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BY Susan Olsen
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Project Title: Assessment of Whitefish Populations in the Treaty Area of Lake Michigan

Period Covered: 10-1-91 to 9-30-94

Prepared by: P. J. Schneeberger

Approved by: Richard D. Clark Jr.

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STUDY COMPLETION REPORT

State: Michigan

Project No.: IFA-3-IJ-17-6

Study No.: 431

Title: Assessment of whitefish populations in the treaty area of Lake Michigan

Period Covered: October 1, 1991 to September 30, 1994

Study Objective: To forecast the total allowable yield of lake whitefish in the treaty waters of Lake Michigan.

Summary

Lake whitefish populations exploited by state-licensed fishers are assessed according to the dictates of the Technical Fisheries Review Committee. During the 1991-93 fishing seasons, 34.5% of the lake-wide state-licensed catch of lake whitefish was harvested from management zone WFM-00, 59.0% from WFM-01, 0.9% from WFM-06, and 5.6% from WFM-08. Average catch (thousands of kg) was 444.8 in WFM-00, 761.5 in WFM-01, 11.4 in WFM-06, and 72.0 in WFM-08. Trends of catch, effort, and catch-per-unit-effort were generally increasing in zones WFM-00 and WFM-08, and decreasing or varying without trend in zones WFM-01 and WFM-06. Total annual mortality rate, calculated from pooled 3-yr data sets, was 69% in WFM-00, 83% in WFM-01, 41% in WFM-06, and 52% in WFM-08. Age-4 whitefish composed the bulk of harvested fish in each zone - 39% in WFM-00, 51% in WFM-01, 38% in WFM-06, and 33% in WFM-08. The proportion of fish 7-yr old and older was minimal in zones WFM-00 (2%) and WFM-01 (<1%) but much more substantial in zones WFM-06 (14%) and WFM-08 (27%). Growth coefficients from length-weight regressions and the von Bertalanffy equation were similar from previous data cycles within given zones. Total allowable catches (thousands of kg) calculated for 1994 were 371.7 in WFM-00, 428.2 in WFM-01, 69.0 in WFM-06, and 119.8 in WFM-08. Average catch of 2-yr old whitefish in modified trawl hauls provided a predictive index of year-class strength that corresponded well with estimates of year-class strength in zones WFM-00 and WFM-01. The index did not correspond well with estimates of year-class strength for whitefish populations in WFM-06, WFM-08, or in Wisconsin waters. When relative age frequencies were adjusted for year-class strength in zones WFM-00 and WFM-01, estimates of total annual mortality were seen to fluctuate dramatically from year to year, with the most recent (1993) estimates below or near the target maximum rate in both zones. Relationships were not evident between mortality rates and catch, catch-per-unit effort, or year-class strength.

Introduction

A large proportion of Michigan waters of Lake Michigan is included in a cession from a treaty signed in 1836 by several Native American tribes and the State of Michigan (Figure 1). Tribal fishers claim unrestricted fishing rights within the ceded waters, while Michigan Department of Natural Resources Fisheries Division (MDNR) claims the right to restrict and regulate fishing as part of its mission to manage resources that are part of the public trust. In 1985, following a long period of dispute and conflict, the State of Michigan, the tribes in the 1836 Treaty-ceded area, and the Federal Government negotiated a consent agreement through the Federal District Court in Grand Rapids, Michigan. The agreement allocated separate and exclusive fishing grounds, delineated by distinct management zones (Figure 1), for the two entities. Accordingly, state-licensed fisheries operate in management zones WFM-01, WFM-06, and WFM-08. State-licensed fishing also occurs in zone WFM-00 which is outside the treaty area. Fishing in zone WFM-07 would be permitted, but at present, no state-licensed fishery exists there due to lack of interest. In further court action, the Technical Fisheries Review Committee (TFRC) was formed with membership consisting of one representative each from the tribes (Chippewa-Ottawa Treaty Fishery Management Authority), MDNR, and the United States Fish and Wildlife Service, Great Lakes Fishery Laboratory (now known as National Fisheries Center-Great Lakes). Among other things, the TFRC was charged with defining and establishing specific protocol to be followed in assessing whitefish stocks. Rybicki and Schneeberger (1990) describe the history and context of the court-ordered arrangement in greater detail.

The negotiated settlement addressed stocks shared by tribal and state-licensed commercial fishers, but to some extent, State of Wisconsin commercial fishers exploit these same lake whitefish stocks in their waters. Many studies have characterized or documented the mixing of whitefish stocks in northern Lake Michigan (e.g., Gunderson 1978; Humphreys 1978; Ebener 1980; Imhoff et al. 1980; Hastreiter 1984; Rowe 1984; Ebener and Copes 1985). Considering all of Lake Michigan, 3,404,153 kg of lake whitefish were commercially harvested in 1993. Native American fishers caught 1,524,427 kg (45% of the total), state-licensed Michigan fishers caught 1,303,832 kg (38% of the total), and state-licensed Wisconsin fishers caught 575,894 kg (17% of the total). It is appropriate and important that ongoing consultation and exchange of data takes place annually among biologists from Michigan, the tribes, and Wisconsin.

Michigan state-licensed commercial fishers in Lake Michigan were prohibited from using gill nets in water less than 73-m deep in the late 1960s. Since that time, almost all commercial operators have converted to trap nets. Trap net pots typically measure 11 m in length, 7 m in width, and 9-12 m in height, with mesh size of 118 mm. Trap net leads may be 201-377 m long, 2-6 m high, and have a mesh size of 356 mm. Trap net fisheries account for the total commercial catch of lake whitefish in management zones WFM-06 and WFM-08. In addition to trap netters, a commercial trawler operates in management zones WFM-00 and WFM-01. The trawl used is a Modified Western Wing Trawl (29-m footrope and graded stretched meshes of 114 mm in the body, 64 mm in the throat, and 102 mm in the cod end). This trawl has longitudinal rib lines which hold cod-end meshes open and allow escapement of pre-recruits (Schorfhaar 1986).

Licensed trap nets may be set in water 27-m deep or shallower, any time of the year except November when a closure is in place to protect spawning whitefish. Although an under-the-ice trap-net fishery operates in WFM-01 during periods when ice cover is sufficient, most harvest by trap nets takes place between the months of May and October. The trawler is permitted to operate at any depth up to a maximum of 36 m, but in practicality, suitable trawling grounds and fish distributions restrict operations to depths between 27 and 34 m. The November closure also applies to the trawl fishery. Considerable trawl catch and effort may occur from December through April when open-water conditions exist and market prices for whitefish are relatively high. The minimum size limit is set at 432 mm for lake whitefish in management zones WFM-00, WFM-01, and WFM-06, and at 483 mm for management zone WFM-08. For management purposes, the target maximum total mortality rate is set at 65% based on a literature review by Clark (1984).

Rybicki (1980) and Rybicki and Schneeberger (1990) have reported on the trends and status of Lake Michigan lake whitefish populations during the 1980s. This report focuses discussion on data from 1991 through 1993, but to gain perspective, information dating back to the early 1980s is included in tables, figures, and appendices.

Methods

Assessment of commercial trap-net fishery: Commercial fishers submit monthly catch reports to MDNR staff in Lansing. From these reports, annual catch and effort are tabulated for each management zone, and catch per effort (CPE) figures are calculated. CPE is calculated as kg per lift for trap nets and as kg per hour for trawls.

In addition to catch reports, MDNR personnel record data from sufficient numbers of net-run lake whitefish collected annually from commercial trap-net catches to determine growth parameters, mortality rates, and total allowable catches (TACs) for populations in each of four Lake Michigan management zones administered by the State of Michigan. The sampling schedule is structured to examine up to 200 legal-sized whitefish in each management zone, during each of the months of May, July, and October. Factors that may affect the number of fish that are actually examined in any given year include: cessation of fishing by particular commercial fishers during certain times of the year; low numbers of fish caught in some seasons; or weather that is bad enough to prevent trap-net lifts during scheduled sampling months.

Total length of each fish is measured to the nearest millimeter, and weights to the nearest gram are recorded. Fish ages are determined by examining scales collected from each whitefish specimen. Growth parameters are estimated by regressing natural logarithms of weight and length against one another and by solving the von Bertalanffy growth equation (Bertalanffy 1938) using length-at-age data. Mortality rates are estimated using coded age frequencies and the best estimate method of Robson and Chapman (1961). TACs are calculated using the SAP1 model (Clark and Smith 1985 - Appendix 1).

TACs are calculated annually, but have never been enforced since their inception in 1979. Although enforcement of TACs is a possible future management option, at the present time the numbers are only used as another means of tracking the fisheries over time.

As mandated by the TFRC, data sets for three years are pooled in an attempt to moderate effects of variable year-class strength. Without pooling, variability of year-class strength violates assumptions inherent in mortality estimates and the quota estimating module of SAP1. Numbers, mean length, and mean weight at age by collection month for individual years are summarized in Appendix 2.

Pre-recruit index from trawl samples: The commercial trawl fishery for lake whitefish operates in Michigan waters of Green Bay outside the 1836 treaty cession. Trawl configuration and mesh size were designed to minimize retention of pre-recruit lake whitefish in the net's cod end. Beginning in 1988, however, MDNR personnel have requested that the trawler modify his net for certain monitored tows so that pre-recruit whitefish would be retained. The goal was to obtain an index of lake whitefish year-class strength prior to their being recruited to the fishery. Creation of such an index has long been a desire of fisheries managers from Michigan, Wisconsin, and Native American entities.

Over the years, several different gear modifications have been attempted to sample pre-recruit lake whitefish in commercial trawl hauls (see footnotes for Appendix 3). Since 1989, however, the methodology has consistently entailed tieing a rope to restrict the net ahead of the sorting portion of the cod end. This has proven both simple and effective. Other methods were effective but more time-consuming and disruptive to the "normal" fishing routine. In all cases, I believe that modified trawl hauls were more-or-less equally efficient at catching pre-recruit lake whitefish and numbers from all methods are therefore comparable after adjusting for differences in tow duration. In the course of a trawling day, from four to seven 1-hr tows are generally executed; during monitored rides, up to two tows of half-hour duration are performed with the net tied off. Data recorded for each tow included: date, location (Loran coordinates), time, duration, depth, weather, approximate weight of the legal catch, composition and approximate number of the non-target catch, and number and length frequency of pre-recruit lake whitefish. In addition, scale samples are collected from a targeted number of 40 pre-recruit lake whitefish per 25.4 mm length interval. Age determination from these scale samples are used to create age-at-length keys (Appendix 4) that are applied to the portion of the catch not aged to obtain overall age frequencies in catches.

To evaluate the validity of the index, some measure of year-class strength is necessary. As described above, the lengths, weights, and ages of legal-sized lake whitefish are determined and recorded each year in each management zone. The total number of fish caught in each zone is estimated by finding the average weight of fish in samples and dividing this number into the total harvest weight reported for the year. The age distributions, assumed to be representative of the entire commercial catch for any given year in any given zone, are then imposed on the total number of fish caught during the year by the commercial fishery. By tabulating the numbers of fish at each successive age as they pass through the fishery, the cumulative contribution of any given year class may be followed. By this method, year class strength is not completely evaluated until the fish have moved completely through the fishery (by about age 8 in WFM-00 and WFM-01), so there is considerable delay between when index data are collected and when the year-class strength has been completely established. However, preliminary indications of year-class strength are often very indicative of the ultimate endpoint, especially since the greatest contributions to the fishery occur when fish are 3-, 4- and 5-years old.

Results and Discussion

Job 1. Title: Monitor whitefish in the commercial trap-net fishery in the treaty area of Lake Michigan

Objective: Determine age and size structure of the landed (legal-sized) whitefish catch.

Findings: **WFM-00:** Harvest averaged 444,819 kg per year during 1991-93. In relation to the other state-regulated whitefish management zones, the percentage of the total annual harvest that was caught within WFM-00 rose from 28% in 1991, to 35% in 1992, to 40% in 1993. Over the 3-yr period, increasing catch, effort, and CPE were recorded for both trap-net and trawl fisheries (Table 1; Figures 2-7).

Estimated total annual mortality dropped from 79% in the 1990-92 period to 69% for the 1991-93 data set (Table 2; Figure 8). The 1991-93 estimate remains above the targeted maximum mortality rate of 65%, so it is hoped that the downward trend will continue in future years.

Most (90.5%) of the lake whitefish were harvested at ages 3-5, and only 2.0% were 7-yr old or older (Figure 9; Appendix 2). A 12-yr old was the oldest fish sampled during the period.

On average, catches constituted 191% of TACs during 1991-93; in 1993, catch represented 226% of the 233.3 thousand kg TAC (Table 3). The TAC calculated for 1994 (371.7 thousand kg) was up from that of 1993 by 59%, apparently because the model was influenced by inputs of high harvest and relatively low mortality.

WFM-01: Average lake whitefish harvest was 761,485 kg per year during 1991-93. Catches represented 59% of the total state-licensed Lake Michigan harvest of lake whitefish for the 3-yr period. The proportion decreased from 67% to 51% between 1991 and 1993. The decrease in relative proportion was due in part to increasing catches in WFM-00, but also reflected catch and effort trends observed in WFM-01. Between 1991 and 1992, trap net catch, effort, and CPE all increased slightly, while trawl catch and effort decreased in spite of an increase in trawl CPE (Table 1; Figures 2-7). Trap-net catch and CPE dropped from 1992 to 1993 even though effort stayed almost the same, and trawl catch, effort, and CPE all declined.

Estimated total annual mortality continued an ascending trend that began with the pooled 1988-90 data set (Table 2; Figure 8). The estimated rate for 1991-93 (83%) was disturbingly high, and was especially discouraging from a management standpoint, since the downward trend for data sets from 1984-86 to 1988-90 was following a desired course to the target maximum value (65%).

Harvested whitefish were almost all between the ages of 3 and 5, with age-4 fish making up the largest proportion of catches (Figure 10; Appendix 2). Only 3.1% of the fish were 6-yr old, and those 7-yr old or older represented a mere 0.6%.

The 1993 TAC (516.4 thousand kg) was exceeded by 28%. This was the closest match between catch and TAC since 1988. The TAC calculated for 1994 (428.2 thousand kg) represented a 17% reduction from that of 1993 (Table 3).

WFM-06: Catch represented around 1% of the lake-wide total for state-licensed fishers in 1991 and 1992 (Table 1). The proportion was less than 1% in 1993. Catch dropped in 1993 in spite of increased effort as CPE fell to 47% of the 1992 value, and 32% of the 1991 value (Figures 2-4). Average harvest during the three years was 11,396 kg per year.

Estimated total annual mortality remained in the low 40s where it has been since the mid-1980s (Table 2; Figure 8). There is only one state-licensed commercial fisherman in this zone, and he often stops fishing in early or mid summer. His catches clearly do not impose undue mortality on the population.

Ages of lake whitefish harvested during 1991-93 ranged from 3 to 17 with 14.3% of the catch composed of fish aged 7 or older (Figure 11; Appendix 2). Compared to more northern zones, relatively few 3-yr old fish were harvested.

Catches have always been well below TAC calculations (Table 3). Only 8% of the 95.6 thousand kg TAC was harvested in 1993. Model inputs apparently signaled some kind of weakness in the WFM-06 whitefish population, so the TAC for 1994 fell to 69.0 thousand kg, down 28% from the 1993 TAC.

WFM-08: Average harvest was 72,026 kg per year for 1991-93. The 1993 catch represented 8% of the lake-wide total for state-licensed fishers, up from around 4% in 1991 and 1992 (Table 1; Figure 2). Effort in 1993 was only slightly higher but CPE was almost 70% higher than in 1992 (Figures 3 and 4).

Total annual mortality for pooled years 1991-93 was 0.52, up from the previous two pooled data sets, but still well below the target maximum of 65% (Table 2). During the last nine data periods, mortality has ranged from 0.43 to 0.52, with no apparent trend (Figure 8).

Lake whitefish 7 years old and older composed a larger proportion (27.4%) of the harvested catch in WFM-08 than in any other management zone (Figures 9-12; Appendix 2). One fish in the catch was 20-yr old. The 483-mm minimum length regulation in WFM-08 accounts for the older age structure relative to other management zones.

The 1993 catch represented only 42% of the 252.9 thousand kg TAC (Table 3). Model inputs resulted in a TAC calculated for 1994 (119.8 thousand kg) that was close to actual harvest in 1993.

All Management Zones: Growth coefficients (intercept and slope of the weight-length regression, and von Bertalanffy coefficients) calculated from pooled 1991-93 data, were similar to those for previous 3-yr periods for any given management zone (Table 4). These similarities should be expected because of the use of running 3-yr pooled data sets.

Job 2. Title: Trawl samples to index pre-recruit whitefish

Objective: Obtain an index of pre-recruit lake whitefish abundance by sampling fish from catches of a commercial trawler.

Findings: Modified trawl hauls caught pre-recruit lake whitefish from ages 1 through 4, but all ages were not caught with equal efficiency. Age-1 whitefish are probably not caught in numbers representative of their relative abundance both because of their small size (generally less than 250 mm) and because they may not be distributed in representative numbers at depths at which the trawl operates (27-34 m). Age-3- and age-4 lake whitefish have already begun to recruit to the fishery (5-year old fish are considered fully recruited), so their numbers as pre-recruits are affected by fishing effort and growth rates as well as abundance. Thus, CPEs of age-2 lake whitefish are the best index of year-class strength.

Examining CPEs of age-2 lake whitefish in modified trawl hauls, it appears that the 1986, 1987, and 1991 year classes were all of medium strength, the 1989 year class was somewhat stronger, and the 1988 and 1990 year classes were exceptionally strong (Table 5). The index corresponded well to the estimations of lake whitefish year-class strength in WFM-00 (Figure 13), where 84% of the trawling effort and 86% of the trawl catch occurred from 1988 through 1993, the years of the index. Good correspondence was also found between the index and estimated whitefish year-class strength in the contiguous zone of WFM-01 (Figure 14), where the remainder of the trawling catch and effort occurred. In an attempt to further extend the scope of the index, data from Wisconsin's commercial fishery were manipulated to make estimates of year-class strength in a similar way as was done for Michigan data. Correspondence was poor between the index and year-class strength in Wisconsin waters, but further manipulation of the data may be necessary to compensate for differences in sampling. Correspondence was also poor between the index and estimates of whitefish year-class strength in management zones WFM-06 and WFM-08, somewhat dispelling my previous belief that some kind of lake-wide or global factors might determine whitefish year-class strength, above and beyond more localized conditions. Future testing of the index may be attempted using data from tribal fisheries.

