STUDY PERFORMANCE REPORT

State: Michigan **Project No.:** F-81-R-4

Study No.: 451 **Title:** Evaluation of lake trout stocks in Lake Huron

Period Covered: October 1, 1996 to September 30, 2002

Study Objective: To determine such stock parameters as: diet; maturity; condition and growth indices; mortality rates from fishing, lamprey, and natural causes; and natural recruitment rates. To use the parameters to help measure progress toward the lake trout rehabilitation goal and to help evaluate management options.

Summary: Lake trout *Salvalinus namaycush* were the major deep-water predator in Lake Huron and supported a commercial harvest of more than 2 million kg per yr before the 1940s, but they were virtually extinct by the 1950s due to sea lamprey *Petromyzon marinus* predation and intensive commercial fishing (Coble et al. 1990; Eshenroder 1992; Eshenroder et al. 1995). Following lake trout population collapse, nonnative prey fish such as alewives *Alosa pseudoharengus* and rainbow smelt *Osmerus mordax* proliferated, and their dominance in turn caused declines in native planktivores (Smith 1968). To restore lake trout in Lake Huron, sea lamprey control, accompanied by increased commercial fishery regulation, was begun in the early 1970s. Lake trout numbers were rebuilt and maintained by annual stocking of yearlings or fall fingerlings from hatcheries. The combination of stocking and sea lamprey control has contributed to recovery of both sport and commercial fisheries for lake trout in Lake Huron (Eshenroder et al. 1995).

Lake Huron tributaries have continued to receive chemical treatments at an annual cost of more than U.S. $1,000,000, but the St. Marys River, Lake Huron's largest tributary, was untreated before 2000. Sea lamprey predation has remained the most serious source of lake trout mortality in Lake Huron. Since year 2000, there has been an integrated program of sea lamprey control in the St. Marys River (Adams et al. 2003; Morse et al. 2003). One objective of Study 451 is to measure response of the lake trout population, if any, to this recent treatment effort.

Commercial exploitation has remained high in tribal and Ontario waters. Exploitation rates are low in Michigan waters of central and southern Lake Huron, where lake trout have been protected from commercial harvest. Total mortality rates in the south and central management units were near or below the level targeted by the lake trout rehabilitation plan (Eshenroder et al, 1995; Ebener 1998.

Natural reproduction of lake trout has been documented in Lake Huron by both the Ontario Ministry of Natural Resources and the Michigan Department of Natural Resources, but the contribution of wild lake trout to recruitment has remained low and been confined to isolated sites. Wild age-0 lake trout were taken in bottom trawls from Thunder Bay every year from 1986-1999. The proportion of wild lake trout in assessment and sport catches has been higher in the Thunder Bay area than in other Michigan waters since 1986 (Johnson and VanAmberg 1995).

Catch-at-age models have been completed, covering each of three management units, including both Ontario and Michigan waters of the Main Basin of Lake Huron. The models are used for managing commercial harvest and bycatch in treaty waters and in Ontario, and regulating

recreational harvest in Michigan recreational fisheries. The models are also used to partition mortality rates, and estimate population abundance and biomass, spawning stock biomass, spawning stock biomass per recruit, trends in survival, and impacts of sea lamprey depredation on lake trout. Sea lamprey-induced and commercial fishing-induced mortalities on lake trout declined measurably after 2000 (Johnson et al. in press), evidently as the result of the combined effects of the St. Marys River sea lamprey treatment and fishing controls arising from the Year 2000 Consent Decree between tribal fishing authorities, the State of Michigan, and the United States. Stocking effectiveness, in terms of assessment catch per recruit, appears to have increased, evidently because of improvements in quality control in federal hatcheries and use of the stocking vessel *R.V. Togue* to transport juvenile lake trout to offshore stocking sites (Johnson et al. in press). Incidence of unclipped, potentially wild, lake trout in spring assessments in the Thunder Bay area has been above background levels and higher than in other areas of Lake Huron. Unclipped, potentially wild, spawning lake trout were sampled on reefs during fall in Thunder Bay. Wild age-0 lake trout were taken in bottom trawls in Thunder Bay from 1984-1999, but the trawl catch dropped to zero in 2000 and 2002. Evidently, lake trout rehabilitation was verging on success in Thunder Bay, but recovery collapsed from a combination of factors potentially including thiamine deficiency from diets dominated by alewives, invasion of Thunder Bay by round gobies *Neogobius melanostomus*, and continued losses of adult lake trout to sea lampreys (Johnson and VanAmberg 1995; Johnson et al. in press).

