# STUDY PERFORMANCE REPORT

**State:** Michigan **Project No.:** F-81-R-6

**Study No.:** 230451 **Title:** Assessment of lake trout stocks in Lake Huron

**Period Covered:** October 1, 2004 to September 30, 2005

**Study Objective:** To determine such stock parameters as: diet; maturity; condition and growth indices; mortality rates from fishing, lamprey, and natural causes; natural recruitment rates, movement between management units, and to compare performance of different strains and sizes of stocked lake trout. To use the parameters to help measure progress toward the lake trout rehabilitation goal and to help evaluate management options.

**Summary:** All job requirements for 2005 were met. This was the second year since we implemented a new design for the spring gillnetting survey. The focus of the new design was to cover a wider depth range at the usual 12 fixed stations. There were four depth strata designed into each station, and the exact depth fished each year within each depth strata was randomly selected. Catch rates were relatively low at the shallowest and deepest depth strata, and relatively high at the two middle depth strata. Such a pattern suggested that we covered a reasonable depth range, and the design can be relatively stable in future years, even with considerable year to year changes in lake trout depth distribution. Catch per unit effort for young age groups continued to decrease. Observed sea-lamprey wounding rates have remained relatively low since the lamprey population of the St. Marys River was brought under better control. Contribution of alewives to lake trout diets declined sharply, and round gobies and rainbow smelt became the dominant prey. Lake trout catch-at-age modeling was accomplished for management units of the main basin, based on our surveys and coordination with other agencies. Estimated abundance for age 5 and older has increased more than 38% in the main basin of Lake Huron from 1999 to 2004. Female spawning stock biomass increased more than 87% in the main basin from 1999 to 2004, partially because of declines in age of maturity. Sea lamprey induced mortality is the highest in northern Lake Huron, and fishing mortality is the highest in southern Lake Huron. Modeling analyses of annual growth variation demonstrated the importance of accounting for temporal and spatial differences in growth; our models must address different time varying patterns, rather than rely on time-invariant growth curves. Incidence of wild, age-0, lake trout rose in Thunder Bay, with 11 and 15 appearing in the bottom trawl catches in 2004 and 2005, respectively. We caught them in much wider depth strata than previous years during the end of July and early August. By that time, these wild lake trout appeared to start a major redistribution to deeper water; their total body length was 52–73 mm.

**Findings:** Jobs 1 through 5 were scheduled for 2004-05, and progress is reported below.

**Job 1. Title: Spring assessment using gillnets.**–Total gill net effort in the 2005 spring survey was 13,167 m, similar to 2004 (Table 1). There was no reason to increase the effort to the level of earlier years because the current catch per unit effort was 15–20 lake trout per 305 m of gill net, in comparison with 4–15 fish per 305 m in early years.

Before 2004, there were typically only two depth strata at each station. In 2004, we started a new sample design that covered four depth strata at each station. That year, we found that catch per unit effort was the highest at the deepest strata. The new depth strata could not be completely implemented in 2004, however, because of site-specific conditions we had not anticipated. In 2005, the new design was completely implemented (Table 2). We continued to use 12 fixed stations. There were four depth strata within each station, and the exact start depth (where we began setting each gillnet) within each stratum was determined using a random number generator. A total of 674 lake trout *Salvelinus namaycush* were caught during the 2005 survey (Table 1), including 15 non-clipped lake trout and 38 with coded-wire tags (CWT). These CWT samples and related catch and effort information will be sent to the USGS Great Lakes Science Center for a cooperative study on lake trout movement. In 2005, catch rates were relatively low at the shallowest and deepest depth strata, and relatively high at the two middle depth strata. Such a pattern suggested that our gear encompassed the range of depths occupied by lake trout and that the design can be reasonably stable even with considerable year to year variation in lake trout depth distribution. Among stations, we found that catch rates were highest in north-central Lake Huron.

Sea lamprey wounding rates (Table 3) have decreased in the past four years for lake trout in all areas of Lake Huron’s main basin, and have remained consistently below the levels that prevailed prior to treatment of sea lampreys in the St. Marys River.

A total of 276 lake trout stomachs were analyzed in the laboratory in 2005. The rest of stomachs from the 674 lake trout sampled were checked in the field. There were major changes in lake trout diets during 2005. In 2004, alewives *Alosa pseudoharengus* were still dominant in the lake trout diet in central and northern Lake Huron, and rainbow smelt *Osmerus mordax* were the dominant diet item in southern Lake Huron. In 2005, round gobies *Neogobius melanostomus* and rainbow smelt were dominant in diets in all areas of the west side of Lake Huron’s main basin.

**Job 2. Title: <u>Fish fall assessment gill nets as called for to evaluate spawning developments.</u>**–Experimental gill nets were set at spawning reefs of Thunder Bay and Black River mouth. Two options were evaluated. One was 2 hours of evening netting. The other was to set nets over night. Although the first option aimed at reducing the total kill during the survey, the crew found that it was difficult to operate at night and the unpredictable difficulty in handling nets and fish during darkness was actually the major cause of lake trout deaths. A design for regular gill net surveys on lake trout spawning reefs will be implemented, starting in fall 2005.