Also, the index will be further tested and refined as more data are collected and analyzed from the two primary zones, WFM-00 and WFM-01. Contributions to the fishery by additional ages for the 1990 and 1991 year classes will show if the relationships indicated by the recruitment of 3- and 4-year old fish were good indicators of the ultimate contribution by respective year classes. As more years of information are compared, it may be possible to determine cut off points demarcating what actually constitutes weak, medium, and strong year-class strength in the index.

Fluctuations of abundance and variability of year-class strength are normal occurrences in the population cycles of lake whitefish and most other species. Some of the factors believed to affect lake whitefish year-class strength have been identified (Miller 1952; Christie 1963; Lawler 1965; Taylor et al. 1987; Freeberg et al. 1990; Brown et al. 1993), but these factors have not been used by managers in a cohesive predictive model. Whitefish managers most fear occurrence of several consecutive weak year classes because exploitation of these cohorts could result in the decimation of future spawners to the extent that subsequent population build up and rehabilitation would not be possible. If the pre-recruit index proves to be reliable, its value will be in signaling an advanced warning should such consecutive weak year classes be detected. On the other hand, indices showing strong year classes, as are interpreted from present data, can partially offset concerns about population stability when other indicators like total annual mortality appear to be too high.

As an initial application of the assessment of year-class strength, total annual mortality rates were calculated for individual years in management zones WFM-00 and WFM-01 after adjusting numbers-at-age according to relative year-class strength. The moderate 1986 year class was chosen as the base-line. Since 4-yr old whitefish composed the bulk of the harvest in these management zones (Figures 9 and 10), adjustment factors were calculated by finding the multiplier necessary to equalize the number of 4-yr olds contributed to the fishery by any given year class with the number of 4-yr olds contributed by the 1986 year class in each of the management zones. The adjustment factor for any given year class was then applied to all ages of that year class, and mortality rates were calculated using adjusted age frequencies. As would be expected, the mortality rates calculated for individual years (Figure 15) had higher year-to-year variation than the rates smoothed by using pooled 3-yr data sets (Figure 8). An encouraging sign from the individual year calculations of total annual mortality is that the estimate for 1993 was below the target maximum in WFM-00 and approaching the target maximum in WFM-01. Fluctuations in mortality rate do not appear to be correlated with fluctuations in catch, CPE, or year-class strength. Further study is necessary to determine the other factors affecting mortality.

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Prepared by: P.J. Schneeberger

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Table 1.--Commercial whitefish harvest (kg round weight), effort (trap-net lifts, trawl hours) and catch-per-unit-effort (CPE), by Lake Michigan management unit and year.

Mgt. unit	Gear	Stat-istic	Year 1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
WFM-00	Trap net	Yield	226,511	207,948	263,507	253,466	130,748	186,181	199,517	210,640	271,241	301,588
		Effort	2,365	1,812	2,523	2,138	1,873	2,612	1,626	1,468	1,620	1,698
		CPE	96	115	104	119	70	71	123	144	167	178
	Trawl	Yield	86,494	96,778	110,990	81,496	40,989	134,483	117,304	113,322	212,114	225,349
		Effort	589	569	607	547	408	368	703	564	948	984
		CPE	147	170	183	149	100	365	167	201	224	229
	Total	Yield	313,005	310,064[a]	374,497	334,962	171,737	320,664	316,821	324,165[b]	483,355	526,937
WFM-01	Trap net	Yield	474,411	704,411	684,739	591,931	402,136	599,698	613,985	730,983	809,877	658,085
		Effort	3,743	4,432	4,848	4,954	4,415	4,915	4,834	4,974	5,181	5,087
		CPE	127	159	141	120	91	122	127	147	156	129
	Trawl	Yield	12,038	8,563	13,759	43,344	12,986	14,389	20,185	54,027	25,946	5,568
		Effort	84	48	97	243	140	82	121	265	104	23
		CPE	143	177	142	179	93	174	167	204	249	242
	Total[c]	Yield	486,449	712,974	698,498	635,275	415,122	614,087	654,809[d]	785,010	835,823	663,653
WFM-06	Trap net	Yield	16,182	9,023	4,867	11,253	9,689	10,025	15,341	11,471	15,146	7,572
		Effort	446	334	130	208	240	268	324	142	276	294
		CPE	36	27	37	54	40	37	47	81	55	26
	Total[e]	Yield	24,636	9,863	13,728	15,500	22,927	13,472	15,484	11,471	15,146	7,572
WFM-08	Trap net	Yield	44,087	42,467	80,507	53,378	63,836	63,864	68,126	51,456	58,951	105,670
		Effort	370	315	610	427	531	475	721	612	487	517
		CPE	119	135	132	125	120	134	94	84	121	204

[a]Includes 5,338 kg caught in seines
[b]Includes 203 kg caught in pound nets
[c]Includes tribal catches in 1984 and 1985
[d]Includes 20,639 kg caught in pound nets
[e]Includes tribal catches

Table 2.--Total annual mortality rates of lake whitefish, with 95% confidence intervals (C.I.) and ages included in calculations. Data from each Lake Michigan management unit were pooled over 3-year intervals. Mortalities were estimated using the "best" minimum-variance unbiased estimators of survival derived from coded age frequencies (Robson and Chapman 1961).

		Management zone			
Years	Statistic	WFM-00	WFM-01	WFM-06	WFM-08
1983-85	Mortality	0.81	0.83	0.51	0.48
	95% C.I.	0.03	0.03	0.05	0.07
	Ages	4-7	4-7	6-12	5-9
1984-86	Mortality	0.77	0.86	0.46	0.48
	95% C.I.	0.03	0.03	0.04	0.04
	Ages	4-8	4-7	5-12	5-12
1985-87	Mortality	0.88	0.78	0.49	0.45
	95% C.I.	0.04	0.03	0.04	0.03
	Ages	5-7	5-10	5-12	5-12
1986-88	Mortality	0.80	0.73	0.45	0.45
	95% C.I.	0.04	0.03	0.04	0.03
	Ages	5-8	5-8	5-12	6-12
1987-89	Mortality	0.72	0.70	0.44	0.44
	95% C.I.	0.03	0.04	0.03	0.02
	Ages	5-9	6-12	6-12	6-16
1988-90	Mortality	0.71	0.65	0.44	0.52
	95% C.I.	0.04	0.01	0.04	0.03
	Ages	5-9	4-12	6-14	8-19
1989-91	Mortality	0.67	0.72	0.41	0.45
	95% C.I.	0.06	0.03	0.03	0.04
	Ages	5-9	4-8	4-12	7-15
1990-92	Mortality	0.79	0.77	0.40	0.43
	95% C.I.	0.04	0.02	0.04	0.04
	Ages	5-8	4-9	8-13	5-10
1991-93	Mortality	0.69	0.83	0.41	0.52
	95% C.I.	0.04	0.03	0.02	0.06
	Ages	5-8	5-7	4-16	9-14

Table 3.--Total allowable catch (TAC) estimate and yield (round weight) of whitefish, by Lake Michigan management unit, 1986-94. TAC and yield in thousands of kilograms.

Management unit	Year	TAC	Reported yield	Percent of TAC
WFM-00	1986	182.3	375.3	206
	1987	226.0	335.7	149
	1988	172.8	172.1	100
	1989	182.6	320.7	176
	1990	194.2	316.8	163
	1991	198.5	324.2	163
	1992	263.3	483.4	184
	1993	233.3	526.9	226
	1994	371.7	---	---
WFM-01	1986	407.6	700.0	172
	1987	356.8	636.6	178
	1988	539.2	416.0	77
	1989	436.9	614.1	140
	1990	453.2	634.2	140
	1991	559.6	785.0	140
	1992	502.8	835.8	166
	1993	516.4	663.6	128
	1994	428.2	---	---
WFM-06	1986	43.5	13.7	31
	1987	48.6	15.5	32
	1988	29.6	22.9	77
	1989	59.2	13.5	23
	1990	58.3	15.5	34
	1991	48.2	11.5	24
	1992	85.0	15.1	18
	1993	95.6	7.6	8
	1994	69.0	---	---
WFM-08	1986	138.9	80.7	58
	1987	145.6	53.4	37
	1988	193.5	64.0	33
	1989	212.7	63.9	30
	1990	246.2	68.1	28
	1991	123.8	51.5	42
	1992	187.3	59.0	32
	1993	252.9	105.7	42
	1994	119.8	---	---

Table 4.--Vital statistics from pooled 3-year data sets used to generate lake whitefish total allowable catches calculated with the SAP 1 (Clark and Smith 1985).

			Weight-length coefficients[b]		Von Bertalanffy coefficients				
Manage-ment unit	Years pooled	Instantane-ous fishing mortality[a] (F)	Intercept	Slope	K	L∞ (mm)	T_o	Mean weight of fish in catch (kg)	Yield (1000's of kg)[c]
WFM-00	1983-85	1.21	-17.59	2.86	0.23	763.3	-0.03	1.0	298.7
	1984-86	1.02	-17.80	2.89	0.24	734.0	-0.03	1.0	333.2
	1985-87	1.67	-17.18	2.79	0.33	618.2	-0.01	1.0	340.6
	1986-88	1.16	-17.02	2.77	0.33	603.7	-0.01	1.0	294.3
	1987-89	0.83	-14.22	2.32	0.43	568.1	-0.01	1.0	247.8
	1988-90	0.78	-17.93	2.92	0.45	560.5	-0.01	1.0	241.8
	1989-91	0.67	-17.79	2.90	0.44	558.9	-0.01	1.0	292.6
	1990-92	1.10	-16.37	2.67	0.36	527.7	-0.01	1.0	374.8
	1991-93	0.73	-16.75	2.73	0.52	546.1	0.00	1.1	444.8
WFM-01	1983-85	1.32	-17.69	2.87	0.25	717.3	-0.02	1.0	724.0
	1984-86	1.52	-16.05	2.60	0.25	718.2	-0.01	1.0	807.3
	1985-87	1.04	-18.67	3.03	0.25	698.5	-0.02	1.0	786.9
	1986-88	0.86	-18.60	3.02	0.29	647.5	-0.02	1.1	595.0
	1987-89	0.78	-19.18	3.12	0.43	569.2	-0.01	1.0	552.7
	1988-90	0.60	-18.25	2.96	0.31	674.6	-0.03	1.0	559.2
	1989-91	0.82	-18.66	3.03	0.63	502.8	0.00	1.0	675.7
	1990-92	1.05	-18.76	3.05	0.36	619.9	-0.14	1.0	758.5
	1991-93	1.33	-18.40	2.99	0.54	543.8	0.00	1.0	761.5
WFM-06	1983-85	0.26	-19.66	3.21	0.28	703.2	-0.04	1.5	21.7
	1984-86	0.17	-19.06	3.11	0.26	708.6	-0.04	1.5	16.2
	1985-87	0.22	-18.74	3.06	0.28	687.9	-0.03	1.5	13.0
	1986-88	0.15	-18.29	2.99	0.27	697.1	-0.02	1.5	15.8
	1987-89	0.13	-18.45	3.02	0.31	675.7	-0.03	1.6	15.3
	1988-90	0.12	-19.88	3.24	0.31	674.6	-0.03	1.5	13.5
	1989-91	0.08	-19.90	3.24	0.29	683.6	-0.04	1.5	13.5
	1990-92	0.07	-19.54	3.18	0.27	707.7	-0.19	1.6	14.0
	1991-93	0.08	-20.13	3.29	0.30	685.9	-0.04	1.7	11.4
WFM-08	1983-85	0.20	-18.91	3.09	0.32	711.1	-0.02	2.0	45.6
	1984-86	0.20	-19.49	3.18	0.35	673.7	-0.01	1.5	55.8
	1985-87	0.15	-19.51	3.18	0.38	644.7	-0.01	1.5	58.9
	1986-88	0.15	-19.30	3.15	0.32	677.2	-0.01	1.6	66.0
	1987-89	0.12	-19.56	3.20	0.34	677.0	-0.03	1.7	60.4
	1988-90	0.28	-20.23	3.30	0.35	675.7	-0.02	1.8	65.3
	1989-91	0.14	-19.40	3.17	0.28	702.8	-0.03	2.2	61.1
	1990-92	0.11	-18.48	3.02	0.35	672.2	-0.21	2.0	59.5
	1991-93	0.29	-20.30	3.31	0.33	683.9	-0.04	2.0	72.0

[a] Instantaneous rate of natural mortality (M) is assumed to be 0.45 and target fishing mortality is 0.60 in all zones.

[b] $\log_e(\text{Weight}) = a + b(\log_e[\text{Length}])$

[c] Computed from yield data in Table 1.

Table 5.--Catch of 2-yr old lake whitefish (CPE) in modified trawl hauls, 1988-1993.

Sample year	Year class	CPE
1988	1986	23.22
1989	1987	21.86
1990	1988	75.60
1991	1989	45.50
1992	1990	62.00
1993	1991	32.83

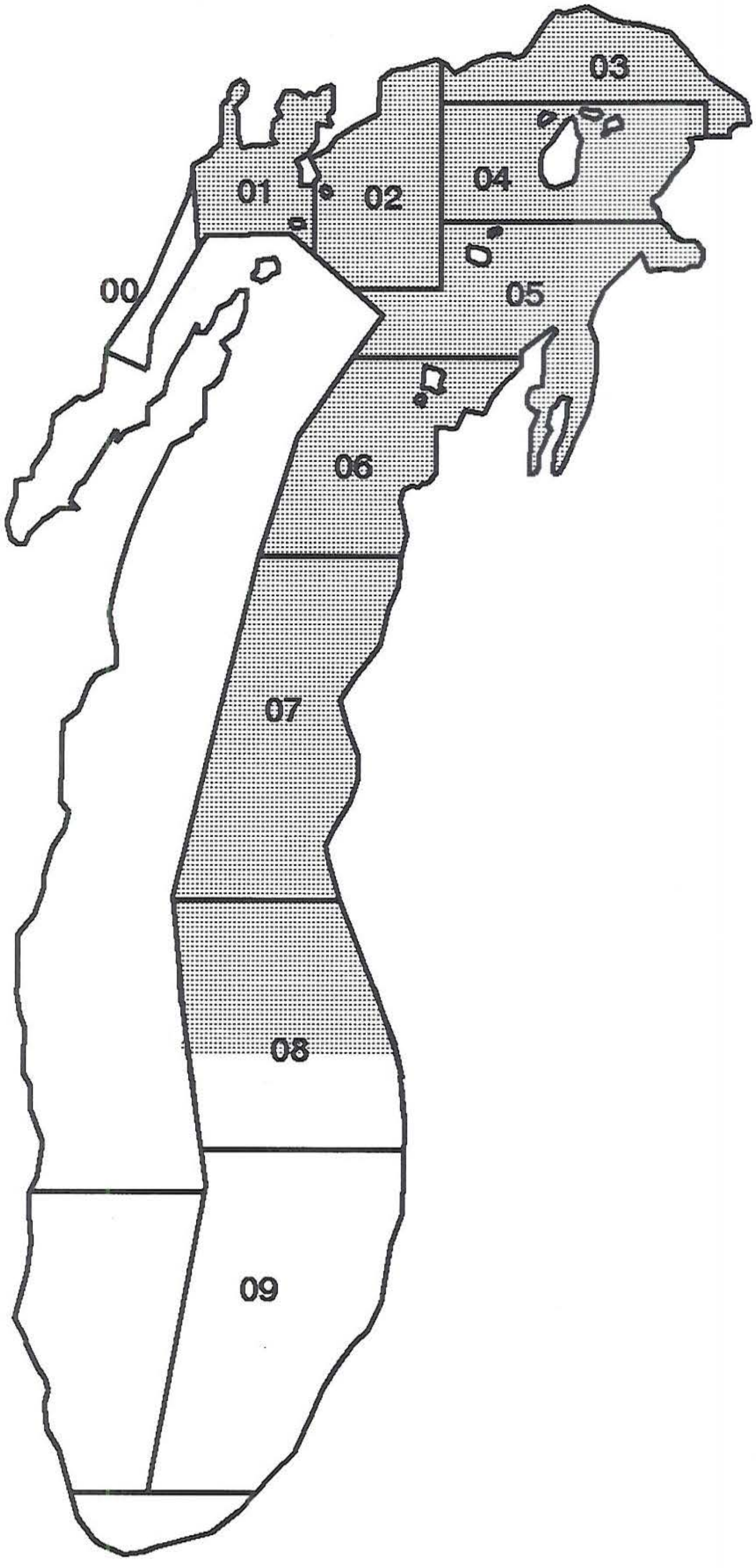

Figure 1.--Waters of Lake Michigan ceded by the Treaty of 1836 (shaded area) and lake whitefish management zones (WFM).

