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Comparison of Recreational and Commercial Fisheries for Lake Whitefish in Michigan Waters of Lake Superior, 1997-2004

Philip J. Schneeberger

Michigan Department of Natural Resources
Marquette Fisheries Research Station
484 Cherry Creek Road
Marquette, Michigan 49855

Abstract.–Yield, effort, and biological data were examined to determine whether conflicts existed between recreational and commercial fisheries for lake whitefish in Michigan waters of Lake Superior. Recreational and commercial fisheries were found to be largely segregated from one another because of differences in the times of year when peak fishing activity occurred, differences in fishing depths, and differences in sizes of fish harvested. Commercial gill-net and trap-net fisheries did not adversely affect each other at detected levels of exploitation. Based on two methods of estimation, lake whitefish stocks across Lake Superior generally did not experience excessive mortality rates during 1997-2004. Where catch quotas were generated, yields were below recommended harvest levels. The data examined indicated little or no conflict between co-existing recreational and commercial fisheries for lake whitefish.

Introduction

Lake whitefish *Coregonus clupeaformis* in Michigan waters of Lake Superior are exploited by state-licensed and tribal commercial fisheries and, to a much lesser extent, by recreational fisheries. State and tribal agencies collect and analyze lake whitefish data that are organized by management unit. Management unit boundaries (Figure 1) were defined following rationale outlined by Smith et al. (1961) and are reasonable delineations of lake whitefish stocks in the lake based on their growth and mortality characteristics, and on patterns of commercial fishing.

Lake whitefish management is affected by two treaties that encompass all Michigan waters of Lake Superior: the 1836 Treaty of Washington covers waters east of a line running north of the Chocolay River mouth near Marquette, Michigan, and the Ojibwe Treaty of 1842, also called the Treaty with the Chippewa, applies to waters west of the Chocolay River mouth (Figure 1). Lake whitefish management in 1842 Treaty waters is cooperative between tribal and state personnel, with no formal, legal agreement that is binding to either party in place at this time. State and tribal fisheries in 1836 Treaty waters have been allocated, managed, and regulated according to stipulations detailed in two court-mediated consent decrees, the first of which was in place from 1985 through 2000, and the second mandated to be in force from 2000 through 2020.

The objective of this study was to compare trap-net, gill-net, and recreational (hook-and-line) fisheries for lake whitefish using data collected to monitor and manage exploited stocks in Michigan waters of Lake Superior. Schorfhaar and Schneeberger (1997) addressed a similar objective using 1983-1996 data, and the current study examines 1997-2004 data to further evaluate different aspects of the fisheries.

Methods

The Fisheries

Lake whitefish exploitation varied across management units. Gill-net fisheries for lake whitefish were minimal (< 1000 kg/year) in WFS-00 (Isle Royale) during 1997-2004, and associated data were limited; therefore, this unit is not considered further in this report. State-licensed and tribal fisheries co-existed in management units WFS-01 through WFS-05; whereas, only tribal commercial fishing was conducted in WFS-06, WFS-07, and WFS-08. State-licensed commercial fishers used trap nets; tribal commercial fishers used gill nets in management units WFS-01 through WFS-06, and both gill nets and trap nets in WFS-07 and WFS-08 (Figure 1).

All aspects of commercial fishing (e.g., season, species, area, gear configuration, net marking, reporting) are regulated by applicable state statute and administrative rules, or by tribal codes and regulations. Regulations pertinent to this study included: depth restrictions (4-27 m) applied to state-licensed trap nets but not to gill nets; both trap- and gill-net fisheries were restricted by spawning season closures (all of November for trap nets, most of November for gill nets); minimum stretch mesh measures of 114 mm were specified for commercial gill nets as well as for trap-net pots; and a minimum size limit for lake whitefish was set at 432 mm for both state and tribal commercial fisheries.

Recreational fishing regulations govern anglers who fish in Michigan waters of Lake Superior. There was no closed season and no minimum size limit for lake whitefish caught by recreational anglers. A possession limit of 12 lake whitefish, in combination with lake herring *Coregonus artedi*, was in effect for the recreational fishery during 1997-2004.

Data Sources

State-licensed commercial trap-net fishers submitted monthly catch and effort reports that were entered into a central database by Fisheries Division personnel in Lansing, Michigan. The central commercial database was accessed remotely through an Open Database Connectivity (ODBC) interface, and queries were constructed to obtain annual and monthly summaries of yield and effort by lake whitefish management unit. Michigan Department of Natural Resources (MDNR), Marquette Fisheries Research Station personnel collected lake whitefish biological data (length, weight, sex, scale samples) during monitoring of state-licensed commercial operations.

Information pertaining to tribal gill-net fisheries operating in 1842 Treaty waters was obtained from the Great Lakes Indian Fish and Wildlife Commission (GLIFWC), Biological Services Division. Tribal gill-net and trap-net data from 1836 Treaty waters were made available by the Inter-Tribal Fisheries and Assessment Program of the Chippewa/Ottawa Resource Authority (CORA). Personnel from both agencies provided catch, effort, and biological data summaries for tribal commercial fishing activities conducted in their waters.

Lake whitefish angler information was obtained from MDNR creel surveys conducted during 1997-2004. Data collections followed a stratified design using structured sampling within strata (see Lockwood et al. 1999 for details). Creel survey data were analyzed and summarized by personnel at the MDNR, Charlevoix Fisheries Research Station. Recreational catch and effort were estimated for individual ports for each survey month. The central creel survey database was accessed remotely through an ODBC interface and queries were constructed to obtain summarizations by lake whitefish management unit. Creel sites (ports) for lake whitefish management units were: Black River Harbor and Ontonagon (WFS-01), Traverse Bay (WFS-02), Keweenaw Bay (WFS-03), Marquette (WFS-04), Au Train and Munising (WFS-05), and Grand Marais (WFS-06). Where more than one port was surveyed within a management unit, the estimates from each port were combined. Angler effort recorded from creel surveys was non-targeted. That is, effort during surveys was totaled for all anglers, regardless of whether they were specifically targeting lake whitefish or other species. Creel survey clerks collected biological data (length, weight, scale samples) from a small proportion of lake whitefish caught by recreational anglers.

Estimates of lake whitefish biomass, recruitment, mortality rates, and catch quotas were obtained from Modeling Subcommittee, Technical Fisheries Committee reports (2002, 2003, 2005, 2006). These estimates were produced from statistical catch-at-age (SCAA) models constructed for lake whitefish stocks in shared management units (WFS-04 and WFS-05) in 1836 Treaty waters as mandated by the 2000 Consent Decree (U.S. v. Michigan 2000). Methodology for these models was described in detail by Ebener et al. (2005).

Data Analyses

Recreational and commercial fishery data were used to summarize information across management units and to evaluate yield, effort, and catch-per-unit effort (CPUE). Yield and biological weight data from CORA and MDNR were reported as round (whole fish) weight. Weight information obtained from GLIFWC was recorded as dressed (gutted fish) weight which was converted to round weight for this report using a 1.17 conversion factor. Fishery-specific definitions of CPUE were as follows: kg per lift for trap nets, kg per km of net for gill nets, and number of fish per angler hour for recreational anglers.

Possible interactions between commercial gear types, within management units and for all management units combined, were examined by calculating Pearson product moment correlation coefficients for annual values of CPUE of one gear vs. effort for the other gear. Coefficients were then squared to determine what proportion of the variance in CPUE was attributable to variance in effort between gear types.

Fish scales were examined by personnel from each agency to determine ages of sampled fish. Biological data were used to calculate annual mean length, weight, and age values in each lake whitefish management unit for the different fisheries. Total yields for the recreational fishery were calculated using an average of the estimated number caught each year multiplied by the overall mean weight for angler-caught lake whitefish.

Lake whitefish total annual mortality rates were derived from estimates of survival calculated with coded age frequencies (Robson and Chapman 1961) using state-licensed commercial trap net data from management units WFS-01 through WFS-05. These estimates were calculated from data sets pooled over three years to help smooth year-to-year variation in year-class strength and survival.

Beginning in 2001, the modeling effort related to the 2000 Consent Decree (U.S. v. Michigan 2000) generated total allowable catches (TACs) in WFS-04 and WFS-05 by setting reference point maxima for total annual mortality and spawning potential reduction (see Ebener et al. 2005). Apportionment of TACs between state and tribal fishers was dictated by the 2000 Consent Decree. In non-shared management units WFS-06 through WFS-08, all of the commercial lake whitefish harvest was allocated to tribal fishers, and non-enforceable Harvest Regulation Guidelines (HRGs) were established annually as defined in a Tribal Plan and identified in the Consent Decree. Catch quotas were not calculated for management units WFS-01 through WFS-03 in 1842 Treaty waters.

Mortality estimates from catch-at-age models in management units WFS-04 and WFS-05 were averaged over the same years and the same fully vulnerable ages used for coded age frequency estimates in those units, except that age-12 and older fish were lumped together into a “12+” age category for SCAA estimates. Separate WFS-04 and WFS-05 model estimates of mortality were also averaged over all ages represented in commercial gear, not just those that were fully vulnerable.

Results

Trap-net Fisheries

During 1997-2004, average annual lake whitefish yield from trap-net fisheries in all management units combined was 244,433 kg (Table 1). There was no trap-net fishery in WFS-06, but in the other management units, average annual yields ranged from 10,883 kg in WFS-03 to 87,596 kg in WFS-07 (Table 1). Average reported effort (trap-net lifts) followed the same pattern as yield (i.e., none in WFS-06, low in WFS-03, and highest in WFS-07). Average trap-net CPUEs were highest in WFS-01 through WFS-03, lowest in WFS-04 and WFS-05, and intermediate in WFS-07 and WFS-08 (Figure 2).