**Job 3. Title: <u>Analysis of data and coordination of interagency research, management, and planning.</u>**–Catch per unit effort (CPUE) was highest for age-4 lake trout in northern Lake Huron, and for age 6 in central and southern Lake Huron (Figures 1–3). In central and southern Lake Huron, CPUE has continued to decrease for ages 2–4, but has been increasing for older ages. There is larger uncertainty in estimating abundance of young lake trout than estimating abundance of older age groups. CPUE for age-5 lake trout also decreased in some areas in recent years. One possibility was that their vulnerability to gillnets has decreased because of changes in their distributions or size at age. This hypothesis will be supported if, and only if, CPUE for older age groups continues to increase or remain high.

Catch-at-age models have been maintained based on many data sources including Michigan DNR spring survey data, Chippewa/Ottawa Resource Authority fishery independent data, U.S. Fish and Wildlife Service stocking data, and recreational and commercial harvest and effort data. The modeling effort for northern and central Lake Huron was accomplished in conjunction with the Modeling Subcommittee of the Technical Fisheries Committee as mandated by the Year-2000 Consent Decree for 1836 Treaty Waters. Total Allowable Catches for these two management units were estimated using the models. The modeling efforts for southern Lake Huron were coordinated with Ontario Ministry of Natural Resources, U.S. Fish and Wildlife Service, Chippewa/Ottawa Resource Authority, and Michigan State University.

Estimated abundance of age-5 and older lake trout increased more than 38% in the main basin of Lake Huron from 1999 to 2004 (865,000 vs. 1,195,000, Figure 4). The increasing trend of abundance started in 1992 and can be attributed to decreases in mortality (Figure 5). As of 2004, lake-wide instantaneous natural mortality and sea lamprey-induced mortality combined was 0.3 $y^{-1}$, and exceeded fishing mortality. Total mortality was below the target of 0.51 $y^{-1}$ (40% annual rate) in northern and north-central Lake Huron. In southern Lake Huron, total mortality also declined through 2002 but increased in 2003–04 due to increased commercial and recreational fishing.

Estimated female spawning stock biomass increased more than 87% in the main basin of Lake Huron from 1999 to 2004 (509,000 vs. 953,000 kg). The percentage increase in spawning stock biomass was more than twice the increase in abundance of age-5 and older lake trout because of declines in age of maturity (Figure 6). Fifty percent of female lake trout matured at age 6.0, 5.7, and 5.4 years in northern, north-central, and southern Lake Huron, respectively, during 2000–04. Age at 50% maturity was 6.7, 6.1, and 5.8 years, respectively, during 1995–99, and 8.2, 7.3, and 6.3 years before 1990.

There was no evidence that changes in maturity schedule were related to changes in mortality. In northern Lake Huron, decreases in maturity-at-age appeared to be associated with increases in length-at-age. In southern Lake Huron, age-4 lake trout were about the same length over all years, but length at age-5 and older apparently decreased while lake trout became mature at relatively younger ages. Observations were similar in north-central Lake Huron to those in the south, although decreases in length-at-age were apparent only for age-7 and older lake trout.

Annual variations in lake trout size at age have been interpreted by modeling cohort-specific growth with year-specific von Bertalanffy growth parameters. This modeling work was done by cooperating with Jim Bence at Michigan State University. Because of the combination of cohort-specific growth and year-to-year changes in growth conditions, it is subjective and inadequate to use one or two age groups to characterize the long-term patterns or trends in growth, as has been done in past years. In southern Lake Huron, we observed decreases in size at age 5 and older fish. This can be attributed to decreases in asymptotic length. We also observed decreases in the estimated growth coefficient, *K*. This suggested that growth at young ages also decreased, and the relative stable size at age 4 might be partially due to increases in the size at stocking. In future studies, we will use the new models to vigorously compare lake trout growth among northern, central and southern Lake Huron. Conventional time-invariant growth models are not sufficient when there are spatially explicit time-varying growth patterns. Accordingly, we included many advanced statistical details and functions in our growth models. They allowed us to clarify conceptual difficulties such as biological meaning of correlations among growth parameters. Such clarification facilitated our analyses of observed growth changes. The models were implemented using AD Model Builder, and they provided tangible and reliable foundations for studying the complex changing ecosystem of Lake Huron.