Most elements of this study, including catch per unit effort, statistical catch-at-age modeling, and lamprey wounding rate trends have been documented in Wilberg et al. (2002) and Johnson et al. (in press). Here, we only address those elements that were not covered by those two publications.

Findings: Jobs 1 through 5 were scheduled for 2002-03, and progress is reported below.

Job 1. Title: Experimental gillnetting at assessment stations.–Gill nets were set across contours at 12 assessment stations, including South Harbor Beach, North Harbor Beach, Port Austin, Au Sable Point, Sturgeon Point, South Point Thunder Bay, Rockport, Presque Isle, Adams Point, 9-mile Point, Spectacle Reef, and Rabbit's Back Peak. These stations represented three lake trout modeling units for the Main Basin of Lake Huron: North, Central, and South. Mesh sizes were 51-152 mm with increments 12.7 mm (Johnson et al. in press). Total effort and maximum survey depth are plotted and can be compared with earlier study segments in Figures 1 and 2, respectively.

Alewife and rainbow smelt composed the majority of the diet of lake trout for the entire time series (Figure 3). In central and southern Lake Huron they accounted for more than 85% of diet. There was an increasing gradient of alewife dominance in diet from the North to the South. The number of diet items per lake trout stomach increased after 1997 in each of the three lake units (Figure 4). The increase in number of items per stomach may reflect a decline in size of alewives and smelt. Alewife abundance declined in 1997 and a large year class of alewives was produced in 1998 (USGS Great Lakes Science Center, unpublished data). The especially large numbers of prey per stomach in 1999 suggested lake trout were preying heavily on the abundant, but small, age-1 alewives of the 1998 year class. We have measured mean weights of prey ingested since 1996. The average weight of alewives consumed in 1999 was 3.4 g, less than a third the average size (11.1 g) of alewives consumed during the other years in the time series.

The proportion of age-6 and older lake trout in the spring assessment catch increased during the last 5-yr period of study in comparison with previous study segments. In northern Lake Huron, the percentage of age-6^+ lake trout increased from near zero to 20%; in central Lake Huron, from less than 40% to more than 60%; and in southern Lake Huron, from about 60% to more than 70% (Figure 5).

Since the early 1990s, total length at age appears to have increased in northern Lake Huron, but decreased in central and southern Lake Huron, particularly for older and mature fish. Decreases in central Lake Huron were apparent in age-8 and older lake trout, and decreases in southern Lake Huron were among age-5^+ and older fish (Figure 6). The decline in size at age probably is a function of declining alewife body size and scarcity of alternative larger-sized prey species. Declining growth rates could lead to later ages at maturity and lower fecundity, both questions that will be addressed further in the next 5-yr study segment.

Trends in survival, lamprey wounding, and catch per effort per recruit are given in Johnson et al. (in press). Modeled partitioned mortality rates, trends in sea lamprey-induced mortality rates, and stock biomass, spawning stock biomass, and spawning stock biomass per recruit estimates are also given in that publication.

Job 2. Title: Net for adults on spawning reefs.–Fall assessments of spawning-stage lake trout were conducted to assess whether certain reefs were used for spawning by lake trout and whether unclipped, potentially wild, lake trout were appearing on these spawning sites. The amount of effort deployed in a given year was often determined by weather conditions during the spawning period, which was approximately from October 15 to October 30. In many years, weather conditions restricted netting or prevented netting altogether. Thus, CPUE of fall assessments is particularly subject to weather effects, which can obscure trends in catch rates of the target species. The most valuable index from fall assessments is fin clip composition. As a proportion of catch, it is less biased by variables affecting total catch (Table 1).

Since 1990 it has become apparent that lake trout reproduction is occurring in Thunder Bay, central Lake Huron. From 1990 to 2002, the percentage of lake trout without fin clips averaged 2.4% on reefs sampled outside of Thunder Bay, but in northern Thunder Bay unclipped, potentially wild, lake trout composed 57.9% of the fall assessment catch. Spawning on Mischley Reef, where lake trout lacking fin clips made up the majority of the fall assessment catch, was documented by Johnson and VanAmberg (1995). In addition to indexing proportions of unclipped lake trout, fall assessment catches were used to supply the United States Geological Survey, Great Lakes Science Center, and the International Joint Commission with lake trout for contaminant trend analysis.