Commercial trap-net yield was relatively low from November through April and consistently high June through October (Figure 3 and Table 2). June, July, and August were the months of overall highest yield, though October had some of the highest monthly yields in WFS-02, WFS-03, and WFS-04.

Pearson product moment correlation coefficients indicated that the proportion of trap-net CPUE variance attributable to gill-net effort variance (r^2 values) ranged from 0.00 in WFS-01 to 0.57 in WFS-08 (Table 3). Correlations in individual management units WFS-01 through WFS-07 and for all units combined were not significant ($P>0.05$). There was a significant ($P=0.03$) positive correlation between test variables in WFS-08 (Table 3).

Biological data from state-licensed trap-net fisheries were obtained from an average of 500 fish per management unit per year (range: 78 - 1,203). Among management units, average 1997-2004 values for length ranged from 480 to 543 mm TL and average weights were between 1.01 and 1.49 kg (Table 4). Average values were lower (< 485 mm, <1.1 kg) in management units WFS-01, WFS-02, and WFS-08, and were higher (> 510 mm, >1.2 kg) in WFS-03 through WFS-07 (Table 4). The overall average weight of lake whitefish harvested from trap nets was 1.22 kg. Average age of lake whitefish in state nets ranged from 6.3 years (WFS-02, WFS-07) to 7.6 years (WFS-05), and the overall average age was 7.0 years (Table 4). Fish 5 years old were generally large enough to be recruited to the gear and fish aged 5-21 were represented in catches.

Gill-net Fisheries

Gill net yield for lake whitefish averaged 371,232 kg/year during 1997-2004 (Table 5). Average annual yield was lowest in WFS-04 (12,667 kg/year) and highest in WFS-07 (115,966 kg/year). Average tribal commercial gill net effort ranged from 125 km/year in WFS-04 to 1,442 km/year in WFS-07. Overall gill-net yield and effort peaked at 432,796 kg and 4,378 km of net in 1998. Lowest values were recorded in 1999—318,633 kg and 3,131 km of net. Average gill-net CPUEs were highest in WFS-01 and WFS-02 (162–166 kg/km) and generally decreased from west to east (Figure 2).

Seasonally, April and May were months of highest gill net yield (Figure 3 and Table 6). Relatively high yields also occurred in August, October, and December. November (mostly closed to fishing) and January through March were months of lowest gill net yield.

The proportion of gill-net CPUE variance attributable to variance in trap-net effort (r^2) averaged 0.14 across all management units based on Pearson product moment correlation coefficients (Table 3). Correlations were not significant for any individual management unit ($P>0.05$), but there was a significant ($P=0.01$) negative correlation for data from all units combined (Table 3).

Average size of lake whitefish in commercial gill nets ranged from 496 mm and 1.21 kg in WFS-01 to 601 mm and 2.29 kg in WFS-06 (Table 7). Overall averages for length and weight were 540 mm and 1.61 kg (Table 7). Average ages were higher for fish in management units WFS-01 through WFS-04 (range: 8.0 to 9.2 years) than in WFS-05 through WFS-08 (range: 7.1 to 7.7 years). Overall average age of lake whitefish in gill-net fisheries was 8.1 years.

Recreational Fisheries

Among different lake whitefish management units, creel surveys were conducted during 2-8 years (Table 8) and for 3-10 months per year (Table 9) over the 1997-2004 study period. The average annual catch estimate increased in management units from west to east and was highest (6,318 lake whitefish/year) in WFS-06 (Table 8). The highest estimated annual catch (7,985 fish) occurred in WFS-06 in 2001. Average estimated annual angler fishing effort (non-targeted) ranged from 12,369 angler hours in WFS-02 to 51,534 hours in WFS-04 (Table 8). Patterns in effort were not evident for any management zone except WFS-04 which showed a declining trend from 1997 to 2004.

Seasonally, the estimated number of lake whitefish caught by recreational fishers was highest during February (ice fishery), even though only two management units included February in the creel season (Figure 3 and Table 10). One third of the 1997-2004 recreational total catch came from February in WFS-05 (Munising Bay). May was the month of second highest catch, followed by June, March, and October. Of the months during which creel surveys were conducted, September had the lowest overall catch.

Biological data from angler-caught lake whitefish were limited to samples from an average of 9 to 88 fish per year, for 2 to 7 years, in management units WFS-04, WFS-05, and WFS-06 (Table 11). Overall average size and age of lake whitefish in creel bio-samples, weighted by annual sample sizes in each unit, ranged from 334 to 356 mm TL, from 0.35 to 0.43 kg, and from 3.1 to 5.0 years of age. Calculated total yields of angler-caught lake whitefish ranged from 106 to 881 kg/year in WFS-04, from 219 to 2,637 kg/year in WFS-05, and from 1,707 to 2,536 kg/year in WFS-06.

Mortality

Coded age frequency (Robson-Chapman) estimates of lake whitefish total instantaneous mortality rates varied considerably among management units; they also changed abruptly within a given management unit from one pooled data set to another (Table 12). The lowest and highest estimated rates over three-year pooled data sets were 0.38/year in WFS-03 (1998, 1999, and 2004) and 1.24/year in WFS-02 (1997, 1999, and 2000). Ages that were included in estimates (fully vulnerable to fishing gear) also varied among management units as well as from year-to-year within management units.

Mortality estimates from SCAA models were lower than corresponding Robson-Chapman estimates in 8 of 12 possible comparisons (same years and ages pooled in data sets) in units WFS-04 and WFS-05 (Table 12). Model estimates of mortality that included all ages of fish vulnerable to commercial gear in WFS-04 and WFS-05 were lower than Robson-Chapman estimates for all 12 comparisons (Table 12).

Other Parameters

Model outputs showed stable estimates for lake whitefish biomass in WFS-04 and somewhat variable estimates in WFS-05 during 1986-2004 (Figure 4). After TACs were imposed in 2001, the estimated stock biomass increased through 2004 in WFS-04 and increased with a leveling off between 2003 and 2004 in WFS-05. Recruitment estimates were variable during 1986-2004, with peaks for year classes produced in 1984, 1991 and 1998 (depicted as high levels of 4-year old fish in 1988, 1995, and 2002) in WFS-05 (Figure 5). Recruitment trends were similar in WFS-04 except there was no peak for the 1991 year-class. Weight-at-age for 7-year old lake whitefish in trap nets (selected as an average age harvested across management units) fluctuated within a range of 1.2-1.7 kg in WFS-04 and between 1.0-2.0 kg in WFS-05 during 1986-2004 (Figure 6). Mean weight-at-age estimates (1.3-1.5 kg in WFS-04; 1.0-1.2 kg in WFS-05) were narrow during 2001-04 when catch quotas were in place.

Trap nets accounted for 0-67% of the total yield from any particular management unit in Michigan's waters of Lake Superior, averaged over 1997-2004. Gill-net yield represented 32-88% of the yield across management units. Estimated recreational catch represented <0.05% of the average total yield in WFS-01 through WFS-03, 1.2% in WFS-04, 2.9% in WFS-05, and 10.6% in WFS-06 (Figure 7). From 2001 through 2004, the ratio of annual total yield (combined from commercial trap nets, tribal gill nets, and recreational fisheries) to annual TAC averaged 0.29 in WFS-04 and 0.21 in WFS-05 (Figure 7). Ratios of total annual yields to HRGs averaged 0.31 in WFS-06, 0.98 in WFS-07, and 0.70 in WFS-08 (Figure 7).

Discussion

I compared recreational and commercial fisheries in terms of areas fished, size and age of harvested fish, fishing gear, and seasonality of fishing activities. In addition, mortality rates and exploitation in relation to catch quotas were evaluated in an attempt to determine status of stocks within management units.

Area

Recreational and commercial fisheries, for the most part, operated in different areas of the lake separated by depth. A high proportion of the recreational catch occurred during February when anglers were fishing near shore through the ice over relatively shallow depths, mostly in Munising Bay (WFS-05). A limited amount of under the ice gill-net fishing also occurred (e.g., in WFS-07), but winter was a season of relatively low commercial productivity (Figure 3). Safe ice for anglers on Lake Superior is limited not only by the time of year, but also to the few locations like Munising Bay where shallow or protected bays and harbors offer areas where ice can form with any reliability. The open water recreational catch of lake whitefish also came from shallow water, largely from fishing off piers and break walls, or from small boats close to shore. Recreational anglers in larger boats, having the capability to ply deeper offshore waters, mostly employed techniques and gear that targeted and caught trout and salmon, not lake whitefish.

In contrast, commercial fishers operated mostly in deeper waters, setting their gear to capitalize on diurnal movements, seasonal schooling, and migratory behaviors of lake whitefish. The exception was during fall when nets were set to capture fish concentrated near shore prior to spawning. Maximum fishing depth was unrestricted for tribal fishers, and state-licensed fishers set traps as deep as the administrative rule allowed (27 m) for most of the fishing season. Perception that gill nets were producing higher catches at greater depths prompted state-licensed fishers to request a deeper limit for trap nets. This led to a 3-year study which showed that more lake whitefish were caught in Lake

Superior traps set at 39 m than at 27 m, and that the difference was significant during spring (Marquette Fisheries Research Station, unpublished data). Furthermore, fishing with deeper nets did not adversely affect other parameters such as bycatch of lake trout or mortality of sub-legal lake whitefish. Consequently, after a thorough evaluation, a decision was made to allow state fishers to set trap nets out to 39 m starting in 2005 (report in preparation). Although not necessarily the intended result, this decision will serve to further expand the separation between commercial and recreational fisheries by depth.