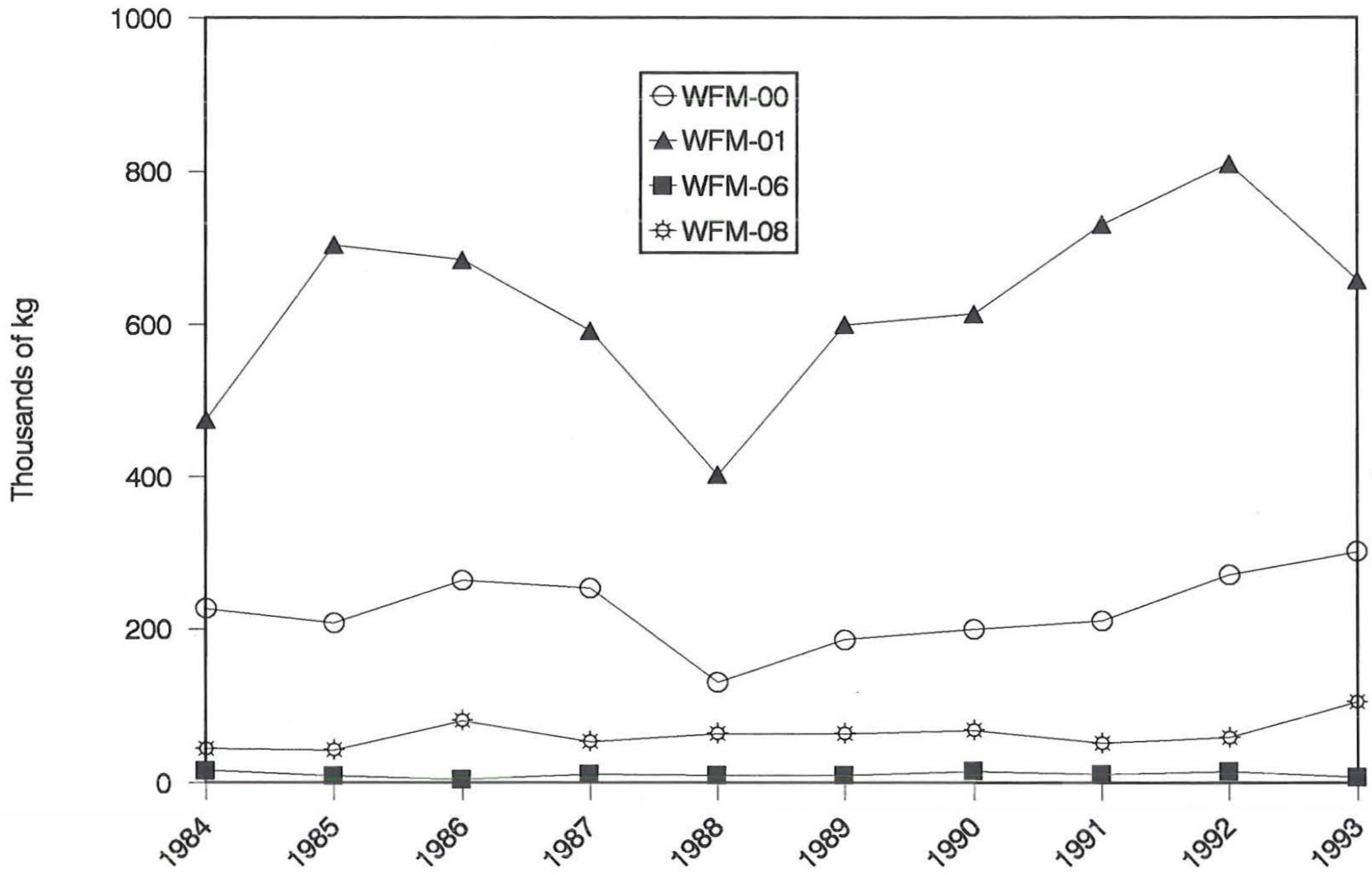

Figure 2.--Trap-net catches of lake whitefish in Lake Michigan, 1984-93.

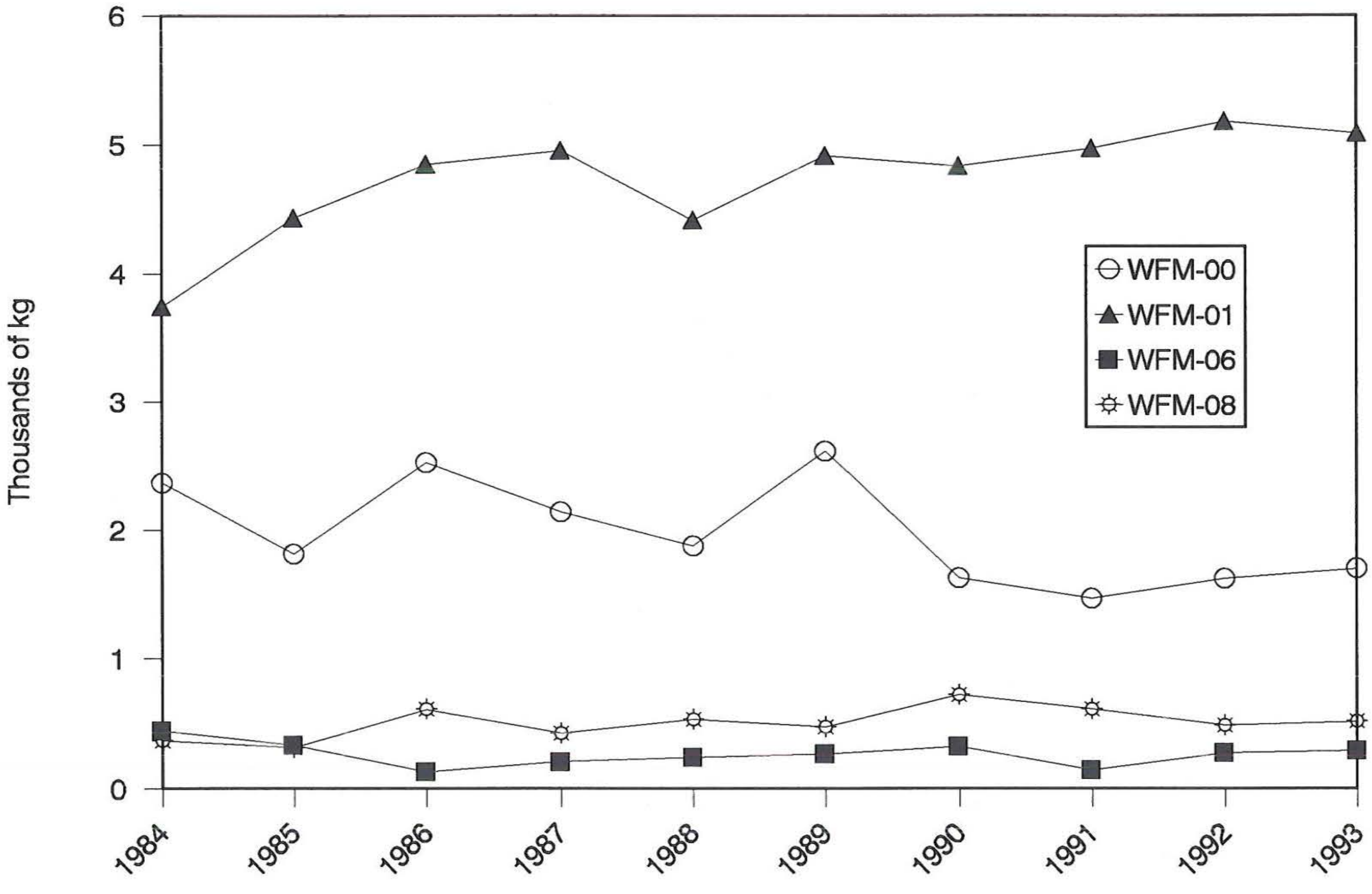

Figure 3.--Trap-net effort for lake whitefish in Lake Michigan, 1984-93.

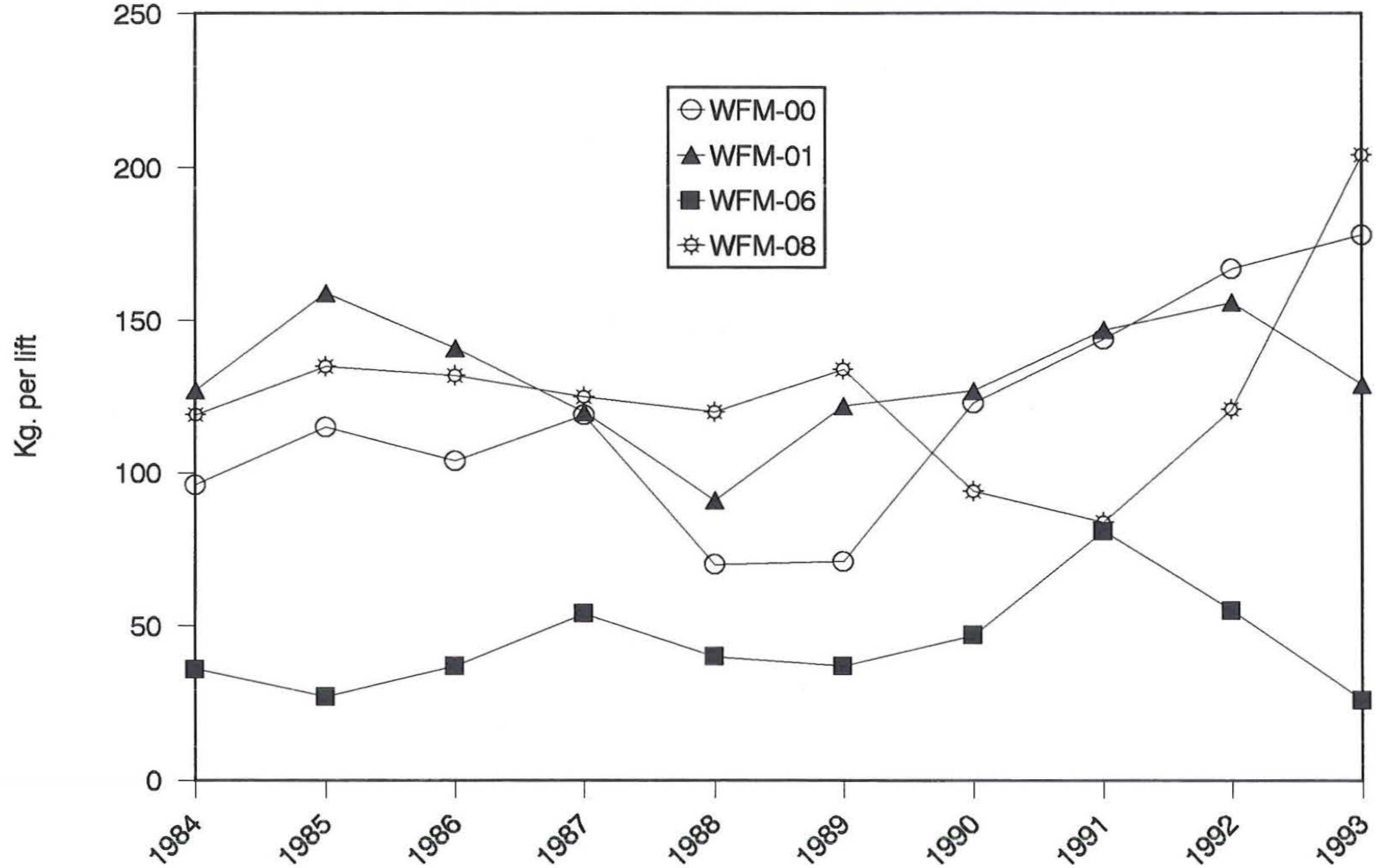

Figure 4.--Trap-net CPE for lake whitefish in Lake Michigan, 1984-93.

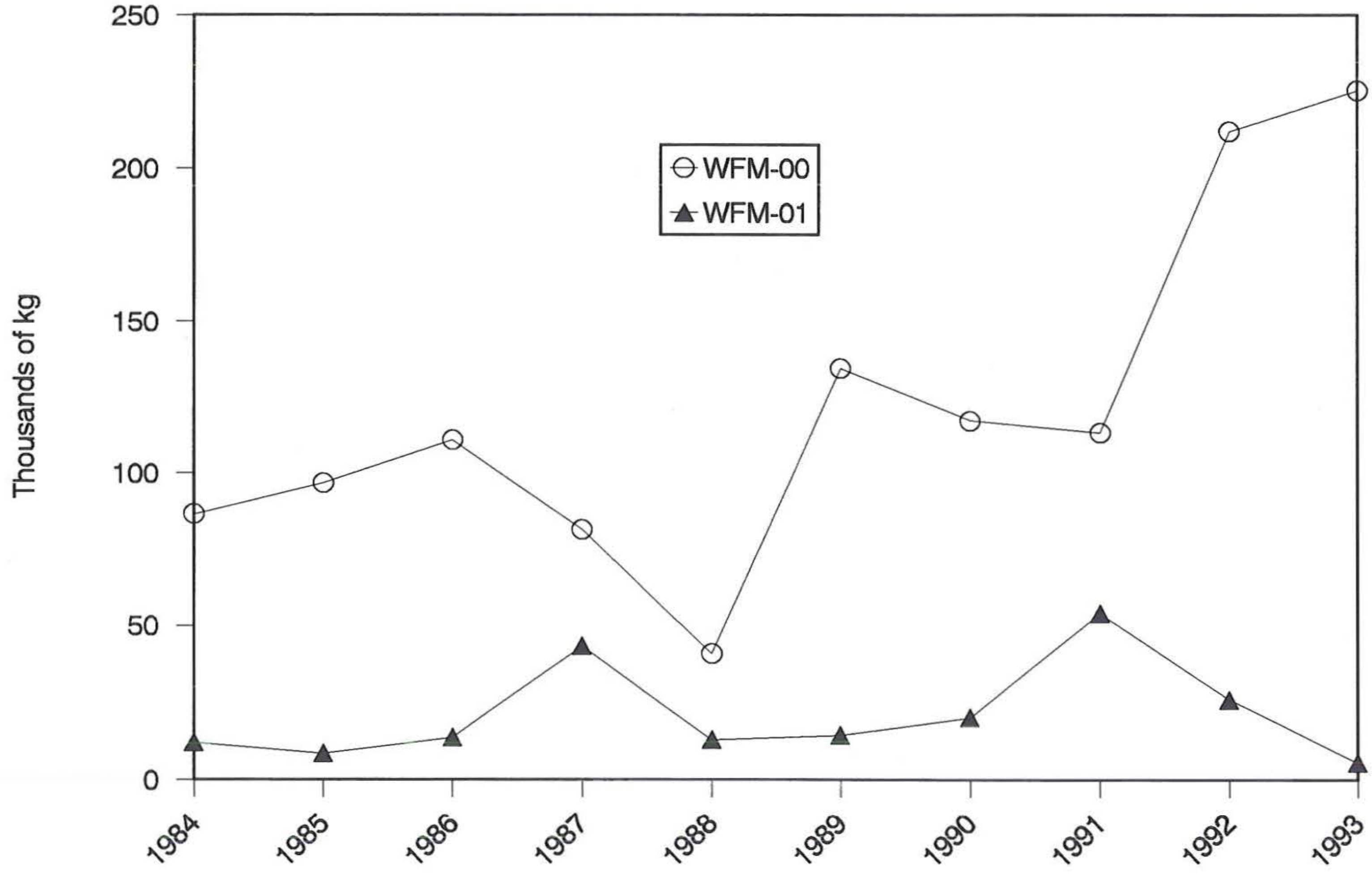

Figure 5.--Trawl catches of lake whitefish in Lake Michigan, 1984-93.

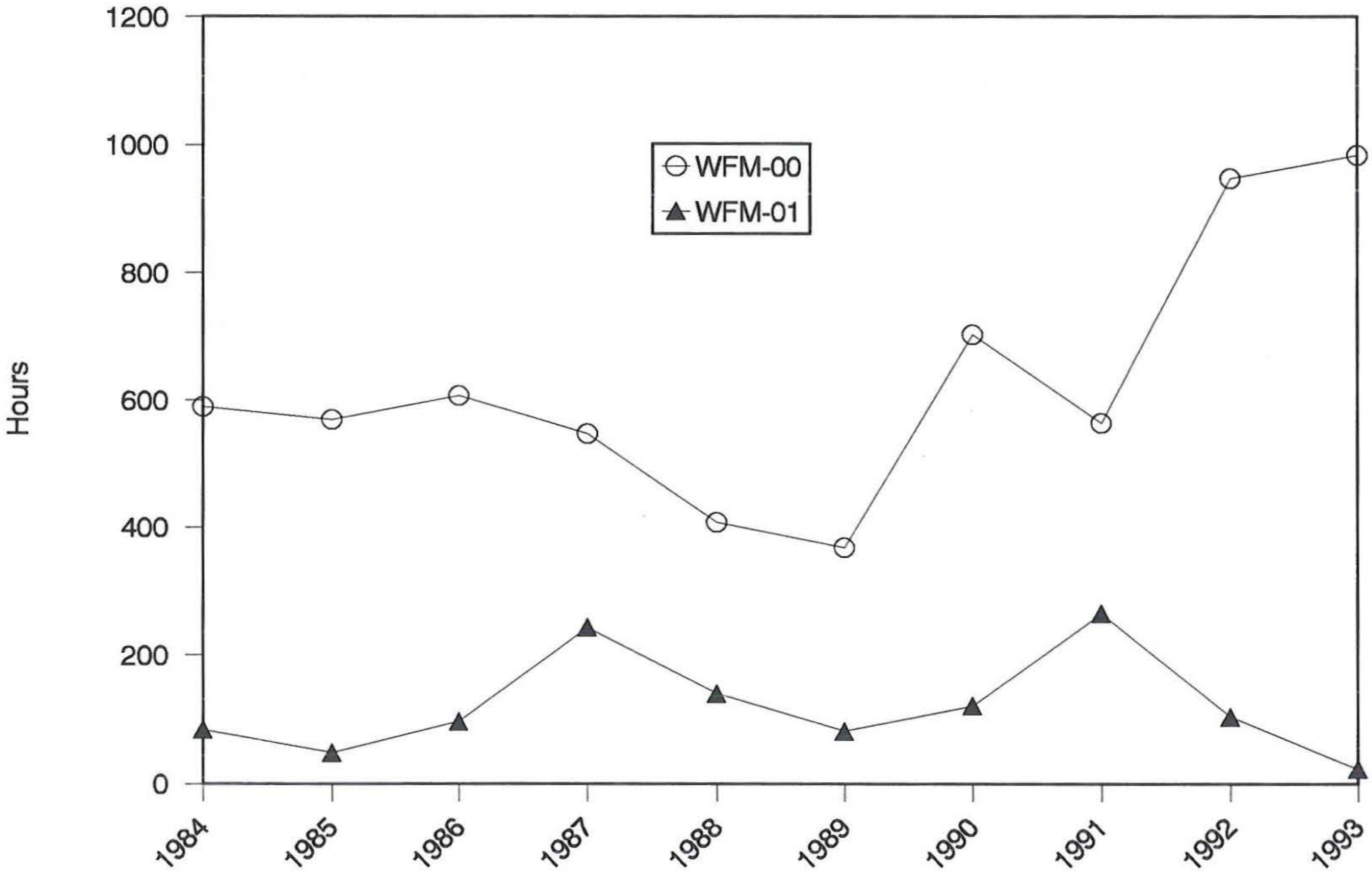

Figure 6.--Trawl effort for lake whitefish in Lake Michigan, 1984-93.