Job 3. Title: Analysis of data and coordination of interagency research, management, and planning.–The lake trout data base, including spring and fall assessments and trawling data, was better organized and documented, scrubbed of errors, and combined into relational tables. The resulting data were used in negotiations over tribal harvest of lake trout in 1836 Treaty waters. The data were also used in setting annual harvest quotas for tribal commercial fishing in 1836 Treaty waters and revision of regulations for recreational fishing in all Michigan waters of Lake Huron. Results of jobs 2 and 5 were presented at the symposium *Propagated Fish in Resource Management* at Boise, Idaho in June 2003. This presentation (Johnson et al. in press) will be published in the symposium's proceedings in early 2004. The principal investigators worked closely with the Lake Huron Technical Committee to coordinate lake trout assessment, research, stocking, and management and to produce lake trout models that represented the combined, international, lake trout stocks of the main basin of Lake Huron. Study 451 was the source of data used in describing the state of lake trout and burbot stocks in the Lake Huron Committee 1999 State of Lake Huron report (Ebener [ed] 2003).

Job 4. Title: Write annual and final reports.–Annual reports were submitted on schedule. This report, in combination with Wilberg et al. (2002) and our presentation and manuscript "Lessons in rehabilitation stocking and management of lake trout in Lake Huron" for the American

Fisheries Society Symposium "*Propagated Fish in Resource Management*" (Johnson et al. in press) satisfy the requirements for the final report of this study segment.

Johnson, J. E., and J. P. VanAmberg. 1995. Evidence of natural reproduction of lake trout in western Lake Huron. Journal of Great Lakes Research 21 (Supplement 1):253-259.

Johnson, J. E., J. X. He, A. P. Woldt, M. P. Ebener, and L. C. Mohr. In Press. Lessons in rehabilitation stocking and management of lake trout in Lake Huron. Propagated Fish in Resource Management, Special Publication, American Fisheries Society.

Wilberg, M. J., J. R. Bence, and J. E. Johnson. 2002. Survival of juvenile lake trout stocked in western Lake Huron during 1974-1992. North American Journal of Fisheries Management 22:213-218.

Job 5. Title: Conduct annual trawl surveys for age-0 lake trout.–Bottom-trawl catch of age-0 lake trout decreased after 1998 (Table 2). The catches in 2000 and 2002 were zero. Low lake trout survival from egg to yearling stages has been attributed to predation by adult alewives on lake trout fry (Krueger et al. 1995) and thiamine deficiency in eggs (Fitzsimons and Brown 1998), which is caused by dominance of alewives and rainbow smelt in adult lake trout diets. These two major factors were not new to this period of the study. We suspect that recent changes in benthic community structure, primarily due to zebra mussel *Dreissena polymorpha*, quagga mussel *Dreissena bugensis*, and round goby invasions in the 1990s, have increased vulnerability of lake trout eggs and larvae to predation. Recent proliferation of round gobies, in particular, is suspected to be another major source of predation mortality. Continuous changes in benthic fish community structure might also influence catchability of lake trout in the survey. These issues will be further addressed in the next segment of this study.

Literature Cited:

Adams, J. V., R. A. Bergstedt, G. C. Christie, D. W. Cuddy, M. F. Fodale, J. W. Heinrich, M. L. Jones, R. B. McDonald, K. M. Mullett, and R. J. Young. 2003. Assessing assessment: can we detect the expected effects of the St. Marys River sea lamprey control strategy? Journal of Great Lakes Research 29 (Supplement 1):in press.

Coble, D.W., R.E. Bruesewitz, T.W. Fratt, and J.W. Scheirer. 1990. Lake trout, sea lampreys, and over-fishing in the upper Great Lakes: A review and reanalysis. Transactions of the American Fisheries Society 119:985-995.

Ebener, M.P. [ED.]. 1998. A lake trout rehabilitation guide for Lake Huron. Great Lakes Fishery Commission, Ann Arbor, Michigan.

Ebener, M.P. [ED.]. 2003. The state of Lake Huron in 1999. Great Lakes Fishery Commission Special Publication, Ann Arbor, Michigan.

Eshenroder, R.L. 1992. Decline of lake trout in Lake Huron. Transactions of the American Fisheries Society 121:548-554.

Eshenroder, R.L., N.R. Payne, J.E. Johnson, C.B. Bowen, and M.P. Ebener. 1995. Lake trout rehabilitation in Lake Huron. Journal of Great Lakes Research. 21(Supplement 1):108-127.