Use of the two types of commercial gear was somewhat segregated by area on a management unit scale. In units where both gear types were fished, average tribal gill net yield was dominant (>60% of the commercial harvest) in management units WFS-01, WFS-02, and WFS-03, and trap net yield was dominant in WFS-04, WFS-05, and WFS-08 (Tables 1 and 5). Overall average yields for both trap and gill nets were higher, and more equivalent to each other, in WFS-07 than in any other management unit. Gill and trap net CPUEs did not appear to be affected by whichever gear type was dominant in a particular management unit and were larger in WFS-01 and WFS-02 than in more easterly management units (Figure 2). These data indicated an apparent lack of conflict between commercial fishing methods.

Size and Age of Harvested Fish

Recreational fisheries exploited a smaller, younger segment of the lake whitefish population than did commercial fisheries (Tables 4, 7, and 11). There are far more small (young) fish than large (older) ones in natural populations, and unlike commercial fishers, recreational anglers were permitted to keep lake whitefish of any size. Also, recreational hook-and-line fishing gear was indiscriminate, whereas commercial gear was selective for larger fish because of mesh-size regulations. As a result, the overall mean length of lake whitefish in the recreational catch (348 mm) was below the minimum size limit (432 mm) imposed on commercial fisheries.

The smaller fish size for recreational catches might also be related to a depth separation between small and large lake whitefish. Examining trap-net and trawl catches in northern Lake Michigan, Rybicki and Schneeberger (1990) speculated that older lake whitefish were distributed in deeper waters than young fish. However, immature lake whitefish switch to having diets and temperature preferences similar to adults after their first summer of life (Reckhan 1970) and as such, age-1 and older fish may generally have the same depth distribution.

Commercial traps and gill nets exploited the same segment of lake whitefish populations in general. Overall, however, lake whitefish mean length, weight, and age were greater in gill nets than in trap nets (Tables 4 and 7) for a variety of reasons. For example, in WFS-04, a high proportion of the gill net yield was caught during fall and early winter when lake whitefish were aggregated prior to or after spawning, and these predominantly larger, older fish skewed the gill-net fishery size and age statistics upward in this management unit. The especially high mean ages of lake whitefish in WFS-01 through WFS-04 also might have reflected a difference in aging techniques used by different agencies, both tribal and state. Lake whitefish have become increasingly difficult to age in recent years, to the extent that managers are discussing standardization of techniques, cross-readings among agencies, and using structures other than scales, such as fin rays and otoliths, to help with aging accuracy.

Another consideration is gear selectivity. Although both commercial gear types have the same minimum 114 mm stretch mesh restriction as well as the same minimum length regulation for lake whitefish, gill nets generally selected for larger, older fish than did traps (Tables 4 and 7). Retention in gill nets is mostly a function of fish girth rather than length, so fish weight and condition determine whether or not lake whitefish near the minimum length limit are caught. In contrast, scuba divers observing trap lifts reported that even lake whitefish small enough to swim easily through pot meshes could be retained in traps due to behavioral reactions to the lifting of the net (Schneeberger et al. 1982; Rutecki et al. 1983). Because trap-net fishers sort live fish, they may choose to keep fish down to the minimum length limit regardless of fish girth, and this could have the effect of lowering mean size and age of lake whitefish in trap-net samples.

Gear

Pearson product-moment correlation coefficient comparisons of effort and CPUE between gear types were limited to commercial fisheries because recreational effort, as recorded by creel clerks, was non-targeted and therefore not meaningful for these analyses. The significant positive correlation between trap-net CPUE vs. gill-net effort in WFS-08 appeared to be spurious because correlations were not significant in any other management unit, or for all management units combined (Table 3). No gill-net CPUE vs. trap-net effort correlations were significant for individual management units, but a significant negative correlation for all management units combined indicated that 11% of the variance in gill-net CPUE was accounted for by variance in trap-net effort (Table 3). The general lack of significance between gear-specific CPUE and effort statistics showed that commercial fishing during 1997-2004 was not at a level where fishers of either gear type affected one another.

Season

Recreational and commercial fisheries were segregated by season (Figure 3). The highest proportion of recreational catches occurred in February when there was little or no commercial catch. April was the peak for gill-net harvest but it was a month during which recreational and trap-net yield and effort were relatively low. Trap-net yield was highest in July, coincident with moderate gill net and low recreational yields. As described above, monthly catches by gear type were associated with seasonal distributions of lake whitefish, weather, and vulnerability to the different fisheries. In the case of the commercial fisheries, operator preference and characteristics of gear handling also played a role. For example, when commercial fisheries re-commenced in spring following the winter lull, it was relatively easy for gill-net fishers to quickly deploy their full complement of gear. Time, effort, and deck space limitations required a longer reaction time for trap fishers to set their nets, and additional time was required each time a trap net was pulled and moved to new locations during the year.

Mortality

The coded age frequency mortality estimation method is a derivation, or idealization of catch-curve analysis, and operates under assumptions of constant year-class strength and constant survival rates over the age groups fully vulnerable to the fishing gear. When assumptions of constant year-class strength and survival are questionable, Robson and Chapman (1961) recommended obtaining catch data over a series of years. Accordingly, managers have often used running three-year pooled data sets to increase sample size and to smooth age structure representations.

A total annual mortality rate of 65% (instantaneous total mortality rate of 1.05) has been used by managers for many years as a target maximum for lake whitefish in the Great Lakes. This benchmark was based on work by Healey (1975) and Clark (1984). Lake whitefish stocks were described by Clark (1984) as being “in danger of collapse” when subjected to mortality rates in excess of 70%. Negotiators for the 2000 Consent Decree also adopted 65% as the target maximum total annual mortality rate for lake whitefish in 1836 Treaty waters (U.S. v. Michigan 2000).

Lake whitefish total instantaneous mortality estimates during 1997-2004 in Michigan waters of Lake Superior using coded age frequencies were all well under the target maximum rate of 1.05 with one exception (Table 12). The 1997-2000 estimate for the WFS-02 stock was 1.24, a rate considered excessively high. However, the four mortality estimates calculated from subsequent years (1999-2004) in WFS-02 were consistently lower and averaged only 0.62 (Table 12). Abrupt changes in annual year-class strength were indicated from variable SCAA model estimates of recruitment (Figure 5), and these changes were large enough to cause coded age frequency estimates of mortality to swing substantially through time, even with the use of three-year pooled data sets.

Mortalities estimated with catch-at-age models were all below the target maximum rate. Catch-at-age models use long-term data sets to estimate fish abundance and mortality, accounting for changes over time throughout the duration of each year-class. Model fit is dependent on agreement between model predictions and observed data. As such, SCAA models are considered state-of-the-art (Hilborn and Walters 1992). Model estimates of mortality incorporate more information from the stock and are less reliant on the assumptions that are critical to catch-curve-type analyses. Therefore, SCAA mortality estimates are considered here to be more robust than those calculated from coded age frequencies.

Mortality estimates from SCAA models were compared to coded age frequency estimates for stocks in WFS-04 and WFS-05. When SCAA and coded age frequency calculations included the same age groups, the SCAA estimates were lower in two-thirds of the cases (Table 12), and on average were 11% lower. When SCAA model calculations were made by averaging mortalities across all ages vulnerable to fisheries, estimates were lower than those for coded age frequencies in every comparison, by an average of 26%. Excessive mortality was not a problem for lake whitefish in Michigan waters of Lake Superior during the study period because estimates from both methods were generally lower than the target maximum.

Exploitation

Lake whitefish stocks in this study were not subjected to overexploitation based on a comparison of yield (all fisheries combined) to quotas. Yield to HRG ratios were highest for stocks in WFS-07 and WFS-08, but only the WFS-07 ratio was close to one. Yields, on average, were less than a third of the quotas (TACs or HRGs) calculated for WFS-04, WFS-05, and WFS-06 (Figure 7). In other words, exploitation was below calculated sustainable yield in four of five management units where an annual catch quota was generated.

In the absence of models, quotas were not generated for lake whitefish populations in WFS-01 through WFS-03. However, CPUEs for both trap- and gill-net fisheries were relatively high in these western-most management units, with the exception that gill-net CPUE was moderate in WFS-03. Temporal patterns of CPUEs, fish size, and age during the study period were not indicative of stocks being over fished. Further, lake-wide mean biomass of lake whitefish in Lake Superior has remained stable during 1996-2004, and lake whitefish abundance in western Lake Superior is very high based on bottom trawl surveys conducted by the United States Geological Survey (Stockwell et al. 2005). Bronte et al. (2003) reported that during recent years, lake whitefish abundance in Lake Superior had approached former historic levels.

Stock biomass and, to a lesser extent, mean weight-at-age were variable over the longer time frame incorporated into catch-at-age models for WFS-04 and WFS-05 (Figures 4 and 6). However, during the latter half of the 1997-2004 study segment, estimated biomass increased and mean weight-at-age remained relatively stable. These trends are at least partly attributable to the controlling of exploitation through catch quotas that were instituted in 2001.

Summary

Analyses indicated that there was little conflict between recreational and commercial fisheries for lake whitefish in Michigan waters of Lake Superior. The fisheries were separated physically by depth, they exploited fish of different size and age segments in populations, and they operated at somewhat different times of the year. With very few exceptions, the levels of fishery exploitation and mortality were acceptable for stocks across all management units. Commercial fisheries extractions had little effect on recreational anglers who mostly harvested lake whitefish before they were recruited to commercial gear. Conversely, the relatively low level of harvest by recreational fishers had a negligible impact on commercial fisheries. Overall commercial fishing intensity was not found to be at levels that would cause undue depletion of stocks, and impacts between different gear types appeared minimal. Total yields below calculated quotas also were an indication that no one fishery (recreational, trap net, or gill net) was adversely affected by the others. In management units where either gill-net or trap-net fisheries were predominant, the situation appeared to be a function of relative fishing effort by gear type rather than any competitive superiority of one fishery over the other. Schorfhaar and Schneeberger (1997) reached a similar conclusion regarding the lack of conflict between recreational and commercial trap-net fisheries based on temporal, spatial, and biological comparisons of 1983-1996 data.