**Job 4. Title: Conduct annual trawl surveys for age-0 lake trout.**–This was the second year that we conducted bottom trawl surveys based on a new design aimed at developing a wild lake trout recruitment index in the Thunder Bay area. In earlier years, the survey was conducted within a wide time period from June to October, and the objective was to demonstrate the presence of lake trout natural reproduction in the lake, and settle on an optimal period and depths to sample for the index. In the 1990s, the trawling was to focus on the "best" depth strata of 18.3, 21.3, and 24.4 m (60, 70, and 80 ft), in the month of August or early September. After several recent years of zero catch, we caught 11 age-0 lake trout at the end of July 2004, but nothing in August. We caught these lake trout in a wide depth range from 12.2 to 27.4 m (40–90 ft). We had a new design to focus on the best time window and cover much wider depth strata from 12.2 to 30.5 m (40–100 ft). The best time window was earlier than before, and maintained repeat trawling in August. The step between two depths was 3.1 m (10 ft). Depth coverage was determined by a rule of sampling consecutively deeper strata until encountering zero catch of lake trout in two consecutive depths. A total of 12 age-0 lake trout were caught at the end of July 2005. As in 2004, the highest catch rate was at 27.4 m (90 ft). We only caught 3 lake trout in August 2005, and all of them were from 27.4 m (90 ft) depth. Total catches and catch rates in 2004 and 2005 were the highest annual catch since 1995, and low alewife abundance in these two years was a likely explanation. Catch rates at different depth strata, however, also suggested that dramatic redistribution of age-0 wild lake trout might occur during the end of July and early August (Table 4). Age-0 lake trout were about 52–73 mm by this time period. We are in the process of standardizing the catch per unit effort (CPUE) index by regarding time and depth as covariates, instead of using annual average CPUE from the raw data.

**Job 5. Title: Write annual performance report.**–The required reports and documents were completed as scheduled. Spring 2004 gill-netting data were used by the Technical Fisheries Committee of the Year 2000 Consent Decree for 1836 Treaty Waters. Results from catch at age modeling were used by the committee for recommending 2005 total allowable catch for the treaty waters. Similar data and modeling results for southern Lake Huron were reported to the Lake Huron Technical Committee during its 2005 summer meeting. All of these survey and modeling results were reported at 2005 Upper Great Lakes annual meeting of the Great Lakes Fishery Commission, Ann Arbor, Michigan. Based on these new findings, our recommendation of a change in size limit for lake trout recreational fishing in northern Lake Huron was reported to Michigan Natural Resource Commission. We also reported our findings about long-term trends in lake trout body condition at the 2005 annual meeting of the International Association of Great Lakes Research, Ann Arbor, Michigan. Compiled 2005 data for lake trout samples with coded-wire tags will be sent to USGS Great Lakes Science Center, and the completed central database will be used for studying lake trout movement patterns in Lake Huron. Sea lamprey wounding rates and survey CPUE for 2005 will be reported to the Great Lakes Fisheries Commission.

**Prepared by:** Ji X. He and James E. Johnson
**Date:** September 30, 2005

Table 1.–Total effort and total lake trout catch of annual spring gill net survey in Lake Huron by the Michigan Department of Natural Resources.

| | Gillnetting effort (m) | | | | Number of catch | | | |
|---|---|---|---|---|---|---|---|---|
| Year | MH-1 | MH-2 | MH-3+ | Total | MH-1 | MH-2 | MH-3+ | Total |
| 1970 | 7,314 | – | – | 7,314 | 26 | – | – | 26 |
| 1971 | 4,389 | – | – | 4,389 | 2 | – | – | 2 |
| 1972 | 2,438 | – | – | 2,438 | 2 | – | – | 2 |
| 1973 | 1,524 | – | – | 1,524 | 1 | – | – | 1 |
| 1974 | 9,144 | – | – | 9,144 | 7 | – | – | 7 |
| 1975 | 24,144 | 6,036 | – | 30,180 | 20 | 9 | – | 29 |
| 1976 | 24,144 | 15,090 | 9,054 | 48,288 | 586 | 42 | 28 | 656 |
| 1977 | 24,144 | 6,036 | 9,054 | 39,234 | 1,476 | 61 | 96 | 1,633 |
| 1978 | 18,108 | 12,072 | 12,072 | 42,252 | 1,307 | 393 | 263 | 1,963 |
| 1979 | 9,054 | 6,036 | 21,126 | 36,216 | 425 | 488 | 549 | 1,462 |
| 1980 | 18,108 | 6,036 | 21,126 | 45,270 | 747 | 336 | 788 | 1,871 |
| 1981 | 21,126 | 6,036 | 18,108 | 45,270 | 795 | 232 | 788 | 1,815 |
| 1982 | 15,090 | 6,036 | 21,126 | 42,252 | 379 | 121 | 1,369 | 1,869 |
| 1983 | 21,126 | 6,036 | 15,090 | 42,252 | 472 | 203 | 993 | 1,668 |
| 1984 | 24,144 | 12,072 | 18,108 | 54,324 | 573 | 495 | 1,130 | 2,198 |
| 1985 | 21,126 | 12,072 | 15,090 | 48,288 | 347 | 488 | 1,201 | 2,036 |
| 1986 | 6,036 | 12,072 | 12,072 | 30,180 | 180 | 452 | 947 | 1,579 |
| 1987 | 6,036 | 12,072 | 9,328 | 27,436 | 71 | 420 | 728 | 1,219 |
| 1988 | 3,018 | 12,072 | 10,427 | 25,517 | 117 | 321 | 835 | 1,273 |
| 1989 | 6,036 | 12,072 | 10,427 | 28,535 | 95 | 452 | 615 | 1,162 |
| 1990 | 0 | 12,072 | 8,778 | 20,850 | 0 | 265 | 575 | 840 |
| 1991 | 6,036 | 4,116 | 6,857 | 17,009 | 56 | 175 | 240 | 471 |
| 1992 | 6,036 | 5,793 | 6,584 | 18,413 | 121 | 245 | 408 | 774 |
| 1993 | 6,036 | 4,664 | 7,408 | 18,108 | 116 | 142 | 392 | 650 |
| 1994 | 6,036 | 7,408 | 7,408 | 20,852 | 173 | 254 | 495 | 922 |
| 1995 | 10,730 | 4,938 | 7,134 | 22,802 | 363 | 221 | 440 | 1,024 |
| 1996 | 6,036 | 4,938 | 7,682 | 18,656 | 148 | 447 | 498 | 1,093 |
| 1997 | 3,840 | 4,116 | 6,310 | 14,266 | 25 | 261 | 414 | 700 |
| 1998 | 5,486 | 4,390 | 7,682 | 17,558 | 103 | 604 | 434 | 1,141 |
| 1999 | 6,860 | 3,017 | 8,230 | 18,107 | 235 | 393 | 710 | 1,338 |
| 2000 | 7,957 | 3,017 | 8,230 | 19,204 | 242 | 342 | 734 | 1,318 |
| 2001 | 9,604 | 3,017 | 8,778 | 21,399 | 320 | 191 | 605 | 1,116 |
| 2002 | 7,957 | 3,291 | 7,134 | 18,382 | 220 | 247 | 552 | 1,019 |
| 2003 | 7,132 | 2,743 | 6,309 | 16,185 | 159 | 262 | 640 | 1,061 |
| 2004 | 4,663 | 3,292 | 5,486 | 13,442 | 109 | 269 | 477 | 855 |
| 2005 | 4,389 | 3,292 | 5,486 | 13,167 | 104 | 267 | 303 | 674 |