Fitzsimons, J. D. and S. B. Brown. 1998. Reduced egg thiamine levels in inland and Great Lakes lake trout and their relationship with diet. Pages 160-171 *in* G. McDonald, J. D. Fitzsimons, and D. C. Honeyfield, editors. Early life stage mortality syndrome in fishes of the Great Lakes and Baltic Sea. American Fisheries Society Symposium 21, Bethesda, Maryland.

Krueger, C. C., Perkins, D. L., Mills, E. L., and Marsden, J. E. 1995. Predation by alewives on lake trout fry in Lake Ontario: role of an exotic species in preventing restoration of a native species. Journal of Great Lakes Research. 21(Supplement 1):458-469.

Morse, T. J., M. P. Ebener, E. M. Koon, S. B. Morkert, D. A. Johnson, D. W. Cuddy, J. W. Weisser, K. M. Mullett, and J. H. Genovese. 2003. A case history of sea lamprey control in Lake Huron: 1979-1999. Journal of Great Lakes Research 29 (Supplement 1):in press.

Smith, S.H. 1968. Species succession and fishery exploitation in the Great Lakes. Journal of the Fisheries Research Board of Canada 25:667-693.

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Table 1.–Gillnet effort, total lake trout catch, and catch of non-clipped lake trout in fall (October 15-October 30) assessments of spawning lake trout in three zones of Lake Huron.

	Gill net effort (m)			Total number of catch			Number of non-clipped fish		
Year	Northern	Central	Southern	Northern	Central	Southern	Northern	Central	Southern
1980	244	3660	732	79	362	111			
1981	183	639	274	10	122	171			
1982		915	183		149	41			
1983	2928	1098	366	127	311	196	1	1	4
1984		910	182		163	88		2	
1985		1001	273		214	118		1	1
1986		364	182		40	46		2	3
1987		1092	364		66	106		8	1
1988		819	273		51	61		1	
1989		457	319		30	60			1
1990		7267	91		28	8		1	
1991		486			37			27	
1992		2495	2927		58	387		50	9
1993		1830	1188		35	233		24	3
1994		364			3				
1995									
1996		2997	91		55	27		2	
1997		273	91		16	1		13	
1998		730			120			32	
1999									
2000		1002			77			4	
2001		183	732		7	63			1
2002		941	395		134	6		6	

Table 2.–Bottom trawl catch of age-0 lake trout in the waters of Thunder Bay, Lake Huron.

Year	Number of tows	Catch	Catch per tow
1981	20		
1982	20		
1983	21		
1984	32	9	0.28
1985	106		0.00
1986	32	24	0.75
1987	80	19	0.24
1988	86	24	0.28
1989	120	27	0.23
1990	85	43	0.51
1991	38	4	0.11
1992	42	8	0.19
1993	45	14	0.31
1994	55	19	0.35
1995	36	4	0.11
1996	35	2	0.06
1997	47	5	0.11
1998	40	3	0.08
1999	39	2	0.05
2000	36	0	0.00
2001	36	1	0.03
2002	36	0	0.00

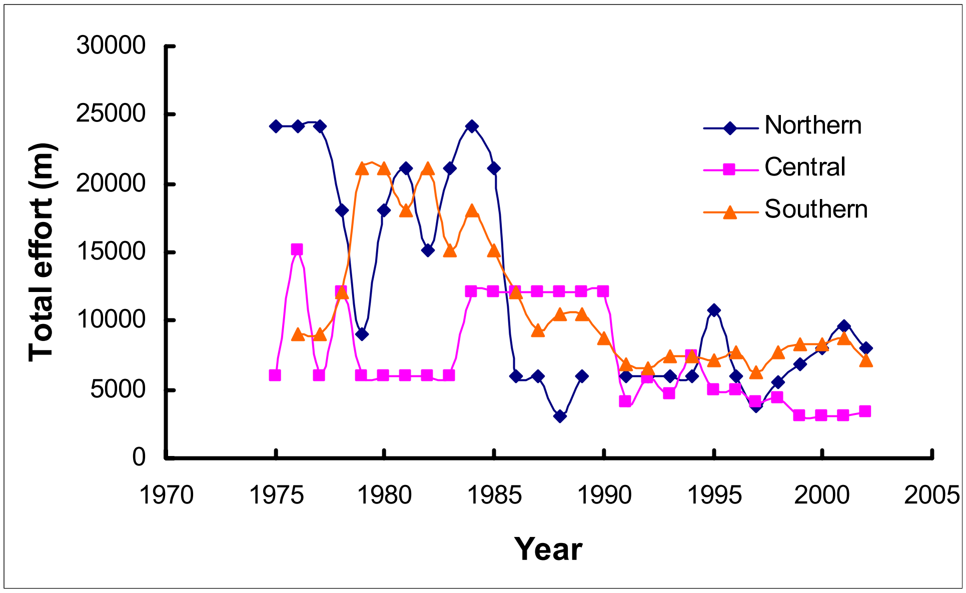


Figure 1.–Total spring gillnet survey effort in northern, central, and southern Lake Huron.