Recommendations

1. Continue monitoring fisheries to keep track of changes over time and to provide inputs needed to maintain and update catch-at-age models.
2. Continue to generate and enforce annual catch quotas in management units within 1836 Treaty waters.
3. Assemble data to develop catch-at-age models for western management units WFS-01 to WFS-03 in 1842 Treaty waters.
4. Work to improve and standardize lake whitefish aging within and among management agencies.

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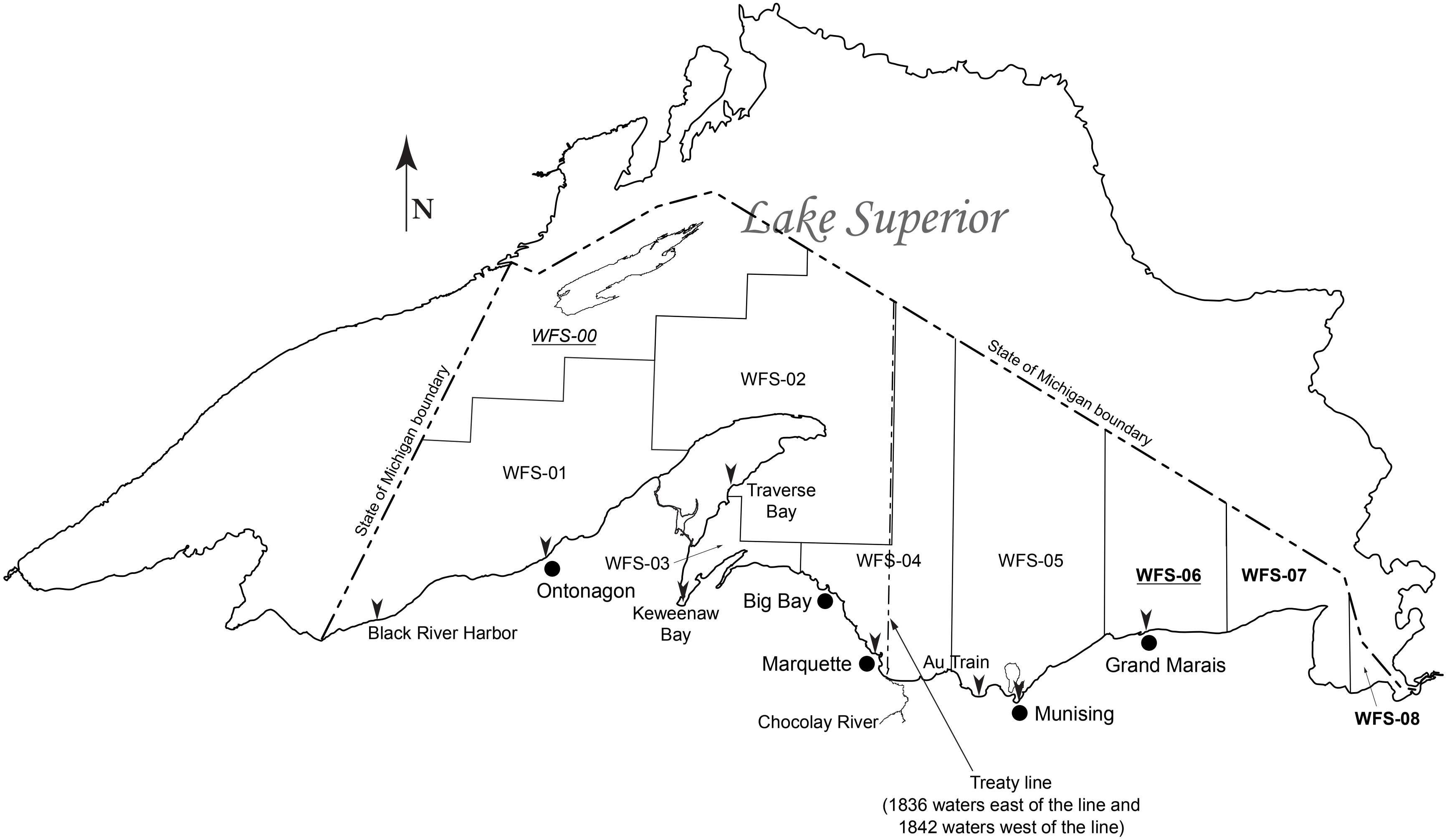

Figure 1.–Lake whitefish management units (WFS-00 to WFS-08) and location of the boundary separating treaty waters in Michigan waters of Lake Superior. Management units shared between state-licensed and tribal commercial fisheries (WFS-01 through WFS-05) are shown in regular font, tribal-only units (WFS-06 through WFS-08) are bolded, and the state-only unit (WFS-00) is italicized. Gill-net only units WFS-00 and WFS-06 are underlined; trap- and gill-net fisheries co-occur in all other units. Ports where creel surveys were conducted are indicated by an arrow point.

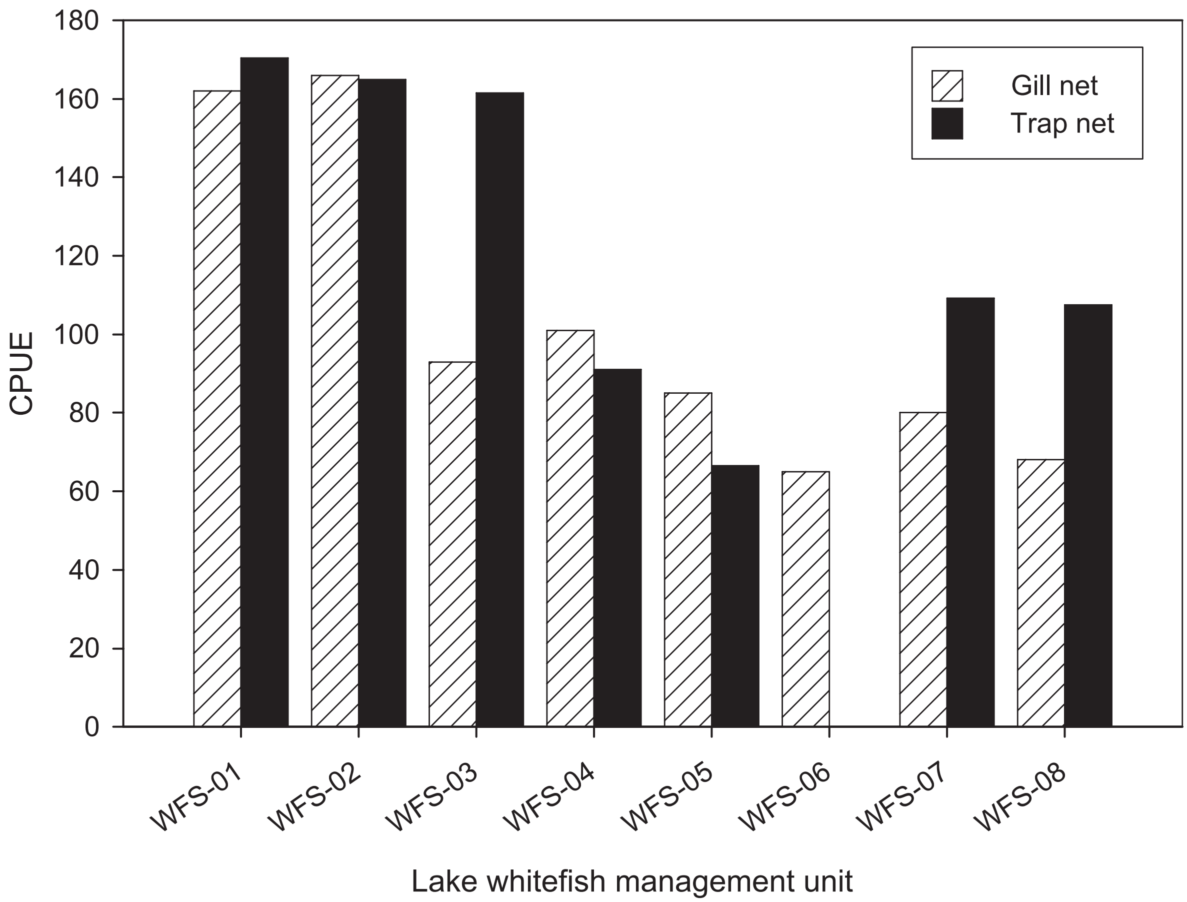

Figure 2.–Average catch-per-unit effort (kg per km of gill net; kg per trap-net lift) for commercial fisheries in Michigan waters of Lake Superior, 1997–2004.