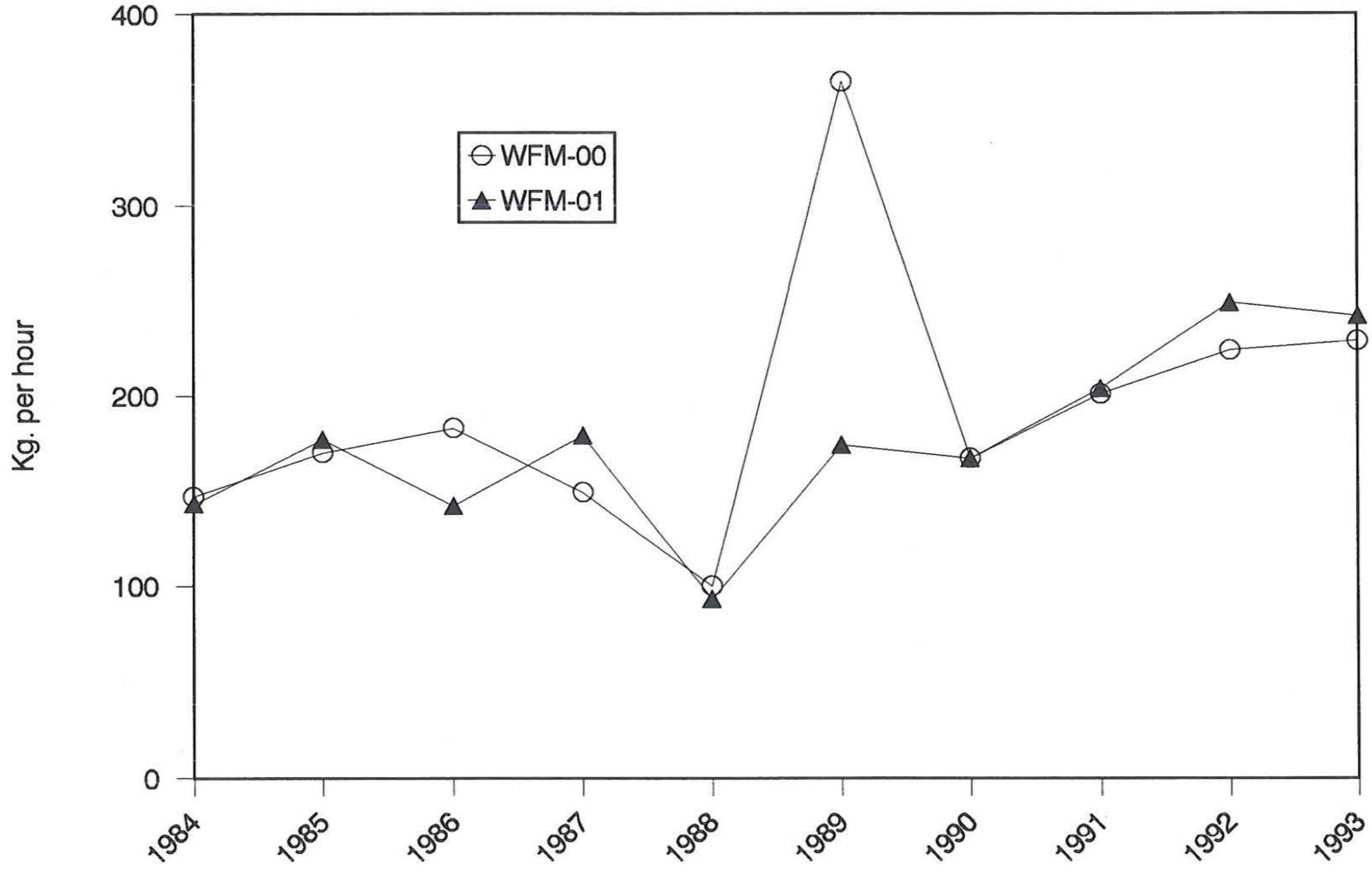

Figure 7.--Trawl CPE for lake whitefish in Lake Michigan, 1984-93.

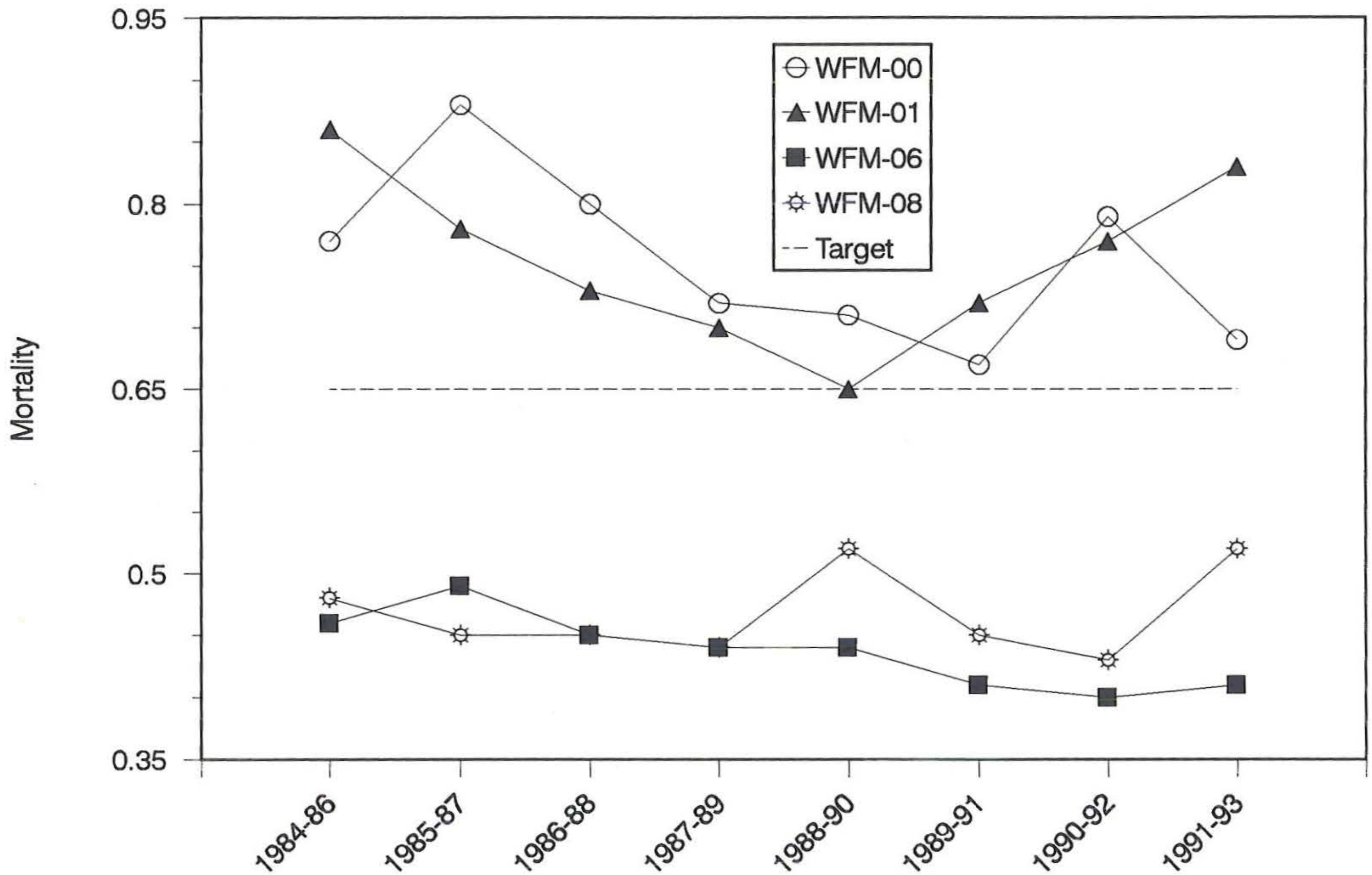

Figure 8.--Whitefish mortality rates, using pooled data sets, 1984-86 through 1991-93.

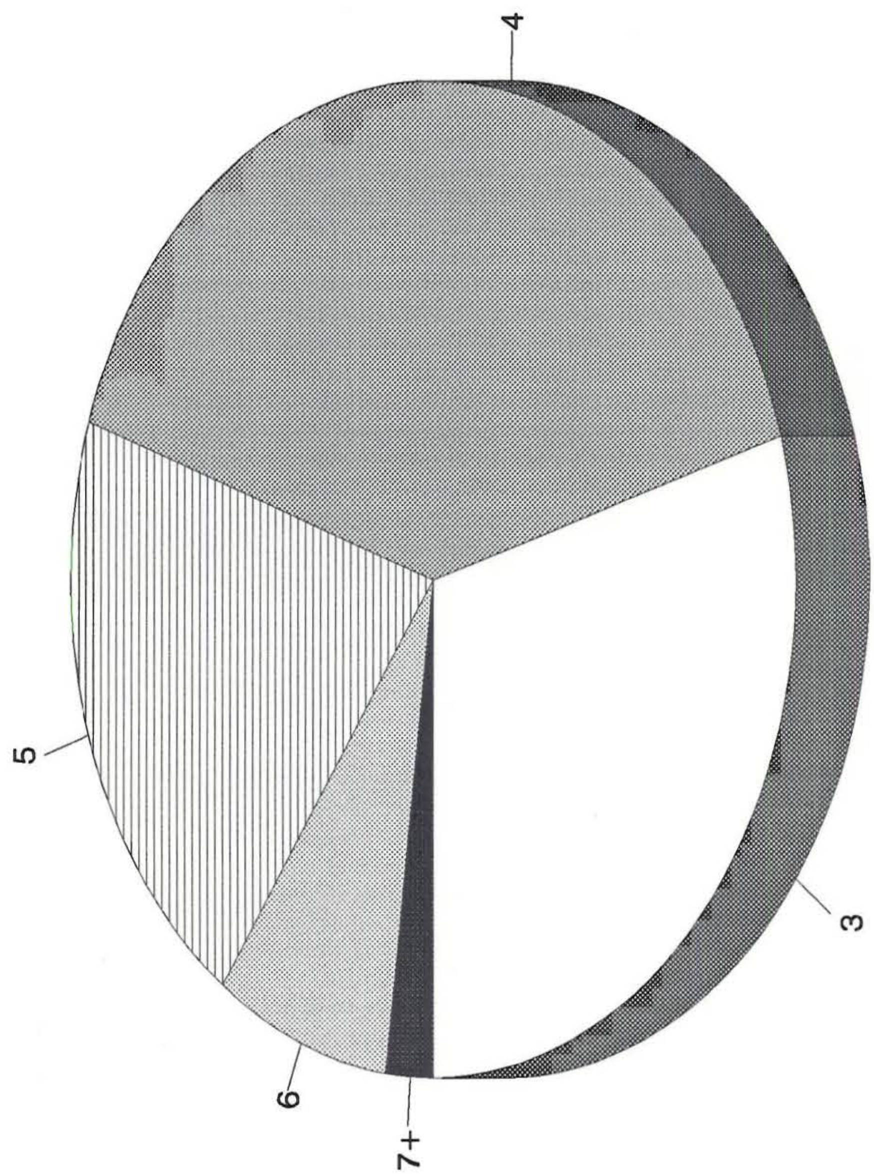

Figure 9.--Age distribution of whitefish caught in WFM-00, 1991-93.

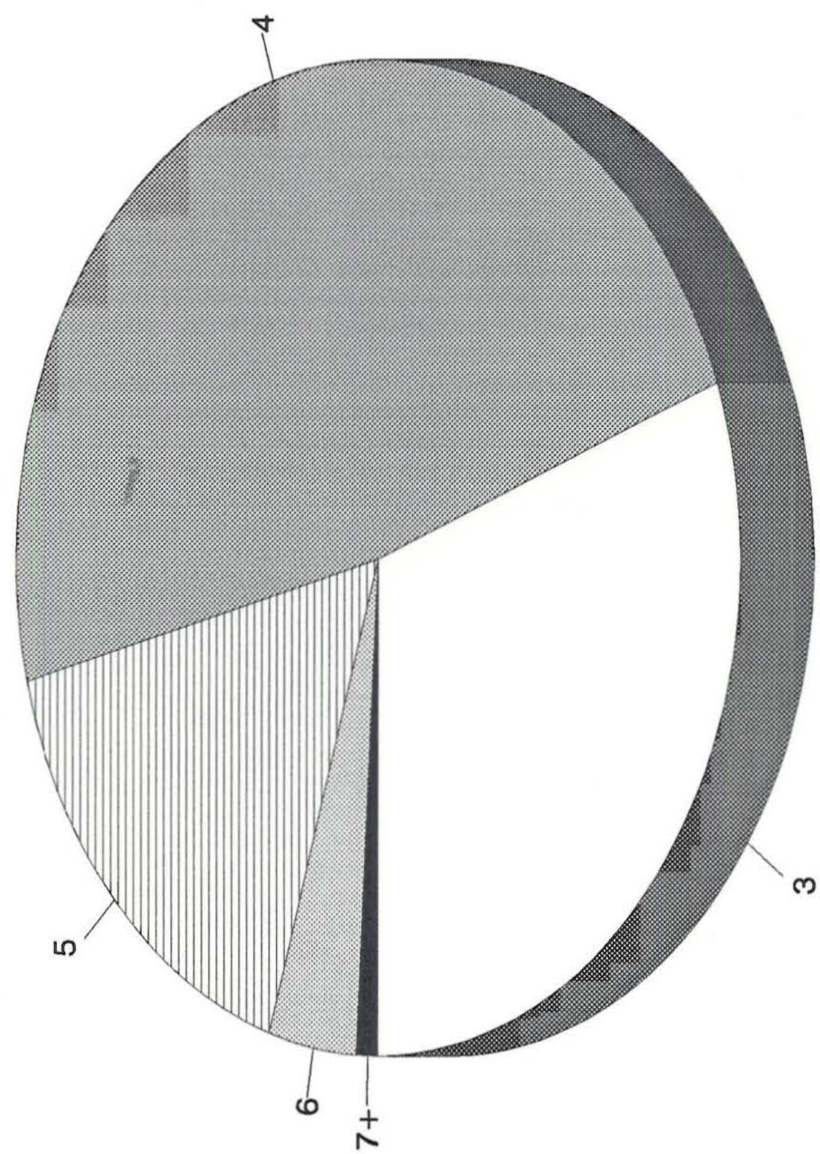

Figure 10.--Age distribution of whitefish caught in WFM-01, 1991-93.

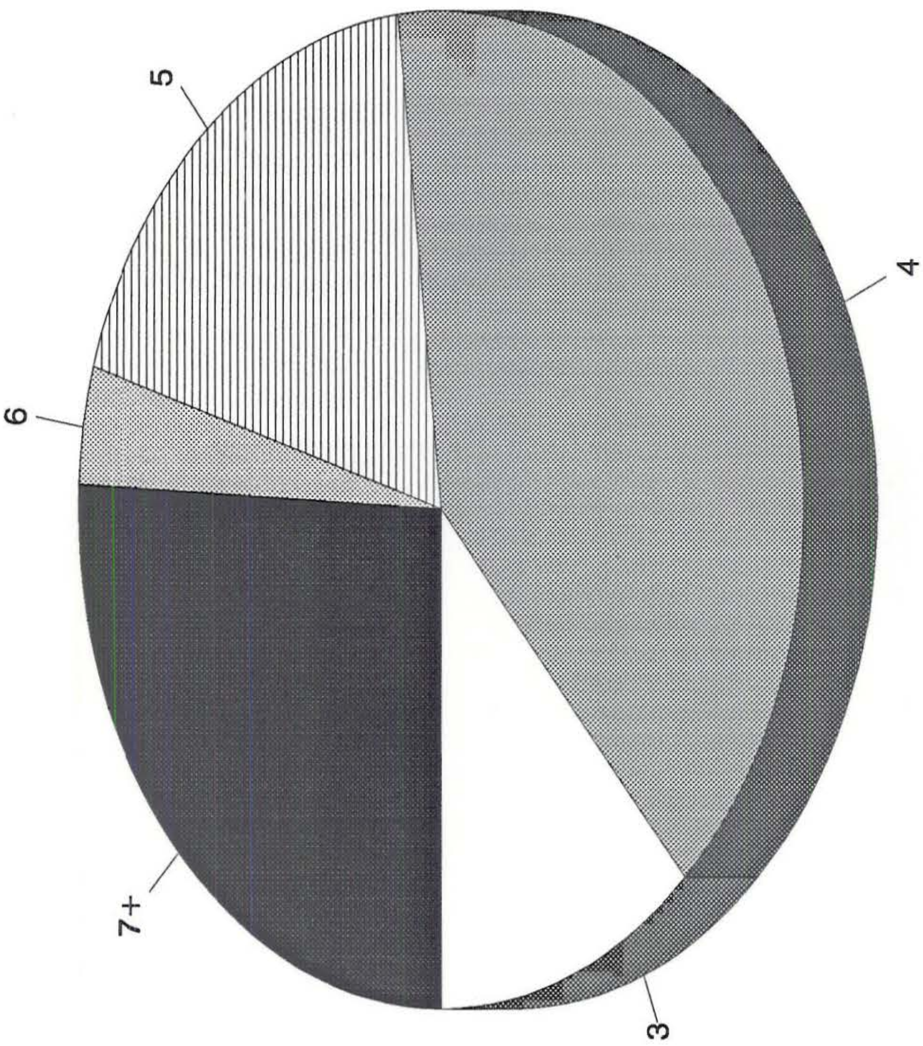

Figure 11.--Age distribution of whitefish caught in WFM-06, 1991-93.