Table 2.–Survey design and survey catch in 2005 spring gill netting survey in Lake Huron. There were four depth strata at each station. Start depth for each gill net set within each stratum is a random number. Gillnets were set down the bank from each start depth. Total effort at each stratum was 275 m.

| | Strata and actual start depth (0.305 m, or 1 ft) | | | | Catch per 275 m at each stratum | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Station | 30–50 | 51–100 | 101–150 | 150–200 | 30–50 | 51–100 | 101–150 | 150–200 | Station total |
| 1 | 33 | 57 | 110 | 181 | 14 | 11 | 12 | 4 | 41 |
| 2 | 47 | 90 | 135 | 174 | 10 | 33 | 18 | 10 | 71 |
| 3 | 47 | 71 | 123 | 177 | 13 | 17 | 35 | 2 | 67 |
| 4 | 35 | 84 | 116 | 179 | 4 | 13 | 16 | 19 | 52 |
| 5 | 47 | 87 | 135 | 181 | 4 | 15 | 42 | 11 | 72 |
| 6 | 41 | 53 | 102 | 180 | 22 | 13 | 8 | 31 | 74 |
| 7 | 39 | 92 | 145 | 218 | 9 | 5 | 73 | 48 | 135 |
| 8 | 48 | 82 | 120 | 152 | 4 | 32 | 12 | 10 | 58 |
| 9 | 32 | 75 | 110 | 173 | 13 | 27 | 5 | 8 | 53 |
| 10 | 33 | 83 | 123 | 150 | 6 | 10 | 11 | 6 | 33 |
| 11 | 42 | 90 | 126 | 155 | 1 | 2 | 3 | 4 | 10 |
| 12 | 40 | 47 | 110 | 170 | 0 | 4 | 3 | 1 | 8 |
| | | | | Strata total | 100 | 182 | 238 | 154 | |

Table 3.–Sea lamprey wounding rates observed in northern (MH1), north-central (MH2), and southern (MH3) Lake Huron, 2002–05.

| | | Size groups (mm) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Unit | Year | <430 | 430–529 | 530–629 | 630–734 | 735–835 | 836–963 | Total |
| MH1 | 2002 | 0.00 | 4.31 | 5.13 | 6.67 | 0.00 | na | 4.55 |
| | 2003 | 0.00 | 7.14 | 12.50 | 5.00 | 100.00 | na | 9.43 |
| | 2004 | 0.00 | 0.00 | 0.00 | 6.52 | 25.00 | na | 3.67 |
| | 2005 | 0.00 | 0.00 | 6.98 | 3.03 | na | na | 3.85 |
| MH2 | 2002 | 0.00 | 2.78 | 5.15 | 3.92 | 0.00 | na | 4.05 |
| | 2003 | 0.00 | 0.00 | 7.84 | 14.62 | 0.00 | na | 10.27 |
| | 2004 | 0.00 | 0.00 | 10.75 | 7.75 | 21.43 | na | 8.55 |
| | 2005 | 0.00 | 0.00 | 3.30 | 4.29 | 0.00 | na | 3.37 |
| MH3+ | 2002 | na | 0.00 | 10.28 | 8.36 | 9.52 | 100.00 | 8.88 |
| | 2003 | na | 0.00 | 10.50 | 8.03 | 9.68 | na | 8.28 |
| | 2004 | 0.00 | 0.00 | 11.26 | 7.63 | 10.71 | 0.00 | 8.39 |
| | 2005 | 0.00 | 5.00 | 5.75 | 7.02 | 0.00 | 0.00 | 5.94 |