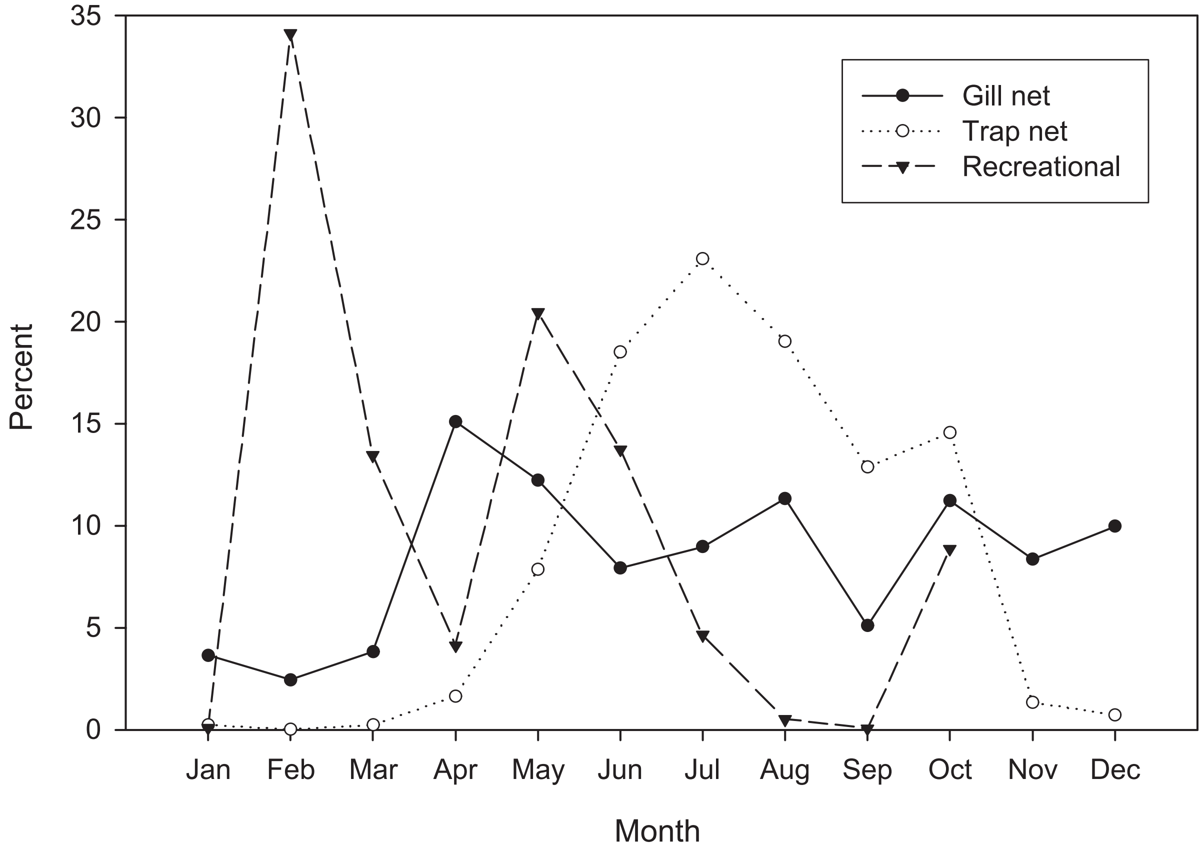

Figure 3.–Percent of annual yield by month for fisheries in Michigan waters of Lake Superior, 1997–2004, all management units combined.

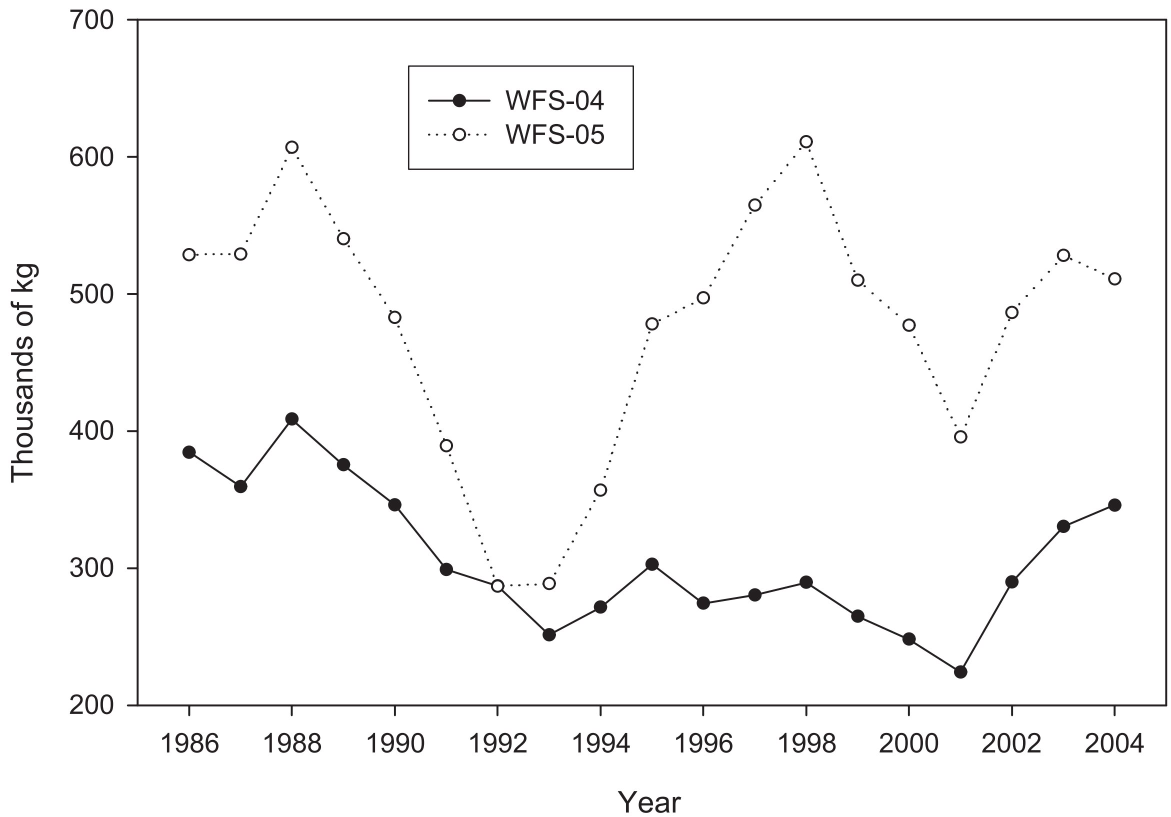

Figure 4.–Catch-at-age model estimates of total lake whitefish biomass in Lake Superior management units WFS-04 and WFS-05.

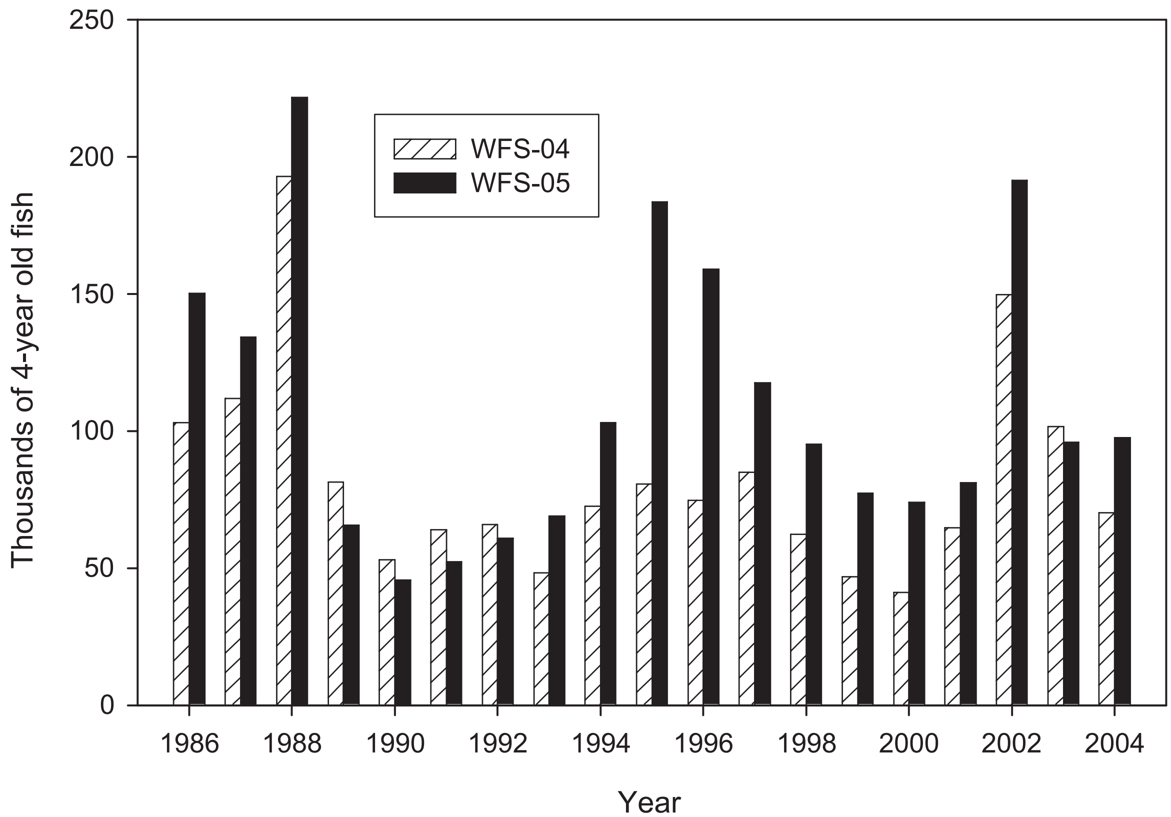

Figure 5.–Catch-at-age model estimates of lake whitefish recruitment in Lake Superior management units WFS-04 and WFS-05.