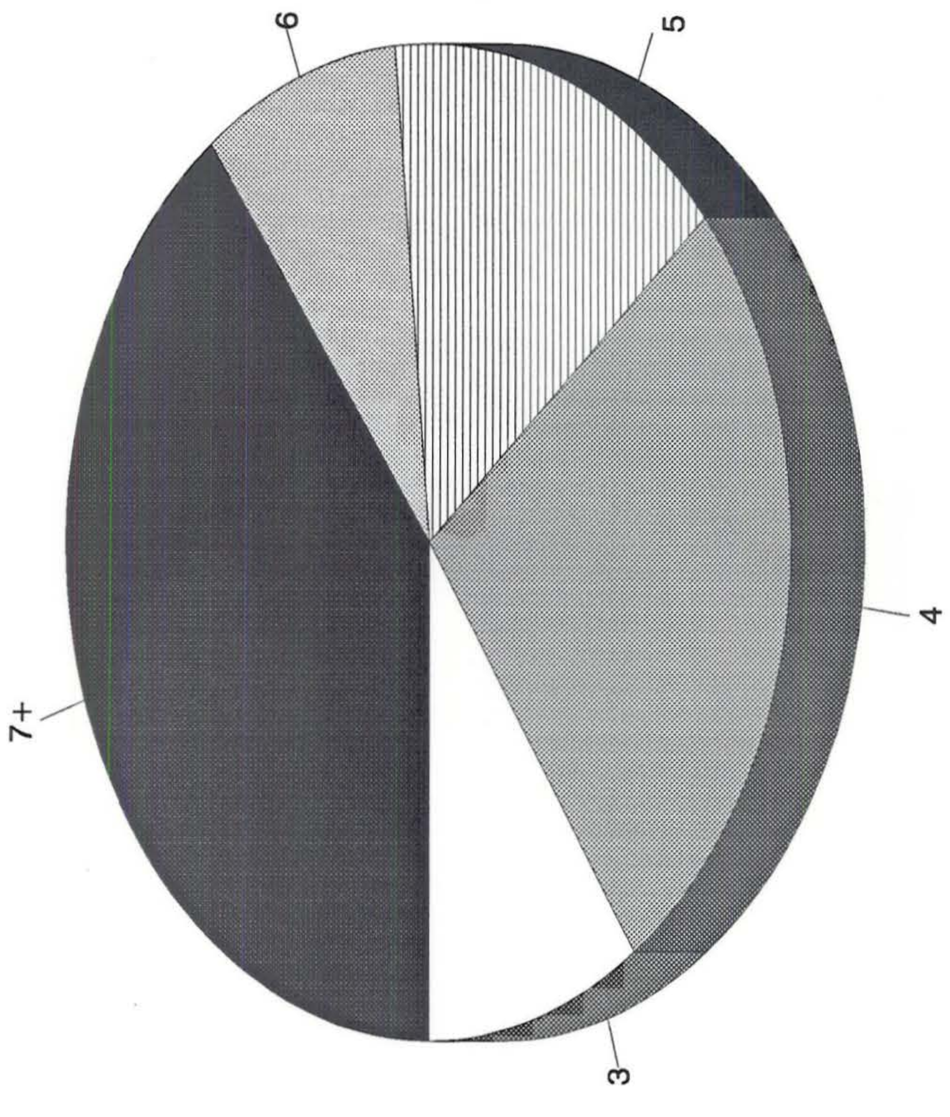

Figure 12.--Age distribution of whitefish caught in WFM-08, 1991-93.

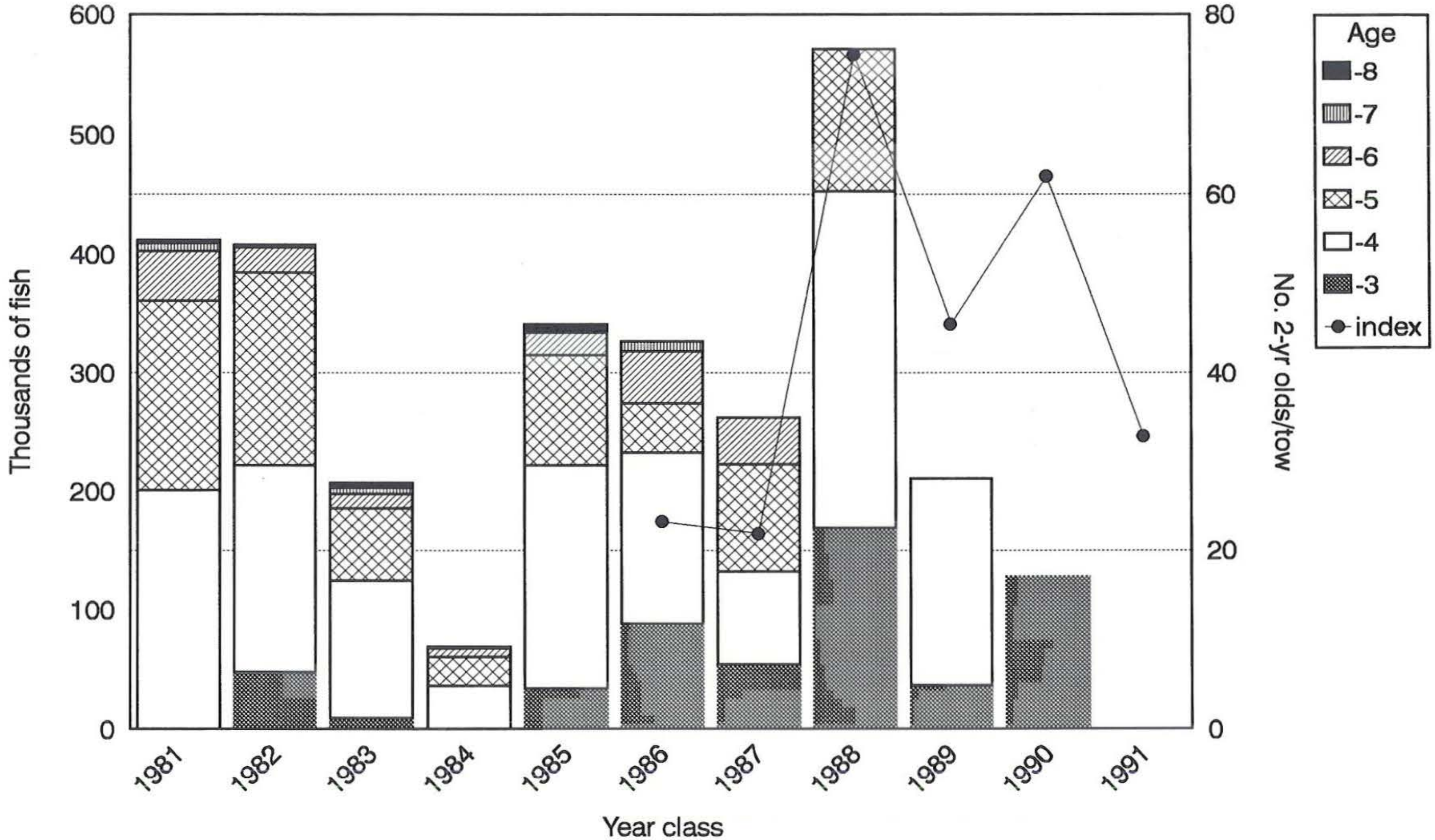

Figure 13.--Relative year-class strength of lake whitefish in WFM-00, depicted as cumulative contributions to the fishery by age, and indexed as the average number of 2-yr old pre-recruits caught inmodified trawl hauls.

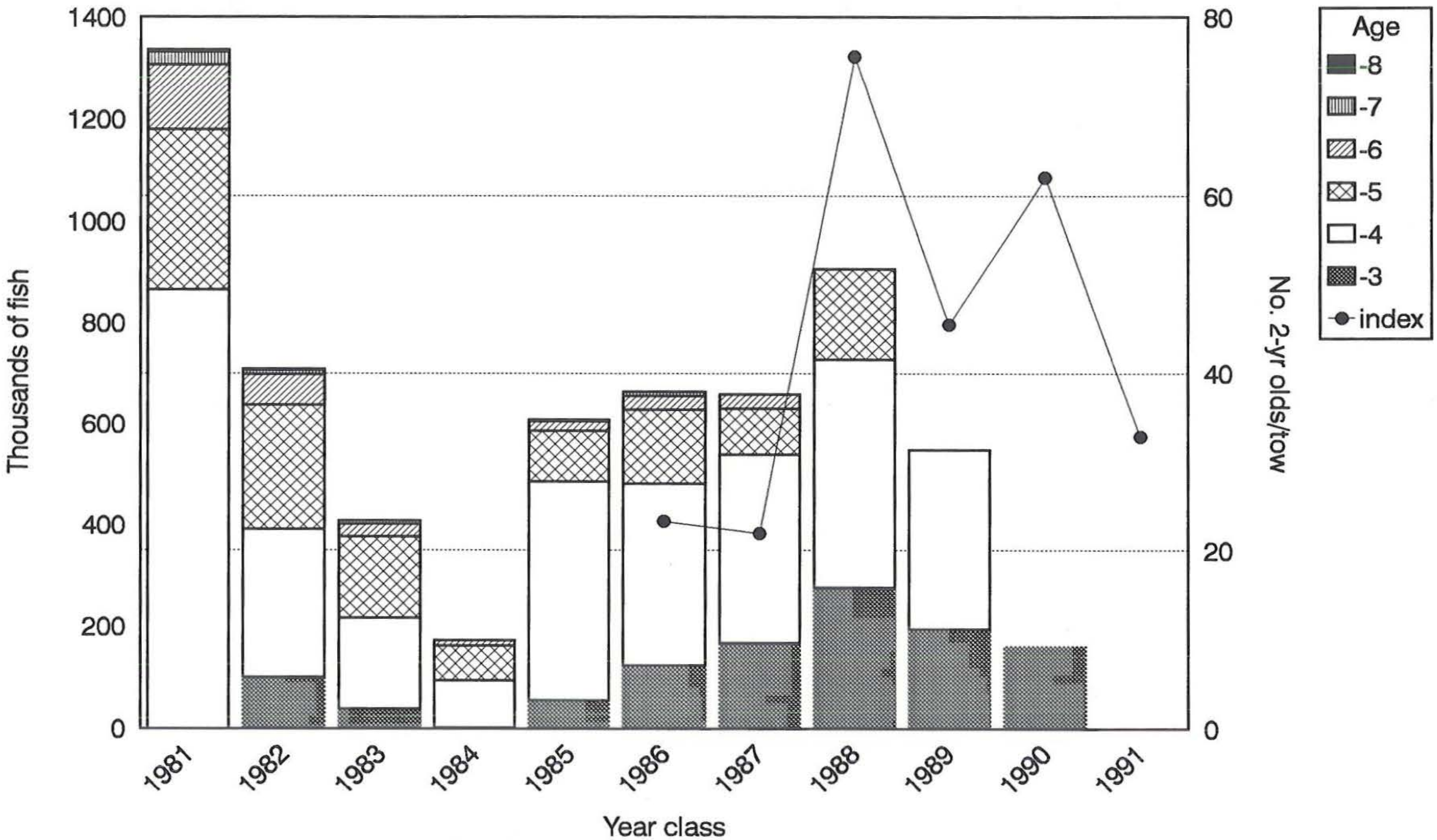

Figure 14.--Relative year-class strength of lake whitefish in WFM-01, depicted as cumulative contributions to the fishery by age, and indexed as the average number of 2-yr old pre-recruits caught in modified trawl hauls.

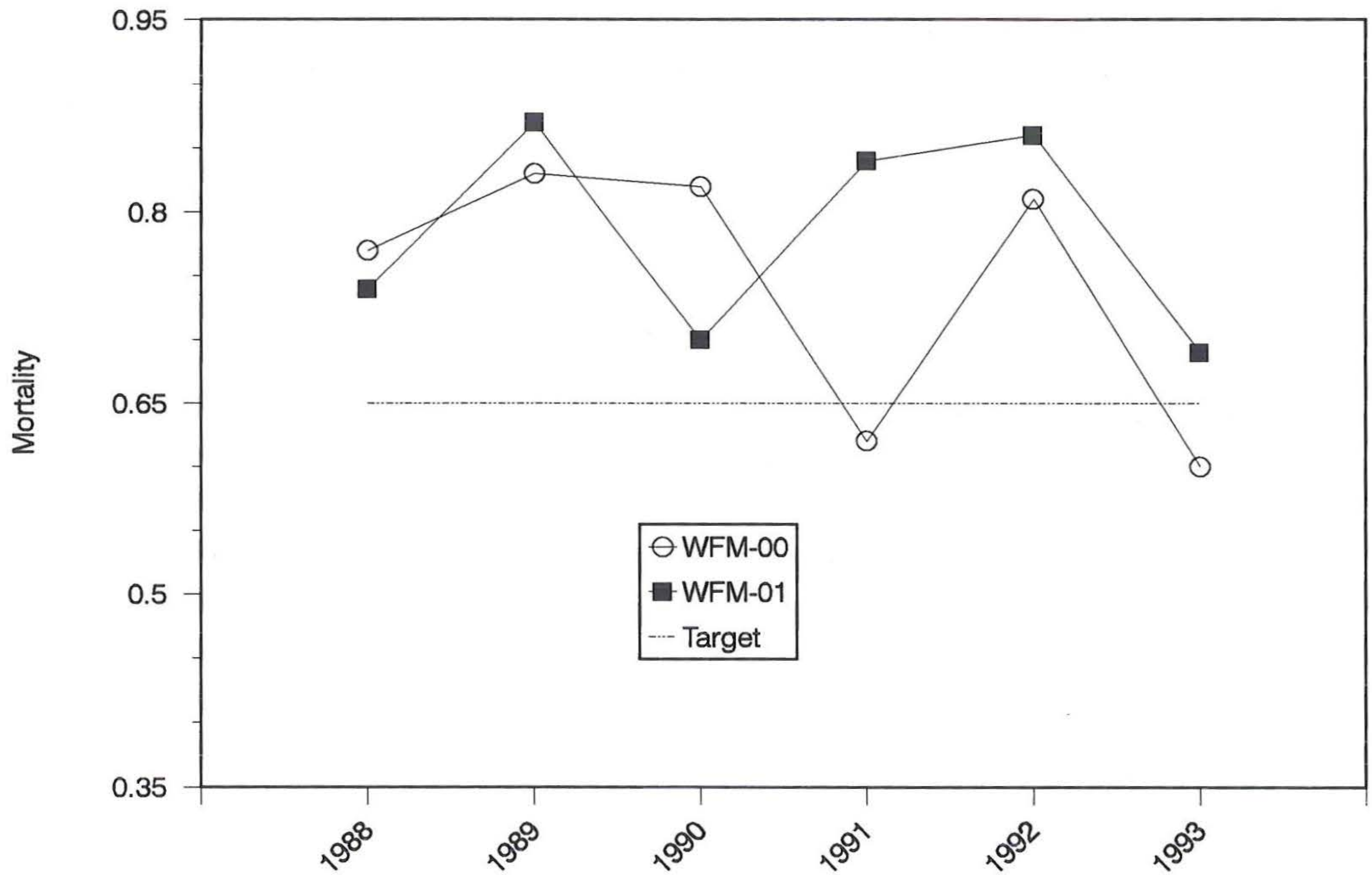

Figure 15.--Lake whitefish mortality rates, 1988-93, adjusted for year-class strength.

Appendix 1.

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Institute for Fisheries Research
Ann Arbor, Michigan 48109

QUOTA CALCULATIONS WITH SAP1
(Stock Assessment Package One)

Richard D. Clark, Jr.

and

Kelley David Smith

Appendix 1. Continued

I. Brief description of SAP1 (Stock Assessment Package One)

A. Purpose: SAP1 is a package of computer programs designed to calculate catch quotas for exploited fish stocks.

B. Programs were written in Applesoft Basic for use in Apple II and IIe computers, but they are also available in FORTRAN. The programs are interactive and user- friendly". The user selects a program from the menu, and the program prompts him for the needed input data. All programs allow error checking before executing. The package consists of the following seven programs.

1. PLOT - gives a scatter plot of input data.

2. VONB - estimates von Bertalanffy growth parameters given length at age data.

3. L-W REGRESSION - performs a linear regression on length-weight data, where: $\log_e(W) = A + B \cdot \log_e(L)$.

4. CATCH CURVE REGRESSION - performs a linear regression on catch-at-age data, where: $\log_e(C) = A - Z \cdot \text{age}$.

5. YPR - F(OPT) - F(MAX): estimates the fishing rate giving maximum yield per recruit and fishing rate giving maximum economic return based on growth and mortality data.

6. RECRUITMENT ESTIMATOR - Estimates the average number of recruits entering a fishery and the age structure of the population (number), catch (number), and yield (weight). Data on the mean annual yield in weight, the average size of a fish in the catch, growth, and mortality are needed.

7. QUOTA ESTIMATOR - A multiple-cohort-yield-per-recruit model which estimates harvest quotas for a specified number of years into the future. The optimal fishing rate from YPR - F (OPT) - F(MAX), the average number of recruits from RECRUITMENT ESTIMATOR, and growth and mortality data are needed.

II. Step-by-step procedures for estimating quotas with SAP1.

A. Estimate instantaneous mortality rates Z, F, and M for a period in which recent harvest data are available. Total mortality rate (Z) can be estimated using catch-at-age data with the CATCH CURVE REGRESSION program, but an independent estimate of natural (M) or fishing (F) mortality is also needed to properly partition Z.

Appendix 1. Continued.

B. Determine the length-weight relationship for fish in the population. The L-W REGRESSION program or another regression program can be used. If another program is used, be sure data are transformed using natural, base-e logarithms.

C. Calculate mean length at age of fish when scale annuli are formed. Use either a scale-back-calculation procedure or calculate mean lengths from spring samples.

D. Use the VONB program to estimate von Bertalanffy growth coefficients (K, L-infinity, and t-zero for growth in length over time.