Table 4.–Percent composition by weight of major diet items observed in lake trout stomachs from northern (MH-1), north-central (MH-2), and southern (MH-3+) Lake Huron, 2005.

| Species | MH-1 | MH-2 | MH-3 | All |
|---|---|---|---|---|
| Zebra mussel | 0.02 | 0.07 | 0.33 | 0.12 |
| Insects | 0.49 | 0.00 | 0.00 | 0.20 |
| Lake whitefish | 0.75 | 0.00 | 0.00 | 0.30 |
| Stickleback | 3.34 | 0.99 | 0.73 | 1.86 |
| Slimy sculpin | 0.46 | 6.96 | 0.00 | 2.40 |
| Bloater | 0.00 | 10.57 | 0.00 | 3.36 |
| Alewife | 1.08 | 11.34 | 1.91 | 4.58 |
| Rainbow smelt | 26.92 | 9.41 | 65.42 | 32.20 |
| Round goby | 66.94 | 60.66 | 31.61 | 54.98 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |

Table 5.–Depth strata and bottom trawl effort, Thunder Bay, 2004–05, and catches of age-0 wild lake trout.

| Year | Depth (m) | 7/26–8/04 | | 8/08–8/09 | |
|---|---|---|---|---|---|
| | | # of Tows | Catch | # of Tows | Catch |
| 2004 | 12.2 | 2 | 1 | – | – |
| | 15.2 | 2 | 0 | – | – |
| | 18.3 | 3 | 4 | 2 | 0 |
| | 21.3 | 2 | 2 | 2 | 0 |
| | 24.4 | 3 | 1 | 2 | 0 |
| | 27.4 | 2 | 3 | 1 | 0 |
| | 30.5 | – | – | 2 | 0 |
| 2005 | 12.2 | 2 | 0 | – | – |
| | 15.2 | 2 | 1 | – | – |
| | 18.3 | 2 | 1 | 2 | 0 |
| | 21.3 | 2 | 3 | 2 | 0 |
| | 24.4 | 2 | 0 | 2 | 0 |
| | 27.4 | 2 | 6 | 2 | 3 |
| | 30.5 | 2 | 1 | 2 | 0 |

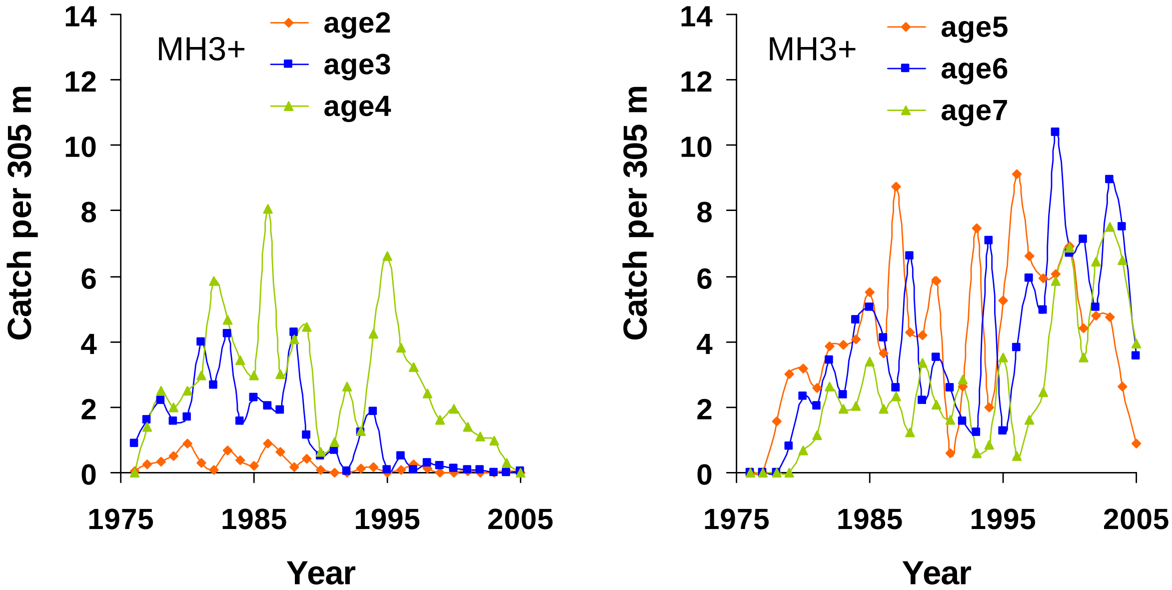



Figure 1.–Catch per unit effort of lake trout age groups in southern Lake Huron (MH3+).

