects		T(25)	T(10)
Chironomidae		T(25)	T(10)
Crustaceans	8(50)	T(25)	
Mysis sp.	8(50)		
Pontoporeia affinis	T[1](25)	T(25)	
Stomachs Examined	4	4	31

[1] T is trace, less than 0.5%.

TABLE 5. *Total length of measurable alewives in stomachs of lake trout, coho salmon, and chinook salmon collected in Indiana waters of Lake Michigan in 1970.*

Salmonid Total Length (cm)	Alewife Total Length (MM)					
	Lake Trout		Coho Salmon		Chinook Salmon	
	Range	Mean	Range	Mean	Range	Mean
25.4-27.2					88	88
27.8-30.2					65-80	73
30.3-32.8					67-92	82
32.9-35.3	133	133			84	84
35.4-37.8						
37.9-40.4						
40.5-42.9						
43.0-45.5	148	148				
45.6-48.0			63-67	65		
48.1-50.5	75-133	113	72-190	138		
50.6-53.1	107-175	146	152-186	166		
53.2-55.6	178	178	68-159	103		
55.7-58.2	70-176	123	67-170	93	91-93	92
58.3-60.7	139-179	155				
60.8-63.2	143-182	161				
63.3-65.8	126-155	143				
65.9-68.3	151-177	169			118-132	123
68.4-70.9						
71.0-73.4	152	152				

of the volume but they were not found in chinook salmon stomachs. Coho salmon consumed alewives between 63 to 190 mm while chinook salmon fed on alewives from 65 to 132 mm long (Table 5). The difference in maximum size of alewives consumed is probably related to season since, as noted, most chinook salmon were captured in October when large alewives are not present due to migration to deeper offshore water. Anonymous (1) reported an occurrence of 64% for alewives and 7% for smelt in stomachs of coho salmon from Indiana waters in 1969.

Summary

1) The mean calculated total lengths of known-age reintroduced lake trout for first through fifth years of age revealed faster growth than reported for original native Lake Michigan lake trout. Stocked fish were also slightly heavier at a given length. Factors which may be implicated in the rapid growth of the reintroduced lake trout include genetic differences, the readily available alewife forage base, and the possibility of bias due to the low sample size. The growth differences noted, however, appear too great to be attributed solely to the latter factor. Future studies may provide additional insight to growth characteristics of the reintroduced lake trout.

2) Sea lamprey scars or wounds were found on 25% of the lake trout captured and were restricted to fish 50 cm or greater in total length. No scars or wounds were noted on coho salmon or chinook salmon.

3) The alewife was the major food consumed by lake trout (93 percent volume), coho salmon (97 percent volume) and chinook salmon (100 percent volume). Lake trout smaller than 58.3 cm total length tended to consume some smaller alewives (70-187 mm) while larger lake trout ate larger alewives (126-182 mm) exclusively.

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