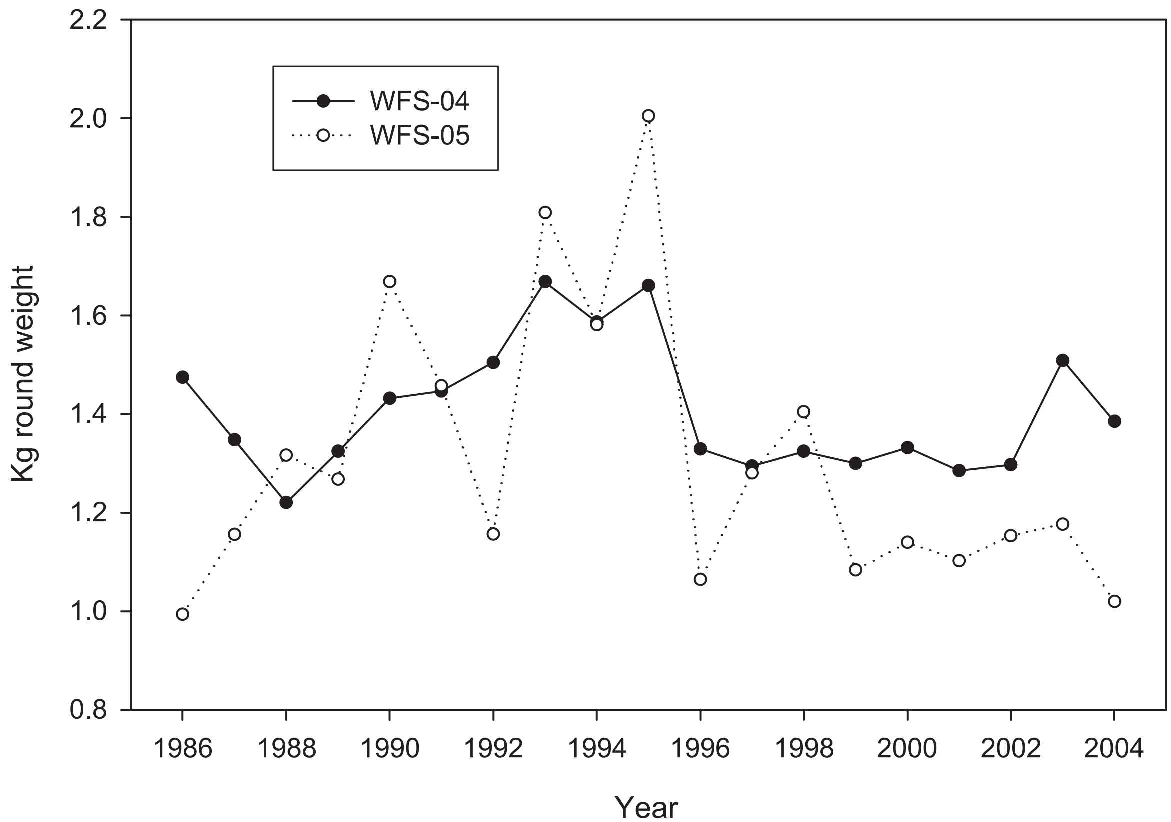

Figure 6.–Population mean weight-at-age for 7-year old lake whitefish harvested by commercial trap nets in Lake Superior management units WFS-04 and WFS-05.

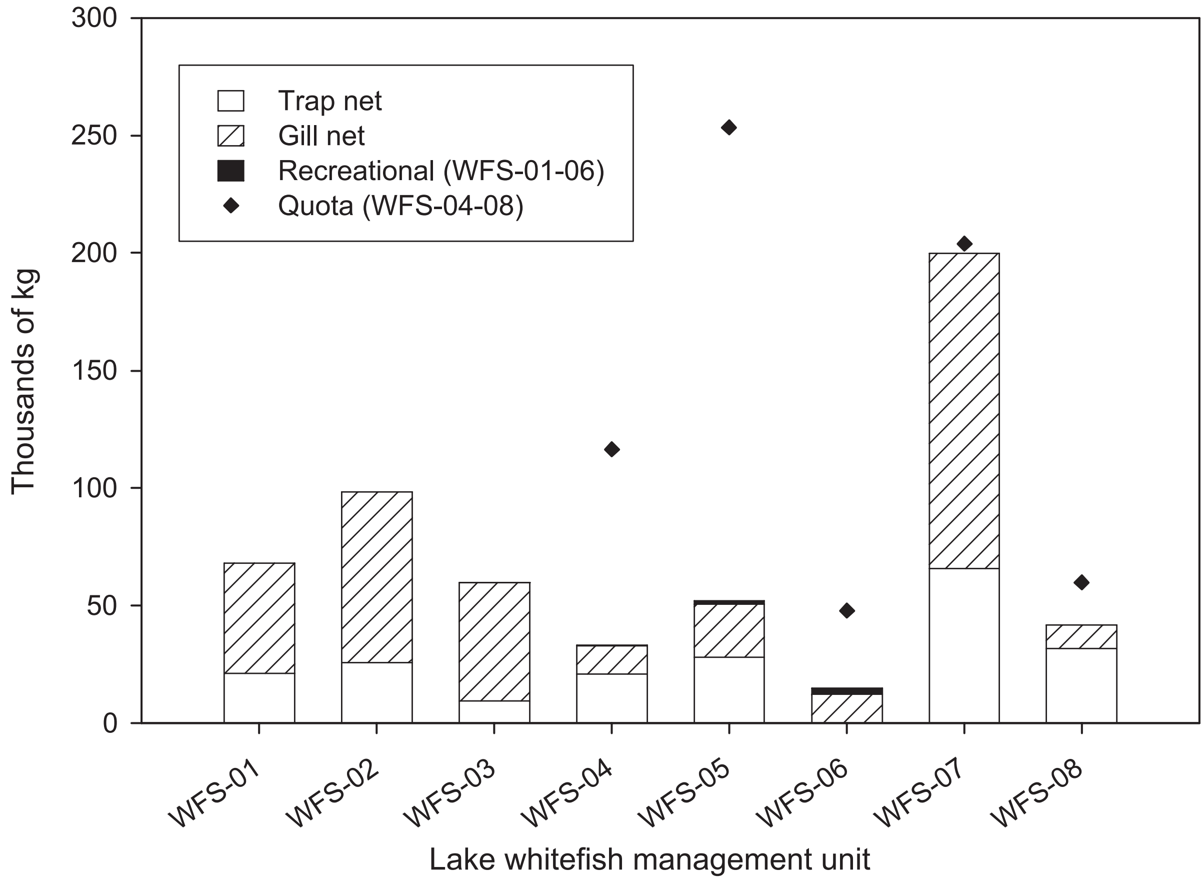

Figure 7.–Average yield and average quota by fishery in Michigan waters of Lake Superior, 2001–04.

Table 1.–Lake whitefish yield (kg) and effort (lifts) for commercial trap-net fisheries in Michigan waters of Lake Superior, 1997-2004.

		Year									
Parameter	Management unit	1997	1998	1999	2000	2001	2002	2003	2004	Total	Average
Yield	WFS-01	0	27,202	51,904	46,271	39,762	14,370	12,287	18,225	210,020	26,253
	WFS-02	14,292	0	42,373	34,220	26,855	25,619	26,857	23,843	194,058	24,257
	WFS-03	14,311	11,199	10,660	12,973	5,418	5,572	9,852	17,082	87,068	10,883
	WFS-04	23,146	23,128	25,472	30,817	20,913	10,973	21,811	30,398	186,658	23,332
	WFS-05	29,839	49,091	48,812	69,422	35,271	28,572	28,048	21,096	310,151	38,769
	WFS-07	97,264	123,562	116,728	99,438	34,504	62,549	83,829	82,898	700,771	87,596
	WFS-08	23,745	9,502	70,787	35,187	28,020	21,388	22,471	55,634	266,734	33,342
	All	202,597	243,684	366,736	328,328	190,742	169,042	205,155	249,176	1,955,460	244,433
Effort	WFS-01	0	200	221	222	286	124	108	72	1,233	154
	WFS-02	135	0	181	224	161	177	129	169	1,176	147
	WFS-03	70	65	78	61	57	40	58	110	539	67
	WFS-04	217	283	334	282	272	170	249	244	2,051	256
	WFS-05	337	791	718	930	527	371	556	432	4,662	583
	WFS-08	131	80	538	505	268	262	286	418	2,488	311
	All	1,676	2,460	3,074	3,385	1,746	1,748	1,917	2,153	18,159	2,270

Table 2.–Yield (kg) of lake whitefish in commercial trap nets in Michigan waters of Lake Superior, by management unit and month, cumulative over 1997-2004.

Month	Management unit							Monthly total
	WFS-01	WFS-02	WFS-03	WFS-04	WFS-05	WFS-07	WFS-08	
Jan						4,423		4,423
Feb					20			20
Mar					761	3,658		4,419
Apr	1,201	354		136	2,523	25,612	2,149	31,974
May	23,043	3,935	75	7,815	18,056	67,842	32,904	153,670
Jun	58,142	17,746	6,645	26,826	35,061	151,562	65,912	361,894
Jul	49,406	35,332	20,702	49,651	89,466	148,347	58,173	451,077
Aug	48,949	39,513	18,656	32,753	96,927	99,101	36,087	371,986
Sep	21,807	39,541	16,014	19,970	44,271	77,179	32,806	251,587
Oct	7,473	57,639	24,975	49,508	18,341	97,354	29,156	284,445
Nov						16,449	9,540	25,989
Dec					4,725	9,244	6	13,975
Unit total	210,020	194,059	87,068	186,658	310,151	700,771	266,734	1,955,461

Table 3.–Pearson product-moment correlation coefficients (r) comparing catch-per-unit effort (CPUE) for one commercial fisheries gear with effort (trap-net lifts, km of gill net) of the other gear for Michigan waters of Lake Superior. Significant P values (<0.05) shown underlined in bold.