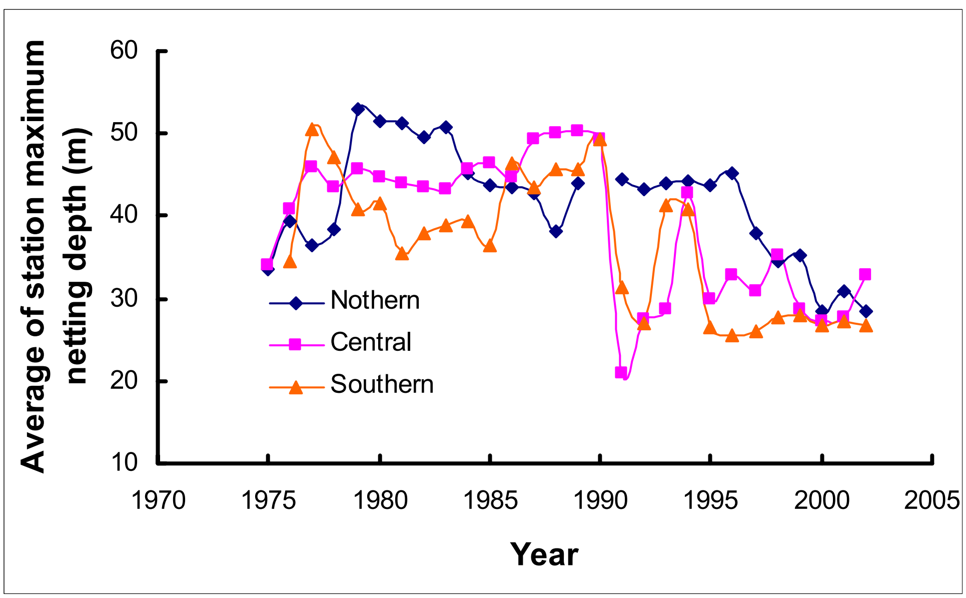


Figure 2.–Maximum netting depth in spring gillnet assessment, northern, central, and southern Lake Huron.