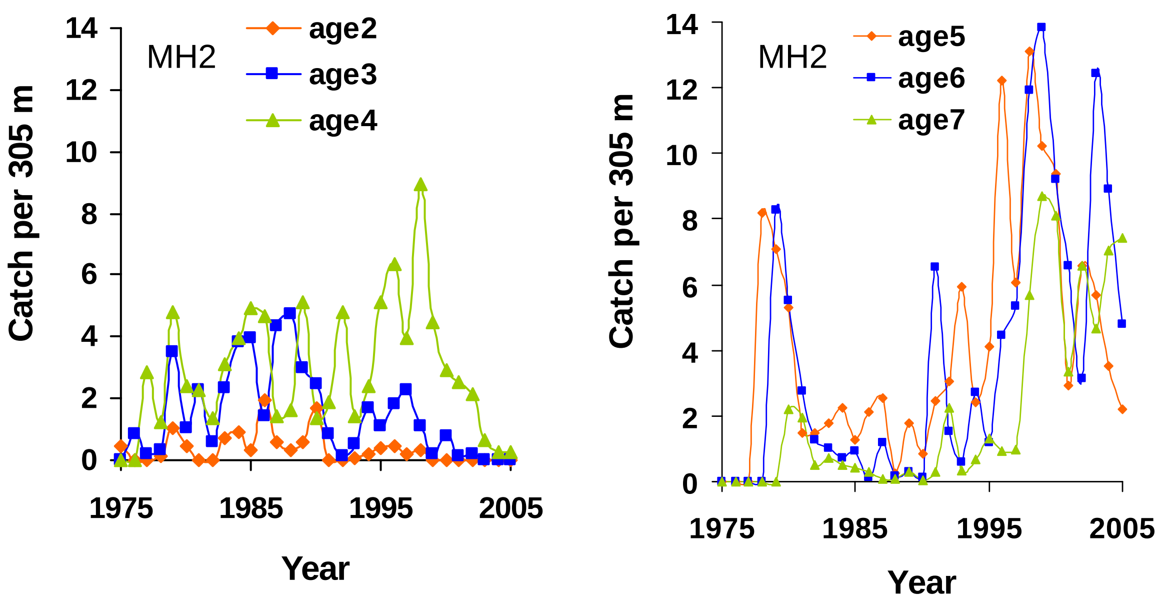



Figure 2.–Catch per unit effort of lake trout age groups in central Lake Huron (MH2).

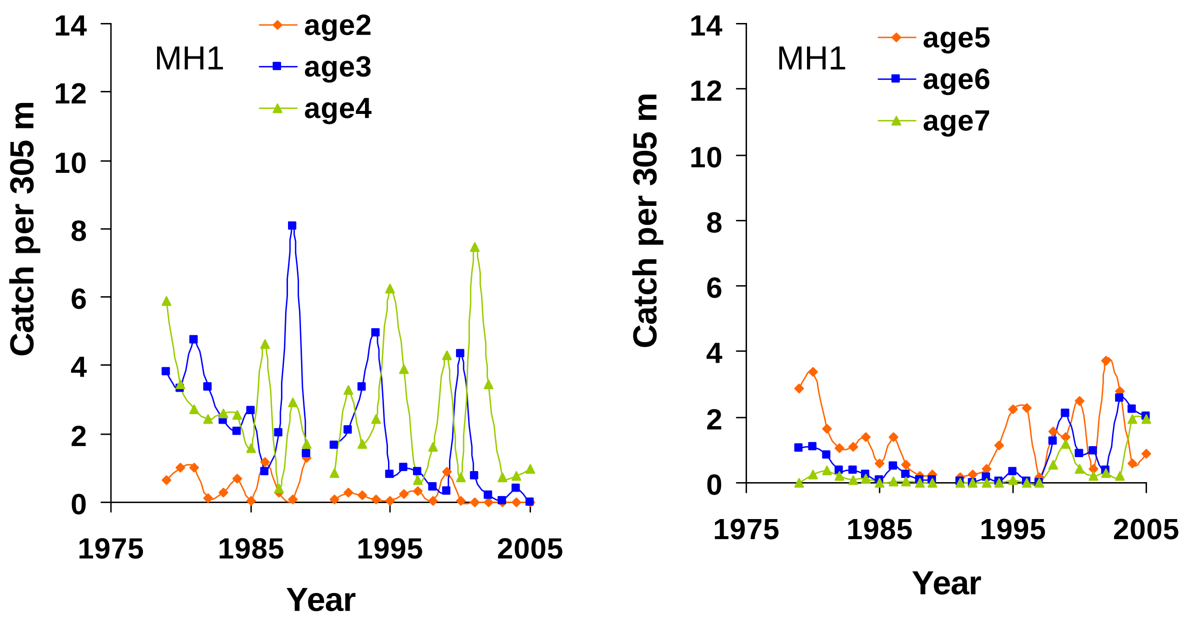



Figure 3.–Catch per unit effort of lake trout age groups in northern Lake Huron (MH1).