E. Use harvest data for the same period in which Z, F, and M were estimated and calculate:

1. The mean annual yield in weight;

2. The length of fish at recruitment (or use the legal minimum size limit); and

3. The mean weight of an individual fish in the catch.

F. Use the YPR - F(OPT) - F(MAX) program to estimate the optimum fishing rate.

G. Use the RECRUITMENT ESTIMATOR program to estimate the number of recruits and age structure of the population necessary to produce the observed level of yield.

H. Use the QUOTA ESTIMATOR program to estimate quotas for the needed number of years into the future.

III. The need and rationale for using $F_{0.10}$ as calculated by the YPR - F(OPT) - F(MAX) program.

A. The need:

1. Agreement on the level of annual catch quotas is more easily reached if they are determined by objective, scientific criteria.

2. Biological theory and data alone are rarely sufficient to define annual quotas.

a. The effects of fishing on the rate of recruitment are rarely known (i.e., stock-recruitment relationship is usually unknown.)

Appendix 1. Continued.

b. Yield-per-recruit often increases to an asymptote as fishing mortality (or effort) increases. Theoretically, maximum yield-per-recruit can only be obtained with an infinitely high fishing rate in such a case.

B. The rationale:

1. From the practical viewpoint, it is undesirable to increase the amount of fishing beyond the level where the gain in the yield is small compared to the costs of the extra effort required to produce that yield. The question then arises as to what might be considered as small. An arbitrary figure which was suggested Gulland and Boerema (1973), and has been used successfully in the fisheries of the North Atlantic, is a marginal yield equal to one-tenth of the original catch-per-unit-effort in the very lightly exploited fishery. Although the one-tenth figure is arbitrary, is usually gives a fishing rate ($F_{0.10}$) which is near the economic optimum yield per unit of effort. And of course, these economics are based on the biological productivity of the recruits in terms of their growth and mortality over their life. In the end though, biological caution is still needed because there is no guarantee that the optimum fishing rate ($F_{0.10}$), based only on growth and mortality, will not cause a decline in the recruitment rate.

2. References:

Gulland, J. A., and L.K. Boerema. 1973. Scientific advice on catch levels. Fishery Bulletin 71:325-335.

Rakoczy, G. P. 1983. Harvest levels for commercially exploited stocks of lake whitefish in Michigan waters of Lake Superior. Michigan Department of Natural Resources, Fisheries Research Report 1912, Ann Arbor, Michigan, USA.

Sissenwine, M. P. 1981. An overview of some methods of fish stock assessment. Fisheries 6:31-35.

IV. The importance of monitoring fluctuations in year-class strength.

A. The RECRUITMENT ESTIMATOR calculates the average number of recruits entering the fishery over the period in which catch data were obtained. The QUOTA ESTIMATOR assumes this average recruitment will continue into the future. Fluctuations in year-class strength are not considered.

B. If the period in which catch data were obtained was short (say less than 5 years) or the fishery was undergoing significant changes (for example, the population

Appendix 1. Continued.

was not near equilibrium or the fishery was expanding), then past recruitment estimates may not be representative of future recruitment rates.

C. It is highly desirable to sample strength of year classes before they enter the fishery. This allows time to adjust annual quotas either to prevent overfishing when year-class strength is weak or to take advantage of surplus fish when year-class strength is strong. Also, by the time reproductive failures are detected in commercial catches, it is usually too late to prevent the collapse of the fishery (Evans 1981).

D. References:

Evans, G. T. 1981. The potential collapse of fish stocks in a developing fishery. NAJFM 1:127-133.

V. Mathematical description of the major programs in SAP1. (Note: L-W REGRESSION and CATCH CURVE REGRESSION programs use standard least-squares regression techniques. No further description will be given of these programs.)

A. VONB program:

1. The von Bertalanffy growth equation can be written as follows:

$$L_t = L\infty[1.0 - EXP\{-K\ (t-t_0)\}]$$

Where parameters to be estimated are:

$L\infty$ = asymptotic length

K = growth coefficient

t_0 = theoretical age at which length equals zero

These parameters are estimated by the nonlinear least squares technique of Allen (1966). However, a first guess for the growth coefficient (K) is needed to start Allen's procedure. This is obtained by an interval search technique.

Appendix 1. Continued.

2. References:

Allen, K. R. 1966. A method of fitting growth curves of the von Bertalanffy type to observed data. Journal of the Fisheries Research Board of Canada 23:163-179.

B. YPR - F(OPT) - F(MAX) program:

1. Calculates yield-per-recruit for a series of instantaneous fishing rates from 0.0 to 5.0 using the standard Beverton and Holt (1957) yield equation.

2. Determines the slope of this yield-per-recruit curve at various points by evaluating the first derivative of the Beverton and Holt equation at these points.

a. Determines slope at F = 0.0.

b. Determines the value of F(OPT) and the yield-per-recruit at that value. F(OPT) is located at the point in the curve where the slope is 10% (or other percentage defined by the user) of the slope at F = 0.0.

c. Determines the maximum yield per recruit if it exists in the interval $0<F\leq 5.0$, and calculates the fishing rate, F(MAX), at this point.

3. References:

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fisheries Investigations Series 2, Marine Fisheries, Great Britain, Ministry of Aquaculture, Fisheries and Food, Volume 19.

C. RECRUITMENT ESTIMATOR program:

1. Calculates number of recruits ($N(X_c)$) as:

$N(X_c)$ = (YBAR/WBAR) (Z)/F

X_c = age of entry

YBAR = average annual yield in weight

Appendix 1. Continued.

WBAR = mean weight of individual in catch

Z = instantaneous total mortality

F = instantaneous fishing mortality

2. Approximates population age structure for current total mortality (Z):

$N(X_{i+1}) = N(X_i) \cdot EXP[-Z\ (X_{i+1} - X_i)]$

Where:

X_i's = ages

$N(X_i)$ = number of fish at age X_i, and

$N(X_c)$ is the first "$N(X_i)$"

3. Calculates catch at age using Baranov catch equation:

$C(X_i) = F \cdot N(X_i) \cdot$

$\{1\text{-}EXP[-Z_i\ (X_i)]\}/[Z_i((X_{i+1}\text{-}X_i)]$

Note that $(X_{i+1} - X_i)$ always equals 1.0 except for the first age group where $(X_i - X_c)$ probably will be less than 1.0. This is because the age of entry (X_c) usually has some fraction of a year associated with it.

4. Growth in length of fish follows the von Bertalanffy growth function.

5. Estimates average yield at age as:

$Y(X_i) = C\ (X_i) \cdot \overline{W}$

Where:

$\overline{W}$ = mean weight of a fish of age X_i

Appendix 1. Continued.

And (using length/weight regression);

$$\overline{W} = \text{EXP}\ [A+B \cdot \text{LOG}_e\ (L)]$$

And (using von Bertalanffy equation):

$$\bar{L} = L\infty\ \{1\text{-EXP}\ [-K\ (X_i+0.5 - X_0)]\}$$

See Clark and Huang (1983) Appendix B for more detail.

6. References:

Clark, R. D., Jr., and B. Huang. 1983. The dynamics of competition between sport and commercial fishing: effects on rehabilitation of lake trout in Lake Michigan. Michigan Department of Natural Resources, Fisheries Research Report 1909, Ann Arbor, Michigan, USA.

D. QUOTA ESTIMATOR program

1. Assumes the number of fish at age that was calculated by the RECRUITMENT ESTIMATOR is the current population and then estimates catch in number, yield in weight, and egg production for a given number of years into the future. The yield in weight for each year into the future can be used as the annual catch quota for that year. The optimum fishing rate ($F_{0.10}$) that was calculated in YPR - F(OPT) - F(MAX) is usually used as the fishing rate which will be maintained into the future by regulating with the quotas.

2. The model assumes recruitment will remain constant at the same level as given in the initial conditions. Each cohort is retained separately in a population matrix with growth, mortality, catch, and yield being calculated on an annual basis using the same equations as the RECRUITMENT ESTIMATOR.

3. The annual egg production of the population is calculated to help examine the potential effects of fishing on natural reproduction. However, these calculations are of little use without some knowledge of the early life history

Appendix 1. Continued.

and survival of the juvenile fish. <u>The model assumes the fish are fall spawners.</u> The following equations are used:

$$EGGS = \sum_{i=1}^{X_\lambda} N(X_{i+1})\cdot(0.5)\cdot W(X_i)\cdot FM(X_i) \cdot EC$$

Where:

$N(X_{i+1})$ = number of fish at age X+1

$W(X_i)$ = mean weight in the fall of the year of a female of age X_i

$FM(X_i)$ = proportion of females mature at age X_i

EC = number of eggs per unit of female biomass

Several assumptions were made in this equation. First, it was assumed that the number of fish of age X_i in the fall of that year was closer to the number in the spring of age X_{i+1} than to the number in the spring of age X_i. This is because most of the total mortality in any given year occurs in summer. Hence, the number of fish at age X_i fish. Second, the mean weight in the fall of age X_i is estimated by first estimating the mean length as:

$$\bar{L} = L\infty \{1- EXP [-K(X_i+0.5 - X_0)]\}$$

where it is assumed that using age X_i+0.5 in the von Bertalanffy equation will approximate the mean length of a female in the fall of the year. Mean weight is then estimated from this mean length in the length-weight regression equation. Finally, it is assumed that the sex ration is 1:1.

Appendix 2.--Age frequency and size-at-age of lake whitefish sampled from Lake Michigan management zones, 1986-93. Total length in millimeters, round weight in kilograms.

					Length		Weight	
Zone	Year	Month	Age	Number	Mean	95% C.I.	Mean	95% C.I.
WFM-00	1986	May	2	1	295	-	0.27	-
			3	50	389	6	0.68	0.03
			4	129	438	4	0.91	0.02
			5	99	472	4	1.06	0.03
			6	5	507	22	1.38	0.29
		Jul	2	2	367	178	0.52	0.89
			3	54	403	6	0.68	0.03
			4	231	449	3	0.93	0.02
			5	172	479	3	1.09	0.02
			6	12	529	14	1.47	0.13
			7	2	569	38	1.84	0.32
		Oct	2	21	290	5	0.22	0.02
			3	37	402	14	0.68	0.07
			4	40	458	7	0.98	0.07
			5	23	493	16	1.20	0.12
			6	3	531	32	1.65	0.17
			7	1	574	-	1.86	-
			8	1	683	-	3.63	-
			12	1	770	-	5.58	-
	1987	May	3	9	397	12	1.00	0.00
			4	155	423	4	1.00	0.00
			5	117	465	4	1.00	0.00
			6	22	514	13	1.09	0.13
		Jul	4	89	453	3	1.00	0.00
			5	86	482	5	1.07	0.05
			6	28	521	13	1.25	0.17
			7	2	555	305	1.00	0.00
			8	1	572	-	2.00	-
	1988	May	2	8	314	15	0.33	0.05
			3	112	396	5	0.69	0.02
			4	50	445	7	0.92	0.05
			5	95	468	6	1.07	0.05
			6	29	487	12	1.22	0.09
			7	10	556	28	1.64	0.27
			8	5	604	45	2.10	0.63
			14	1	693	-	4.40	-

Zone	Year	Month	Age	Number	Length Mean	Length 95% C.I.	Weight Mean	Weight 95% C.I.
WFM-00	1988	Jul	3	57	440	4	0.82	0.04
			4	64	459	6	0.95	0.04
			5	110	468	6	1.03	0.04
			6	38	485	12	1.16	0.08
			7	13	500	25	1.25	0.17
			8	2	521	197	1.41	0.57
			9	1	429	-	0.73	-
		Oct	2	36	390	5	0.59	0.02
			3	103	420	5	0.74	0.03
			4	16	462	22	0.99	0.16
			5	8	513	34	1.31	0.23
			6	5	542	65	1.61	0.60
			12	1	711	-	4.26	-
	1989	May	2	1	368	-	0.45	-
			3	100	417	5	0.76	0.03
			4	172	446	4	0.93	0.03
			5	19	483	18	1.19	0.18
			6	9	515	26	1.49	0.29
			7	3	552	161	1.60	1.14
			8	2	621	76	2.70	2.60
			9	2	584	159	2.57	3.75
		Jul	3	32	443	5	0.86	0.04
			4	148	464	4	1.00	0.03
			5	18	481	12	1.10	0.08
			6	11	498	30	1.24	0.29
			8	1	584	-	2.13	-
		Oct	2	21	383	12	0.59	0.06
			3	142	438	4	0.83	0.02
			4	45	455	8	0.93	0.05
			5	3	475	72	1.05	0.63
			8	1	673	-	2.59	-
	1990	Apr	2	9	309	10	0.31	0.03
			3	68	377	6	0.61	0.03
			4	46	441	8	0.96	0.05
			5	41	456	10	1.05	0.08
			6	1	490	-	1.13	-
			7	2	549	292	1.75	2.03
			13	1	716	-	3.81	-

					Length		Weight	
Zone	Year	Month	Age	Number	Mean	95% C.I.	Mean	95% C.I.
WFM-00	1990	May	3	2	442	64	0.86	1.14
			4	56	455	5	1.01	0.04
			5	68	462	6	1.03	0.04
			6	8	468	21	1.05	0.13
			7	6	480	30	1.09	0.23
		Jul	3	15	447	6	0.89	0.05
			4	108	460	4	1.01	0.03
			5	55	474	7	1.13	0.06
			6	2	490	324	1.23	4.00
			7	2	540	83	1.82	2.35
		Oct	2	80	385	5	0.60	0.02
			3	94	445	5	0.82	0.02
			4	65	474	7	0.97	0.05
			5	14	513	28	1.24	0.21
			6	2	544	616	1.38	4.32
			8	1	599	-	1.91	-
	1991	May	2	17	301	15	0.28	0.05
			3	53	369	8	0.56	0.04
			4	38	427	11	0.87	0.07
			5	21	463	11	1.10	0.10
			6	14	500	18	1.30	0.15
			8	3	517	47	1.32	0.34
		Oct	2	37	388	8	0.58	0.04
			3	191	443	3	0.87	0.02
			4	45	474	10	1.04	0.07
			5	12	500	14	1.27	0.11
			6	1	521	-	1.50	-
			7	1	640	-	2.68	-
		May	2	18	302	9	0.33	0.03
			3	75	377	6	0.67	0.03
			4	119	446	4	0.95	0.03
			5	34	473	10	1.08	0.06
			6	16	496	16	1.22	0.12
			7	1	523	-	1.59	-
	1992	Jul	3	15	444	8	0.85	0.04
			4	59	473	6	1.04	0.04
			5	16	517	16	1.34	0.17
			6	8	554	32	1.67	0.32

Zone	Year	Month	Age	Number	Length Mean	Length 95% C.I.	Weight Mean	Weight 95% C.I.
WFM-00	1993	May	2	4	298	43	0.31	0.15
			3	96	374	5	0.55	0.03
			4	103	451	5	0.96	0.04
			5	60	482	7	1.13	0.06
			6	19	521	18	1.36	0.15
			7	4	533	50	1.34	0.20
			8	1	559	-	1.50	-
			11	1	681	-	3.67	-
			12	1	660	-	3.18	-
		Jul	3	25	439	4	0.92	0.04
			4	43	462	6	1.01	0.05
			5	26	484	9	1.19	0.07
			6	10	516	22	1.45	0.22
			7	4	542	34	1.45	0.42
			8	4	561	23	1.85	0.18
		Oct	2	8	380	16	0.56	0.10
			3	203	431	4	0.78	0.02
			4	53	478	9	1.08	0.06
			5	28	527	11	1.44	0.12
			6	8	547	23	1.59	0.27
			7	1	417	-	0.64	-
WFM-01	1986	May	3	140	380	4	0.60	0.02
			4	315	437	3	0.88	0.02
			5	197	474	3	1.01	0.02
			6	11	498	18	1.30	0.17
			12	1	696	-	2.68	-
		Jul	3	13	431	6	0.79	0.05
			4	162	444	3	0.92	0.02
			5	166	468	3	1.03	0.03
			6	11	498	18	1.30	0.17
			12	1	696	-	2.68	-
		Oct	1	1	282	-	0.18	-
			2	2	348	102	0.34	0.25
			3	193	424	2	0.72	0.01
			4	264	460	3	0.93	0.02
			5	227	496	3	1.17	0.03
			6	40	534	8	1.47	0.09
			7	4	560	51	1.69	0.53

Zone	Year	Month	Age	Number	Length Mean	Length 95% C.I.	Weight Mean	Weight 95% C.I.
WFM-01	1986	Oct	8	2	624	210	2.54	5.21
	1987	May	2	52	295	4	0.14	0.01
			3	27	373	8	0.46	0.06
			4	222	424	3	0.77	0.02
			5	145	465	4	1.00	0.03
			6	72	500	5	1.17	0.05
			7	6	552	27	1.59	0.33
		Jul	3	2	428	76	0.82	0.00
			4	84	444	3	0.91	0.02
			5	52	470	5	1.03	0.03
			6	7	501	25	1.09	0.09
		Oct	3	2	436	19	0.75	0.25
			4	119	463	3	0.98	0.03
			5	77	513	6	1.32	0.06
			6	60	554	7	1.65	0.08
			7	15	594	13	2.17	0.22
			8	5	617	22	2.19	0.33
			9	1	693	-	3.45	-
			10	2	689	222	3.75	2.60
			11	3	687	82	3.54	0.70
			12	3	713	72	3.90	1.11
	1988	May	3	9	436	13	0.86	0.08
			4	87	442	3	0.93	0.03
			5	135	448	3	0.98	0.02
			6	58	488	9	1.21	0.06
			7	34	530	15	1.43	0.13
			8	1	546	-	1.68	-
		Jul	2	1	432	-	0.91	-
			3	82	435	3	0.82	0.03
			4	120	451	4	0.94	0.03
			5	139	462	5	1.03	0.03
			6	39	479	12	1.13	0.08
			7	11	514	23	1.28	0.17
		Oct	3	115	428	76	0.82	0.00
			4	31	465	10	0.89	0.06
			5	25	521	14	1.31	0.15
			6	15	556	19	1.60	0.20
			7	7	600	21	2.15	0.37