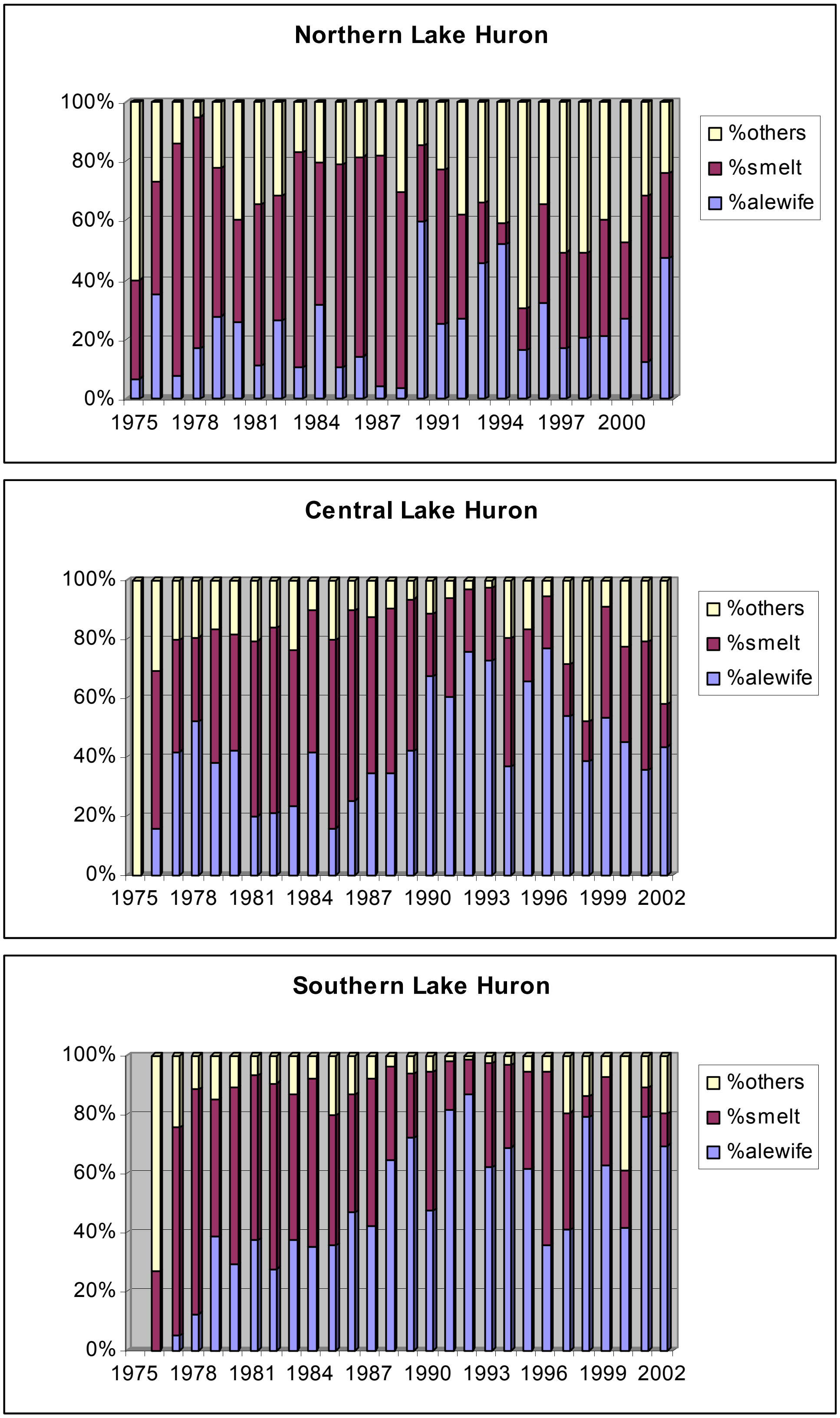


Figure 3.–Diet composition in Lake trout stomachs from spring assessment gillnets, Lake Huron.