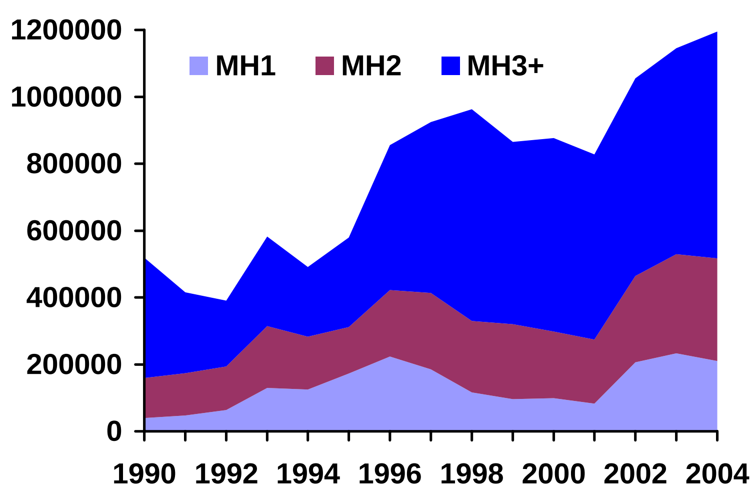
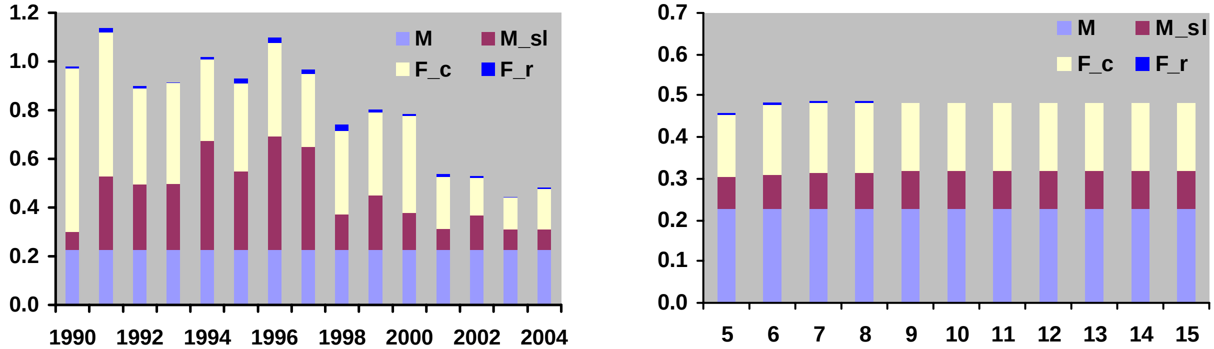
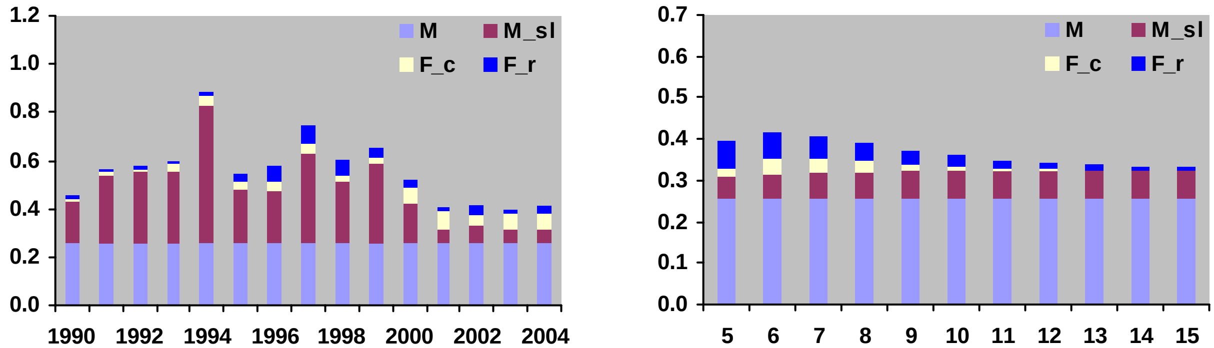



Figure 4.–Estimated lake trout number at age 5 and old in northern (MH1), north-central (MH2), and southern Lake Huron (MH3+), based on statistical catch-at-age models, and fisheries and survey data up to 2004.