Management unit	Trap-net CPUE vs. gill-net effort			Gill-net CPUE vs. trap-net effort		
	r	r^2	P	r	r^2	P
WFS-01	0.06	0.00	0.90	0.50	0.25	0.21
WFS-02	0.20	0.04	0.64	-0.43	0.18	0.29
WFS-03	-0.19	0.03	0.66	0.66	0.43	0.08
WFS-04	0.23	0.05	0.58	-0.07	0.01	0.87
WFS-05	-0.66	0.43	0.08	-0.13	0.02	0.75
WFS-07	0.13	0.02	0.76	-0.22	0.05	0.60
WFS-08	0.76	0.57	**0.03**	-0.11	0.01	0.80
All	0.20	0.04	0.14	-0.33	0.11	**0.01**
Average	0.07	0.16	0.52	0.03	0.14	0.51

Table 4.–Mean size and age of lake whitefish from commercial trap-net operations in Michigan waters of Lake Superior. Total length in mm, round weight in kg, age in years.

Management unit	Year	N	Length		Weight		Age	
			Mean	SD	Mean	SD	Mean	SD
WFS-01	1998	78	482	26	1.03	0.19	6.9	0.9
	1999	202	495	30	1.01	0.21	7.5	1.2
	2000	400	493	35	1.09	0.27	8.3	1.8
	2001	200	502	42	1.21	0.36	7.8	1.7
	2004	400	451	17	0.82	0.10	6.3	0.6
	Average	256	484	30	1.03	0.22	7.4	1.3
WFS-02	1997	201	456	21			6.3	1.0
	1999	401	485	33	1.02	0.25	6.3	1.1
	2000	397	471	28	0.94	0.20	6.3	1.1
	2001	601	487	42	1.04	0.37	6.8	1.9
	2002	569	489	39	1.02	0.32	6.3	1.4
	2003	601	486	31	1.02	0.25	6.0	1.6
	2004	401	491	37	1.09	0.31	6.5	1.5
	Average	453	480	33	1.02	0.29	6.3	1.4
WFS-03	1998	399	524	47	1.26	0.41	6.8	1.2
	1999	199	516	38	1.22	0.32	7.0	1.2
	2004	200	571	79	1.86	0.94	8.5	3.1
	Average	266	537	55	1.45	0.56	7.4	1.8
WFS-04	1997	591	532	50	1.45	0.71	7.1	1.5
	1998	388	553	64	1.58	0.81	7.9	2.3
	1999	594	537	52	1.40	0.44	7.3	1.4
	2000	800	537	53	1.43	0.51	7.5	1.6
	2001	717	535	55	1.38	0.52	7.3	1.5
	2002	790	552	65	1.56	0.66	7.5	1.6
	2003	801	565	74	1.71	0.77	7.8	2.6
	2004	600	536	60	1.43	0.54	6.9	1.9
	Average	660	543	59	1.49	0.62	7.4	1.8
WFS-05	1997	200	525	65	1.21	0.43	7.1	2.0
	1998	959	545	68	1.54	0.79	7.5	1.9
	1999	867	512	59	1.20	0.60	8.0	1.8
	2000	642	525	77	1.37	0.74	8.0	2.3
	2001	1,143	508	61	1.21	0.60	7.8	1.7
	2002	1,199	521	81	1.37	0.83	7.6	2.4
	2003	1,203	532	79	1.43	0.82	7.8	2.5
	2004	755	498	66	1.22	0.74	6.9	2.0
	Average	871	521	69	1.32	0.69	7.6	2.1

Table 4.–Continued.

Management unit	Year	N	Length Mean	Length SD	Weight Mean	Weight SD	Age Mean	Age SD
WFS-07	1997	283	508	53	1.26	0.49	6.8	1.6
	1998	374	505	47	1.22	0.40	6.4	1.5
	1999	870	503	52	1.20	0.45	5.5	1.3
	2000	622	503	51	1.12	0.45	6.3	1.5
	2001	285	537	62	1.45	0.60	6.7	1.7
	2002	568	510	62	1.20	0.66	6.5	1.9
	2003	718	512	44	1.20	0.41	6.2	1.5
	Average	531	511	53	1.24	0.49	6.3	1.6
WFS-08	1997	230	468	36	0.94	0.28	7.1	1.2
	1998	145	487	35	1.05	0.27	6.8	1.1
	1999	103	470	39	0.88	0.27	5.5	1.0
	2000	223	480	50	1.01	0.38	6.9	1.8
	2001	182	499	54	1.17	0.43	6.8	1.3
	2002	217	472	39	0.97	0.29	6.8	1.5
	2003	195	481	41	1.03	0.29	6.4	1.2
	Average	185	480	42	1.01	0.32	6.6	1.3
All	Average	500	508		1.22		7.0	

Table 5.–Lake whitefish yield (kg) and effort (km of net) for commercial gill-net fisheries in Michigan waters of Lake Superior, 1997-2004.

Parameter	Management unit	Year								Total	Average
		1997	1998	1999	2000	2001	2002	2003	2004		
Yield	WFS-01	64,938	116,851	104,292	157,679	66,238	56,829	50,755	70,810	688,392	86,049
	WFS-02	48,625	59,861	42,275	44,124	54,056	52,493	129,735	26,405	457,573	57,197
	WFS-03	38,000	44,617	40,977	39,058	33,634	49,928	28,009	59,945	334,167	41,771
	WFS-04	9,994	12,977	6,800	23,798	12,179	16,627	7,954	11,008	101,337	12,667
	WFS-05	13,925	22,704	18,410	27,599	29,609	11,682	26,858	21,210	171,999	21,500
	WFS-06	38,470	32,354	24,726	20,344	15,242	16,492	5,333	12,083	165,044	20,631
	WFS-07	133,579	115,940	66,495	76,635	108,663	116,536	120,058	189,826	927,732	115,966
	WFS-08	33,853	27,492	14,658	7,719	13,388	7,937	3,865	14,700	123,612	15,452
	All	381,384	432,796	318,633	396,957	333,010	328,524	372,566	405,986	2,969,856	371,232
Effort	WFS-01	501	691	523	560	456	589	433	500	4,253	532
	WFS-02	484	262	306	237	382	436	450	197	2,754	344
	WFS-03	384	615	503	429	425	540	262	426	3,584	448
	WFS-04	38	108	64	153	98	186	139	215	1,001	125
	WFS-05	169	282	198	310	289	109	416	260	2,035	254
	WFS-06	469	464	326	301	171	366	101	345	2,542	318
	WFS-07	1,163	1,522	982	1,212	1,384	1,503	1,694	2,079	11,539	1,442
	WFS-08	460	434	229	149	272	74	38	168	1,824	228
	All	3,667	4,378	3,131	3,352	3,478	3,803	3,532	4,191	29,532	3,692

Table 6.–Yield (kg) of lake whitefish in commercial gill-net fisheries in Michigan waters of Lake Superior, by management unit and month, cumulative over 1997-2004.

Month	Management unit								Monthly total
	WFS-01	WFS-02	WFS-03	WFS-04	WFS-05	WFS-06	WFS-07	WFS-08	
Jan	1,587	52,557	38,776	8,409	13,076	2,442	34,189	718	151,751
Feb	22,255	26,141	8,141	8,586	12,145	0	16,514	5,129	98,911
Mar	80,516	40,632	7,754	4,073	16,370	619	26,244	9,571	185,779
Apr	171,407	30,742	28,315	11,094	31,768	23,226	149,464	4,917	450,934
May	89,392	33,781	26,979	6,320	31,988	10,136	119,495	7,966	326,056
Jun	61,845	35,684	26,910	5,509	12,484	26,656	62,960	7,773	239,821
Jul	58,183	40,200	22,626	4,169	6,868	25,492	89,109	3,047	249,693
Aug	73,610	37,555	25,721	10,301	12,415	45,228	92,473	6,955	304,258
Sep	65,329	24,279	40,026	7,611	1,526	11,130	51,450	6,595	207,945
Oct	60,918	35,321	37,116	11,547	7,873	1,949	109,643	36,352	300,719
Nov	0	15,834	13,059	7,314	9,822	4,276	83,826	18,091	152,221
Dec	3,349	84,849	58,746	16,404	15,664	13,892	92,366	16,499	301,768
Unit total	688,392	457,573	334,167	101,337	171,999	165,044	927,732	123,612	2,969,856

Table 7.–Mean size and age of lake whitefish from tribal commercial gill-net operations in Michigan waters of Lake Superior. Total length in mm, round weight in kg, age in years.

Management unit	Year	N	Length Mean	Length SD	Weight Mean	Weight SD	Age Mean	Age SD
WFS-01	1997	1,223	485	28	1.06	0.20	7.4	1.4
	1998	818	491	29	1.16	0.23	9.0	1.6
	1999	887	510	33	1.54	0.93	9.1	1.7
	2000	1,260	500	37	1.27	0.36	8.5	1.5
	2001	258	503	33	1.22	0.28	10.0	1.3
	2002	670	506	40	1.30	0.33	9.0	1.7
	2003	861	480	38	1.05	0.26	9.0	1.5
	2004	957	489	39	1.09	0.31	8.4	1.7
	Average	867	496	34	1.21	0.36	8.8	1.5
WFS-02	1997	814	483	37	1.10	0.25	7.4	1.4
	1998	318	487	24	1.07	0.18	9.0	1.3
	1999	114	510	36	1.44	0.39	8.3	1.2
	2000	429	519	36	1.33	0.28	8.2	1.4
	2001	426	497	26	1.17	0.22	9.8	1.5
	2002	149	506	28	1.31	0.21	10.1	1.0
	2003	716	511	39	1.20	0.33	9.3	1.5
	2004	832	503	31	1.16	0.26	8.9	1.6
	Average	475	502	32	1.22	0.26	8.9	1.4
WFS-03	1997	339	519	52	1.35	0.42	6.7	1.4
	1998	624	506	39	1.31	0.34	7.7	1.3
	1999	490	514	46	2.48	2.82	7.8	1.4
	2000	448	526	51	1.49	0.47	8.3	1.5
	2001	491	541	53	1.54	0.49	8.6	2.1
	2002	274	546	57	1.66	0.65	8.2	2.4
	2003	512	503	38	1.17	0.30	8.5	1.9
	2004	733	520	39	1.32	0.38	8.5	1.8
	Average	489	522	47	1.54	0.73	8.0	1.7
WFS-04	1997	97	634	66	2.50	1.05	10.8	3.2
	1998	167	546	51	1.58	0.56	8.7	1.8
	1999	98	550	66	1.83	1.26	8.2	2.9
	2001	38	597	74	1.95	0.87	9.0	2.9
	2002	91	611	68	2.13	0.82	10.5	2.9
	2003	82	535	50	1.62	0.50	8.0	2.2
	2004	17	578	86	2.17	1.47	9.5	4.6
	Average	84	579	66	1.97	0.93	9.2	2.9

Table 7.–Continued.