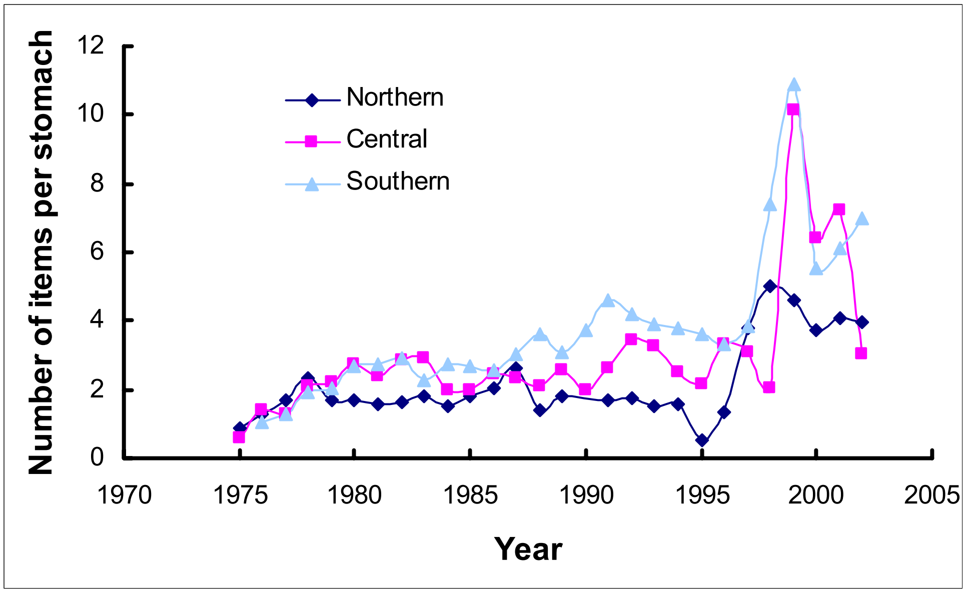
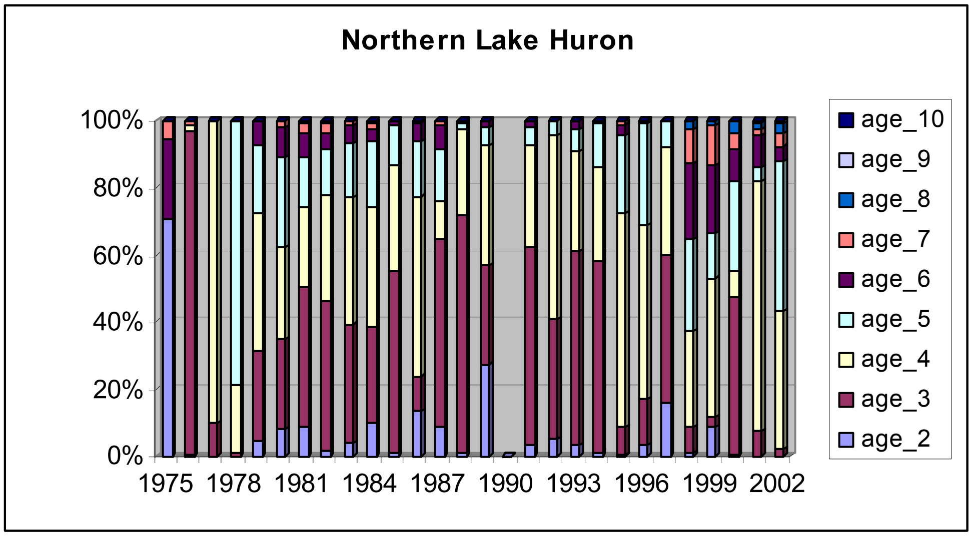
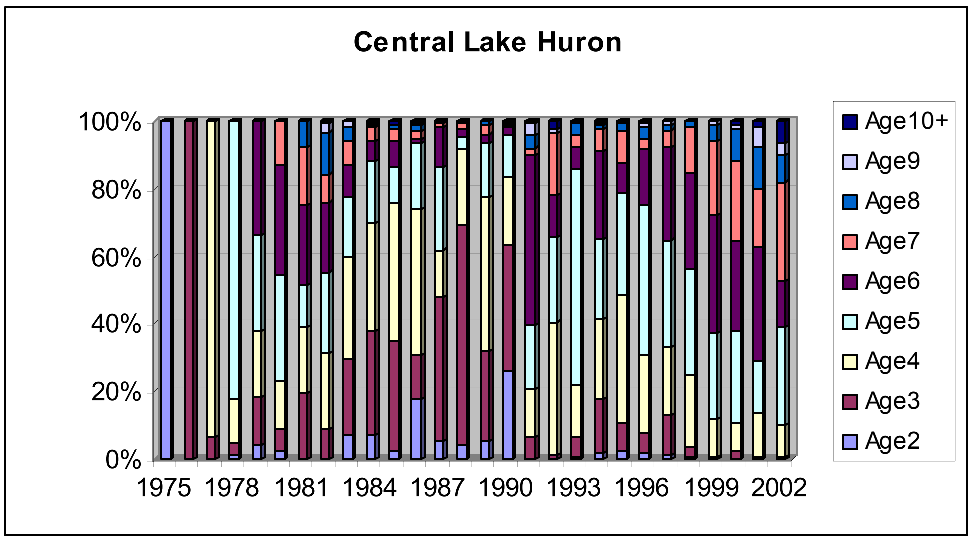


Figure 4.–Number of diet items per lake trout stomach in northern, central and southern Lake Huron, from spring gillnet assessment.





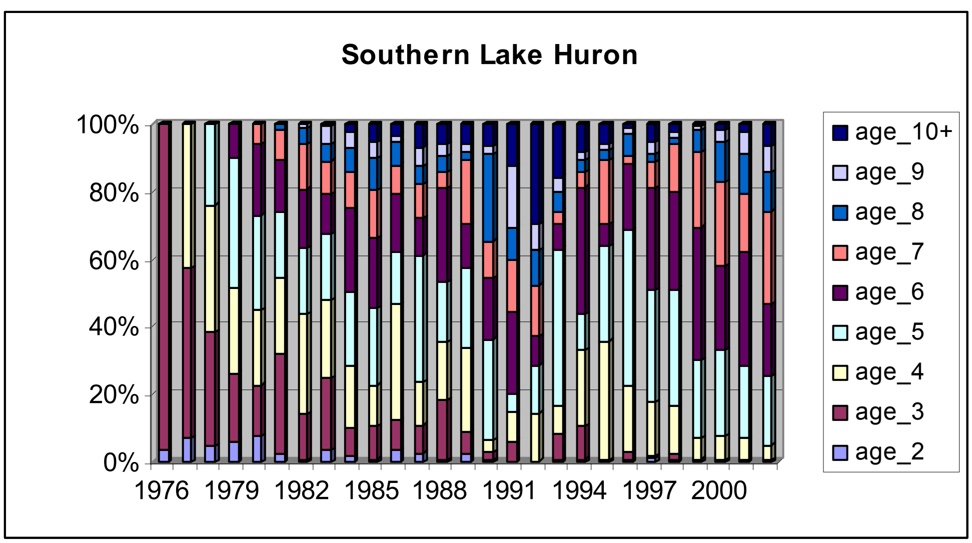


Figure 5.–Lake trout age composition in northern, central, and southern Lake Huron, based on spring gillnet assessment.