					Length		Weight	
Zone	Year	Month	Age	Number	Mean	95% C.I.	Mean	95% C.I.
WFM-01	1988	Oct	8	2	621	76	2.98	2.60
			10	1	653	-	2.72	-
	1989	May	1	1	180	-	0.05	-
			2	39	298	6	0.23	0.02
			3	100	387	5	0.58	0.03
			4	439	441	2	0.88	0.02
			5	78	454	5	0.98	0.04
			6	30	486	16	1.24	0.13
			7	9	502	34	1.35	0.27
			8	3	512	74	1.33	0.13
		Jul	1	2	212	51	0.12	0.32
			2	15	315	9	0.40	0.11
			3	122	412	4	0.69	0.02
			4	267	448	3	0.93	0.02
			5	34	460	11	1.00	0.08
			6	10	504	29	1.35	0.18
			7	4	543	42	1.58	0.38
			8	1	485	-	1.13	-
		Oct	2	34	370	8	0.47	0.05
			3	399	427	2	0.69	0.02
			4	275	457	4	0.88	0.03
			5	25	477	11	0.96	0.08
			6	7	516	34	1.29	0.22
			7	3	545	187	1.51	0.84
			8	2	590	32	1.98	0.25
			9	1	630	-	2.41	-
			10	1	617	-	2.00	-
	1990	Jul	2	6	326	52	0.39	0.18
			3	109	406	4	0.66	0.02
			4	194	448	3	0.87	0.02
			5	44	469	11	1.00	0.06
			6	9	496	27	1.20	0.20
		Oct	1	1	257	-	0.14	-
			2	99	381	5	0.56	0.02
			3	286	433	3	0.76	0.02
			4	231	481	4	1.04	0.03
			5	70	511	9	1.28	0.07
			6	2	538	210	1.34	3.18
			7	6	582	38	1.97	0.33

					Length		Weight	
Zone	Year	Month	Age	Number	Mean	95% C.I.	Mean	95% C.I.
WFM-01	1990	Oct	8	2	597	165	2.13	3.43
			9	4	644	84	2.85	0.59
			12	2	748	114	5.20	1.97
	1991	May	2	22	293	7	0.26	0.03
			3	164	373	4	0.54	0.02
			4	137	438	4	0.88	0.03
			5	52	477	6	1.10	0.05
			6	7	496	29	1.24	0.20
		Jul	1	3	229	6	0.09	0.00
			2	30	327	12	0.33	0.05
			3	215	409	4	0.65	0.02
			4	90	457	6	0.90	0.04
			5	28	488	11	1.10	0.08
			6	3	514	65	1.25	0.45
		Oct	1	7	289	10	0.21	0.02
			2	83	374	6	0.49	0.03
			3	218	430	3	0.74	0.02
			4	42	472	10	1.02	0.08
			5	7	532	13	1.47	0.07
			6	1	488	-	1.04	-
	1992	May	2	18	285	12	0.21	0.05
			3	79	379	6	0.60	0.03
			4	72	443	5	1.02	0.05
			5	7	488	25	1.32	0.21
			6	4	536	3	1.69	0.24
		Jun	2	42	296	7	0.23	0.03
			3	50	392	10	0.63	0.06
			4	61	448	7	0.98	0.06
			5	14	495	22	1.30	0.16
			6	12	524	18	1.44	0.16
			7	1	561	-	1.54	-
		Jul	2	1	366	-	0.50	-
			3	55	440	6	0.90	0.04
			4	264	470	3	1.08	0.02
			5	67	498	8	1.27	0.06
			6	10	534	25	1.51	0.16
			7	3	534	50	1.50	0.40

Zone	Year	Month	Age	Number	Length Mean	Length 95% C.I.	Weight Mean	Weight 95% C.I.
WFM-01	1992	Oct	1	13	258	10	0.18	0.09
			2	57	364	6	0.41	0.03
			3	224	447	3	0.82	0.02
			4	176	495	4	1.16	0.03
			5	24	527	10	1.43	0.13
			6	7	559	16	1.62	0.18
	1993	May	2	12	284	13	0.20	0.06
			3	154	380	4	0.55	0.02
			4	141	455	5	0.91	0.03
			5	72	481	7	1.14	0.05
			6	12	521	18	1.38	0.21
			7	4	547	13	1.57	0.21
		Jul	3	140	453	3	0.93	0.03
			4	190	473	3	1.04	0.03
			5	63	500	6	1.23	0.06
			6	8	524	25	1.40	0.27
			7	1	528	-	1.41	-
		Oct	2	27	362	12	0.43	0.05
			3	206	421	3	0.63	0.01
			4	12	475	31	0.94	0.17
			5	4	527	50	1.26	0.48
WFM-06	1986	Dec	2	1	391	-	0.68	-
			3	17	404	7	0.71	0.04
			4	124	446	5	0.95	0.03
			5	67	475	4	1.16	0.04
			6	13	522	13	1.46	0.12
			7	7	566	21	1.85	0.36
			8	7	595	27	2.20	0.30
			9	5	616	41	2.53	0.53
			11	1	655	-	2.83	-
			12	2	700	83	4.11	5.53
			14	1	683	-	3.45	-
			15	2	700	51	4.06	2.03
			17	1	747	-	4.58	-
	1987	May	2	1	284	-	0.23	-
			3	13	400	13	0.72	0.07
			4	35	435	9	0.94	0.06
			5	117	505	5	1.42	0.05
			6	36	536	8	1.64	0.08

					Length		Weight	
Zone	Year	Month	Age	Number	Mean	95% C.I.	Mean	95% C.I.
WFM-06	1987	May	7	11	582	19	2.12	0.24
			8	6	630	10	2.68	0.17
			9	5	628	21	2.68	0.38
			10	8	648	21	3.04	0.46
			11	1	683	-	3.76	-
			12	1	650	-	3.31	-
		Jul	4	9	484	25	1.29	0.25
			5	44	512	7	1.51	0.07
			6	24	554	13	1.88	0.18
			7	2	596	19	2.47	3.18
			8	6	619	18	2.84	0.29
			9	5	641	36	2.89	0.44
			10	1	665	-	3.13	-
			11	2	689	222	3.97	7.24
			16	1	757	-	5.22	-
	1988	May	2	2	347	19	0.45	0.00
			3	16	417	10	0.76	0.06
			4	20	470	18	1.11	0.13
			5	50	535	12	1.63	0.11
			6	97	564	7	1.89	0.07
			7	11	590	17	2.14	0.28
			8	18	621	15	2.57	0.25
			9	7	633	39	2.65	0.63
			10	7	652	20	3.15	0.25
			11	6	691	16	3.58	0.28
			14	1	732	-	4.76	-
		Jul	3	3	433	37	0.91	0.39
			4	11	494	20	1.33	0.14
			5	53	521	9	1.55	0.09
			6	86	553	7	1.86	0.08
			7	17	550	25	1.93	0.28
			8	11	621	27	2.89	0.40
			9	25	635	13	2.93	0.20
			10	11	650	14	3.30	.02 5
			11	6	663	14	3.52	0.10
	1989	May	2	2	328	70	0.35	0.32
			3	125	414	3	0.78	0.02
			4	40	470	10	1.15	0.07
			5	44	516	10	1.46	0.08

					Length		Weight	
Zone	Year	Month	Age	Number	Mean	95% C.I.	Mean	95% C.I.
WFM-06	1989	May	6	36	542	11	1.70	0.11
			7	31	577	15	2.13	0.17
			8	6	605	36	2.41	0.56
			9	2	589	521	2.60	5.21
			10	3	645	105	2.78	1.21
			11	3	696	115	5.49	8.63
			12	1	666	-	3.11	-
		Jul	3	9	457	10	1.01	0.08
			4	17	490	11	1.22	0.09
			5	14	515	12	1.48	0.20
			6	22	554	10	1.80	0.14
			7	82	585	6	2.22	0.10
			8	20	602	13	2.36	0.14
			9	12	624	21	2.67	0.38
			10	16	637	21	2.96	0.33
			11	11	665	21	3.33	0.38
			12	9	663	31	3.64	0.56
	1990	Apr	3	86	406	5	0.71	0.04
			4	44	453	12	0.95	0.08
			5	8	464	50	1.05	0.34
			6	5	530	62	1.62	0.22
			7	4	579	41	1.83	0.25
			8	11	615	24	2.46	0.38
			9	5	613	31	2.59	0.82
			11	1	647	-	3.10	-
			12	1	715	-	3.55	-
			17	1	712	-	5.22	-
			22	1	767	-	6.35	-
		May	3	19	426	12	0.86	0.15
			4	45	466	7	1.09	0.07
			5	16	500	19	1.29	0.17
			6	5	569	42	1.98	0.39
			7	28	585	8	2.08	0.12
			8	26	588	13	2.40	0.15
			9	6	625	44	2.42	0.56
			10	3	667	46	3.06	1.01
			11	7	650	32	2.92	
			12	3	689	40	3.52	
		Jul	2	1	437	-	0.85	-
			3	35	450	5	0.94	0.04

					Length		Weight	
Zone	Year	Month	Age	Number	Mean	95% C.I.	Mean	95% C.I.
WFM-06	1990	Jul	4	34	482	9	1.14	0.07
			5	7	504	21	1.30	0.19
			6	11	576	36	2.16	0.49
			7	37	596	10	2.31	0.13
			8	40	613	9	2.60	0.14
			9	20	641	14	2.91	0.22
			10	15	642	14	3.02	0.25
			11	11	668	21	3.42	0.48
			12	10	675	31	3.68	0.58
			13	3	616	315	3.08	4.34
		Oct	2	2	371	241	0.45	0.76
			3	98	446	4	0.82	0.03
			4	57	467	8	0.99	0.06
			5	5	485	28	1.19	0.28
			6	3	592	96	2.19	1.27
			7	6	592	40	2.21	0.58
			8	10	602	20	2.43	0.35
			9	2	584	6	2.26	2.41
			10	1	642	-	3.09	-
			11	2	667	318	4.12	2.41
			13	3	691	75	3.90	1.86
	1991	May	3	46	408	8	0.70	0.04
			4	177	470	3	1.05	0.02
			5	30	501	10	1.23	0.08
			6	3	526	66	1.42	0.59
			7	2	552	83	1.66	0.32
			8	5	587	94	2.25	0.62
			9	8	635	23	2.77	0.47
			10	1	673	-	3.36	-
			11	2	690	83	2.63	16.10
		Jul	3	1	457	-	0.91	-
			4	135	487	4	1.16	0.03
			5	24	509	18	1.38	0.14
			6	7	590	34	2.22	0.48
			7	7	625	7	2.66	0.22
			8	11	627	18	2.60	0.28
			9	4	622	54	2.56	0.29
			10	5	655	43	3.07	0.48
			11	3	612	382	4.27	1.93
			12	3	720	54	4.34	2.39

					Length		Weight	
Zone	Year	Month	Age	Number	Mean	95% C.I.	Mean	95% C.I.
WFM-06	1992	Jun	3	5	448	11	1.14	0.50
			4	28	476	9	1.15	0.08
			5	72	526	6	1.50	0.06
			6	5	537	28	1.61	0.35
			7	4	590	16	2.10	0.35
			8	4	619	54	2.62	0.60
			9	5	622	27	2.62	0.59
			10	8	654	31	3.00	0.46
			11	2	730	51	4.76	5.65
			13	8	717	21	4.18	0.44
		Jul	3	15	478	13	1.17	0.10
			4	80	494	6	1.29	0.05
			5	81	534	6	1.61	0.06
			6	8	537	36	1.76	0.38
			7	2	602	146	2.22	2.99
			9	4	640	20	2.98	0.77
			10	9	663	24	3.41	0.59
			11	1	698	-	4.05	-
			12	3	647	70	2.76	1.75
		Oct	3	5	468	17	0.97	0.12
			4	21	507	11	1.24	0.07
			5	35	549	9	1.72	0.11
			6	8	557	8	1.77	0.19
			7	5	560	26	1.92	0.10
			8	2	542	801	1.48	4.76
			9	2	622	44	2.43	5.21
			10	3	658	21	3.24	0.75
			11	6	657	20	3.26	0.44
			12	1	663	-	4.15	-
			13	2	648	146	3.36	1.84
			17	1	703	-	4.33	-
	1993	May	2	1	273	-	0.19	-
			3	70	422	5	0.77	0.03
			4	20	479	14	1.18	0.11
			5	43	520	7	1.44	0.06
			6	70	550	6	1.68	0.06
			7	13	587	19	2.05	0.22
			8	5	610	21	2.14	0.17
			9	2	619	172	1.97	2.35
			10	6	655	25	3.08	0.59
			11	8	657	23	3.07	0.47

Zone	Year	Month	Age	Number	Length Mean	Length 95% C.I.	Weight Mean	Weight 95% C.I.
WFM-06	1993	May	12	1	665	-	3.33	-
			13	1	663	-	2.88	-
			14	1	772	-	5.59	-
			15	1	648	-	2.58	-
		Jul	3	25	455	6	2.06	0.12
			4	20	481	26	2.61	0.25
			5	19	530	18	3.45	0.33
			6	46	563	7	4.07	0.23
			7	2	565	508	4.34	11.94
			8	1	677	-	7.00	-
			9	1	627	-	6.54	-
			10	8	648	19	6.56	1.00
			11	1	671	-	8.04	-
			12	1	680	-	8.74	-
			14	1	743	-	8.62	-
		Oct	1	1	254	-	0.15	-
			2	20	371	14	0.46	0.06
			3	58	459	6	0.90	0.04
			4	12	489	10	1.11	0.14
			5	11	545	12	1.57	0.16
			6	12	578	19	2.02	0.25
			7	2	629	48	2.12	2.03
			8	1	638	-	3.12	-
			9	2	622	323	2.78	3.30
			10	4	674	37	3.59	0.49
WFM-08	1986	Dec	3	8	435	20	0.88	0.11
			4	98	496	6	1.33	0.06
			5	243	527	3	1.61	0.04
			6	110	562	6	2.00	0.08
			7	76	607	5	2.59	0.10
			8	38	626	8	2.89	0.14
			9	19	652	13	3.32	0.33
			10	12	654	14	3.29	0.34
			11	2	689	159	3.72	2.29
			12	1	671	-	3.08	-
			13	3	709	167	5.61	6.86
			15	1	792	-	7.03	-
			16	1	770	-	6.80	-
	1987	May	4	7	482	34	1.27	0.27
			5	37	523	7	1.49	0.06

Zone	Year	Month	Age	Number	Length Mean	Length 95% C.I.	Weight Mean	Weight 95% C.I.
WFM-08	1987	May	6	82	558	5	1.86	0.07
			7	27	582	8	2.12	0.11
			8	21	616	13	2.56	0.18
			9	19	635	8	2.80	0.15
			10	11	655	11	3.08	0.18
			11	3	642	44	2.75	0.13
			12	2	710	534	3.95	5.15
			13	2	691	191	3.34	0.32
		Jul	4	6	495	23	1.31	0.25
			5	37	526	9	1.62	0.10
			6	46	550	8	1.86	0.10
			7	8	591	9	2.35	0.29
			8	13	605	11	2.68	0.20
			9	10	632	15	2.93	0.33
			10	10	637	6	2.88	0.15
			11	3	654	20	3.43	0.66
			12	3	648	51	3.13	0.41
		Oct	3	1	371	-	0.45	-
			4	14	525	9	1.51	0.13
			5	97	535	4	1.64	0.05
			6	69	567	5	2.01	0.08
			7	15	597	13	2.43	0.22
			8	5	617	36	2.73	0.46
			9	3	628	29	2.77	0.99
			10	4	646	24	3.01	0.52
			11	2	663	32	3.29	1.40
	1988	May	2	1	363	-	0.50	-
			3	13	431	23	0.82	0.13
			4	8	487	26	1.18	0.13
			5	36	547	9	1.86	0.14
			6	71	564	5	2.02	0.07
			7	34	586	8	2.27	0.12
			8	27	614	11	2.54	0.17
			9	22	637	9	2.89	0.16
			10	13	638	14	2.91	0.25
			11	3	627	71	2.87	1.03
		Jul	4	1	584	-	2.00	-
			5	15	549	22	1.93	0.22
			6	76	586	6	2.34	0.08
			7	39	610	8	2.67	0.15

					Length		Weight	
Zone	Year	Month	Age	Number	Mean	95% C.I.	Mean	95% C.I.
WFM-08	1988	Jul	8	25	636	14	3.07	0.22
			9	24	657	13	3.36	0.28
			10	17	685	16	3.92	0.26
			11	6	681	42	4.01	0.30
			12	2	666	324	4.15	1.40
			13	1	714	-	4.26	-
			15	1	754	-	4.26	-
			16	1	742	-	4.26	-
		Oct	2	19	407	8	0.74	0.04
			3	15	442	29	1.02	0.26
			4	9	532	39	1.71	0.29
			5	73	566	5	2.08	0.09
			6	67	589	6	2.34	0.10
			7	14	617	12	2.85	0.21
			8	19	638	16	3.10	0.19
			9	15	633	10	3.11	0.18
			10	2	645	64	3.38	6.61
			11	2	666	70	3.47	0.89
			13	1	665	-	3.08	-
	1989	May	3	18	429	9	0.89	0.09
			4	7	469	52	1.18	0.37
			5	5	537	40	1.73	0.29
			6	8	569	28	1.95	0.38
			7	46	601	10	2.43	0.12
			8	13	619	26	2.83	0.45
			9	15	645	17	3.15	0.28
			10	14	660	17	3.33	0.22
			11	9	668	15	3.68	0.51
			12	6	681	36	3.74	0.60
			13	4	701	28	3.75	1.12
			14	3	665	227	4.18	2.77
			15	1	704	-	3.76	-
			19	1	732	-	4.67	-
		Jul	3	1	454	-	0.96	-
			4	4	506	29	1.54	0.25
			5	11	542	12	1.87	0.12
			6	47	577	8	2.27	0.11
			7	99	596	5	2.51	0.08
			8	21	602	30	2.83	0.24
			9	26	641	10	3.13	0.21
			10	5	655	21	3.46	0.44