Management unit	Year	N	Length		Weight		Age	
			Mean	SD	Mean	SD	Mean	SD
WFS-05	1997	98	523	81	1.55	0.96	6.9	1.9
	1998	159	497	38	1.08	0.24	7.2	0.8
	1999	190	525	65	1.42	0.75	7.7	1.4
	2000	177	488	39	1.16	0.31	7.5	1.2
	2001	384	501	45	1.19	0.43	8.2	1.9
	2002	22	474	70	1.05	0.47	5.6	1.5
	Average	172	501	56	1.24	0.53	7.2	1.5
WFS-06	1997	157	557	64	1.77	0.81	6.5	2.1
	1998	157	610	64	2.46	0.86	8.0	2.5
	1999	80	622	70	2.53	0.94	8.4	2.7
	2000	256	588	62	2.11	0.73	7.5	6.2
	2001	117	626	52	2.50	0.58	8.2	2.1
	2002	67	602	53	2.39	0.65	7.9	1.9
	Average	139	601	61	2.29	0.76	7.7	2.9
WFS-07	1997	937	552	65	1.70	0.73	7.2	4.7
	1998	857	562	65	1.77	0.75	7.4	2.2
	1999	557	565	61	1.68	0.69	6.9	2.1
	2000	294	576	63	1.84	0.69	7.3	2.3
	2001	697	556	59	1.67	0.66	7.2	1.7
	2002	377	527	50	1.40	0.45	6.6	1.8
	2003	659	519	48	1.45	0.51	7.2	1.5
	Average	625	551	59	1.64	0.64	7.1	2.3
WFS-08	1997	767	502	54	1.22	0.47	6.9	3.6
	1998	432	551	64	1.62	0.64	8.1	1.9
	1999	368	543	67	1.53	0.64	7.6	1.8
	2000	230	532	51	1.45	0.51	7.3	1.6
	2001	200	512	38	1.22	0.27	6.8	1.11
	2002	76	535	54	1.36	0.50	6.6	1.6
	2003	91	516	42	1.2	0.33	7.6	2.1
	Average	309	527	53	1.37	0.48	7.3	2.0
All	Average	415	533		1.54		8.1	

Table 8.–Recreational fishery catch (numbers of fish) and effort (angler hours) estimates for lake whitefish in Michigan waters of Lake Superior. Blanks indicate no survey.

		Year									
Parameter	Management unit	1997	1998	1999	2000	2001	2002	2003	2004	Total	Average
Catch	WFS-01	0	28							28	14
	WFS-02	0	0	0	0	0	0	0	0	0	0
	WFS-03	0	2	267	159	67	0	0	9	504	63
	WFS-04	2,259	1,868	520	1,226	271	880	905	740	8,669	1,084
	WFS-05	562	4,797	6,223	5,273	4,649	4,878	6,761	3,746	36,889	4,611
	WFS-06					7,985	4,376	6,502	6,408	25,271	6,318
	All	2,821	6,695	7,010	6,658	12,972	10,134	14,168	10,903	71,361	8,920
Effort	WFS-01	30,607	26,922							57,529	28,765
	WFS-02	9,806	13,003	12,768	14,878	12,388	11,376	9,196	15,538	98,953	12,369
	WFS-03	32,815	25,978	39,145	28,887	41,564	27,519	40,359	45,686	281,953	35,244
	WFS-04	69,139	52,150	57,109	55,739	51,910	50,598	39,505	36,121	412,271	51,534
	WFS-05	53,129	41,423	57,533	52,862	58,834	40,246	46,558	47,194	397,779	49,722
	WFS-06					15,732	20,030	17,360	19,404	72,526	18,132
	All	195,496	159,476	166,555	152,366	180,428	149,769	152,978	163,943	1,321,011	165,126

Table 9.–Months when creel surveys were conducted in Michigan waters of Lake Superior, 1997-2004.

Year	Management unit WFS-01	WFS-02	WFS-03	WFS-04	WFS-05	WFS-06
1997	May-Sep	May-Oct	Mar-Oct	Mar-Oct	Mar-Sep	
1998	May-Jul	Apr-Oct	Feb-Oct	Mar-Oct	Feb-Sep	
1999		Apr-Oct	Jan-Oct	Mar-Oct	Feb-Sep	
2000		Apr-Oct	Jan-Oct	Mar-Oct	Feb-Sep	
2001		May-Oct	Jan-Oct	Mar-Oct	Feb-Sep	May-Aug
2002		May-Oct	Mar-Oct	Mar-Oct	Feb-Sep	May-Sep
2003		May-Oct	Jan-Oct	Mar-Oct	Feb-Sep	May-Sep
2004		Apr-Oct	Jan-Oct	Mar-Oct	Feb-Oct	May-Sep

Table 10.–Creel survey estimates of lake whitefish in Michigan waters of Lake Superior, by management unit and month, cumulative over 1997-2004. Blanks indicate no survey.

Month	Management unit WFS-01	WFS-02	WFS-03	WFS-04	WFS-05	WFS-06	Monthly total
Jan			70				70
Feb			92		24,246		24,338
Mar			36	947	8,604		9,587
Apr		0	147	1,618	1,181		2,946
May	23	0	159	56	215	14,138	14,591
Jun	0	0	0	0	1,681	8,114	9,795
Jul	5	0	0	0	361	2,943	3,309
Aug		0	0	4	291	76	371
Sep		0	0	12	24	0	36
Oct		0	0	6,032	286		6,318
Unit total	28	0	504	8,669	36,889	25,271	71,361

Table 11.–Mean size and age of lake whitefish caught by recreational anglers in Michigan waters of Lake Superior. Total length in mm, round weight in kg, age in years. Averages weighted by sample size.

Management unit	Year	N	Length		Weight		Age	
			Mean	SD	Mean	SD	Mean	SD
WFS-04	1998	14	343	32	0.28	0.09	4.0	0.7
	1999	3	366	22	0.36	0.05		
	2000	3	317	19	0.23	0.05		
	2001	7	415	68	0.56	0.32	4.5	1.2
	2002	2	545	264	2.06	2.41	4.0	
	2003	6	337	40	0.24	0.13	3.0	0.6
	2004	26	341	48	0.32	0.14		
	Average	9	356		0.39		3.9	
WFS-05	1998	67	364	61	0.43	0.26	5.8	1.9
	1999	73	372	79	0.45	0.37		
	2000	83	347	72	0.36	0.30		
	2001	42	328	103	0.38	0.37	5.2	3.3
	2002	99	321	68	0.32	0.33	4.6	2.2
	2003	42	324	88	0.35	0.43	4.7	2.8
	2004	106	297	63	0.25	0.18		
	Average	73	334		0.35		5.0	
WFS-06	2003	100	338	85	0.37	0.36	3.1	1.3
	2004	75	374	86	0.51	0.41		
	Average	88	353		0.43		3.1	
All	Average	47	348		0.39		4.0	

Table 12.–Estimates of total instantaneous mortality (Z) for lake whitefish stocks in Michigan waters of Lake Superior.

Management unit	Years pooled	Ages included in calculations	Z		
			RC[a]	SCAA1[b]	SCAA2[c]
WFS-01	2000, 2001, 2004	6 - 13	0.52		
WFS-02	1997, 1999, 2000	7 - 14	1.24		
	1999 - 2001	8 - 14	0.55		
	2000 - 2002	9 - 14	0.65		
	2001 - 2003	6 - 14	0.62		
	2002 - 2004	7 - 17	0.64		
WFS-03	1998, 1999, 2004	9 - 21	0.38		
WFS-04	1997 - 1999	10 - 19	0.44	0.49	0.41
	1998 - 2000	10 - 21	0.46	0.52	0.43
	1999 - 2001	10 - 21	0.66	0.53	0.43
	2000 - 2002	8 - 21	0.77	0.52	0.43
	2001 - 2003	8 - 19	0.58	0.51	0.41
	2002 - 2004	8 - 19	0.51	0.51	0.41
WFS-05	1997 - 1999	10 - 19	0.48	0.37	0.32
	1998 - 2000	11 - 19	0.39	0.44	0.37
	1999 - 2001	8 - 19	0.62	0.45	0.38
	2000 - 2002	8 - 21	0.54	0.42	0.36
	2001 - 2003	8 - 21	0.49	0.39	0.34
	2002 - 2004	8 - 21	0.42	0.37	0.32

[a] Estimate from coded age frequencies (Robson and Chapman 1961).
[b] Statistical catch-at-age model estimate averaged over ages shown in "Ages included" column.
[c] Statistical catch-at-age model estimate using all ages (4 and older) vulnerable to commercial gear.

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