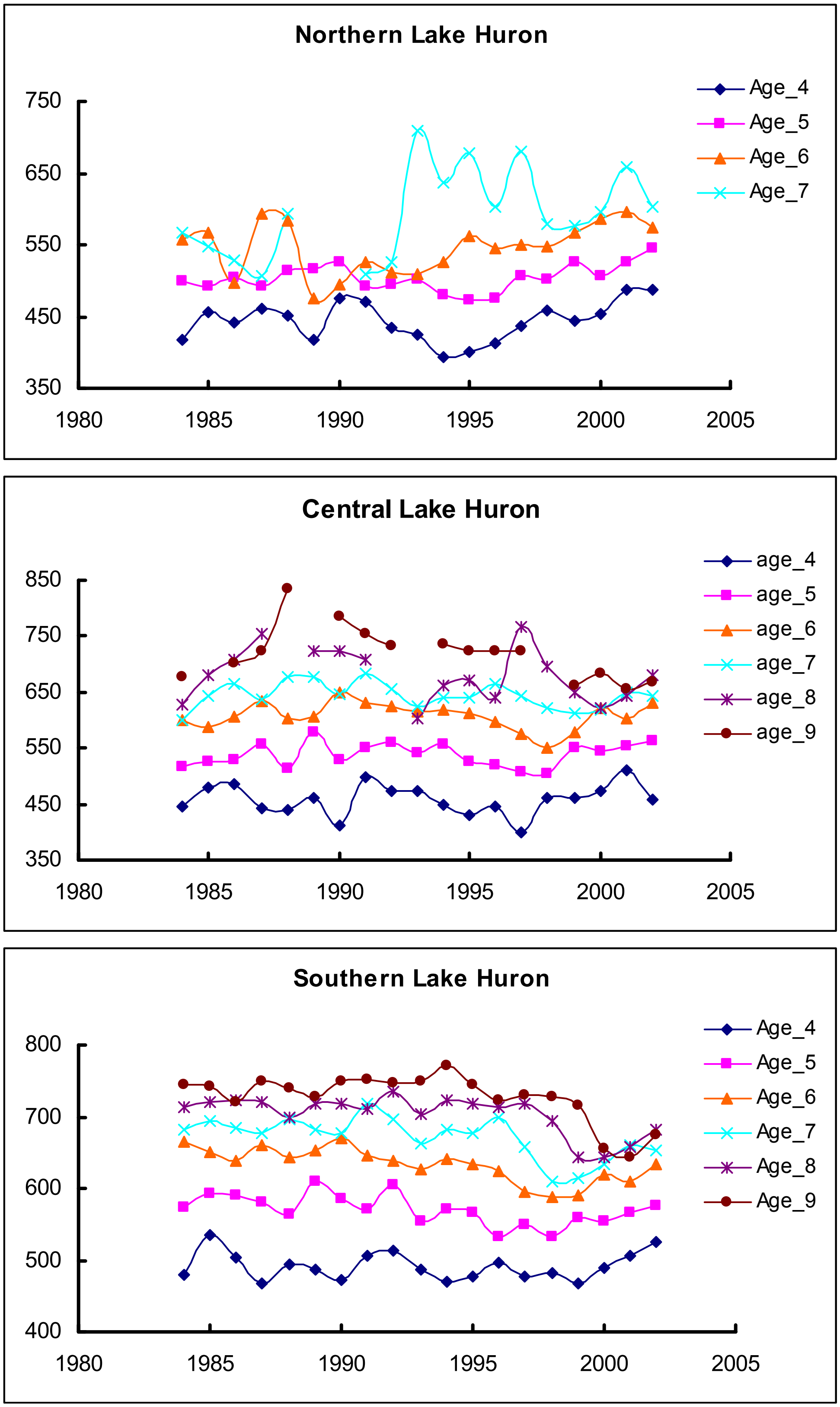


Figure 6.–Average total length (mm) at age for lake trout sampled in spring gillnet assessments, Lake Huron, 1984-2002.