MH1




MH2




MH3+

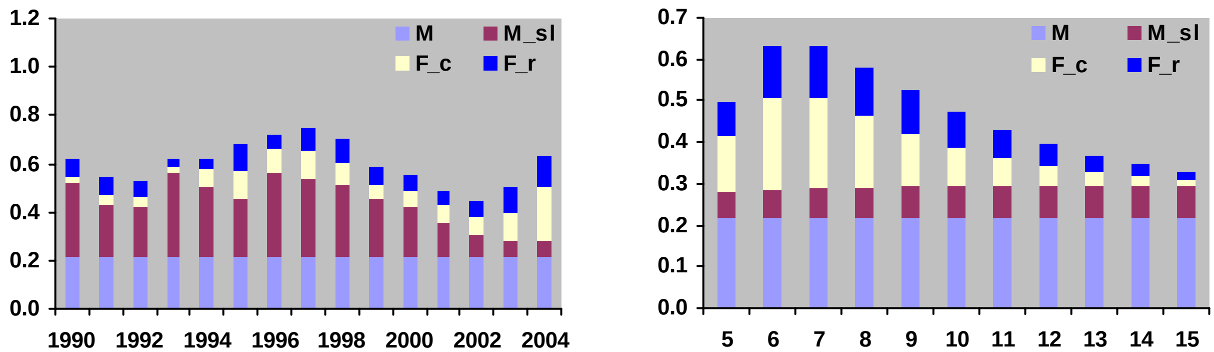



Figure 5.–Estimated annual mortality rate of age 6 lake trout from 1990 to 2004 (left column), and 2004 mortality rates of age 5–15 lake trout (right column). These estimates were based on statistical catch-at-age models for northern (MH1, first row), north-central (MH2, second row), and southern Lake Huron (MH3+, third row). The total mortality rates were separated into natural (M), sea lamprey induced (M_sl), commercial fishing (F_c), and recreational fishing mortality (F_r).

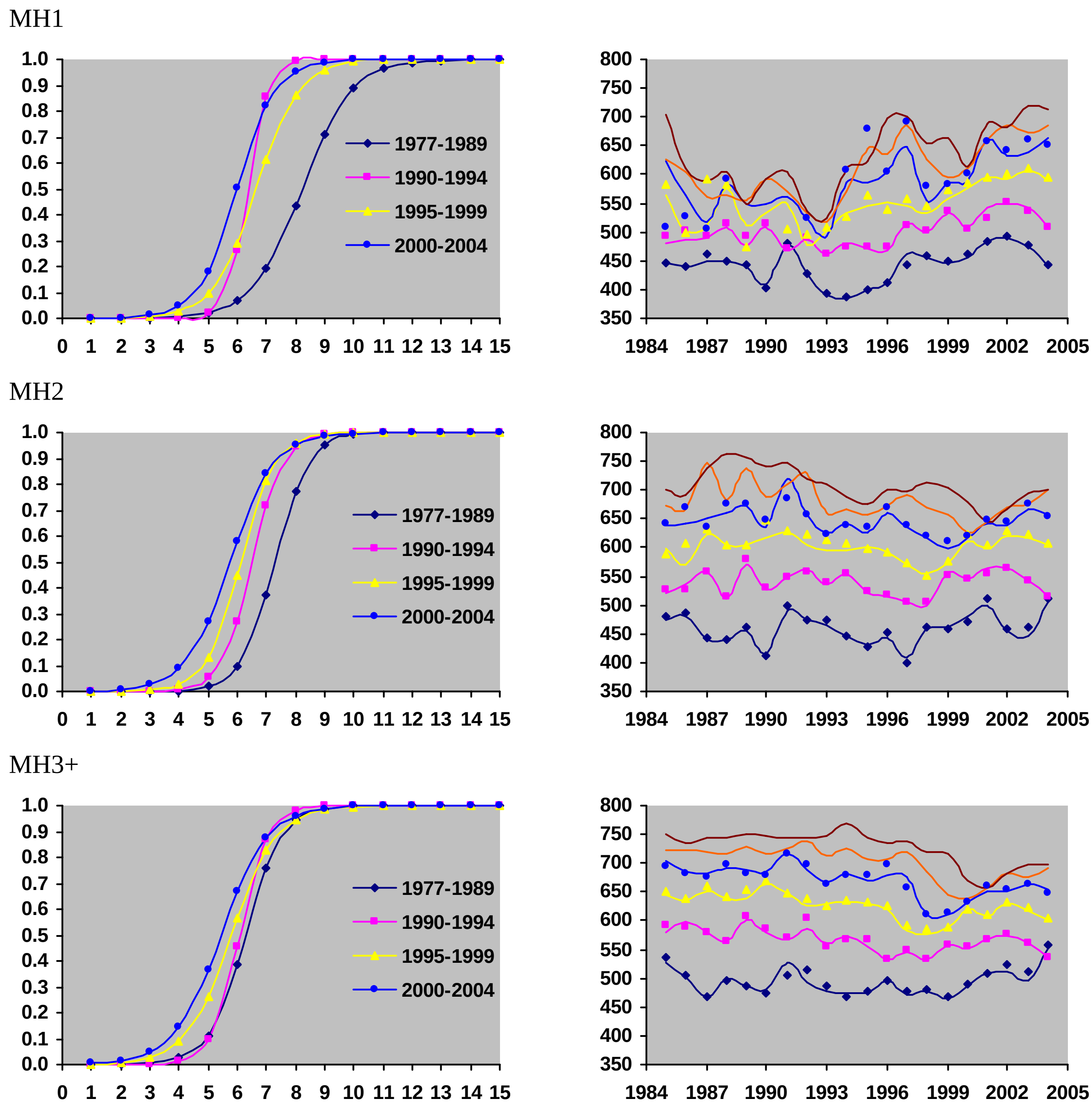



Figure 6.–Female lake trout maturity as logistic function of age (left column), and estimated (lines) and observed (symbols) lake trout length at age 4–9 (sexes combined, right column). There were separate models for lake trout in northern (MH1), north-central (MH2), and southern (MH3+) Lake Huron. Growth model was the von Bertalanffy growth function with time-varying parameters.