					Length		Weight	
Zone	Year	Month	Age	Number	Mean	95% C.I.	Mean	95% C.I.
WFM-08	1989	Jul	11	2	682	32	3.49	0.64
			15	1	670	-	3.71	-
		Oct	3	64	480	6	1.11	0.04
			4	19	504	20	1.34	0.18
			5	10	526	36	1.62	0.38
			6	85	583	4	2.16	0.07
			7	45	596	7	2.29	0.10
			8	1	634	-	2.41	-
			9	2	612	432	2.53	2.92
			10	1	645	-	3.25	-
	1990	May	2	1	298	-	0.21	-
			4	51	502	7	1.38	0.07
			5	8	553	38	1.58	0.38
			6	25	569	9	1.91	0.13
			7	59	590	6	2.23	0.09
			8	54	607	7	2.43	0.10
			9	7	607	17	2.40	0.29
			10	7	615	14	2.57	0.32
		Jul	3	2	479	114	1.10	0.25
			4	21	517	11	1.56	0.16
			5	13	551	30	1.81	0.35
			6	27	584	10	2.16	0.14
			7	67	605	7	2.52	0.09
			8	55	613	6	2.67	0.09
			9	23	628	8	2.84	0.15
			10	4	625	27	2.75	0.25
		Oct	1	1	300	-	0.23	-
			3	26	481	7	1.18	0.07
			4	72	508	14	1.57	0.12
			5	21	540	10	1.75	0.14
			6	21	572	12	2.15	0.15
			7	45	600	6	2.39	0.10
			8	32	615	7	2.76	0.11
			9	11	622	10	2.81	0.24
			10	3	651	50	3.48	0.64
	1991	Apr	2	3	336	21	0.35	0.06
			3	45	419	7	0.78	0.04
			4	61	469	8	1.11	0.06
			5	26	520	14	1.57	0.16

Zone	Year	Month	Age	Number	Length Mean	Length 95% C.I.	Weight Mean	Weight 95% C.I.
WFM-08	1991	Apr	6	9	563	31	1.87	0.29
			7	7	601	24	2.19	0.51
			8	22	619	14	2.63	0.16
			9	3	621	43	2.68	0.56
			10	1	594	-	2.36	-
			11	1	615	-	2.86	-
		May	3	4	464	17	1.05	0.12
			4	41	500	11	1.42	0.11
			5	42	527	11	1.57	0.11
			6	3	553	70	2.04	0.71
			7	1	617	-	2.63	-
			8	6	577	30	2.16	0.23
			9	2	596	210	2.02	2.60
		Jul	3	3	490	63	1.28	0.94
			4	80	500	5	1.37	0.05
			5	42	537	9	1.74	0.11
			6	24	581	14	2.29	0.20
			7	36	612	10	2.70	0.13
			8	16	617	18	2.52	0.22
			9	7	630	13	2.94	0.24
			10	2	642	375	3.24	4.32
		Oct	2	13	414	16	0.73	0.11
			3	65	463	10	1.11	0.06
			4	107	528	5	1.63	0.05
			5	37	549	9	1.84	0.10
			6	7	571	29	2.00	0.36
			7	5	609	24	2.32	0.42
			8	4	600	32	2.45	0.31
	1992	May	2	1	426	-	0.72	-
			3	31	418	5	0.77	0.03
			4	19	461	19	1.05	0.15
			5	36	522	12	1.60	0.13
			6	12	578	19	2.08	0.22
			7	9	596	20	2.31	0.24
			8	11	618	30	2.56	0.39
			9	20	635	18	2.99	0.29
			10	32	646	10	3.05	0.19
			11	28	666	10	3.50	0.14
			12	11	665	16	3.62	0.34

					Length		Weight	
Zone	Year	Month	Age	Number	Mean	95% C.I.	Mean	95% C.I.
WFM-08	1992	May	13	17	704	15	4.46	0.83
			14	10	686	16	4.20	0.53
			15	1	719	-	4.93	-
			16	1	692	-	4.67	-
		Jul	3	1	480	-	1.13	-
			4	10	516	16	1.44	0.12
			5	37	540	11	1.70	0.12
			6	30	568	10	2.09	0.16
			7	11	612	14	2.54	0.25
			8	33	612	30	2.84	0.21
			9	47	634	8	2.97	0.16
			10	41	653	10	3.36	0.18
			11	14	659	54	3.73	0.52
			12	10	680	23	3.85	0.54
			13	3	696	30	4.44	0.20
			14	3	714	83	4.69	1.42
			16	1	707	-	4.03	-
			20	1	760	-	6.12	-
		Oct	3	64	486	3	1.25	0.02
			4	76	508	4	1.43	0.04
			5	44	540	7	1.70	0.07
			6	16	554	14	1.96	0.12
			7	4	552	34	1.93	0.46
			8	2	602	57	2.30	1.78
			9	1	547	-	2.54	-
			10	1	603	-	2.30	-
	1993	May	2	10	352	26	0.38	0.12
			3	3	446	59	0.88	0.47
			4	48	490	4	1.26	0.04
			5	34	530	10	1.62	0.11
			6	47	559	9	1.90	0.11
			7	18	587	16	2.22	0.20
			8	13	617	18	2.65	0.24
			9	12	645	13	2.96	0.23
			10	16	651	18	3.08	0.26
			11	8	654	24	3.11	0.31
			12	4	685	54	3.64	0.75
			13	2	697	242	4.34	6.04
		Jul	3	6	483	12	0.96	0.10
			4	99	504	4	1.27	0.05

Zone	Year	Month	Age	Number	Length Mean	Length 95% C.I.	Weight Mean	Weight 95% C.I.
WFM-08	1993	Jul	5	57	528	7	1.46	0.10
			6	21	551	18	1.68	0.18
			7	7	587	30	2.22	0.26
			8	7	624	21	2.57	0.43
			9	16	650	15	2.93	0.24
			10	4	655	33	3.03	0.88
			11	1	645	-	3.08	-
			12	1	676	-	2.86	-
		Oct	3	8	489	10	1.15	0.04
			4	117	521	4	1.45	0.04
			5	59	538	7	1.62	0.07
			6	20	570	13	1.89	0.15
			7	2	607	129	2.36	0.00
			8	3	643	28	2.62	0.27
			9	1	579	-	2.40	-

Appendix 3.--Length frequencies of pre-recruit lake whitefish (<432 mm TL) caught in monitored commercial trawl hauls.

			Number per length interval (mm range)										
Date	Tow	Code[a]	≤203-228	229-253	254-278	279-304	305-329	330-355	356-380	381-405	406-431	Total number of sublegals	Legal catch (kg)
7-22-88	1	0							2	4	5	11	136
	2	0								2	5	7	181
	3	0						1	1	10	12	24	363
	4	0							1	6	7	14	204
	5	0						1	2	8	2	13	159
8-04-88	1	0										0	91
	2	0									2	2	91
	3	0								2		2	68
	4	1					2	7	46	40	28	123	91
	5	1					1	7	13	29	7	57	?
8-19-88	1	0										0	91
	2	0								1		1	68
	3	0										0	68
	4	1					3	7	24	28	11	73	45
	5	1					1	31	55	52	60	169	91
9-07-88	1	0								9	2	11	272
	2	0							2	5	7	14	227
	3	0								1	3	4	113
	4	0							2	1	6	9	125
	5	2				3	20	97	116	198	119	553	227
	6	2		3	1	1	14	56	42	25	22	164	68
	7	0								1	2	3	159
9-22-88	1	0									2	2	91
	2	0						1		1	2	4	91
	3	2						5	11	19	10	45	68
	4	2					5	21	30	73	40	169	136
	5	0								2	2	4	52
	6	0								1	3	4	50
10-06-88	1	0							1	4	2	7	68
	2	0								1	2	3	91
	3	2			2	2	5	32	90	164	104	399	227
	4	0								1	3	4	34
	5	0									6	6	68
	6	0							1	2	1	4	68
7-27-89	1	0									2	2	7
	2	2				1	11	13	25	43	49	142	159
	3	0								1	1	2	68
	4	0								1	4	5	125
	5	3				2	2	2	4	11	10	31	23
	6	0										0	34
8-10-89	1	0								2	4	6	91
	2	3					1	13	9	16	28	67	45
	3	0							1	1	4	6	113
	4	0						1			2	3	136
	5	3				1	1	9	4	13	20	48	79
	6	0										0	11
	7	0									2	2	11
8-25-89	1	0								1	1	2	23
	2	0									1	1	23
	3	3	1	1		3	44	47	51	123	79	349	159

			Number per length interval (mm range)										
Date	Tow	Code[a]	≤203-228	229-253	254-278	279-304	305-329	330-355	356-380	381-405	406-431	Total number of sublegals	Legal catch (kg)
8-25-89	4	0								1	5	6	45
	5	0								2		2	57
	6	0								1		1	11
9-07-89	1	0									2	2	27
	2	0							1			1	27
	3	3					1	5	3			9	4
	4	3					2	2	4	6	11	25	68
	5	0						1			3	4	34
	6	0						1			1	2	14
8-01-90	1	0									4	4	159
	2	0							1	1	9	11	272
	3	3					1	5	6	17	37	66	227
	4	0					1		3	15	35	54	454
	5	0								7	12	19	181
	6	0								1	4	5	113
	7	0							1	5	12	18	181
	8	0										0	7
8-14-90	1	4					1	3	7	5	9	25	54
	2	4								1	2	3	102
	3	4							1	1	7	9	204
	4	3						9	8	10	19	46	102
	5	0							1	3	8	12	181
	6	0							1	2	4	7	159
	7	0								2	2	4	36
8-29-90	1	0							2	1	1	4	181
	2	3					5	21	29	33	76	164	181
	3	0						1	4	8	4	17	227
	4	0						1	3	1	2	7	136
	5	0									1	1	23
	6	0							1	9	3	13	91
	7	0							3	1	11	15	136
9-13-90	1	0						5	7	9	13	34	363
	2	0							1	3	8	12	181
	3	0							1	2	2	5	68
	4	0							1	3		4	50
	5	3					3	18	40	20	24	105	136
	6	0							1	4		5	102
	7	0									2	2	36
9-25-90	1	0										0	34
	2	0							2	3	5	10	125
	3	3				1	21	132	200	146	62	562	340
	4	0						2	8	8	6	24	363
	5	0							2	4	6	12	170
	6	0						1	1	3	5	10	181
	7	0							5	9	7	21	159
10-09-90	1	0							1		1	2	34
7-11-91	1	5							2	34	82	118	1,179
	2	5								2	9	11	499
	3	6							2	9	20	31	136
	4	5						1		2	21	24	295
	5	5								10	18	28	272
	6	0							1	5	17	23	249

			Number per length interval (mm range)										
Date	Tow	Code[a]	≤203-228	229-253	254-278	279-304	305-329	330-355	356-380	381-405	406-431	Total number of sublegals	Legal catch (kg)
7-11-91	7	0							1	7	15	23	249
7-25-91	1	0									2	2	102
	2	0									3	3	57
	3	3					1	8	7	15	29	60	113
	4	0								2	5	7	136
	5	0							1		5	6	45
	6	3		1				5	2	7	8	23	?
8-20-91	1	0							3	6	31	40	635
	2	3	1	2	1	8	8	41	45	81	98	285	227
	3	0						1		2	4	7	227
	4	0								3	6	9	227
	5	0							2	1	5	8	181
	6	0						1		2	3	6	91
9-04-91	1	0						2	12	8	15	37	499
	2	0							2	1	1	4	91
	3	3		1	2	6	7	41	29	23	34	143	79
	4	0						1	3	1	10	15	227
	5	0						1	3	5	8	17	249
	6	0						1	1		2	4	91
9-27-91	1	0						2	1	1	5	9	102
	2	3		2	1	4	10	36	63	58	67	241	227
	3	0		1					3	5	6	15	170
	4	0						1		3	2	6	68
	5	0						1	1	3	3	8	136
	6	0							2		1	3	34
10-08-91	1	0							1	1	1	3	34
	2	0						1	3	10	15	29	136
	3	3		1	7	4	9	44	87	58	53	263	136
	4	0						1	3	2	6	12	136
	5	0							1	11	17	29	159
	6	0					2	1		1	7	11	54
7-31-92	1	0					1	3	2	1	7	14	181
	2	0					2	3	6	18	33	62	680
	3	0				2	5	1	8	11	19	46	726
	4	0								7	5	12	318
	5	0								3	4	7	?
	6	3	14	3	6	37	91	66	38	22	14	291	68
	7	0							2	1		3	45
8-18-92	1	0						1	1	3	6	11	283
	2	0						2	2	5	12	21	340
	3	0						2	1	1	8	12	227
	4	3				5	28	35	28	25	41	162	193
	5	0						1	2	1	3	7	91
	6	0							2	2	5	9	159
	7	0					1			1	2	4	45
8-25-92	1	0					7	6	7	30	39	89	1,361
	2	0						1	4	7	16	28	726
	3	0					1	5	8	12	28	54	771
	4	0						1	1	7	12	21	363
	5	6				2	9	11	5	7	12	46	45
9-01-92	1	0	1					1			1	3	23

			Number per length interval (mm range)										
Date	Tow	Code[a]	≤203-228	229-253	254-278	279-304	305-329	330-355	356-380	381-405	406-431	Total number of sublegals	Legal catch (kg)
9-01-92	2	0							5	5	5	15	159
	3	0					1	1	4	1	7	14	136
	4	0			1			2	3	7	4	17	?
	5	3	1	3	1	8	14	25	10	5	1	68	14
	6	0								1	2	3	23
9-22-92	1	0						2	5	7	17	31	408
	2	0		1				2	5	11	12	31	363
	3	0						1	3	5	6	15	454
	4	0							1	11	8	20	227
	5	3		1	1		8	17	19	16	15	77	136
	6	0								3	3	6	45
10-07-92	1	0							1	2	1	4	23
	2	0						1	4	1	5	11	45
	3	0					1	3	7	14	16	41	227
	4	0							6	8	12	26	136
	5	6		1			3	4	19	18	10	55	23
8-06-93	1	0					1	1	2	12	21	37	544
	2	0					1			4	7	12	193
	3	3			2	2	4	2	6	10	7	33	23
	4	0							3	3	5	11	113
	5	0							2	2	6	10	45
8-25-93	1	0						1	3	5	13	22	272
	2	3			1	5	9	8	20	50	79	172	544
	3	7			1	2	2	2	3	5	3	18	454
	4	7	1		2	16	28	9	17	32	23	128	363
	5	0					1		2	1	3	7	91
9-02-93	1	0							2	5	14	21	272
	2	3					5	7	8	29	57	106	454
	3	7						1		1	2	4	386
	4	7									1	1	136
	5	7									1	1	9
9-09-93	1	7									1	1	23
	2	7								2	2	4	204
	3	3		1		5	8	6	5	18	16	59	91
	4	7						1			1	2	136
	5	7							1			1	34
9-23-93	1	7		1			1		3	4	3	12	159
	2	3	2	15	8	14	28	49	27	29	63	235	113
	3	7							1			1	91
	4	7										0	23
	5	7									1	1	23
9-29-93	1	7	6		1					3	1	11	68
	2	3		2	2	5	6	8	7	4	18	52	45
	3	7	1	1		1		2				5	23
	4	7										0	1
	5	7										0	9

[a] Codes distinguish normal trawl hauls from those modified to catch sublegal whitefish: 0 = unmodified haul with Western Wing Trawl; 1 = modified haul with alewife trawl (29-mm mesh); 2 = modified haul with Western Wing Trawl tied off ahead of the sorting portion of the cod end; 3 = same as number 2 but the haul was shortened from 1 hr to ½ hr; 4 = modified tow using a small-mesh overliner outside the bag; 5 = modified haul using a square-mesh panel on the top forward portion of the bag and a funnel inside the bag to accelerate water; 6 = same as number 2 but the haul was shortened to ¼ hour; 7 = trouser trawl with diverter and small-mesh bag to catch rainbow smelt.

Appendix 4.--Age-at-length keys applied to pre-recruit lake whitefish caught in trawl hauls, 1988-1993.

Length interval (mm)	N	Percent at age, 1988			
		1	2	3	4
229-253	3	100			
254-278	3	33.3	66.7		
279-304	6	16.7	83.3		
305-329	37		97.3	2.7	
330-355	45		80.0	17.8	2.2
356-380	42		23.8	73.8	2.4
381-405	79		6.3	87.3	6.3
406-431	53		1.9	73.6	24.5
		Percent at age, 1989			
203-228	1	100			
229-253	1	100			
254-278					
279-304	7		100		
305-329	16		93.8	6.2	
330-355	22		72.7	27.3	
356-380	25		36.0	64.0	
381-405	28			71.4	28.6
406-431	34			67.6	32.4
		Percent at age, 1990			
279-304	1		100		
305-329	14		100		
330-355	59		88.1	11.9	
356-380	35		51.4	48.6	
381-405	58		17.2	74.2	8.6
406-431	85			90.6	9.4

Appendix 4. Continued.

Length interval (mm)	N	Percent at age, 1991			
		1	2	3	4
203-228	1	100			
229-253	8	100			
254-278	11	81.8	9.1	9.1	
279-304	22	45.4	54.6		
305-329	35	2.9	91.4	5.7	
330-355	52		84.6	15.4	
356-380	38		60.5	39.5	
381-405	36		5.6	94.4	
406-431	38		2.6	89.5	7.9
		Percent at age, 1992			
203-228	7	100			
229-253	4	100			
254-278	6	16.7	83.3		
279-304	36		97.2	2.8	
305-329	53		100		
330-355	46		84.8	15.2	
356-380	49		51.0	46.9	2.1
381-405	53		9.4	90.6	
406-431	47			89.4	10.6
		Percent at age, 1993			
203-228	3	100			
229-253	15	93.3	6.7		
254-278	12	41.7	58.3		
279-304	31		100		
305-329	45		97.8	2.2	
330-355	54		81.5	18.5	
356-380	44		38.6	61.4	
381-405	49		4.1	91.8	4.1
406-431	57			87.7	12.3